THE GEOCHEMICAL ASPECT OF EGBOHA WELL IN IMO FORMATION IN OKADA, OVIA NORTH EAST, SOUTHERN NIGERIA

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CERTIFICATION

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DEDICATION

This project work is dedicated first and foremost to God Almighty, the one by whom all things were possible. To my family, for their unwavering love and support.

ACKNOWLEDGEMENT

My gratitude goes to God Almighty for the grace and strength He granted me during this project exercise. My sincere gratitude goes to my supervisor Dr. A. J Edegbai for his guidance, effort, and encouragement throughout the work.

My profound gratitude also goes to my Father, MR Ndubuisi Ogbuagu for his unending care, love and support towards my educational pursuit, to my sisters Chidinma and Blessing for being amazing, Ojo Kelvin for being a supportive friend and my other friends. I love you all.

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ABSTRACT

Twenty-two samples were collected from Egboha well in Imo Formation, from which ten(10) samples were used to identify the different lithologies, Degree of effervescence were carried out to determine samples with carbonate minerals. Geochemical analyses were also carried out to get the geochemical data using ICP-MS and ICP-OES. Geochemical data for Imo Formation are presented and applied as proxies for deciphering paleo-environment (detrital influx, redox conditions, paleo-productivity) and providing insight to paleo-environmental conditions responsible for sedimentary geochemistry of Imo Formation. The detrital influx proxies used for this work [Si/Al having values ranging from (5.386-2.976) and Ti/Al having values ranging from (0.099-0.061)], show an increase in detrital influx (rate of deposition) and coarse grain at two depths, and at the other depths there is a decrease in detrital influx and fine grain. Paleo-redox proxies used for this work [Mo/Al having values ranging from (0.539-2.429), Ni/Al having values ranging from (7.181-16.194), U/Al having values ranging from (0.467-2.065)], show an enrichment of (U, Mo, Ni) and the oxygen level being suboxic - anoxic environment. Paleo-productivity proxies [Ba/Al having values ranging from (43.088-27.935)] shows an increase in the paleo- productivity at three depths which indicates high productivity of organisms during the Paleocene period, while at other depths, low productivity of organisms can be observed. Paleo-salinity [Sr/Ba having values ranging from (0.065-0.112)] shows an increase in paleo-salinity, which indicates high salt content at two depths and at other depths low paleo-salinity can be observed at other depths. The result shows that elemental geochemistry can be applied to Study the paleo environment, paleoclimate, and depositional conditions.

CHAPTER ONE
INTRODUCTION

1.1 GENERAL

Shales and mud rocks exhibit a significant abundance of many major elements and trace metals, which serve as indicators of their depositional environment, provenance, and diagenesis. In this study, we provide geochemical data for shaly strata from the Devonian-Mississippian period in the Western Canadian Sedimentary Basin. Our objective is to evaluate the effectiveness of geochemical proxies in identifying thermally mature deposits with a vitrinite reflectance of over 1.5% (VRo). Additionally, we aim to determine the applicability of these proxies in understanding the paleoceanography conditions that influenced the distribution of elements in these deposits. The analysis involves the utilization of specific parameters such as excess silica concentrations, C–S–Fe correlations, Ni/Co ratios, V/Cr ratios, Mo/Al ratios, and Re/Mo ratios. The data reported in this study has ramifications beyond its regional scope, as it pertains to the utilization of trace element geochemistry throughout geologic periods characterized by substantial buildup of organic-rich sediments, specifically during the Devonian-Mississippian period. These sediments later experienced intense thermal diagenesis. The comparison of thermally mature lower Besa River, Golata, Muskwa, and Fort Simpson shales, which exhibit varying levels of thermal maturity (lower Besa River with VRo > 2%, and Golata, Muskwa, and Fort Simpson with VRo between

1.5% and 2%), reveals two key findings. Firstly, the distribution of redox-sensitive elements such as Ni, V, Mo, Tl, Cd, and U remains unaffected by thermal maturation. Secondly, these elements are transported to the sediment in conjunction with organic matter, under conditions of anoxic (possibly euxinic) water-column environments. The geochemistry of major elements, along with optical microscopy, reveals that the lower Besa River and Muskwa sediments, which include a high amount of organic matter, exhibit an enrichment of biogenic silica. This enrichment is shown by higher amounts of excess SiO2. Therefore, caution should be exercised when using Si as a proxy for estimating the input of detrital quartz. Elevated silicon (Si) concentrations have the potential to serve as indicators of past productivity in anoxic sediments, where elements like phosphorus (P) and barium (Ba) are mobilized and not effectively retained within the sedimentary record. The Golata sediments have elevated levels of excess silicon, indicating a significant presence of detrital quartz. Additionally, the enrichment of titanium, niobium, thorium, cerium, hafnium, and lanthanum in relation to typical shale compositions suggests that these elements serve as proxies for detrital input. The top shales of the Besa River, characterized by high organic and sulfur content, were formed in oxygen-deprived environments. This conclusion is drawn from the analysis of C-S-Fe and Re/Mo relationships, which indicate similarities with the lower Besa River and Muskwa shales. Nevertheless, the shales

found in the upper Besa River exhibit no significant concentration of redox-proxying elements such as Mo, U, and V. This suggests that the presence of benthic anoxia was not universally necessary for the sequestration of these elements. The thermal maturation levels of the lower Besa River shales are comparable to those observed in the given context. Consequently, it can be inferred that there is no indication of element loss resulting from diagenesis. One potential explanation pertains to variations in sedimentation rates, which can impact the diffusion and concentration of components within the sediment, thus leading to authigenic enrichment. Under the prevailing sedimentary conditions, the utility of Mo, U, and V as paleo-redox proxies is constrained due to this particular behavior.

1.2 TRACE ELEMENT

Chemical elements known as trace elements are found in very minute amounts—typically less than 0.1% by weight—in rocks, soils, water, and other natural materials. These substances can be used to deduce a variety of geochemical processes, including magma production, mineralization, alteration, and weathering. They are significant markers of the origin, history, and evolution of the Earth's crust. Some typical trace elements are Zinc (Zn), Iron (Fe), Rubidium (Rb), Thorium (Th), Copper (Cu), Chromium (Cr), Boron (B), and Lithium (Li) are a few examples of trace elements.

1.3 MAJOR ELEMENT

Chemical elements known as significant elements in geology are those that commonly occur in concentrations greater than 0.1% by weight in rocks and minerals. These substances are the most prevalent and significant components of the crust of the Earth and are used to categorize and understand different types of rocks. Silicon (Si), Oxygen (O), Aluminum (Al), Iron (Fe), Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Titanium (Ti), and Hydrogen (H) are the most prevalent main elements in geology.

1.4 RARE EARTH ELEMENT

A set of 17 chemical elements known as rare earth elements are essential to the development of numerous modern technology, including wind turbines, electric cars, cellphones, and military hardware. These elements are not genuinely uncommon in the Earth's crust, despite their name; rather, they are frequently distributed and challenging to extract and purify. The following are some examples of rare earth elements: Scandium (Sc), Yttrium (Y), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Th.

1.5 AIM AND OBJECTIVES

1.5.1 AIM

Determining the concentrations of various elements present in the rock. This helps to understand the composition of the rock and the processes that led to its formation. This information is useful for a variety of applications, including oil and gas exploration, environmental studies, and geological research.

1.5.2 OBJECTIVES

1. Identifying the different lithology
2. Identifying the presence of effervescence in each lithology of the study area
3. Determining the paleo salinity, grain size, paleo-environment and paleo-productivity of the study area

1.6. LOCATION OF THE STUDY AREA

Egboha is geographically located at Okada in Ovia North-East, Edo, Nigeria, on the coordinates 6° 38' 92.5" North, 5° 53' 37.7" East.

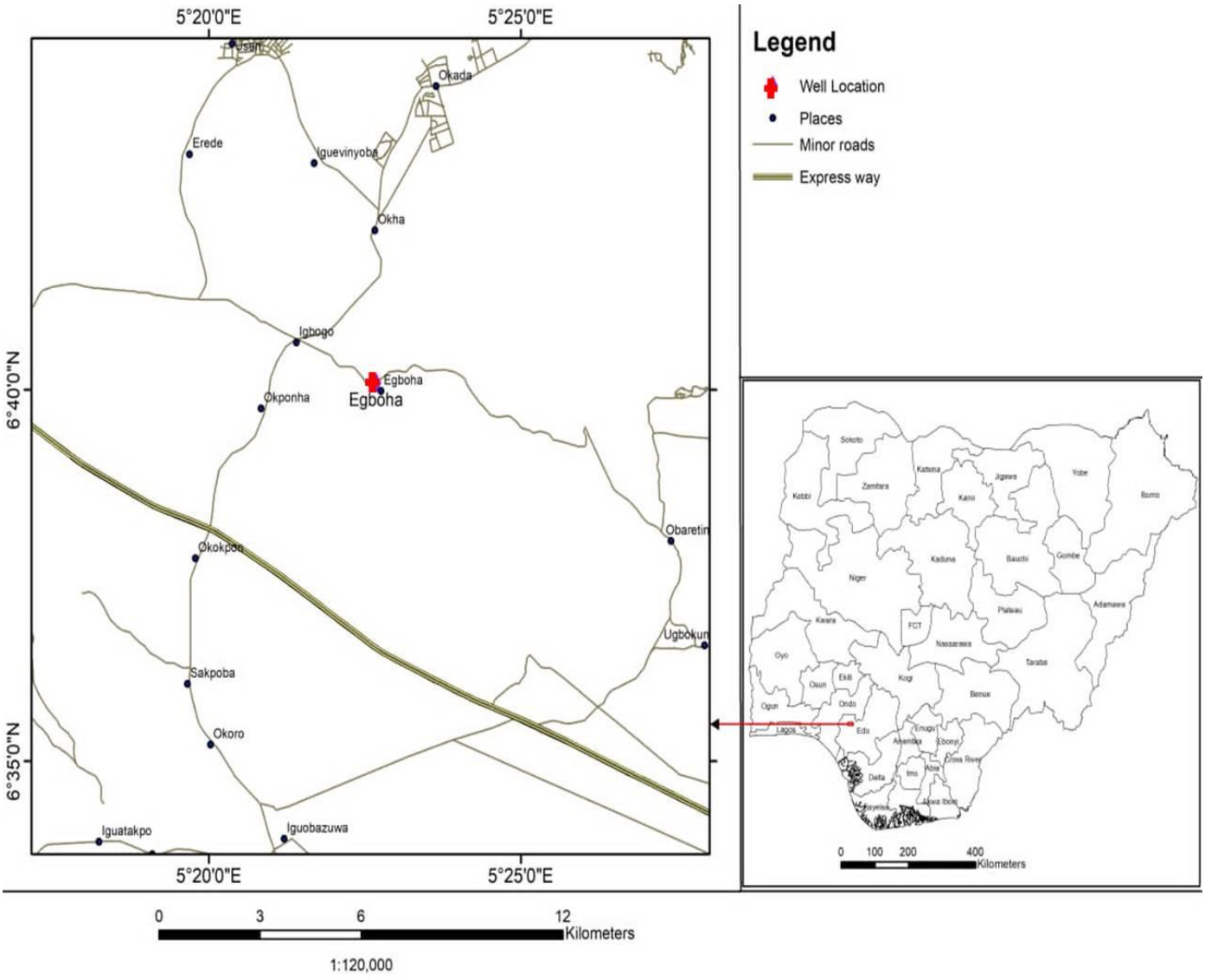

Fig. 1: Location map of study area

1.7. STRATIGRAPHIC CONTROL

The stratigraphic control can be deduced from the local map below owing that the coordinates of the location Egboha in Edo State.

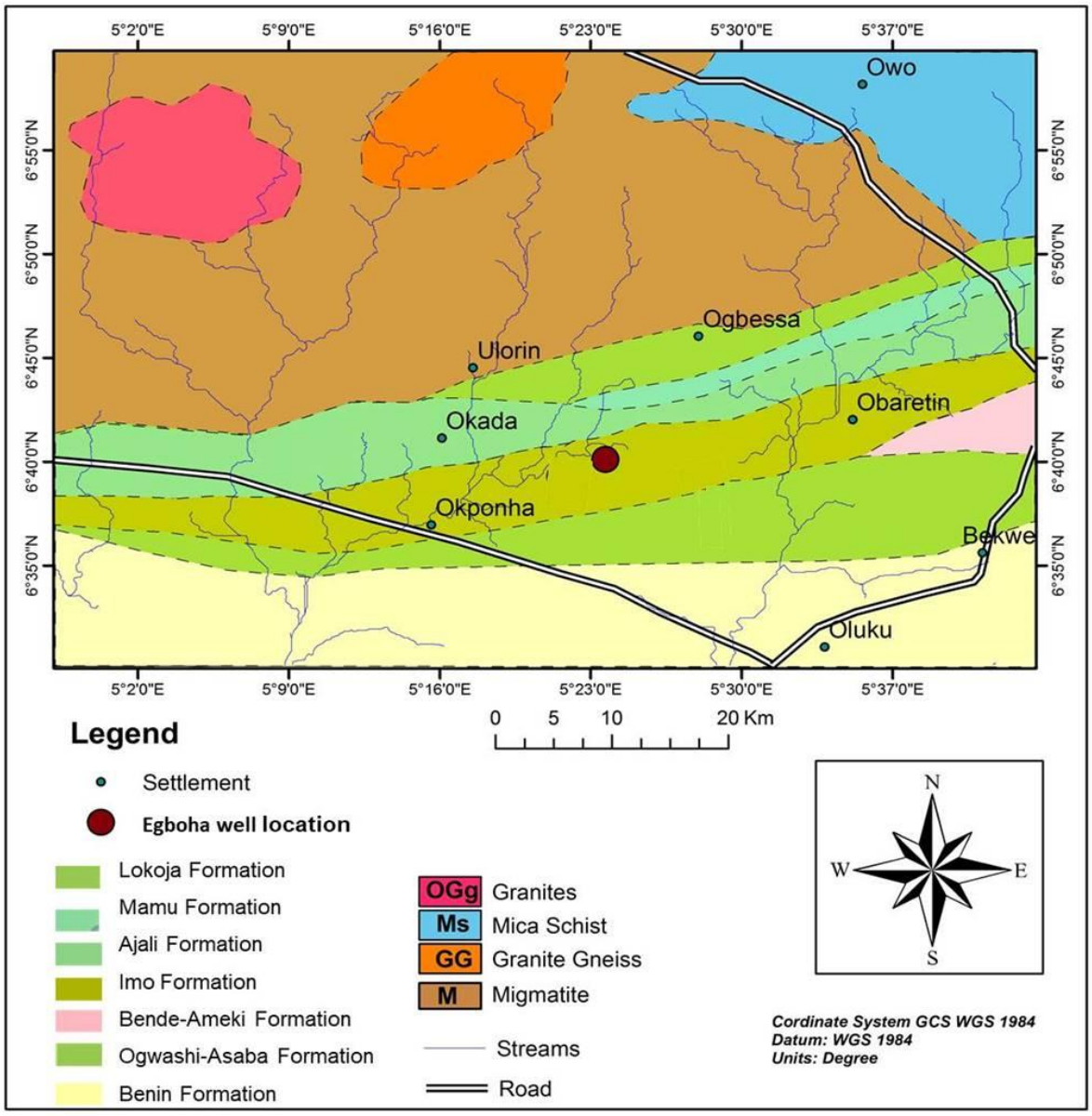

Fig.2: Geological map of study area

1.8. PREVIOUS WORKS ON IMO FORMATION

Omietimi et al. (2022). This work entails the Campano-Maastrichtian deposits of the Nkporo and Mamu Formations of the Anambra Basin represent prospective hydrocarbon resources in southern Nigeria. Results from the research showed that West Africa experienced strong precipitation during the Cretaceous, leading to intense chemical weathering in the region, as documented by the geochemically matured sediments. The paleo-salinity (Sr/Ba) and paleo-productivity (Ba/Al and P/Ti) proxies showed that the studied mud rocks were deposited primarily in brackish to shallow-marine setting, with poor primary productivity due to terrestrial clastic influx and hydrodynamic influenced.

Abubakar et al. (2021). The shales of Sekuliye Formation were investigated to interpret their provenance history, weathering, and tectonic setting based on major and trace element geochemistry. The result showed that Sr/Ba ratios revealed high salinity during the deposition of the studied shale, reflecting a marine depositional environment. Also through geochemical studies, these sediments were classified as shales that are texturally immature and compositionally mature

Ejeh (2021). The geochemistry of Late Cretaceous sandstones and shales in the Anambra basin has been investigated by relatively few subsurface data-based studies. This paper presents the geochemistry of sandstones and shales from cored sections (n = 10) of the Amansiodo_1 well (located in the Anambra basin) with the

intent of unravelling the provenance, tectonic setting, and paleo-conditions. Major elements (n = 10) and the trace element concentrations of Sc, Be, V, Sr, Y, Zr, and Ba were obtained using fusion inductively coupled plasma. Trace (n = 24) and rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) concentrations were obtained using fusion mass spectrometry analytical method.

Malaza et al. (2016). The petrography and geochemistry (major, trace and rare earth elements) of clastic rocks from the Late Palaeozoic Madzaringwe Formation, in the Tshipise-Pafuri Basin, Northern South Africa, have been investigated to understand their provenance. Petrographic and geochemical results of the samples suggest uplifted basement source areas dominated by sedimentary rocks and/or granite-gneiss rocks.

Olawumi et al. (2014). Carried out an investigation that sediments of the Cretaceous Imo Formation were exposed at the south Western flank of Anambra Basin at Sobe, Arimogija and Okeluse area, South Western Nigeria. Petrographic study of these sandstone reveal that its constituents is averagely of angular to sub-angular quartz(85%), feldspar(1.4%), rock fragment (9.5%) and ≤ 3% cementing iron-oxide(goethite and hematite) phases, texturally immature and sub-arkosic.

CHAPTER TWO

LITERATURE REVIEW

2.1 Stratigraphy of the Niger Delta basin

The tectonics of the development of the Benue Trough and the geodynamics associated with the separation of the African and South American continents are both key factors in the evolution of the Niger Delta. The main causes of transgression and regression via the entrant point along the current Niger Delta area, as well as the deposition of marine and non-marine sediments from the late Aptian to the Eocene, are tectonic activity, climate, and eustasy. The subsidence of the Oligocene and younger Niger Delta basin along the NW-SE fault trends preceded the Santonian and later Campanian to Eocene positive motions of blocks bounded by NE-SW and NW-SE trending faults throughout the Benue Trough and the current Niger Delta region. From the Paleocene to the Eocene, the transgressive Imo Shale, the regressive Ameki Formation, and from the Eocene to the Recent, the Akata, Agbada, and Benin Formations filled the Anambra basin. Although rifting and tectonic subsidence are currently inactive, the basin is still in a sag regime with ongoing Benin Formation deposition and minimal alterations to the climate and eustasy. The Niger Delta basin current dynamics have led to a basin that is almost fully.

The three primary lithostratigraphic units identified in the Niger Delta's subsoil (Akata, Agbada, and (Benin Formations) illustrates the age regression of depositional settings inside the Niger Delta clastic wedge. Southern Nigeria has revealed stratigraphic equivalent units to these three formations (Short and Stauble, 1967). The formations were deposited in marine, deltaic, and river environments (Weber and Daukoru, 1975; Weber, 1986) and they show a gross coarsening-upward progradational clastic assemblage, indicate shallow maritime shelf developed, but a change in the climate and the associated eustasy might destabilize the area's ecosystem and have commensurate economic repercussion the delta.

Despite the fact that the stratigraphy of the Niger Delta clastic wedge has been documented throughout oil exploration and production. Short and Stauble (1967) provided a description of the stratigraphic development of the Tertiary Niger Delta and the underlying Cretaceous strata. Three books—Evamy et al. (1978), Doust and Omatsola (1990), and Tuttle et al. (1999)—describe the petroleum geology of the Niger Delta. Based on sequence stratigraphic techniques, Stacher (1995) created a hydrocarbon habitat model for the Niger Delta. The depositional conditions, sedimentation, and physiography of the contemporary Niger Delta were characterized by Allen (1965) and Oomkens (1974).

2.1.1. BENIN FORMATION

Studies on the Benin formation of the Elele-1 well, located 38 kilometers north of Port-Harcourt, were conducted by Short and Stauble in 1967.

Based on the identification of the first marine microfauna within the shale, scientists determined the base of the Benin Formation by analyzing ditch cutting samples obtained at every 10m intervals. The Benin Formation's lithology is primarily made up of sandstone that was deposited in a river and coastal setting. The sandstone is medium-coarse grained with minor gravelly admixtures and poorly sorted. At the base of the formation, there are lignite elements intercalated with small amounts of shale and clay. Alluvial and upper coastal plain sands from the continental last Eocene to Recent deposit are present in the Benin Formation and can reach thicknesses of up to 2000 m (Avbovbo, 1978). It is the newest formation in the Niger Delta strata, and the Agbada Formation lies underneath it. The formation has been connected with very little hydrocarbon accumulation.

2.1.2. AGBADA FORMATION

Sandstone and shale interbedded with one another were deposited in a transitional to marine paralic environment, making up the Agbada Formation.

The type of Agbada Formation segment identified by Short and Stauble (1967) was present in the Agbada II well, located northwest of Port-Harcourt. The base of the formation is defined as the base of the deepest sandstone body in all of the

vertical section, through the Niger Delta sediments, which corresponds with the top of the Akata marine shales. The top of the formation is indicated by the presence of shale that contains brackish water and marine fauna. This Formation, which constitutes the real, deltaic component of the series, is made up of paralic silicic clastic that is almost 3700 meters thick. Shale and sandstone beds were deposited in the lower Agbada Formation.

2.1.3. AKATA FORMATION

The Akata-ll well, located 80 kilometers to the east of Port-Harcourt, contains the part of this formation that Short and Stauble (1967) documented. Mostly plastic, low density, high pressure shallow marine to deep ocean shales make up this body of water. The Asu River group, a Major Stratigraphic Unit of the Albian age, and the calcareous Eze Aku shale, of the Turonian-Coniacian era, make up the oldest formation, the Akata Formation.

Marine-derived thick shale series (possible source rock), turbidity sand (possible reservoirs in deep water), and trace amounts of clay and silt make up the Akata Formation at the base of the Delta.

Starting from the Paleocene and ending in the Recent, when terrestrial organic matter and clays were moved to deep water regions during low stands, which were characterized by low energy levels and an absence of oxygen, the Akata Formation was created (Stacher 1995). According to Doust and Omatsola (1990), the structure

could be up to 7,000 meters thick. The formation, which supports the entire delta, is frequently under pressure.

2.2. LOCAL GEOLOGY OF IMO FORMATION

Earlier names for the Imo Formation were Imo-Anambra Shales and Imo Clay-Shales. Overlying the Nsukka Formation is the Imo Shale. It consists mostly of thick, fine-grained, dark grey or blue grey shale, with sporadic additions of clay, ironstone, thin sandstone bands, and limestone intercalations. The Formation alternates between sandstone and shale at the top, where it becomes sandier. The Imo Shale is a geologic unit that is widely dispersed across several hundred kilometers, from Nigeria's southeast border to the Niger Delta to its western border. Murat claimed that during the Paleocene, when transgression circumstances were once again present in the Anambra basin, the Imo Shale was deposited. According to Nwajide and Reijers, the Imo shale represents a shallow sea shelf with sporadically preserved foreshore and shoreface. Nwajide and Reijers further implied that the Imo shale of the Anambra basin is the source of the subsurface Paleocene deposits in the Niger Delta, which are now of deep marine provenance. Foraminifera are used to date the Imo Shale as Paleocene, although Berggren claimed that the formation's top portion is Lower Eocene in age. For the Imo Shale, Oloto also reported Late Paleocene to Early Eocene. Imo Shale was dated by

Durugbo as being Middle Paleocene to Early Eocene, and a nearshore to marginal marine paleo-environment was indicated.

CHAPTER THREE

METHOD AND MATERIAL

3.1 METHOD OF STUDY

Twenty-two (22) ditch cutting samples were obtained from Egboha well near Okada in Ovia North-East in Edo state. The sampling interval was 10ft and the well covered a depth of 300ft. After the samples were obtained, the samples were described and acid test was carried out on them.

3.1.1 TEST FOR EFFERVESCENCE (CARBONATE MINERALS):

Samples were also taken to Geochemistry Laboratory in the Department of Geology in University of Benin, Benin-City, Edo State. Where the test for effervescence were carried out as follows;

1. A small portion of a sample was put into a mortar using spatula, after which was pulverized with a pestle against the mortar, to obtain either a very fine or fine texture.
2. With a spatula, the pulverized sample was placed on a and the lithology of sample was recorded.
3. After which dilute HCl acid was used to test for the presence of effervescence which indicates the presence of gas bubbles. It's like a fizzy reaction. Degree of effervescence ranging from 1(low), 2(medium) and 3(high).

4. The presence of effervescence in a sample denotes presence of Carbonate minerals.
5. These procedures were repeated for all 22 samples, and results were recorded.

3.1.2 GEOCHEMICAL ANALYSIS:

Samples were taken to Activation Laboratory located at 41 Bittern Street, Ancaster, ON, L9G 4V5, Canada. Where the Ultra trace 7 - Peroxide Fusion - ICP and ICP/MS tests were carried out as follows:

1. Samples are fused with sodium peroxide in a Zirconium crucible. The fused sample is acidified with concentrated nitric and hydrochloric acids. The resulting solutions are diluted and then measured by ICP-OES and ICP-MS. All metals are solubilized.

2. ICP-MS: Fused samples are diluted and analyzed by ICP-MS. Calibration is performed using five synthetic calibration standards. A set of (10-20) fused certified reference material is run with every batch of samples for calibration and quality control. Fused duplicates are run every 10 samples.

3. ICP-OES: Samples are analyzed with a minimum of 10 certified reference materials for the required analytes, all prepared by sodium peroxide fusion. Every 10th sample is prepared and analyzed in duplicate; a

blank is prepared every 30 samples and analyzed. Samples are analyzed using an ICP and internal standards are used as part of the standard operating procedure.

3.2 EQUIPMENT USED FOR THIS STUDY

1. Dilute Hydrochloric Acid: It is used to test for effervescence in each sample after they have been pulverized.

Figure 3: Dilute Hydrochloric Acid

2. Laboratory spatula: It was used for scraping and transferring samples from one place to another.

Figure 4: Laboratory spatula

3. Laboratory mortar and pestle: They are used to pulverize the samples to get a very fine or fine grain texture. After pulverizing each sample, the mortar and pestle are thoroughly cleaned to prevent the previous sample from the getting mixed with the new sample and altering the result of the new sample.

Figure 5: Laboratory mortar and pestle

4. ICP-MS Instrument: ICP-MS (Inductively coupled plasma mass spectrometry). It is a technique used to analyze the elemental composition of a sample or used to interpret the concentration of chemical elements in samples.

Figure 6: ICP-MS Instrument

5. ICP-OES Instrument: ICP-OES (inductively coupled plasma optical emission spectroscopy), it is also known as inductively coupled plasma atomic emission spectroscopy (ICP-AES). It is an analytical technique used for the detection of chemical elements, just like ICP-MS.

Figure 7: ICP-OES Instrument

CHAPTER FOUR

PRESENTATION AND INTERPRETATION OF RESULTS

Table.1: Elemental proxy concentrations in (wt %) or ppm of samples from late Paleocene, Imo Formation on the Niger Delta Basin

Sample Interval of Egboha Well	Al (wt %)	Ba (ppm)	Mo (ppm)	Ni (ppm)	Si (wt %)	Sr (ppm)	Ti (wt %)	U (ppm)
Egboha 30-40Ft	5.57	240	3	40	30	15.5	0.55	2.6
Egboha 50-60Ft	5.41	370	4	50	16.2	14.3	0.31	2
Egboha 90-110Ft	5.98	812	3	50	24	15.3	0.38	2.1
Egboha 120-130Ft	2.54	2140	6	50	10.7	7.4	0.18	3.9
Egboha 160-170Ft	5.55	689	4	40	25.5	13.5	0.42	2.9
Egboha 170-180Ft	7.94	121	4	50	19.1	20.7	0.47	6.9
Egboha 200-210Ft	8.27	134	5	50	20.9	22.5	0.54	4.3
Egboha 230-240Ft	8.64	138	6	50	21.3	23.5	0.53	3.4
Egboha 270-280Ft	4.62	109	5	50	14.3	13.3	0.29	7.2
Egboha 290-300Ft	2.47	69	6	40	7.35	7.7	0.15	5.1

Table 2 : **Sample Interval of Egboha Well and the Ratios of Elemental Proxies**

Sample Interval of Egboha Well	Si/Al	Ti/Al	Sr/Ba	Ba/Al	Mo/Al	Ni/Al	U/Al
Egboha 30-40Ft	5.385996	0.098743	0.064583	43.08797	0.5386	7.181329	0.466786
Egboha 50-60Ft	2.994455	0.057301	0.038649	68.39187	0.739372	9.242144	0.369686
Egboha 90-110Ft	4.013378	0.063545	0.018842	135.786	0.501672	8.361204	0.351171
Egboha 120-130Ft	4.212598	0.070866	0.003458	842.5197	2.362205	19.68504	1.535433
Egboha 160-170Ft	4.594595	0.075676	0.019594	124.1441	0.720721	7.207207	0.522523
Egboha 170-180Ft	2.405542	0.059194	0.171074	15.23929	0.503778	6.297229	0.869018
Egboha 200-210Ft	2.527207	0.065296	0.16791	16.20314	0.604595	6.045949	0.519952
Egboha 230-240Ft	2.465278	0.061343	0.17029	15.97222	0.694444	5.787037	0.393519
Egboha 270-280Ft	3.095238	0.062771	0.122018	23.59307	1.082251	10.82251	1.558442
Egboha 290-300Ft	2.975709	0.060729	0.111594	27.93522	2.42915	16.19433	2.064777

4.1 GRAIN SIZE/ DETRITAL INFLUX

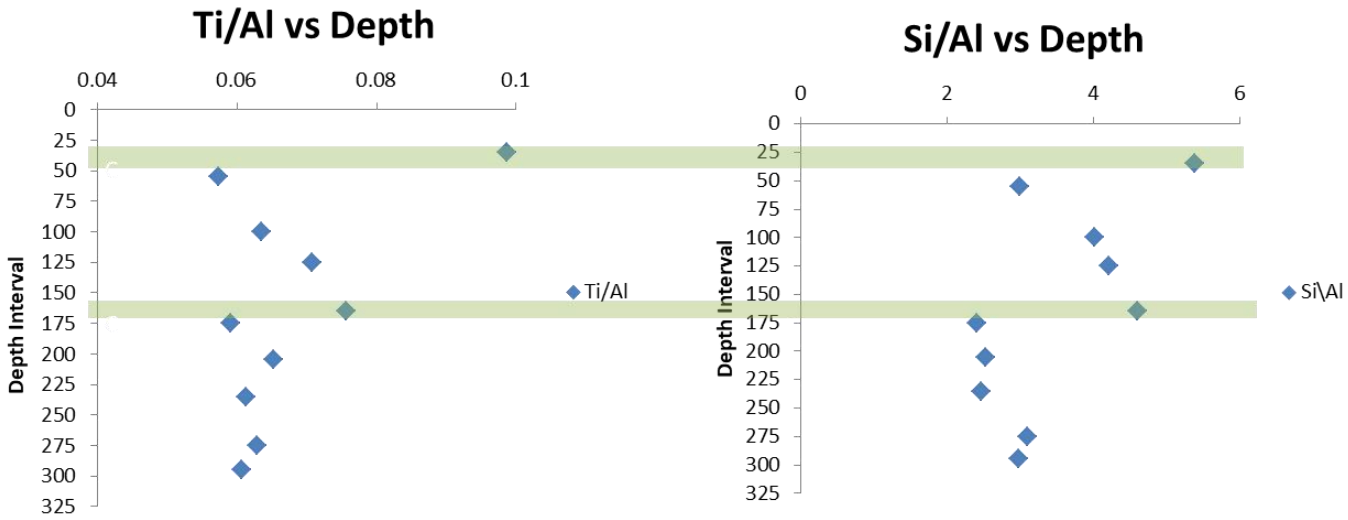

Fig.8: Plot of Si/Al and Ti/Al against depth interval, showing grain size/detrital influx

Grain sizes are the size of individual particles in sediment or soil. It can range from fine (small particles) to coarse (large particles).

Detrital influx refers to the input of detrital or sedimentary material into a geological system. It can influence various geochemical processes, such as the composition of sedimentary rocks and the transport of elements and minerals.

The Si/Al and Ti/Al ratios are likely used as geochemical proxies to understand changes in sediment composition or environmental conditions over time or depth. The plot may reveal trends or patterns in these ratios, indicating shifts in the source materials or depositional processes that influenced the sediment's composition at various depths.

From the Fig.8: above, the depth intervals between 25-50ft highlighted shows that the grain size is coarse grain and there is an increase in detrital influx, also for the depth interval between 150-175ft highlighted in the fig.9: above, it shows that the grain size is coarse grain and there is an increase in detrital influx.

4.2 PALEO-SALINITY

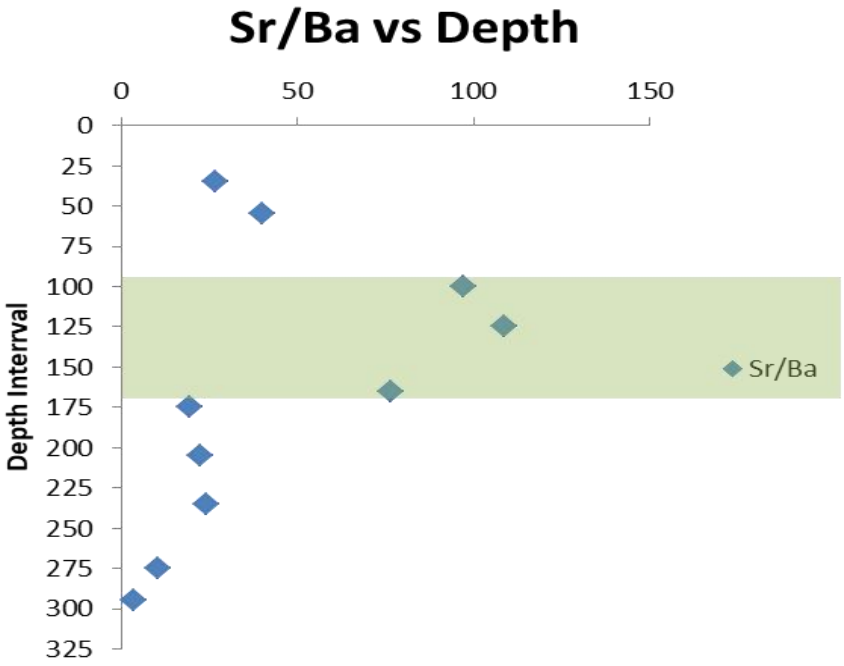

Fig 9: Plot of Sr/Ba against depth interval, showing the paleo-salinity

Paleo salinity described as the estimation or reconstruction of past salt concentrations in ancient environments. It provides insights into changes in water composition, climate, and geological processes over time.

This plot provides valuable information about paleo-salinity variations through different depth intervals. The Sr/Ba ratio is often utilized in paleoceanographic studies as a proxy for tracing changes in past seawater salinity.

By plotting Sr/Ba against depth intervals, variations in the Sr/Ba ratio can be indicative of fluctuations in salinity over time.

From the fig.9: above where Sr/Ba plotted against depth intervals, between the depth intervals of 100 - 175ft highlighted, it shows an increase in paleo-salinity, which indicates high salt content. Low paleo-salinity can be observed at other depths

4.3 PALO-PRODUCTIVITY

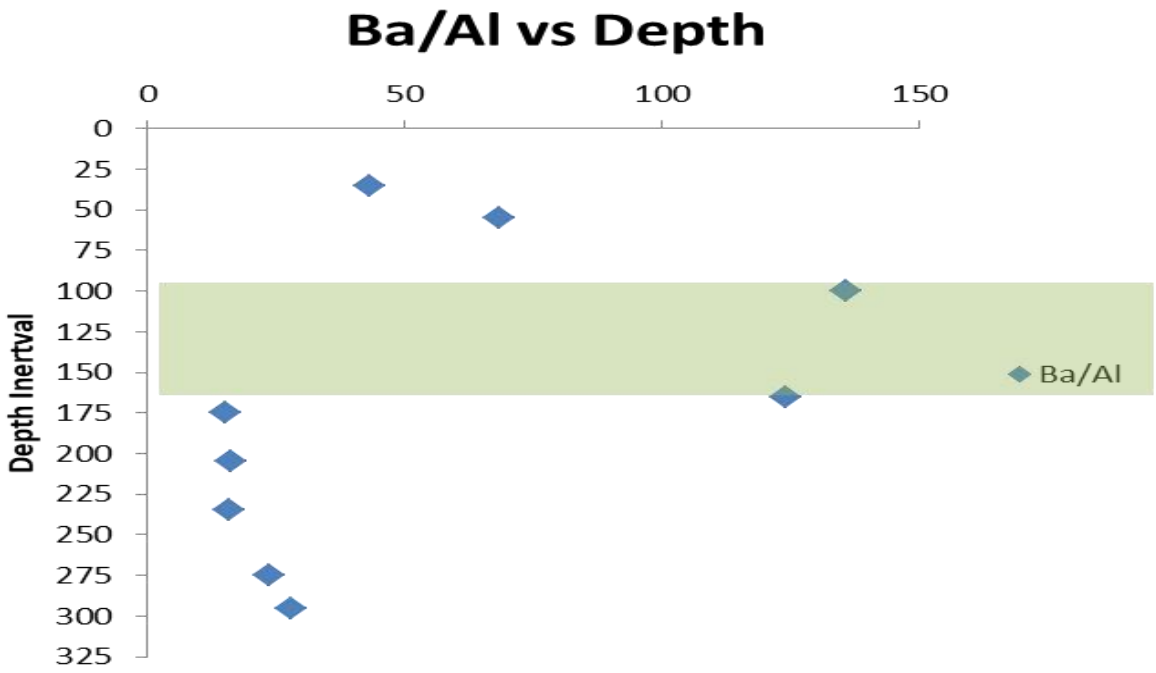

Fig 10: Plot of Ba/Al against depth interval, showing the paleo-productivity

Paleo productivity refers to the study of past biological productivity in ancient environments. It involves analyzing chemical signatures in rocks or sediments to understand the productivity of organisms such as phytoplankton or plants in the past.

This plot is a valuable tool for studying paleo-productivity over different depth intervals. The Ba/Al ratio is commonly used in paleoceanography and sedimentary studies as an indicator of past marine productivity.

By plotting Ba/Al against depth interval, variations in the Ba/Al ratio can provide insights into changes in biological productivity in ancient marine environments.

From the fig.10: above where Ba/Al is plotted against depth intervals, between the depth intervals of 75- 170ft highlighted shows an increase in the paleo-productivity which indicates high productivity of organisms during the Paleocene period. At other depths, low productivity of organisms can be observed.

4.4 PALEO-REDOX

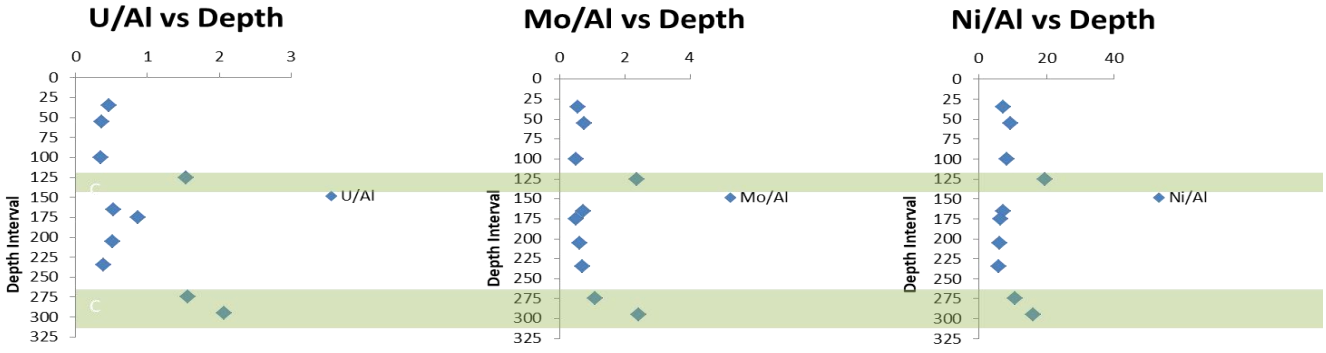

Fig 11: Plot of U/Al, Mo/Al and Ni/Al against depth interval, showing the paleo-redox

Paleo-redox is the study of past changes in the redox (oxidation-reduction) conditions of Earth's environments. It helps us understand how oxygen levels and other elements have evolved over time.

This plot provides a glimpse into the paleo-redox conditions at different depth intervals. The ratios of U/Al, Mo/Al, and Ni/Al are often used in geochemical studies to assess changes in past redox (oxidation-reduction) environments within sedimentary layers.

By charting these ratios against depth intervals, variations in U/Al, Mo/Al, and Ni/Al ratios can offer insights into shifts between oxic (well-oxygenated), suboxic (limited oxygen), and anoxic (absence of oxygen) states in ancient marine or sedimentary settings.

From the Fig.11: above, at the different depth intervals highlighted, shows an enrichment of (U, Mo, Ni) and the oxygen level being suboxic-anoxic environment ($O_2 > 0.2$ - $O_2 < 0.2$).

CHAPTER FIVE

CONCLUSION

5.1 SUMMARY

Major, Trace and Rare-Earth elements data can be used to investigate the grain size, paleo-salinity, paleo-productivity, depositional environment and paleo-redox conditions of the Geochemistry of Imo formation in the late Paleocene

In this study, our investigation focused on the geochemical attributes of the Imo Formation, an important geological unit in the studied area. The Imo Formation composed mainly of sedimentary rocks and the insights it provides into past environmental conditions.

5.2 CONCLUSION

1. Sedimentary Deposition: The Imo Formation exhibits clear evidence of sedimentary deposition, characterized by distinct layers and sedimentary structures. These features suggest that the region experienced a series of environmental changes over geological time scales.

2. Geochemical Signatures: Geochemical analysis revealed the presence of various elements and minerals within the Imo Formation. These compositions shed light on the source of sediments, the depositional environment, and the diagenetic processes that have affected the rocks over time.

3. Implications for Regional Geology: Our findings contribute to a deeper understanding of the geological history of the region. The Imo Formation is a significant unit within the broader geological context and plays a role in the reconstruction of past geological events.

In conclusion, this study has offered valuable insights into the geochemical aspects of the Imo Formation. The sedimentary deposition and geochemical signatures all contribute to our understanding of the formation's history and its implications for regional geology. Further research and analysis in this area hold the potential for even greater discoveries and a more comprehensive understanding of the geological evolution of the Imo Formation.

5.3 SUGGESTION FOR FURTHER STUDIES

Further studies should be carried out using AAS (Atomic Absorption Spectroscopy) used in order to identify trace elements.

REFERENCES

Abubakar, U. Usman, M.B., Aliyuda, K., Dalha, A., Bello, A.M. and Linus, L.N., 2021. Major and trace element geochemistry of the shales of Sekuliye Formation, Yola Sub-Basin, Northern Benue Trough, Nigeria: implications for provenance, weathering intensity, and tectonic setting. Journal of Sedimentary Environments, 6(3), pp.473-484

Adegoke .A.K., Abdullah.W.H., Hakimi M.H., 2014. Geochemical characterisation of Fika formation in the chad (Bornu) basin, northeastern Nigeria: implications for depositional environment and tectonic setting, Applied Geochemistry, 3, 1–12

Adesina. A.M., Adeola. A.V., and Oke, A.O., 2017. Aspects of hydrocarbon potential of the Tertiary Imo Shale Formation in Anambra Basin, Southeastern Nigeria. IOSR Journal of Applied Geology and Geophysics, 5(5), pp.74-83.

Ajibola. O., and David. O., 2004. The sequence stratigraphy of Niger Delta, Delta Field, Offshore Nigeria. Unpublished MSc Thesis, Texas A and M University, pp.1-99.

Allen. J.R.L., 1965, Late Quaternary Niger Delta, and adjacent areas-sedimentary environments and lithofacies: AAPG Bulletin, v.49, p.547-600

Avbovbo.A.A., (1978). Tertiary lithostratigraphy of Niger Delta: Am. Assoc. Petro. Geo. Bull. 62. 295- 306.

Berggren.W. A., 1960 Paleocene biostratigraphy and planktonic foraminifera of Nigeria (W. Africa). Proceedings of the 21st Intern'l Geol. Congress, Copenhagen, ,4-55.

Chen.S.C. Wu D., Liu G.J., 2016. Geochemistry of major and trace elements in Permian coal: with an emphasis on No. 8 coal seam of Zhuji coal mine, Huainan Coalfield, China, Environmental Earth Sciences, 75, 494–500.

Doust, H., and E. Omatsola, 1990, Niger delta: in J. D. Edwards and P.A. Santogrossi ,eds., Divergent/passive margin basins: AAPG Memoir 48, p. 239-248

Durugbo.E. U., Palynostratigraphy, 2013 Age determination and Depositional Environments of the Imo Shale exposures at the Okigwe/Port Harcourt express road junction, southeastern Nigeria.Greener Journal of Physical Sciences, 3 (7), , 255-272.

Ejeh, O.I., 2021. Geochemistry of rocks (Late Cretaceous) in the Anambra Basin, SE Nigeria: insights into provenance, tectonic setting, and other palaeo-conditions. Heliyon, 7(10).

Evamy. B.D., J. Haremboure, R. Kammerling, W.A. Knaap, F.A. Molloy, and P.H. Rowlands,1978. Hydrocarbon habitat of tertiary Niger Delta: AAPG Bulletin, v.62:1-39.

Fregene.T.J., and Onyeachonam, N., 2021. Chemical Classification of Sediments in JVX-Well, Greater Ughelli Depobelt Niger Delta Basin, Nigeria. Journal of Applied Sciences and Environmental Management, 25(6), pp.995-1001.

Gao. G., Titi. A.,Yang S.R., 2017. Geochemistry and depositional environment of fresh lacustrine source rock: a case study from the Triassic Baijiantan Formation shales in Junggar Basin, northwest China, Organic Geochemistry, 113, 75–89.

Ivanic. M., Lojen. G., Dino. J.I., 2017. Geochemistry of sedimentary organic matter and trace elements in modern lake sediments from transitional karstic lan sea environment of the Neretva River delta (Kuti Lake, Croatia), Quaternary International, 494, 286–299

Ji. H., Tao. H., Wang Q., 2019. Petrography, geochemistry, and geochronology of lower jurassic sedimentary rocks from the Northern Tianshan (west Bogdan area), northwest China: Implications for provenance and tectonic evolution, Geological Journal, 54, 1688–1714.

Lopez.J.P., Altenberger .U., Bellos. L.I., 2019. The Cumbres Calchaquíes range (NW-Argentina). geochemical sedimentary provenance, tectonic setting and metamorphic evolution of a Neoproterozoic sedimentary basin, Journal of South American Earth Sciences, 93, 480–49

Malaza.N., Liu. K., and Zhao. B., 2016. Petrology and geochemistry of clastic sedimentary rocks as evidences for provenance of the Late Palaeozoic Madzaringwe Formation, Tshipise-Pafuri Basin, South Africa. Science China Earth Sciences, 59, pp.2411-2426.

Murat. R. C,. **1972** Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria.In T.F. J. Dessauvigie and A.J. Whiteman eds. African Geology,University of Ibadan press, , 635 - 648

Nwajide. C. S., and Reijers.T. J. A, 1996 Sequence architecture in outcrops: examples from the Anambra basin. NAPE Bull.11, , 23-32.

OLAWUMI. H.B., BALE. R.B., and Adesina. S., 2014 Sedimentology and Geochemical Characteristics of Upper Cretaceous Sediments of Imo Formation Around Arimogija Okeluse, Southwestern Nigeria.

Oloto .I. N., 1992, Sucession of palynomorphs from early Eocene of Gbekebo-1 well in S. W. Nigeria, Journal of African Earth Sciences,15 (3/4), 441-452.

Omietimi. E.J., Lenhardt. N., Yang. R., Götz. A.E., and Bumby, A.J., 2022. Sedimentary geochemistry of Late Cretaceous-Paleocene deposits at the southwestern margin of the Anambra Basin (Nigeria): Implications for paleoenvironmental reconstructions. Palaeogeography, Palaeoclimatology, Palaeoecology, 600, p.111059.

Oomkens, E., 1974. Lithofacies relations in late Quaternary Niger delta complex: Sedimentology, v.21, p.195-222.

Qin. J.W., Wang. S.Q., Sanei. H., 2018. Revelation of organic matter sources and sedimentary environment characteristics for shale gas formation by petrographic analysis of middle Jurassic Dameigou formation, northern Qaidam Basin, China, International Journal of Coal Geology, 195, 373–185

Ross, D.J. and Bustin, R.M., 2009. Investigating the use of sedimentary geochemical proxies for a paleoenvironment interpretation of thermally mature organic-rich strata: Examples from the Devonian–Mississippian shales, Western Canadian Sedimentary Basin. Chemical Geology, 260(1-2), pp.1-19.

Short. K. C., and A. J. Stauble, 1967, Outline of Geology of Niger delta: American Association of Petroleum Geologists Bulletin v. 51, p. 761-779.

Stacher. P.,1995, Present understanding of the Niger delta hydrocarbon habitat, in Oti, M. N. and Postma, G., eds., Geology of deltas: Rotterdam, A.A. Balkema, p. 257-267.

Tuttle. M. L., Charpentier .W. R. R., and Brownfield. M. E., 1999, The Niger delta petroleum system: Niger delta province, Nigeria, Cameroon, and Equatorial Guinea, Africa: USGS Open-file report 99-50-H.

Weber. K.J., and . Daukoru E.M., 1975, Petroleum geology of the Niger delta: Proceedings of the 9th World Petroleum Congress, Tokyo, v. 2, p. 202-221

Weber.K.J., 1986, Hydrocarbon distribution patterns in Nigerian growth fault structures controlled by structural style and stratigraphy: AAPG Bulletin, v. 70 p. 661-662

Wirth. S.B., Gilli. A., Niemann H., 2013. Combining sedimentological, trace metal (Mn, Mo) and molecular evidence for reconstructing past water-column redox conditions: the example of meromictic Lake Cadagno (Swiss Alps). Geochimica ET Cosmochimica Acta, 120, 220–238

Xiaochun Zuo, Cunlei Li, Jinliang Zhang, Guiyang Ma, Panpan Chen, 2020 Geochemical characteristics and depositional environment of the Shahejie Formation in the Binnan Oilfield, China, Journal of Geophysics and Engineering, Volume 17, Issue 3, , Pages 539–551,

Yan.Y., Xia. B.. Lin.X.J., 2007. Geochemistry of the sedimentary rocks from the Nanxiong Basin, South China and implications for provenance, paleoenvironment and paleoclimate at the K/T boundary, Sedimentary Geology, 197, 127–140.