

**THE GEOCHEMICAL STUDY OF IMO FORMATION, OBARETIN
WELL, NEAR OKADA, OVIA NORTH EAST, SOUTHERN NIGERIA**

BY

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BENIN CITY, NIGERIA.**

SEPTEMBER, 2023

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF GEOLOGY
UNIVERSITY OF BENIN IN PARTIAL FUFILMENT OF THE
REQUIREMENT FOR THE AWARD OF DEGREE OF BACHELOR OF
SCIENCE (B.Sc) IN GEOLOGY**

SEPTEMBER, 2023

CERTIFICATION

This is to certify that this Project was carried out by **Kelvin OJO** of the Department of Geology, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria.

Dr JOEL. EDEGBAI
Supervisor

Date

Dr S.A. SALAMI
Head of Department

Date

DEDICATION

I dedicate this project especially to God Almighty, my wonderful parents **Mr. and Mrs. OJO**, my siblings, colleagues and friends.

ACKNOWLEDGEMENT

I give thanks to God Almighty who stood by me from the beginning of this program to the end in the course of my study in this great citadel of learning.

Much appreciation to my Supervisor Dr. Joel. Edegbai, for your training and guidance in making this project work a success.

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TABLE OF CONTENTS

Contents	Pages
Title page - - - - -	i
Certification - - - - -	ii
Dedication - - - - -	iii
Acknowledgement - - - - -	iv
Table of Contents - - - - -	vi
List of Figures - - - - -	viii
List of Tables - - - - -	ix
Abstract - - - - -	x
 CHAPTER ONE	
Introduction - - - - -	1
1.1 Elemental Geochemistry - - - - -	1
1.1.1 Major Element - - - - -	2
1.1.2 Trace Element - - - - -	3
1.1.3 Rare Element - - - - -	4
1.2 Aim and Objectives - - - - -	5
1.3 Location of study area - - - - -	6
1.4 Stratigraphy control - - - - -	8

1.5 Previous work	-	-	-	-	-	-	-	-	11
-------------------	---	---	---	---	---	---	---	---	----

CHAPTER TWO

LITERATURE REVIEW	-	-	-	-	-	-	-	-	12
-------------------	---	---	---	---	---	---	---	---	----

2.1 Niger Delta Basin	-	-	-	-	-	-	-	-	13
-----------------------	---	---	---	---	---	---	---	---	----

2.2 Stratigraphy of Niger Delta Basin	-	-	-	-	-	-	-	-	14
---------------------------------------	---	---	---	---	---	---	---	---	----

2.3 Structural Development of Niger Delta	-	-	-	-	-	-	-	-	16
---	---	---	---	---	---	---	---	---	----

2.4 Geological View of Imo Formation	-	-	-	-	-	-	-	-	16
--------------------------------------	---	---	---	---	---	---	---	---	----

CHAPTER THREE

Materials and Methodology	-	-	-	-	-	-	-	-	19
---------------------------	---	---	---	---	---	---	---	---	----

3.1 Ditch Cuttings Sample	-	-	-	-	-	-	-	-	19
---------------------------	---	---	---	---	---	---	---	---	----

3.2 Effervescence Test	-	-	-	-	-	-	-	-	19
------------------------	---	---	---	---	---	---	---	---	----

3.3 Geochemical Analysis	-	-	-	-	-	-	-	-	20
--------------------------	---	---	---	---	---	---	---	---	----

3.4 Equipment Used For Study	-	-	-	-	-	-	-	-	21
------------------------------	---	---	---	---	---	---	---	---	----

CHAPTER FOUR

Results and Interpretation	-	-	-	-	-	-	-	-	25
----------------------------	---	---	---	---	---	---	---	---	----

4.1 Grain size	-	-	-	-	-	-	-	-	27
----------------	---	---	---	---	---	---	---	---	----

4.2 Paleo salinity	-	-	-	-	-	-	-	-	30
--------------------	---	---	---	---	---	---	---	---	----

4.3 Paleo Productivity	-	-	-	-	-	-	-	-	31
------------------------	---	---	---	---	---	---	---	---	----

4.4 Paleo oxyegation	-	-	-	-	-	-	-	-	33
----------------------	---	---	---	---	---	---	---	---	----

CHAPTER FIVE

Conclusion and References	-	-	-	-	-	-	-	37
5.1 Summary	-	-	-	-	-	-	-	37
5.2 Recommendation	-	-	-	-	-	-	-	38
5.3 References	-	-	-	-	-	-	-	39

LIST OF TABLES

Table 1: Results of selected trace elements for proxies studies.

LIST OF FIGURES

Figure 1: Location map of Obaretin 1 Well Niger Delta Basin

Figure 2: Geologic map of the area

Figure 3: ICP-MS Instruments

Figure 4: ICP-OES Instruments

Figure 5: spatula

Figure 6: mortar and pestle

Figure 7: dilute hydrochloric acid

Figure 8: The lithology of the study area showing the different lithologic units and sample points with blue stars

Figure 9: A graph showing the grain size trend line with the use of trace element proxies such as: (a) Si/Al (b) Ti/Al

Figure 10: A graph showing the Paleo salinity trend line with the use of trace element proxies such as: (a) Sr/Ba

Figure 11: A graph showing the Paleo Productivity trend line with the use of trace element proxies such as: (a) Si/Al (b) Ti/Al

Figure 12: A graph showing the Paleo oxygenation trend line with the use of trace element proxies such as: (a) Mo/Al (b) V/Al

Figure 13: Trendline for paleo oxygenation

Figure 14: trendline for paleooxygenation, (a) Ni/Co (b) v/v+Ni/Co

Figure 15: Trendline for paleooxygenation (a)V/Cr

ABSTRACT

The research looked at the sedimentary process and the exact period of environmental deposition in the imo formation. From the thirty-two (32) ditch cutting samples that were collected and processed, twelve (12) samples were forwarded to the Activation Laboratory for geochemical analysis with the aid of the Ultratrace 7 package. The sample was taken from a depth interval of 1060 feet (1,060 meters) at the Obaretin Well in Nigeria's Benin flanks, where it undergone a complete geochemical study. Twelve samples were taken, and they underwent an effervescence test using diluted hydrochloric acid (Hcl). On the sample, carbonate was detectable. There was some strong (3), moderate (2), and weak (1) effervescence notices. Applying the aforementioned elemental proxies, such as trace, major, rare element the following was determined: grain size, paleosalinity, paleoproductivity, and paleooxygenation.

For the grain size, silicon and aluminum, (Si/Al), when silicon increase the aluminium decrease the grain size from sample was coaser and larger in size.

While strontium and barium (Sr/Ba) were the proxies used for paleosalinity, the trend line shows that higher salinities created marine environments, while lower salinities create river channels. A decline in paleoproductivity results in a low input of terrigenous material, whereas an increase in paleoproductivity results in deposits of rich terrigenous material. Barium and aluminum (Ba/Al) were utilized as proxies in the paleoproductivity study.

Oxic, suboxic, and anoxic environments are the core topics of paleo oxygenation.

Numerous elemental proxies, such as Molybdenum and Vanadium (Mo/V), were

employed. Environment quality is determined by paleooxygenation. This study has helped in understanding fully about the sedimentary processes and depositional environment.

CHAPTER ONE

INTRODUCTION

Geochemical analysis is useful in evaluating geological processes such paleo-environmental, paleo oceanographic, paleo climate, and provenance reconstruction (Gavrilov et al., 2017; Podkovyrov et al., 2017). For example the distribution of elements in rocks depend on the physical/chemical properties of the elements themselves, and on the other hand, it is influenced by the paleoclimate and paleoenvironment (Xu *et al.*, 2018; Lopez *et al.*, 2019). In various sedimentary contexts, aqueous conditions and paleoclimatic circumstances can lead to the aggregation or dispersion of components (Chen et al. 2013). The paleosedimentary environment can be recreated either qualitatively or semi-quantitatively by choosing those constituents or combinations of elements that are sensitive to water conditions and paleoclimate, including paleosalinity, paleooxygenation, and paleoclimate.

This particular area of study has been the subject of extensive prior research. For instance, Frederickson & Reynolds (1959) and Couch (1971) employed boron to qualitatively or quantitatively restore historical salinity and paleowater depth. The ratio of V to V+Ni was utilized by Jones & Manning (1994) and Tribovillard et al. (2006) to assess the oxidation of aqueous media under reduction circumstances. According to the findings, quartz and calcite's diluting action causes some elements to be lost during the transportation of sandstone, but mudstone is highly stable and retains the most source information possible. In order to identify provenances using trace elements, mudstone is therefore preferable to sandstone (Liu & Zhou 2007; Grimes et al. 2015).

Sedimentary records have been widely used in paleoenvironmental reconstruction because they are believed to faithfully archive original lithologic characteristics and record the climatic changes during the deposition (Gallet et al., 1996, Ding et al., 2001). Recent studies indicate relationships between some chemical elements and environmental changes. Specifically, elementary abundance is found to be influenced by many factors, including weathering, erosion, transportation and deposition of sediment (Algeo and Maynard, 2004, Tribovillard et al., 2006, Skurzyński et al., 2019). Quantitative analysis of major and trace elements in sediments from the field sections is one of the most commonly used methods to discern the sedimentary environment and provenance (Liu and Zhou, 2007). In this study, efforts are made to analyze major and trace elements as well as elemental ratios in sediments and how they can be used to reconstruct the paleo climate, paleo salinity, and paleoredox of the environment. Our findings are expected to provide insights into future studies on the Paleocene environmental.

1.1 ELEMENTAL GEOCHEMISTRY

In elemental geochemistry, the study of rare, major, and trace elements provides a comprehensive view of Earth's geological materials, their origins, and their interactions over geological time scales. These elements offer valuable insights into geological processes, mineralogy, petrology, and environmental science, an every aspect of geology. These elemental geochemistry also involves evaluating the concentrations of major, trace and rare earth elements.

1.1.1 MAJOR ELEMENT

Chemical elements that frequently exist in rocks and minerals at quantities more than 0.1% by weight are referred to be important elements in geochemistry. These materials are the most common and important parts of the crust of the Earth

and are used to classify and comprehend various types of rocks. The major elements that are most frequently found in geology are Silicon (Si), Oxygen (O), Aluminum (Al), Iron (Fe), Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Titanium (Ti), Hydrogen (H), Carbon(C), Sulfur(S). Understanding the organic content and potential for the shale to produce petroleum requires an understanding of the primary elements in shale, such as carbon, hydrogen, and sulfur. High concentrations of these elements in the Imo shale suggest that it has advantageous source rock qualities and may be able to produce sizable volumes of petroleum. For example oxygen index can be determined using major elements like aluminum, calcium and sodium. The oxygen index which calculates the volume of oxygen needed to thoroughly oxidize the sample, is frequently used to know the thermal maturity of shale.

1.1.2 TRACE ELEMENT

Chemical components known as traces are found in extremely minute quantities in rocks, soils, water, and living things. Numerous geological, biological, and environmental processes depend on them. Lead, arsenic, zinc, copper, and other elements are examples of trace elements.

Furthermore, the presence of certain trace elements can provide information about the depositional environment and source of the organic matter, which can be useful for understanding the shale's petroleum potential. Trace elements in imo shale can have a positive impact on the rock's source properties, such as its total organic carbon content and thermal maturity.

It also affect the shale's mineralogy, porosity, and brittleness, which can impact its ability to generate and expel hydrocarbons during maturation.

1.1.3 RARE EARTH ELEMENT

Rare earth elements (REEs) in Imo shale can have a positive impact on the rock's source properties, such as its total organic carbon content and thermal maturity. The presence of REEs can also be used as a geochemical tracer to identify the source of the organic matter in the shale, which can aid in exploration and production efforts.

In order to better support exploration and production operations, the presence of rare earth element can also be employed as a geochemical tracer to pinpoint the origin of the organic matter in the shale. Rare earth element can also be mined from shale and employed in a wide range of commercial and technological processes, such as the manufacture of powerful magnets, batteries, and electrical gadgets. However, because of the low amounts of these elements and the intricate mineralogy of the shale, extracting rare earth element from it can be difficult and expensive. However, the advantages of rare earth element extraction from shale have raised interest in this field of study.

These qualities suggest that there is a chance for the Imo shale to produce large amounts of gas and oil. Algal and terrestrial organic materials combine to make up the organic matter in the Imo shale. The Imo shale's kerogen/ source rock is primarily type II, which is a sign of marine organic materials. Significant levels of sulfur are also present in the Imo shale, which may have an impact on the hydrocarbons produced.

Stable carbon isotopes, gas chromatography-mass spectrometry (GC-MS), and Rock-Eval pyrolysis organic petrography (kerogen type analysis, maceral analysis, vitrinite reflectance), have all been used to examine the petroleum geochemistry of

the Imo shale. The content and quality of the hydrocarbons that can be produced from the Imo shale have been usefully uncovered by these investigations.

1.2 AIM AND OBJECTIVES

Aim: To determine the nature of depositional process that occurred during the Paleocene in the Northern delta depobelt, Niger delta Basin and also to understand the composition of the rock and the processes that led to its formation during this process of deposition.

Objectives

1. To recognize the various type of lithology that exist in my study area.
2. Determining whether effervescence exists in each type of lithology in the research area.
3. Determine the Paleo-salinity, Grain size, Paleo-environment and Paleo-productivity of the study area.
4. To Identify the Lithofacies type, age, and mineralogy of the clay in the research area.
5. Determine paleo-oceanography, paleo-climate and provenance study reconstruction of the research area.

1.3 LOCATION OF THE STUDY AREA

The study area Obaretin, is geographically located in Ovia North-East, Local Government of Edo, Nigeria.

The area falls along the Niger Delta basin Province of Nigeria.

GPS Coordinates: N 5°.458771, E 6°.632194

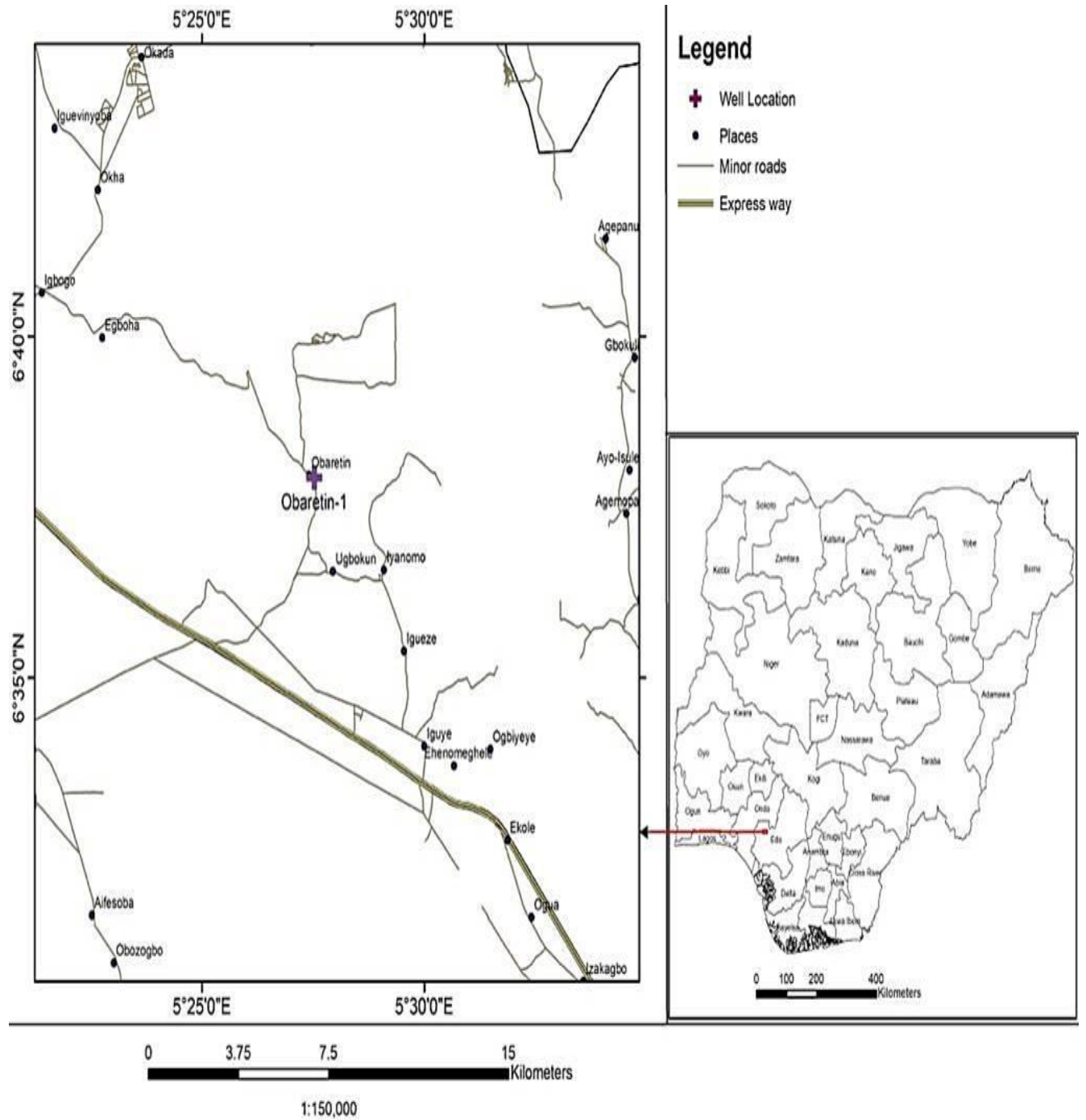


Figure 1: Location map Obaretin well (60ft – 1120ft), Niger Delta Basin.

1.4 STRATIGRAPHIC CONTROL

These helps to know the local map below owing that the coordinates of the location obaretin in Edo state.

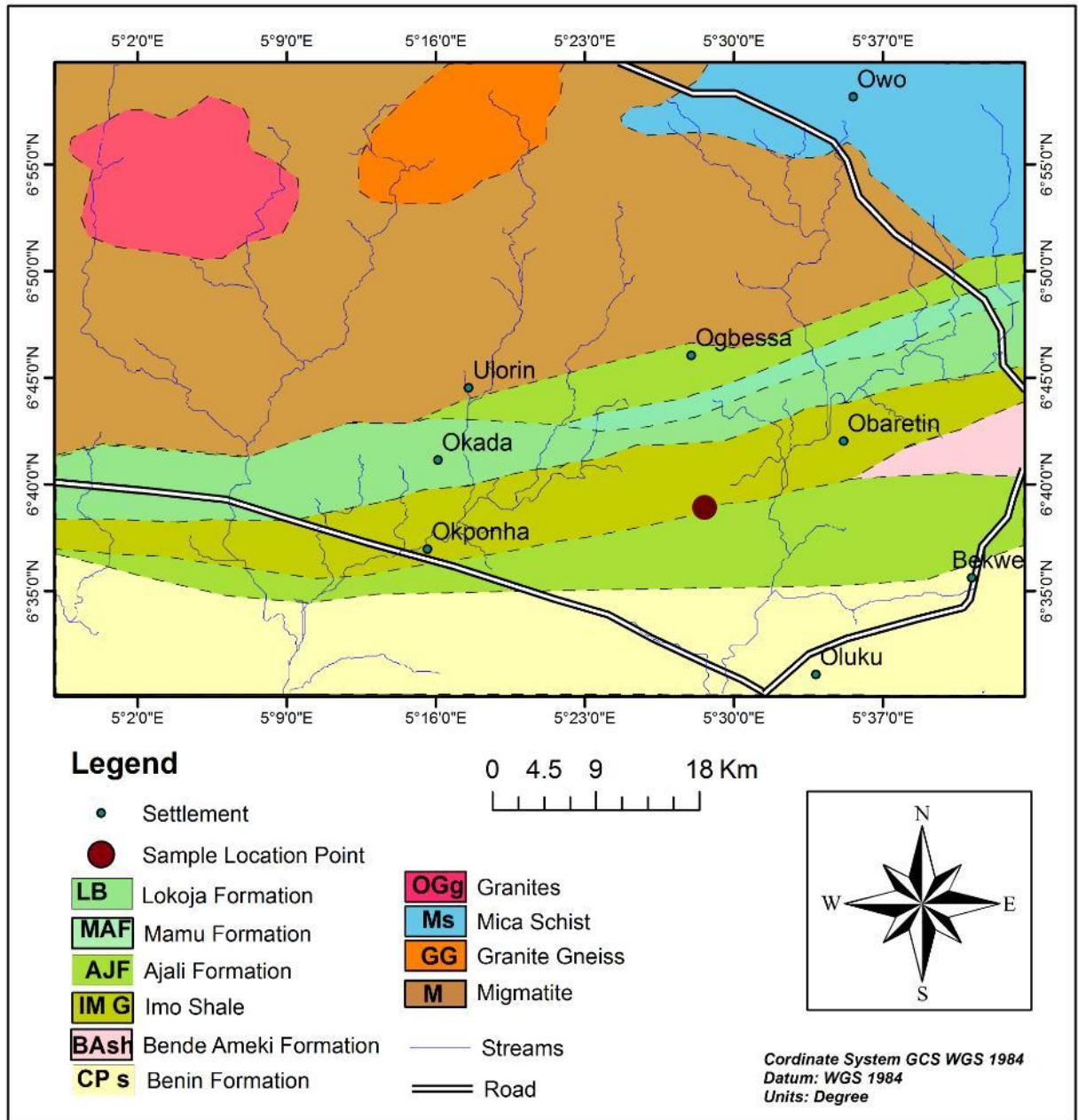


Figure 2: Geological map of the area.

1.5 PREVIOUS WORKS ON THE IMO FORMATION

The Imo Formation is a geological formation in Nigeria that consists of sandstones, shale's, and limestone. It is part of the Niger Delta Basin's sedimentary succession. Because of its potential as a hydrocarbon reservoir, geologists and petroleum firms have conducted substantial research on the formation.

Previous study have showed that research mainly was focused on its lithofacies, depositional environment, and mineralogy, age characteristics. According to studies it has shown that the Imo shale's geochemical makeup has been studied, and it has been discovered to be rich in organic materials, making it a possible source rock for oil and gas.

- ❖ In a previous work done by **Odunze et al (2011)** a sequence stratigraphic framework has been formulated for the unit. This study uses facies associations and results of clay mineral studies to propose a new paleogeographic model for the Imo Shale and its sandstone members. Palynology is also integrated to provide additional information on the depositional environment of the Imo Shale, particularly the Ebenebe–Awka axis and to test the interpreted paleoenvironment of deposition based on sedimentological facies analysis.
- ❖ **Avbovbo (1978) and Short and Stauble (1967)** carried out a project on age Determination of the Imo Shale. The Imo Formation is the outcrop lithofacies equivalent of the Akata Formation in the subsurface Niger Delta. Oloto (1992) had studied core samples of the Late Paleocene- Early Eocene sections of the

Imo Shale from the Gbekebo-1 well in the Benin Flank of the Niger Delta which yielded rich palynomorph assemblages.

- ❖ **Whiteman, A.J. (1982)** worked on Petroleum Geology, Resources and Potential. While Graham and Trotman, both stated that the Imo Formation is the basal unit of the Niger Delta Complex. The outcropping sector of this formation described a concave southward territory stretching from the Benin flank in the west, where it overlies the Nsukka Formation of the Anambra Basin, and widens eastwards.
- ❖ **(Reijers et al., 1997 & Anyanwu and Arua, 1990)**. Have carried various studies out using palynological, sedimentological and strati-graphic which have depicted the lower sandstone member as a fore-shore shore face deposit (Reijers et al., 1997), delta front facies (Anyanwu and Arua, 1990), and an estuarine lithic fill (Oboh-Ikuenobe et al., 2005). A sequence stratigraphic framework has been formulated for the unit. This study uses facies associations and results of clay mineral studies to propose new paleogeographic model for the Imo Shale and its sandstone members. Palynology is also integrated to provide additional information on the depositional environment of the Imo Shale, particularly the Ebenebe–Awka axis and to test the interpreted paleoenvironment of deposition based on sedimentological facies analysis.

CHAPTER TWO

LITERATURE REVIEW

NIGER DELTA BASINS

The Niger Delta Basin ranks among the world's most prolific petroleum producing Tertiary Deltas (Selley, 1997). It occupies the Gulf of Guinea continental margin in equatorial West Africa between Latitude 30 and 60 N and Longitude 50 and 80E in southern Nigeria, It takes approximately 7.5% of Nigeria's landmass, covering an area of roughly 75,000 km² with clastic sequence that has a maximum thickness of 9000–12,000m of the sediment (Frank and Cordry, 1967), The sedimentary basin of the Niger Delta spans approximately 256,000 km² [15].

The Niger Delta is framed on the northwest by a subsurface continuation of the West African Shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif (Murat, 1972). Well sections through the Niger Delta generally display three vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower pro-delta lithofacies. These lithostratigraphic units correspond respectively with the Benin Formation (Oligocene-Recent), Agbada Formation (Eocene-Recent) and Akata Formation (Paleocene-Recent) of (Short and Stauble, 1967) respectively. These units represent the prograding depositional environments, or continental, transitional, and marine settings, which are primarily characterized by shale-sand ratios.

The evolution of the Niger Delta was controlled by pre- and syn-sedimentary tectonics described by (Evamy et al., 1978; Knox and Omatsola, 1989 and Stacher, 1995). The tectonic framework of the continental margin along the West Coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic the fracture zone ridges subdivide the margin into individual basins, and in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki Trough, which cuts far into the West African shield. The trough represents a failed arm of a rift triple junction associated with the opening of the South Atlantic. Rifting started in the Late Jurassic and persisted into

The Middle Cretaceous, In the Niger Delta region, rifting diminished altogether in the Late Cretaceous and the gross paleogeography of the region as well as the relative position of the African and South American plates started to separate since rifting began. After rifting ceased, Niger Delta basin gravity tectonics became the primary deformational process. For any given depobelt, gravity tectonics were completed before deposition of the Benin Formation and are expressed in complex structures, including shale diapirs, roll-overs anticlines, collapsed growth fault crests, back-to back features, and steeply dipping, closely spaced flank faults (Evamy et al., 1978). These faults mostly offset different parts of the Agbada Formation and flatten into detachment planes near the top of the Akata Formation.

The three formations that are locally known as part of the Tertiary sequence in the Niger Delta are listed in increasing order (from which is bordered on its northwest and northeast sides by rift faults. They are Akata Formation, Agbada Formation, and Benin Formation arranging from top to bottom.

The Akata Formation, a succession of planktonic foraminifera-rich Transgressive (Paleocene to Recent) marine shale, clays, and silt, forms the system's foundation. The Agbada Formation is a sandstone and shale interstratified

formation from the (Eocene-Recent). The sedimentary sequence's delta system (delta front, fluviodeltaic facies) is represented by the Agbada Formation. Akata Formation is overlain with Agbada Formation, which consists of intercalation of sandstone and shale with age ranging from Eocene to Recent (Short and Stauble, 1967).

The Benin Formation(Oligocene-Recent), the third layer which is the last continental deposit from the Eocene to Recent alluvial and upper coastal plains lies on top of the Agbada Formation [20]. The fluviatile sands and gravels in the Benin Formation, which sits on top of the Agbada Formation, range in age from the paleocene to the Recent (Avbovbo,1978). The reservoir rocks for the liquid hydrocarbons that exist in this sedimentary basin are the sandstones of the Agbada Formation (Evamy et al., 1978).

2.1 STRAIGRAPHY OF NIGER DELTA BASINS

In Essence, the classifications used in the stratigraphy of the Niger delta are those that exist throughout southern Nigeria. It is fundamentally separated into Modern Delta Stratigraphy and Proto- delta stratigraphy. The Modern Delta Stratigraphy of the Niger delta is divided into three formations based on evidence of sediment logical and faunal arrangement identical to that of the previous formation, Benin Formation, Agbada Formation, Akata Formation.

The Proto delta has the oldest sedimentary rocks in the southern Nigeria. It consist of the non fossiliferous arkoses, gravels, poorly sorted , while they are commonly cross bedded sandstone which was obtained from basement complex.

The stratigraphy of the Niger Delta is intimately related to its structure. The development of each being dependent on interplay between sediment supply and subsidence rate. Short and Stauble (1967) recognized three subsurface stratigraphic

units in the modern Niger Delta. The delta sequence is mainly a sequence of marine clays overlain by paralic sediments which were finally capped by continental sands. The stratigraphy of Niger Delta Basin are as follows:

- ❖ **Benin Formation:** The formation comprising over 90% sandstone with shale intercalations extends from the west across the entire Niger Delta area and southward beyond the present coast line. The thickness though variable is estimated at about 6000ft. It is coarse grained, gravelly, poorly sorted, sub-angular to well-rounded and bears lignite streaks and wood fragment. The formation is characterized by structural units such as channel fills, point bars etc. which indicate variability of the shallow water depositional medium. The Benin formation with very little hydrocarbon accumulation ranges in age from Oligocene to Recent (Avbovbo, 1978).
- ❖ **Agbada Formation:** The formation is a sequence of sandstones and shale's with sandstone dominant in the upper unit and thick shale's in the lower unit. It is very rich in micro fauna at the base decreasing upwards suggesting an increase in the rate of deposition at the delta front. The grains are coarse and poorly sorted indicating a fluvatile origin. The Agbada formation covers the entire subsurface of the delta and may be continuous with the Ogwashi-Asaba and Ameki formations of Eocene-Recent age. It is over 10,000ft thick and are the major hydrocarbon bearing unit in the delta.
- ❖ **Akata Formation:** The formation underlies the entire delta and forms the lower most unit. It is a uniform shale development consisting of dark grey sandy, silty shale with plant remains at the top. The Akata formation is typically over pressured and believed to have formed during low stands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency (Statcher 1995). It is over 4000ft thick and

ranges in age from Paleocene to Recent and is believed to have been deposited in front of the advancing delta. 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 STRUCTURAL DEVELOPMENT OF NIGER DELTA

The tectonics that led to the formation of the Benue Trough and the geodynamics that resulted from the division of the continents of Africa and South America are both significant contributors to the development of the Niger Delta. Tectonic activity, temperature, and eustasy are the primary drivers of transgression and regression via the entrance point along the present-day Niger Delta region, as well as the deposition of marine and non-marine sediments from the late Aptian to the Eocene. Prior to the Santonian and later Campanian to Eocene positive motions of blocks defined by NE-SW and NW-SE trending faults throughout the Benue Trough and the modern Niger Delta region, the Oligocene and younger Niger Delta basin subsided along the NW-SE fault trends. Throughout the Paleocene and Eocene eras, the Anambra basin was filled by the transgressive Imo Shale, the regressive Ameki Formation, and the Akata, Agbada, and Benin Formations from the Eocene to the Recent. The basin is still in a sag regime with continued Benin Formation deposition and minor changes to the climate and eustasy even if rifting and tectonic subsidence are currently dormant. The Niger Delta's existing dynamics have resulted in a nearly developed basin, but a change in the climate and the eustasy that goes along with it might destabilize the ecosystem of the region and have corresponding economic effects a delta.

2.3 GEOLOGICAL OVERVIEW OF IMO FORMATION

Earlier names for the Imo Formation included Imo-Anambra Shale and Imo Clay-Shales, Overlying the Nsukka Formation is the Imo Shale. It was also produced in the Niger delta basin, it is a Paleocene outcrop composed mostly of thick, fine-grained, dark grey or bluish grey shale, with sporadic additions of clay, ironstone, thin sandstone bands, and limestone intercalations. The early Eocene is where the blue gray often localized sandy fossiliferous. This was caused by the marine transgression that took place in southern Nigeria.

The Formation alternates between sandstone and shale near the top, where there is more of sand. The Imo Shale is a geologic unit that is extensively dispersed spanning several hundred kilometers, from Nigeria's southeast border through the Niger Delta to its western border. Imo Shale was reportedly deposited during the Paleocene when transgression conditions returned to the Anambra basin, according to Murat, Nwajide and Reijers the Imo shale represents a shallow maritime shelf with infrequently preserved foreshore and shoreface. Reijers and Nwajide also implied that the Imo shale in the Anambra basin is analogous to the subterranean Paleocene deposits in the Niger Delta, which are primarily of deep marine origin. Foraminifera are used to date the Imo Shale as Paleocene, but Berggren claimed that the formation's upper portion is Lower Eocene in age. Oloto also mentioned Imo Shale as having Late Paleocene to Early Eocene strata. Imo Shale was dated by **Durugbo** as being Middle Paleocene to Early Eocene, and a near-shore to marginal marine pale environment was inferred by **U., Ogundipe O. T. and Ulu, O. K. (2010)**.

Imo shale is a possible source rock for oil and gas since studies on its geochemical makeup have shown that it is rich in organic materials. The presence

of heavy metals in the shale, which researchers have discovered in significant concentrations can have detrimental effects on the ecosystem if it is mined or exploited carelessly. Imo shale was thought to have been deposited in a marine environment, according to some studies, but other researchers contend that it was created in a lacustrine (lake) environment. In order to assess the shale's potential as a source of oil and gas and to comprehend the geological history of the area, it is critical to comprehend the depositional environment in which the shale was formed. This is crucial for figuring out the area's potential **Odunze, O.S., Obi, G.C., (2011)** as a source of oil and gas and for comprehending the region's geological past.

CHAPTER THREE

METHODOLOGY AND MATERIALS

The methodology employed for this research include the following:

- I. Collection of Ditch cutting sample/lithologic description/
- II. Effervescence test
- III. Geochemical analysis

3.1 COLLECTION OF DITCH CUTTING SAMPLE

Thirty two (32) ditch cutting samples were obtained from Obaretin well in Ovia North East, Southern Nigeria. The sampling was done at every 10ft over an interval of 30ft-1110ft. After the samples were obtained, the samples were described and acid test was carried out. Subsequently twelve samples were selected for geochemical analysis.

3.2 EFFERVESCENCE TEST

My samples was send to the Department of Geology's Geochemistry Laboratory at the University of Benin, Benin City, and Edo State. Where the following procedures were used to test for effervescence:

- I. The sample was taken from the sample sac with the help of a spatula and broken up into little pieces and then crushed with a pestle against the mortar to produce either a very fine or fine texture.
- II. The pulverized sample was transferred using a spatula, and it was placed on a slide for the test to be carried out.
- III. After which dilute Hydrochloric acid was used to test for the presence of effervescence which indicates the presence of gas bubbles. The presence of

bubble indicate it contain carbonate, why the absent of bubble shows that there Is no present of carbonate on the sample,
It's like a fizzy reaction. Degree of effervescence ranging from Weak (1), Moderate (two) and Strong (3).

IV. These procedures were repeated for all 32 samples, and results were recorded.

3.3 GEOCHEMICAL ANALYSIS

The twelve sample selected were analyzed for their major and trace element concentration at Activation Laboratory, Canada. The analytical protocol used was Ultratrace 7 package, which entails - Peroxide Fusion, with ICP-OES and ICP-MS. The details of the analytical procedure are as follows:

- I. 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
- II. 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.
- III. 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.

3.4 EQUIPMENT USED FOR STUDY

1. 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.



Fig 3: ICP-MS Instrument

2. 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.

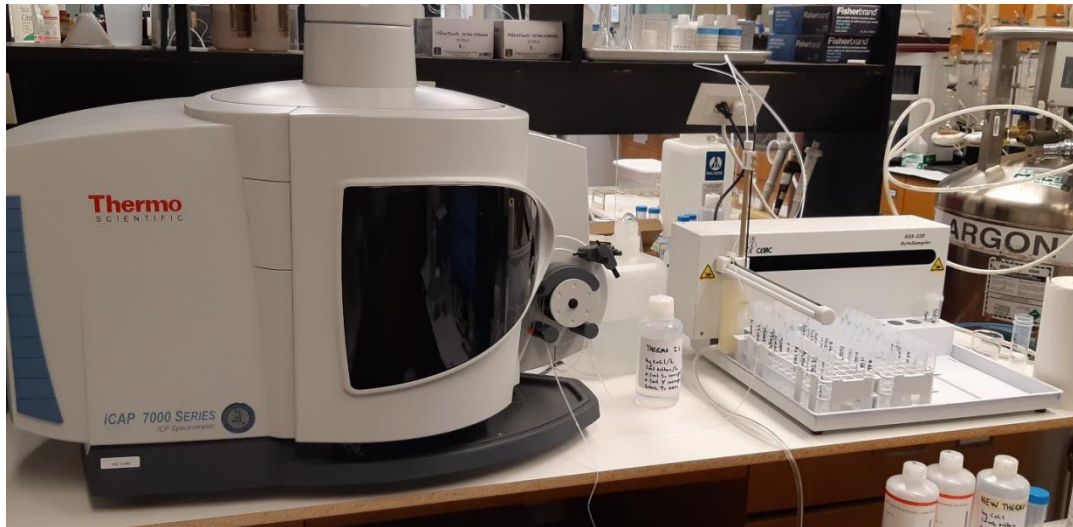


Fig 4: ICP-OES Instrument

3. Spatula: This is a laboratory instrument used to transfer samples from their original containers to weighing paper, so that the test can be carried out.



Fig 5: Spatula

4. Mortar and Pestles: This is to crush up solid chemicals into smaller pieces, or to grind solids into fine powder. This makes it easy for the test of effervescence to be carried out.



Fig 6: A typical mortar and Pestle

5. Dilute hydrochloric acid: After each sample has been pulverized, dilute hydrochloric acid is added to check if effervescence on the sample exists.



Fig 7: Dilute hydrochloric acid

3.4 PRECAUTION

- I. Sample bag must be properly labeled to prevent mix-up of sedimentary units hydrochloric acid (HCl) used was dilute and care was taken to avoid acid burn during the test
- II. Sample was properly crush to ensure that the results was accurate.
- III. Notes were taken immediately as for observations were made to produce an accurate a data as possible.

CHAPTER FOUR

RESULTS PRESENTATION AND DISCUSSION

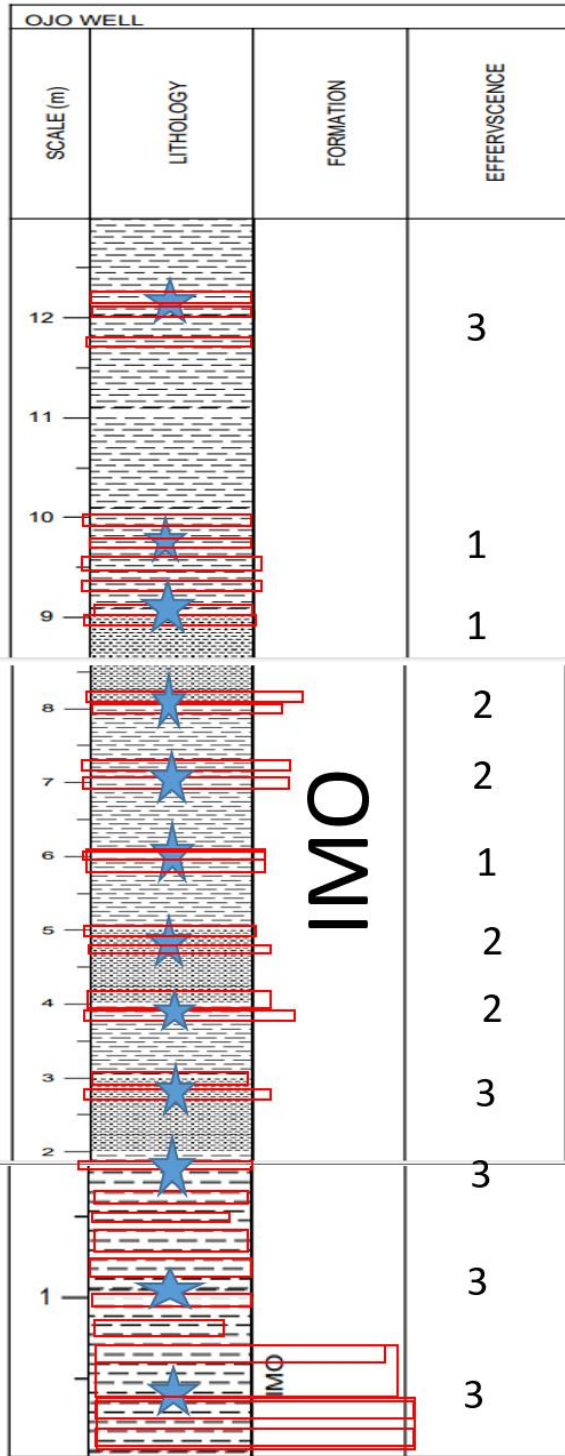


Fig 8: The lithology of the study area showing the different lithology units and sample points with blue stars.

Sample Interval	Si	Al	Ti	Sr	Ba	Cu	U	Mo	V	Ni	CO	Cr
60-70 FT	22.7	8.58	0.71	204	368	45	2.3	3	88	80	15.7	130
120-130 FT	19.1	9.58	0.63	324	136	49	4.2	4	140	70	18.3	140
190-200 FT	18	10.58	0.55	367	108	67	6.3	7	133	100	21.4	130
260-270 FT	19.8	11.58	0.51	332	97	64	4.2	5	149	90	17.8	160
390-400 FT	21	12.58	0.57	304	100	51	3	6	160	70	18.9	200
c 460-470 FT	21.9	13.58	0.58	273	114	43	3	4	164	60	19.6	150
560-570 FT	20.1	14.58	0.47	331	98	27	2.3	4	132	50	16	130
670-680 FT	20.3	15.58	0.48	353	110	33	3.6	5	138	60	17.9	160
740-750 FT	19.8	16.58	0.46	356	112	84	2.7	4	136	70	15.9	140
810-820 FT	21.6	17.58	0.57	305	143	68	3.3	4	156	80	19.3	140
860-870 FT	20.9	18.58	0.51	307	130	49	3.6	5	148	80	18.9	160
1080-1090 FT	25.5	19.58	0.38	264	86	53	3	4	107	70	16.5	100

Table 1: Results of selected trace elements for proxies studies.

4.1 GRAIN SIZE

Grain size is the diameter of individual grains of sediment, or the lithified particles in clastic rocks. The term may also be applied to other Granular materials. During my plotting Si/Al and Ti/Al ratios were actually used as proxies for grain size in sedimentary rocks. Higher Si/Al and Ti/Al ratios generally correspond to coarser grain sizes, while lower ratios indicate finer grain sizes. In my proxies plot from the trend line lower depth from (50- 250ft) there was increase in trend of the **Silicon(S)** and **Titanium (Ti)**, that's suggest that the grain size of the sedimentary rocks becomes more coarser, This indicates that individual

particle in the sediment are larger in size. It could also indicate process such as increase in erosion, transportation, deposition of coarser sediments particle. While from higher depth (1050-1250ft) **Aluminum (Al) decrease**, which leads to the grain size became fine and smaller in size.

The grain-size distribution plots are calculated, in a previous work it was indicate that parameters show that about 50% of the reservoir sandstone is predominantly fine-grained sand. Very fine-grained sand is about 30%, Folk et.al. 1957; while medium and silt sizes constitute minor components of equal proportion, possibly occurring as thin beds, the bed was coarser upward and fine downward.

The sieve analysis was carried out based on Folk and Wards (1957) model and the curve were plotted. This mean values were used for classification of sandstones as it describes the average grain size of the sediments which is obtained with higher percentage of coarser material (0.20-0.99) and lower medium value (1.09-1.50), therefore, the higher mean value of coarser grained sandstones with lower mean values of medium grained sandstones characterized the siliclastics sediments of Imo Formation in the study area. The coarse grained sandstones sediments observed were associated with high energy conditions in which smaller grains were washed away leaving the coarse grains which suggested upper.

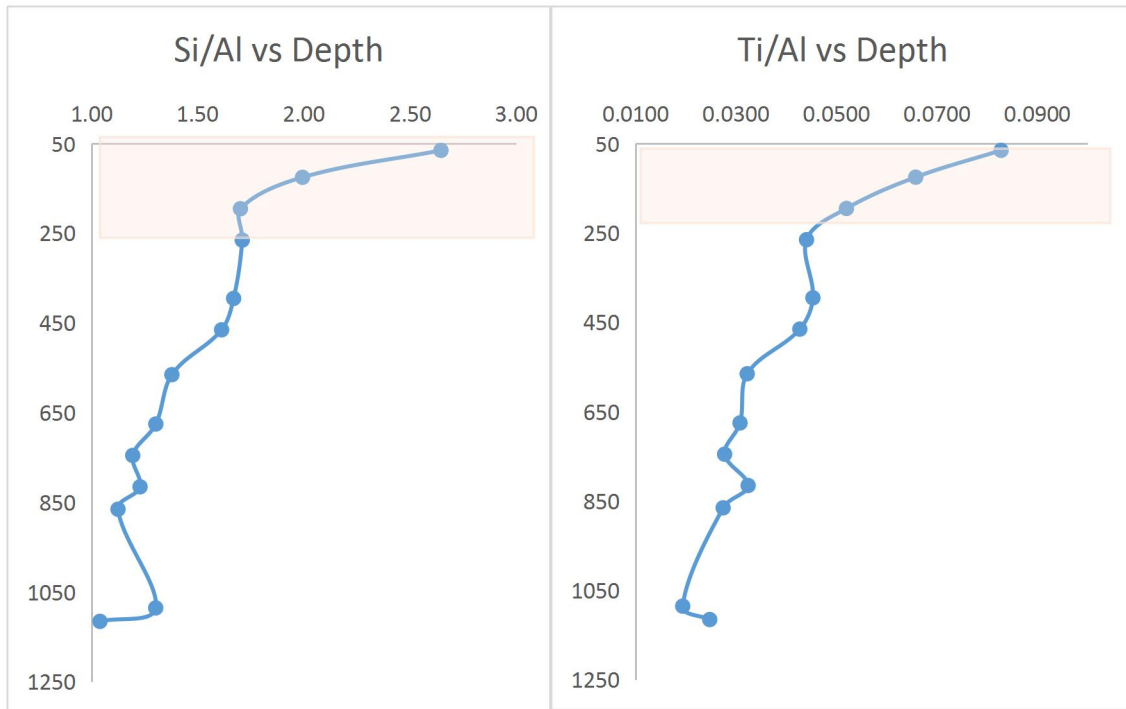


Fig 9: A graph showing the grain size trend line with the use of trace element proxies such as: (a) Si/Al (b) Ti/Al

4.2 PALEOSALINITY

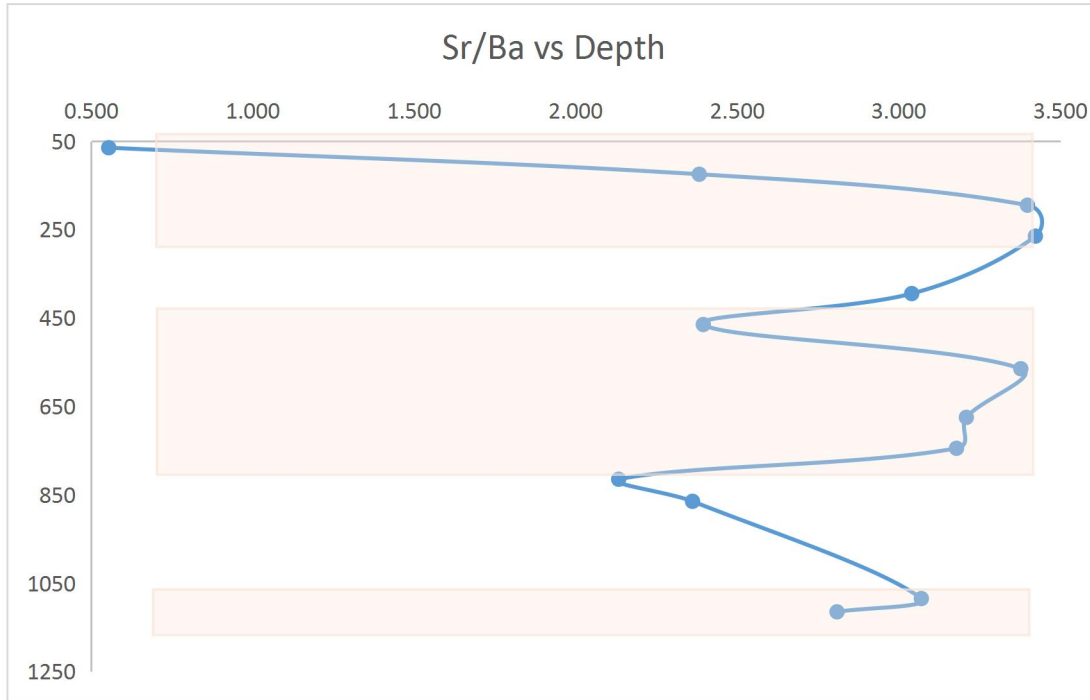


Fig 10: A graph showing the Paleo salinity trend line with the use of trace element proxies such as: (a) Sr/Ba

Paleosalinity is a record of water salinity in ancient sediments, which can be used as important information to analyze the sedimentary characteristics in geological history. There are many methods to distinguish paleosalinity. For example, geochemical methods of proxy's element was the method used to determine paleosalinity in my well of study. The elemental proxies used was Sr/Ba ratio which was used to determine paleo-salinity. **Strontium** (Sr) and Barium (Ba) are elements that can be found in sedimentary rocks. The ratio of Sr to Ba can give us clues about the salinity of ancient environments. When the Sr/Ba ratio is high, it suggests higher salinity in the past, which indicates marine, And when it's a low Sr/Ba ratio indicates lower salinity, which indicates freshwater, for

example in **Fig. 10**, at the depth of (50 -850ft) there was increase in strontium (Sr) while there was decrease barium at the depth of (1050ft – 1250ft) there was an increase in the paleo salinity. In analyzing this ratios, it helps us to solve reconstruct past variation and environmental conditions of ancient oceanic.

Concerning paleosalinity, Deng and Qian, showed that the Sr/Ba ratio can be used as a paleosalinity indicator, and Xu et al. classified high values of Sr/Ba ratio (>1) as more saline water (marine), while low values (<0.6) reflect freshwater environment. In the present study, the estimated Sr/Ba ratios show persistent high values (>1) representing fully marine conditions

4.3 PALEO PRODUCTIVITY

Paleopro- ductivity refers to the record of synthesis in the past. Generally, the term is applied to production that occurred prior to times when direct measurements are available.

On **Fig .11**, there was an increase in barium from the depth of (50ft) and a decrease in aluminum (1050ft) these increase in barium (Ba) and a decrease in aluminum (Al) can suggest higher paleo productivity. Ba is often associated with the presence of organic matter, while Al is typically found in clays and minerals. A decrease in Al indicates a lower input of terrigenous material, which can be a sign of increased biological productivity in the water column. So when Ba increase and Al decrease, it brings about effect on the productivity and preservation.

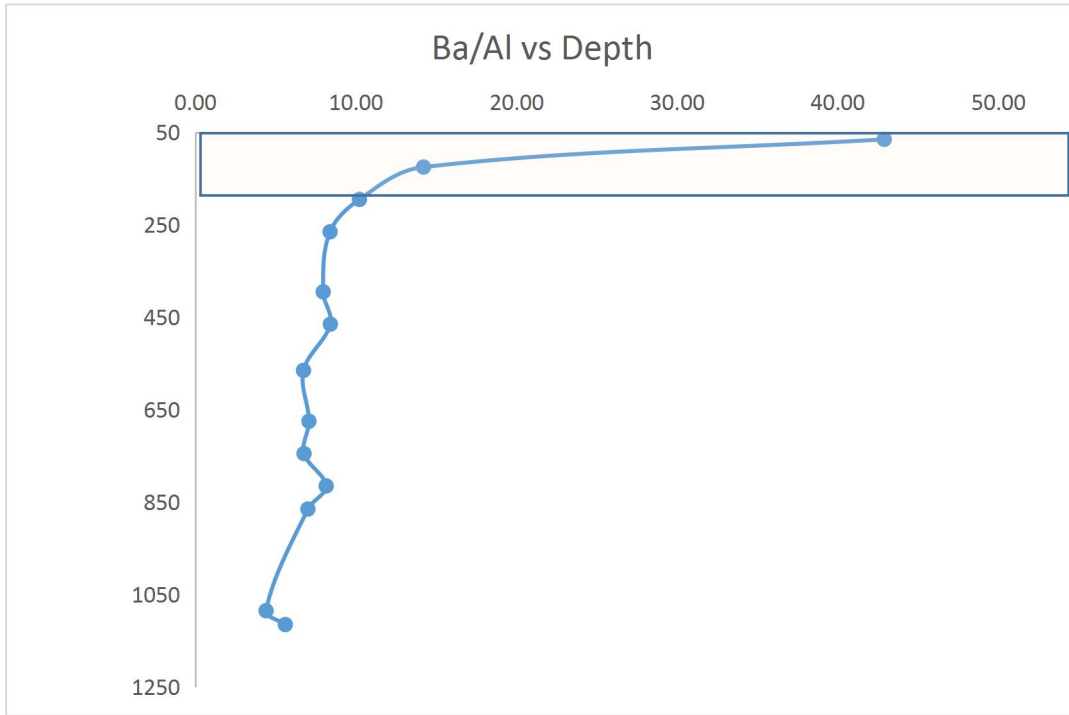


Fig 11: A graph showing the Paleo Productivity trend line with the use of trace element proxies such as: (a) Si/Al (b) Ti/Al

The $(Ba/Al)_{det}$ ratio of crustal composition that ranges from 0.005 to 0.010 (e.g., Taylor and McLennan 1985) is used. Negative Ba_{bio} values may suggest that the Ba in the sediments are generally of detrital origin. While the value are high in the sediments.

4.4 PALEOXYGENATION

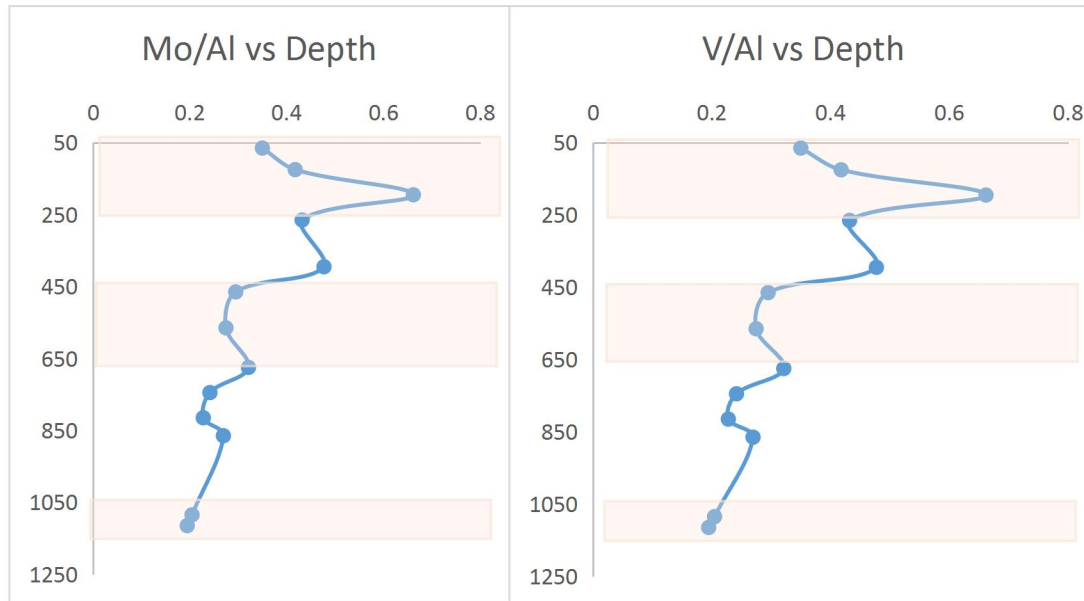


Fig 12: A graph showing the Paleo oxygenation trend line with the use of trace element proxies such as: (a) Mo/Al (b) V/Al

In the fig above, it a paleo-redox graph showing how the trend line moves using an elemental proxies of Mo/Al and V/Al to determine which condition it occurs in the environment, during when the trending line moves at a depth of (50- 250ft), there was increase in the Molybdenum and Vanadium, The molybdenum is found in the **Anoxic** group (A condition where there is lack or depletion of oxygen) and Vanadium is associated with **Oxic group** (A condition where there is an abundance of oxygen present in a particular environment). During the process of decrease in Aluminum (650-1050ft), there is a shift towards anoxic condition.

A process whereby there is decrease in oxygen availability and potentially the presence of oxygen depleted.

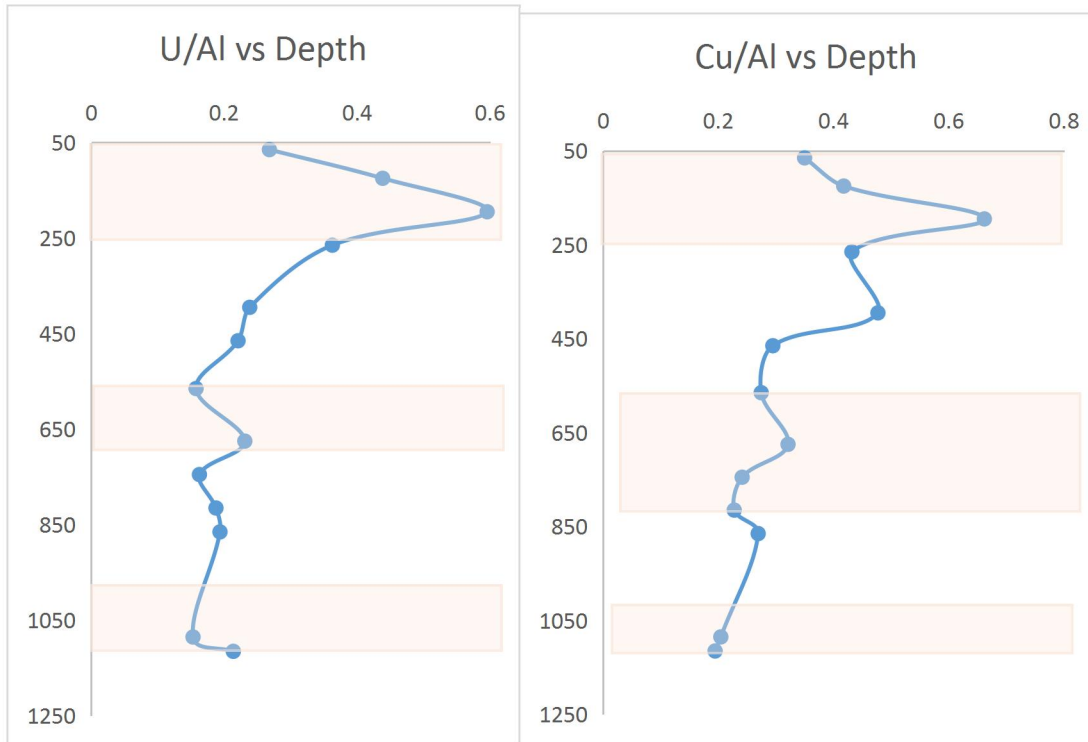


Fig 13: Trend line indicating the movement of elemental proxies for paleo oxygenation

The **fig 13** above, it a paleo-redox graph showing how the trend line moves using a proxies of U/Al and Cu/Al to determine which condition it occurs in the environment, during when the trending line moves at a depth of (50- 250ft),

The uranium used belong to the **Anoxic group**, while Cu belongs to **Oxic group**.

Increase in uranium from depth (50-250ft) and decrease in aluminium brings about shift towards anoxic condition. Increase in copper from depth (50-250ft) and decrease in aluminium brings about shift towards oxic condition.

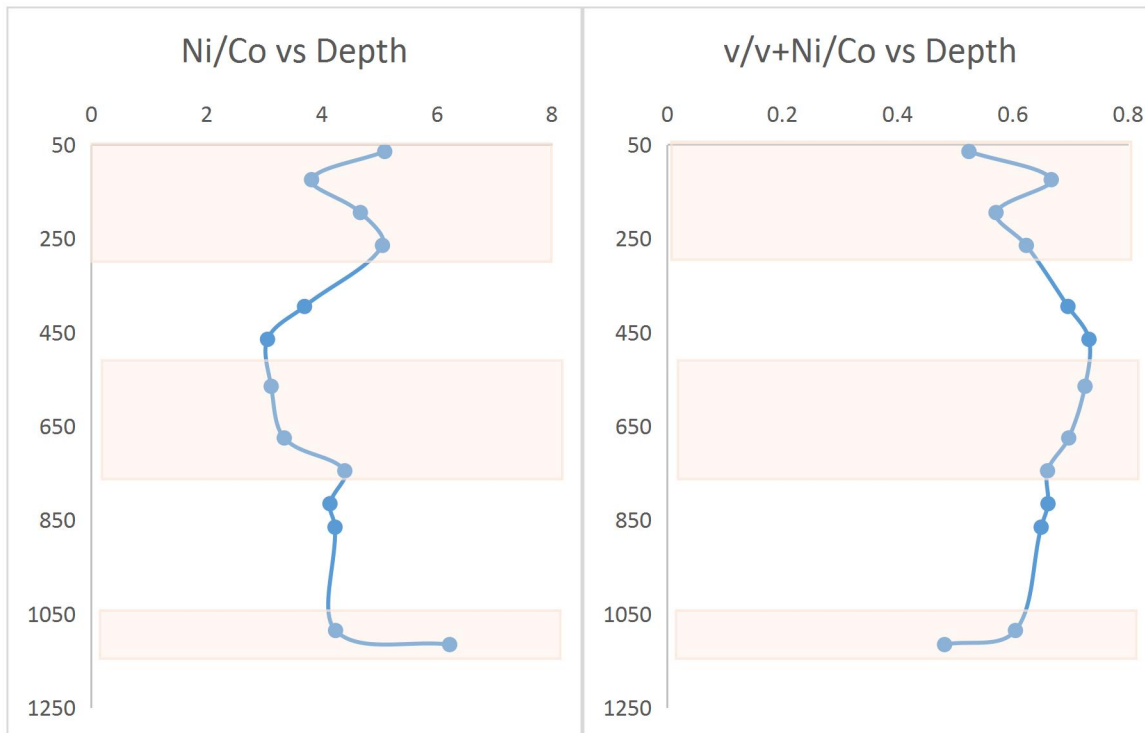


Fig 14: Trend line for paleo oxygenation, (a) Ni/Co (b) v/v+Ni/Co

The **fig 14**, above is a paleo-redox graph showing how the trend line moves using a proxies of (a) Ni/Co and (b) v/v+Ni/Co to determine which condition it occurs in the environment. Nickel belongs to the Anoxic group, while Cobalt and Vanadium belongs to the Oxic group, from the depth of (50-250ft) there was increase in Ni (a) and v/v+Ni, while there was a decrease in cobalt.

(a) / (b) There was a shift towards more anoxic or low oxygen conditions in the ancient's environment.

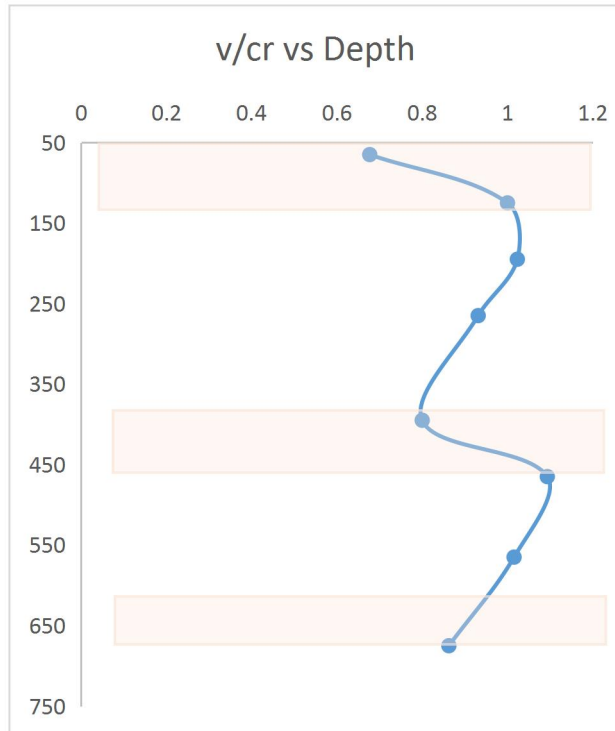


Fig 15: Trend line for paleooxygenation (a) V/Cr

The fig 15, above it a paleo-redox graph showing how the trend line moves using a proxies of v/Cr to determine which condition it occurs in the environment, Chromium can be found in both oxic (oxygenated) and anoxic (oxygen-depleted) conditions. Its presence or absence alone cannot determine the oxygenation levels of an environment. However, when used in conjunction with other elemental proxies, such as V/Cr , it can provide insights into paleo oxygenation or redox conditions. While vanadium belongs to the oxic condition.

When there was increase in vanadium at a depth of (50-150ft), there is a shift from more reducing or low energy conditioning the ancient environment.

CHAPTER FIVE

Summary, Recommendation, and Reference

5.1 Summary

Based on the geochemical study of obaretin well in Imo formation in the Paleocene of the Niger Delta Basin, my summary help to determine and understand more about grain size, paleo salinity, paleo productivity, and paleo oxygenation. The composition and characteristics of the Imo formation have help to provide insights into the past conditions of the basin. Through analyzing the sedimentary record, which enable me to identify the sedimentary size, salinity levels, productivity of marine organisms, preservation, and oxygenation levels in the ancient environment.

This Imo formation in the Paleocene of the Niger Delta Basin, have help to examine the composition and characteristics of the rock to gather information about the past conditions. By analyzing and using elemental proxies and the presence of this certain elements such as trace, major, rare, makes us understand more about paleo salinity, paleo productivity, and paleo oxygenation. For example, determining paelosalinity of an ancient environment using. Similarly, the presence of specific trace elements can provide insights into the oxygenation levels and salinity of the water during that time. By piecing together these clues, it helps to gain a better understanding of the environmental conditions that prevailed in the Niger Delta Basin during the Paleocene. Additionally, the presence of certain trace elements can tell us about the paleo productivity level and the grain size that exist

in this ancient environment. By analyzing all these factors, it's brings a better picture of what the conditions were like in the Niger Delta Basin.

5.2 Recommendation

Obaretin Well with respect to the identified clay and along elemental proxies that can be used for determine grain size, paleo oxygenation, paleo productivity which can be used to determine the condition of the ancient environment and other wells within the basin as well as regional correlation in Southern Nigeria.

A Further study of this well should be integrated with the geochemical study to further delineate more understanding of Obaretin Well.

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