RIVERS STATE UNIVERSITY
PORT HARCOURT

OIL EXPLORATION AND PRODUCTION IN NIGERIA: FROM BOTTOM TO TOP AND BEYOND.

AN INAUGURAL LECTURE

BY

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SERIES NO. 83

Wednesday 14th December, 2022

DEDICATION

It is with deep joy that I dedicate this 83rdInaugural Lecture to the Almighty God and to the loving memory of my late parents (Mr. Ebenezer Eke Thompson Adiela and Mrs. Evelyn Nkwoma Thompson Adiela) and my late siblings (Mr. Augustine Adiela, Mrs. Blessing Wokoma and Mrs.Edith Onyige).

The mustard seed planted and nurtured by them had germinated to proportions based on strong principles, unalloyed dedication and unflinching commitment occasioned by the Grace of God in the pursuit of academic excellence for the Adiela's family and humanity.

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ABBREVIATIONSANDACRONYMS

Bcm: -	Billion cubic meters
ECN: -	Energy Commission of Nigeria
EIA: -	Energy Information Administration
Mtoe: -	Metric tonne of oil equivalent
IEA: -	International Energy Agency
IISD:-	International Institute for Sustainable Development
REMP: -	Renewable Energy Master Plan
UNIDO:	United Nations International Development
WEC: -	World Energy Council
ARDL: -	Auto Regressive Distributed Lag
NARDL:	Non-Linear Autoregressive Distributed Lag
Bscf: -	Billion Standard Cubic Feet

PROTOCOL

PROTOCOL

The Vice Chancellor and Chairman of this Occasion,

- The Deputy Vice-Chancellor (Administration)

The Deputy Vice-Chancellor (Academic)
The Registrar and Secretary to Senate
Members of the University Governing Council
The Provost, College of Medical Sciences,
The Dean, School of Postgraduate Studies,
Deans of Faculties
The Dean, Students Affairs
The University Librarian
The Acting Bursar of this great University
Directors of Centers/Institutes
Heads of Departments
Distinguished Professors and other members of Senate
All Academic Staff, Administrative and Technical Staff
Visiting Academics and Colleagues
My Lords Spiritual and Temporal
Respected Guests, Well Wishers and Family members
Gentlemen of the Press
Undergraduate and Postgraduate Students of this Great University
Distinguished Ladies and Gentlemen

PREAMBLE

Vice Chancellor Sir, I am a man helped by God. I have seen the Lord's goodness, I have tasted of His faithfulness and I am a product of His Grace. I have moved from grass to grace and for me Grace means something that you do not deserve, an unmerited favour. God has been with me from the very beginning. I am highly grateful to God for giving me life, sound mind, good health and this wonderful opportunity to present my inaugural lecture today. In the book of Job 37: 5 – "God thundereth marvelously with His voice; great things doeth He, which we cannot comprehend". This Lord has done great and mighty things in my life. In Him my hope is found, He is my light, my strength and my song.

Vice Chancellor Sir, this is the 83rd inaugural lecture of this great University. The number 83 is a combination of the vibrational energies of the numbers 8 and 3. Number 8 resonates with the energies of abundance, success, prosperity, and achievements. Number 3, on the other hand, signifies unspeakable joy, happiness and peace of mind. Therefore delivering the 83rd Inaugural lecture is a sign of good things to come.

When it comes to matters of love, number 83 is a great number. People who possess this number are delighted with the love and bond they share with their spouses. They are people who can be trusted. They love completely. You can go and verify.

Vice Chancellor Sir, my life journey began when I was born into the family of Mr.Ebenezer Eke Thompson Adiela and Mrs. Evelyn Nkwoma Thompson Adiela(all of blessed memory) of the Umu-Agbida family of Omoku in the Ogba Egbema Ndoni Local Government Area of Rivers State. I had a very humble beginning. My Father was a primary school Headmaster while my mother was a peasant farmer. Today the son of a Headmaster and a peasant farmer is the 1st Professor of Petroleum Geology and Exploration Geophysics in this great University, in Rivers State and indeed, the Niger Delta region and to the best of my knowledge, in Nigeria.

I attended St. Michael's Primary School Omoku and had my Secondary School Education at the famous Sancta Maria High School Omoku. I was gifted in both arts and science subjects but opted for Science because that was the exclusive reserve of the smart and intelligent students. I topped my classes and represented my school in all quiz competitions notably the Nigerian Agip Oil Company (NAOC) Agric quiz competition organized by the Green River project, an initiative of the Nigerian Agip Oil Company amongst Secondary schools in the old Ahoada L.GA. I contributed in the winning of laurels thereby making my school proud. My academic contributions were outstanding to the extent that my school principal Late Chief Anthony Egobueze placed me on scholarship and bought JAMB form for my admission into the University. Because of my

brilliance, I was advised to study Medicine in the University. I exceeded all expectations in the exam by obtaining one of the best JAMB scores at the time and was successfully admitted to study Medicine and Surgery in the University of Port Harcourt but three weeks into my University life, I realized that I was no longer on scholarship. Reality dawned on me and again I was reminded of my humble beginning. I had no choice than to request for a change of course. I accidentally found myself in a relatively unknown course called Geology. Little did I know that God was the brain behind my movement to Geology. Again God's grace located me as I graduated as the best graduating student in the Department of Geology. This is the origin of today's inaugural topic. Vice Chancellor Sir, part of my inaugural topic: "From Bottom to Top and Beyond" is taken from that point in my life when I left Medicine and Surgery, moved to Geology and graduated as the best in Geology. I moved beyond when I was employed in Nigerian Agip Oil Company. My first salary was called "BEYOND".

Graduating as the best student in Geology came with its challenges as I discovered early in life that you need someone to assist you in your journey of life, My first unforgettable assistance academically came from the then Head of Department of Geology, Prof. John Etu Efeotor, who bought a Master's degree form for me immediately after my Youth service. I successfully graduated with distinction in Petroleum

Geology and Exploration Geophysics from the University of Port Harcourt. Grace located me again and I started my first PhD programme in Petroleum Geology (Exploration Geophysics option) in the University of Port Harcourt but this programme was truncated because of limited funds. To the Glory of God, the Rivers state Government and Petroleum Technology Development Fund (PTDF) came to my rescue by offering scholarships to me to the University of Aberdeen for the completion of my PhD Programme. It was Professor David Gray of the University of Aberdeen and Prof. Levi Amajor of the University of Port Harcourt that brokered the peace that facilitated the completion of my first PhD programme in 2010.

In the Oil and gas industry, I rose through the ranks from a pupil Geologist to the management cadre. This is another testament of moving from the bottom to the top and beyond. Here the beyond is what you are seeing now: A very comfortable Professor with peace of mind, who is enjoying so much freedom and who is at liberty to go beyond contrary to human expectations. I left the Oil and gas industry into academics on my own volition and with God by my side. I joined full time academics as a Lecturer in the Akwa Ibom State University (AKSU) where I was the only one employed out of 14 applicants. 13 of the applicants were from Akwa Ibom State. Again I found Grace as the Vice Chancellor of the University and other members of the interview panel never believed that someone could leave a high paying job in an Oil

Industry (NAOC) that is located in a state capital to a University in a remote area for a paltry sum of money. During the interview process, when they saw my last pay slip from the Oil Industry, they almost fainted. I was not interviewed but was rather asked to resume work the following Monday. My stay in Akwa Ibom State University (AKSU) was indeed fruitful but I left AKSU to RSU in 2017 as an Associate Professor and on the 3rd of Oct. 2020, I was promoted to the rank of a Professor. This is another clear demonstration of a gracious movement from the bottom to the top and beyond. Distinquished Ladies and Gentlemen, when the Grace of the Almighty God is upon you, you move beyond limits and you exceed expectations.

1.0 INTRODUCTION

This Inaugural lecture presents an opportunity for me to share my achievements and contributions in teaching, research and development before an audience made up of the members of the University community and the general public. As a Petroleum Geologist, I will attempt to tell us a little about my profession, and what I have been professing.

Vice Chancellor Sir, permit me to unveil the title of my Inaugural lecture. The 83rd Inaugural lecture of this great University is titled "Oil Exploration and Production in Nigeria: From bottom to top and beyond". Let me say that every human being aspires to move from the bottom to the top. The bottom refers to the beginning of anything or the worst thing whereas the top is the peak. At the bottom of the pile means to be in a low or very unimportant position. The meaning of ON TOP is to be on the highest part or surface of something and to go beyond simply means to exceed expectations.

It is pertinent to state that Countries, estabishments, individuals and even Crude Oil moves from the bottom to the top and possibly beyond.This lecture will focus on the movement of oil and gas from the bottom(earth) to the top. The Nigerian Oil and Gas industry is presently at the bottom and is filled with challenges but the good news is that there are numerous opportunities in the sector that we can leverage on and make Nigeria an Eldorado. This inaugural lecture therefore will x-ray

the exploration and production processes involved in crude oil extraction, investigate the challenges encumbering the oil and gas industry, focus on the opportunities and highlight the steps we need in the task of building a better and prosperous nation.

On the contrary, movement can be from the top to the bottom e.g. Lucifer moved from Heaven to the earth. Moving from the top to the bottom is the worst thing that can happen to an individual or a Country. May God never allow us to move from top to bottom in Jesus name. Amen.

1.1 WHAT IS GEOLOGY AND WHO IS A PETROLEUM GEOLOGIST?

Geology is from the combination of the Greek words: *Geo* (The Earth) and *logos* (The Study of). Geology is therefore the science that deals with the history and structure of the earth and its life forms.

Geology is very broad and has several branches namely: Crystallography, Mineralogy, Petrology, Structural Geology, Sedimentology, Paleontology, Stratigraphy, Engineering Geology, Hydrogeology, Marine Geology, **Petroleum Geology**, Environmental Geology, Economic Geology, Geochemistry, Geophysics, Sequence Stratigraphy etc.

Petroleum Geology according to Sceepat Jain, (2014)is the specific branch of Geology that deals with the search for

Hydrocarbons (mainly Oil and Gas). It is the study of the origin, occurrence, **movement**, accumulation and **exploration** of hydrocarbons (Oil and Gas).So, a Petroleum Geologist is a specialist in Oil and Gas discovery.

The earth has its foundation and origin from the Bible and different aspects and perspectives may be explored when talking about the Bible and Geology. Fundamentally Geology started with the creation story (Figure 1).

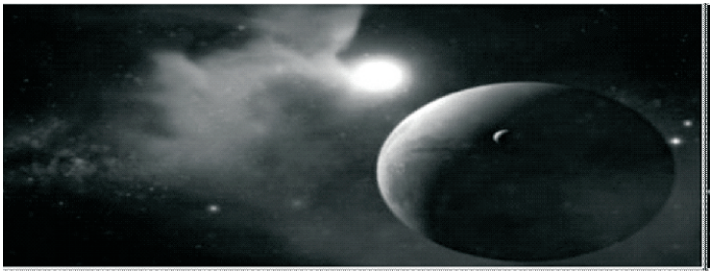

Fig 1: Genesis 1:1 KJV "In the beginning God created the heaven and the earth." (Source: The Holy Bible)

The first verse of the Bible makes this simple declarative statement: *"In the beginning God created the heaven and the earth."* (Genesis 1:1: KJV). He created the Top (Heaven) and the Bottom (Earth).

1.2 HISTORICAL REVIEW OF PETROLEUM EXPLORATION

Petroleum exploration is an old pursuit. Before exploration for oil began, cable-tool drilling was an established technique in many parts of the world in the quest for water and brine (Fig. 2).

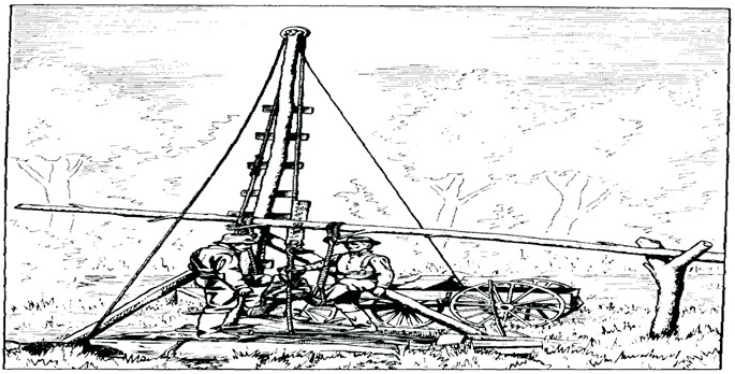

Figure 2: Early cable-tool rig used in America. (Courtesy: British Petroleum.)

The first well to produce oil intentionally in the Western World was drilled at Oil Creek, Pennsylvania, by Colonel Drake in 1859 (Owen, 1975).

A rapid growth in oil production from subsurface wells soon followed. Demand for oil products increased greatly because of the First World War (1914-1918). By the 1920s the oil industry was dominated by seven major companies, termed the "seven sisters" by Enrico Mattei (Sampson, 1975).These companies included: British Petroleum, Shell, Exxon (formerly Essa), Gulf, Texaco, Mobil, and Socal (or Chevron).

History of the Nigerian Oil and Gas Industry

Oil was discovered in Nigeria in 1956 at Oloibiri in the present day Bayelsa State (Niger Delta) after half a century of exploration. The discovery was made by Shell-BP, at the time the sole concessionaire.

Some major events in the history of the Nigerian Oil and Gas Industry are as follows:

1938 - Shell D' Arcy was granted Exploration license to prospect for oil in Nigeria.
1956 - First successful well drilled at Oloibiri by Shell D'Arcy
1958 - First shipment of oil from Nigeria.
1962 - Elf and Nigeria Agip Oil Company started operations in Nigeria.
1968 - Mobil Producing Nigeria Limited was formed.
1977 - Nigerian National Petroleum Corporation (NNPC) was established

1.3 USES AND IMPORTANCE OF CRUDE OIL IN NIGERIA

The oil industry is the backbone of the Nigerian economy. The benefits of crude oil in Nigeria are evident. It provides 90 percent of the country's export revenues. Nigeria is the first in Africa and the eighth in the world when it comes to oil export. Oil production brings about billion investments in the country's economy as well as the development of related sectors of the economy and infrastructure. Besides, it supplies new jobs for Nigerian citizens and improves the social and living standards in general. Nowadays, Nigeria is Africa's main oil producer.

Oil is a major source of energy. It generates heat, drives machineries, and fuels vehicles and airplanes. Its components are used to manufacture almost all chemical products, such as plastics, detergents, paints and even medicines. We also use

crude oil products to propel vehicles, to heat buildings, and to produce electricity(Akinlo, 2012). In the industrial sector, the petrochemical industry uses petroleum as a raw material to make products such as plastics, solvents and other intermediate and end-user goods.

Oil sector provides intermediate inputs to the rest of the economy. These intermediate inputs include crude oil, gas and liquid feedstocks, as well as oil and gas into the refining, petrochemical and electricity and energy intensive industries respectively (Al-Moneef,2006). Generally, as a result of oil production, refining and distribution, there is tendency for oil sector-related services to spring up thus providing opportunity for employment as well as serving as sources of earnings for the operators.

Another major area through which oil industry contributes to the Nigerian economy is in the attraction of foreign direct investments (FDI). The accumulation of foreign reserves can be seen as collateral which the oil producing economies can use in attracting foreign investment (Dooleyetal., 2004).

1.4 THE CONTEXT OF PETROLEUM GEOLOGY

1.4.1 Relationship between Petroleum Geology and Science

Petroleum geology is the application of geology to the exploration for and production of oil and gas. Geology itself is firmly based on chemistry, physics, and biology, involving the application of essentially abstract concepts to observed data (Selley, 1998). It is appropriate to consider in more detail the

roles of chemistry, physics, and biology in petroleum exploration (Fig. 3).

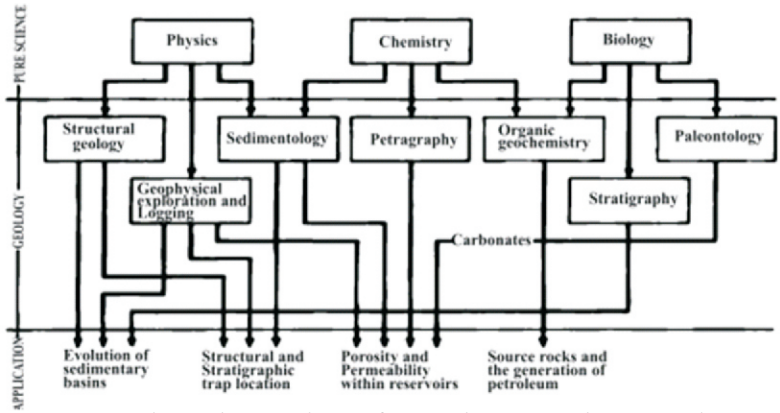

Figure 3: The relationship of petroleum geology to the pure sciences.

1 .4.1.1 Chemistry and Petroleum Geology

The application of chemistry to the study of rocks (geochemistry) has many uses in petroleum geology. Fig. 3

1.4.1.2 Physics and Petroleum Geology

The application of physics to the study of rocks (geophysics) is very important in petroleum geology. Petroleum exploration is unthinkable without the aid of magnetic, gravity, and seismic surveys in finding potential petroleum traps. Fig.3

1.4.1.3 Biology and Petroleum Geology

Biology is applied to geology in several ways, notably through the study of fossils (paleontology) Fig.3

1.4.2 Relationship between Petroleum Geology and Petroleum Exploration/Production.

Petroleum geology is only one aspect of petroleum exploration and production. Petroleum exploration now involves integrated teams of people possessing a wide range of professional skills (Fig. 4).

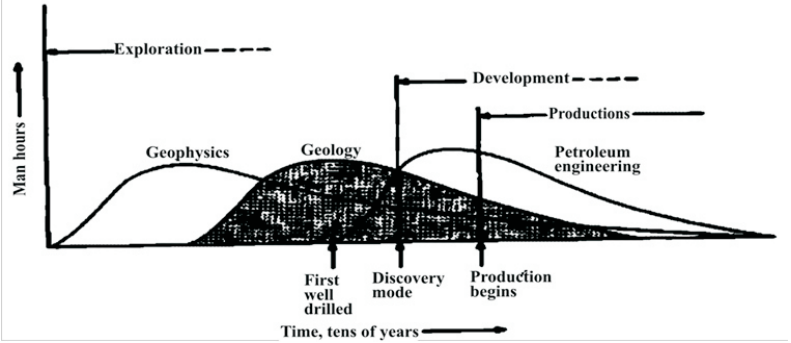

***Figure 4**: Petroleum geology as part of exploration and production of oil and gas.*

Petroleum engineering is concerned with establishing the reserves of a field, the distribution of petroleum within the reservoir, and the most effective way of producing it. Thus petroleum geology lies within a continuum of disciplines, beginning with geophysics and ending with petroleum engineering (Fig. 5).

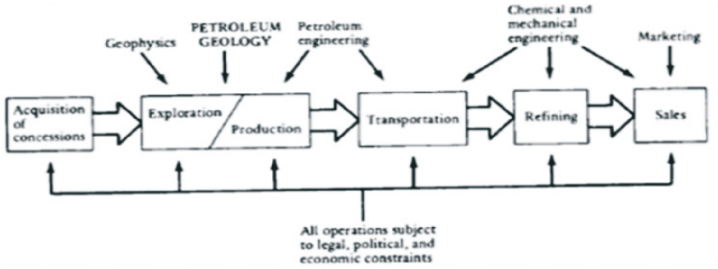

Figure 5: *Petroleum geology as one aspect of petroleum exploration and production.*

2.0 THE EARTH AND PETROLEUM GEOLOGY

The earth is composed of three basic layers: the core, the mantle, and the crust (North, 1985)Fig. 6. The crust is the layer that is of most importance in petroleum geology.

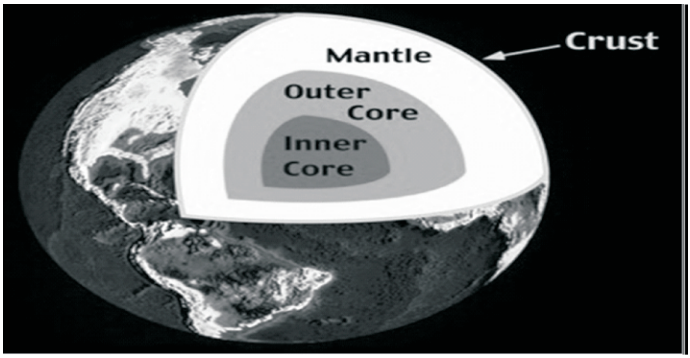

Figure 6: The Earth's Structure.

2.1 Building of Sedimentary Basinsand the Concept of Plate Tectonics

When the Earth cooled more than 4.6 billion years ago, magma

solidified into**igneous rocks**. Over geologic time the Earth's stresses caused these igneous rocks to slowly form mountain chains and accompanying depressions and the seas quickly filled these depressions. Because of weathering caused by wind and water, the mountains were eroded into particles of many different sizes, which in turn were carried downward by water and wind, where they eventually settled in and filled the depressions ("**basins**")(Hyne, 2001). The sediments that filled the basins became compacted by subsequent layers of particles, and cemented into new forms of rock called **Sedimentary rocks**. These sedimentary rocks are the source of all oil and gas reservoirs. **Metamorphic rocks** are formed from igneous and sedimentary rocks through the forces of heat and pressure (**Figure 7**) - **The Rock Cycle.**

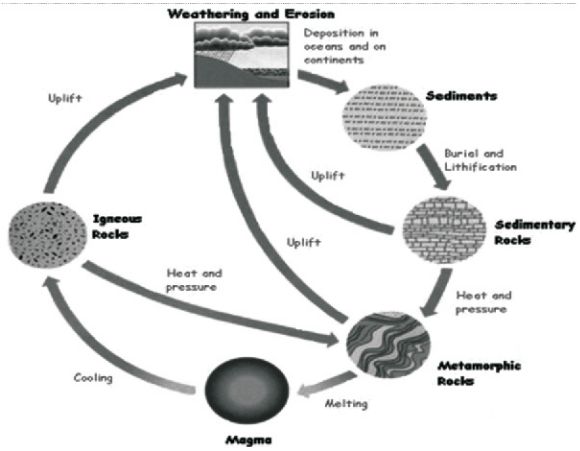

Figure 7: The Rock Cycle

The crust is continuously changing and moving because of two major forces of nature—**Orogeny (Mountain Building)** and **weathering/erosion**. Orogeny, or mountain building, is a process in which the layers of the crust are folded and pushed upward by processes such as plate tectonics and volcanism. Weathering and erosion are the opposing forces in which the sediments are broken down and transported.

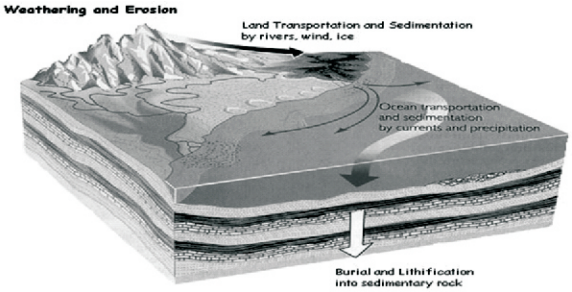

Figure 8: ***Weathering and Erosional geological processes***

Weathering and **erosion** are closely interrelated geological processes. As a rock weathers, it becomes susceptible to erosion. These and additional forces and processes have resulted in the creation of subsurface geological formations in which petroleum reservoirs are found. *Figure 8*

Sedimentary rocks are the most important type of rock to the petroleum industry because most oil and gas *accumulations* occur in them; igneous and metamorphic rocks rarely contain oil and gas **(**Iwuoha, **Adiela**, Nwannah, & Okeke, 2016).

Although the earth's crust was formed billions of years ago, most sedimentary rocks were formed only in the past 575 million years. According to Gradstein, Ogg and Smith (2004), Geologists have grouped these 575 million years into Periods and Series - the Geologic Time Scale (Figure 9).

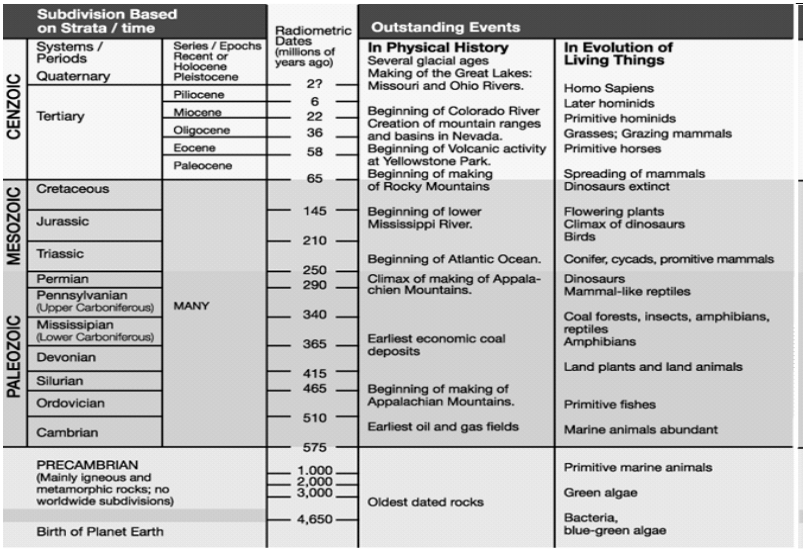

Figure 9: The Geological Time Scale

In the Geological Time Scale, we consider outstanding Events both in the context of Physical History and the Evolution of Living Things (Figure 9). The depressions (Basins) grew deeper and became filled with both sediments, created by mountain erosion, and organic matter that was carried downstream in rivers to the seas.

In the late Triassic Period a second major physical event began to take place on the earth's crust that created many new basins for

the accumulation of sediments. Prior to the Triassic Period, the continents were all held together in a single land mass called Pangea, (Figure 10) but during that period(between 210 and 250 million years ago), continents began to separate, forming many new oceans, including the Atlantic Fig. 11.

Figure 10: Pangea. A single landmass

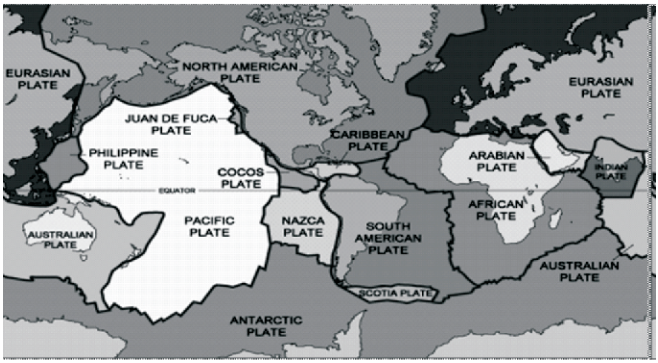

Figure 11: The continents, once joined together in a single landmass, began separating during the Triassic Period, forming new oceans at their boundaries.

At a given time during its formation, each basin contains a number of different environments where sediments may be deposited.

2.2 Sedimentary Environments and Sedimentary Rock Properties

As basins were being formed, sedimentary particles were carried down along streams and rivers, or transported by winds until they slowed down in certain places, which became zones of sediment accumulation (geological environments)Fig 12.

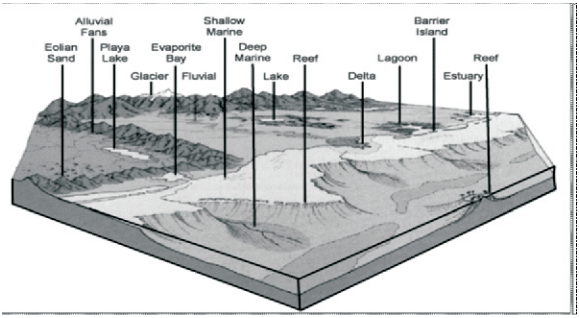

Figure 12: *Major geological environments.*

Some of these sediments (Figure 12) are deposited onshore and are called Continental deposits. Others are formed along the Shoreline and even others are formed in the deeper Marine environment along the shelf, slope and deep offshore (Figure 13).

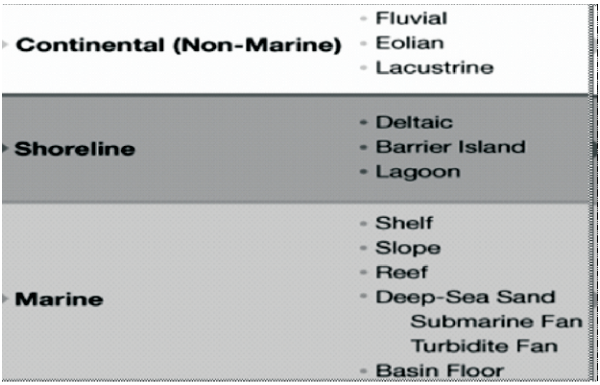

Figure 13: The three geographical settings in which sedimentary rocks are formed and the classification of their depositional environments.

The location at which **clastic sediments** drop out of the flowing stream in each depositional environment depends on gravity forces. As a stream widens or reaches a larger body of water and slows down, the largest, heaviest particles fall to the bottom of the flow stream and are deposited first. Smaller, lighter particles are carried further downstream. Thus, there is a separation and layering of grain sizes within clastic sedimentary rocks, which gives us a convenient way of naming them (**Figure 14**). A rock composed of the largest-size grains is called a **conglomerate**; one of medium-grain sizes is sandstone; one with smaller grain sizes is a **siltstone**; and one made up of very fine particles is called shale. Fluids can flow easily through conglomerates and sandstones because the openings between their grains are comparatively large **(Adiela**& Ofuyah 2018). However, fluids flow more slowly through siltstones and not at all through shale; because they are made of tightly packed, very fine particles that are **impermeable** to fluid flow.

Because of the natural layering of clastic rocks by average grain size, especially in the near and deep offshore environments, many basins may contain layers of different types of sedimentary rocks as shown in **Figure 14**.

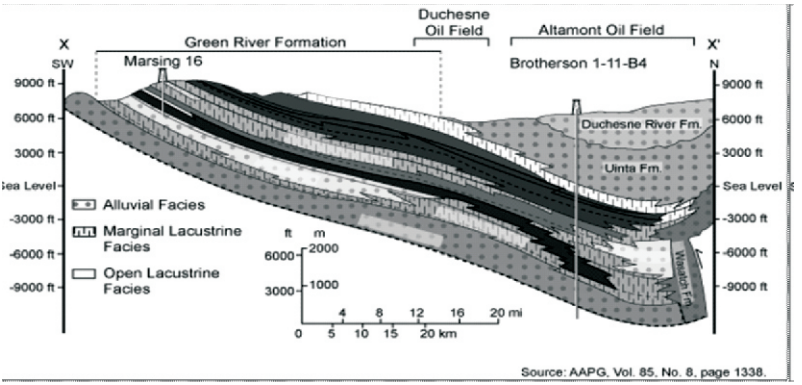

Figure 14: The cross-section of the Uinta Basin in Utah shows the sequence in which the various sedimentary rocks were deposited.

Sedimentary Rock Properties: Porosity and Permeability

Because sedimentary rocks are formed by the compaction of particles in the presence of water, the rock volume contains "pore" space around the grains that can be filled with fluids, water, oil or gas. The percent of the gross rock volume that is fluid-saturated is referred to as **Porosity** (**Adiela** & Jayeola 2018) **Figure 15**.

Porosity: Porosity is the ratio of void space in a rock to the total volume of rock, and reflects the fluid storage capacity of the reservoir.

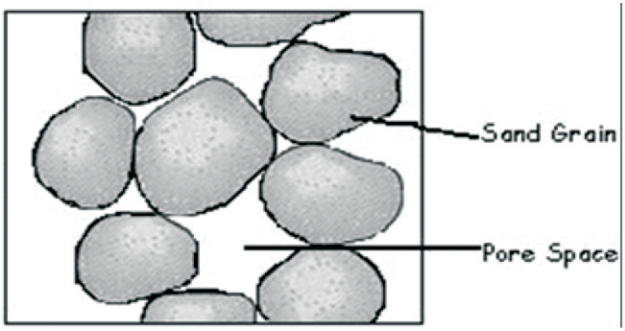

Figure 15: Porous sandstone

Permeability is a second important characteristic of a sedimentary rock – it is a measure of the ability of a fluid to flow through the rock under a pressure gradient (Figure 16 and 17). The higher the permeability, the greater the fluid flow capacity of the rock will be.Permeability is a measure of the ease with which a formation permits a fluid to flow through it (**Adiela**& Omoboriowo 2018).

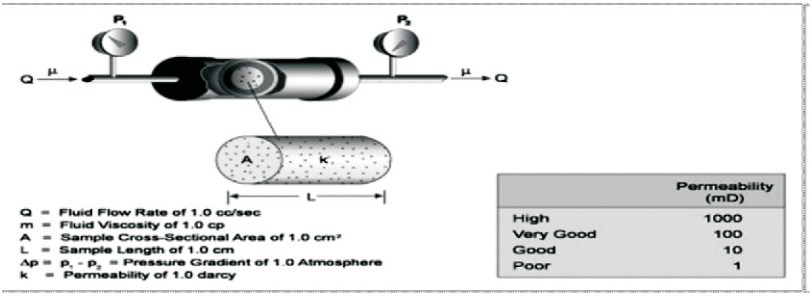

Fig. 16: How the permeability of sedimentary rock is measured in the laboratory.

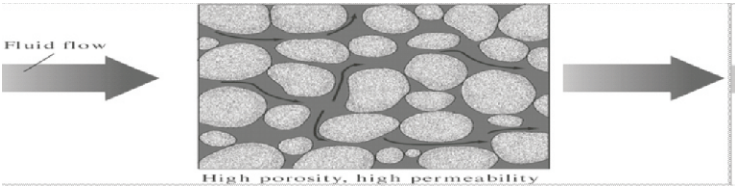

Fig. 17: A hydrocarbon reservoir rock with high porosity and high permeability.

2.3 Formation of Crude Oil and Natural Gas

Petroleum formation takes place in sedimentary basins, which are areas where the Earth's crust subsides and sediments accumulate within the resulting depression. As the sedimentary basin continues to subside, sediment accumulations continue to fill the depression. This results in a thickening sequence of sediment layers in which the lower sediment layers eventually solidify into sedimentary rocks as they experience greater pressures and temperatures with burial depth.

It is critical to petroleum formation that at some time during the accumulation of sediments at least one of the sediment layers contains the remains of deceased plants or microorganisms(Gluyas J. & Swarbrick R., 2004).

Development of stagnant water conditions in some of the expanded oceans caused the bottom waters to be depleted in oxygen (anoxic), which allowed portions of decaying plankton (e.g., algae, copepods, bacteria, and archaea) that originally lived in the upper oxygen bearing (oxic) waters to be preserved as a sediment layer enriched in organic matter. Figure 18. In Swampy and marshy depositional settings, sediment layers

enriched in decaying land plants (e.g., trees, shrubs, and grasses) may occur.

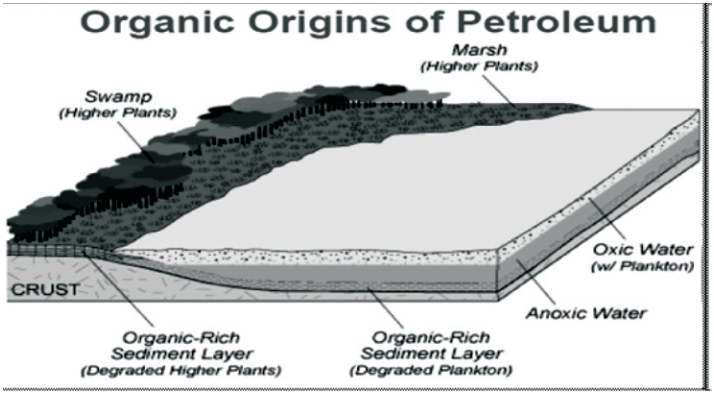

Figure 18: Formation of organic-rich sediment layers.

Burial of the organic-rich rock layer may continue in some subsiding basins to depths of 1800 to 5500 m. At these depths, the organic-rich rock layer is exposed to temperatures of 66 to 177 ºC for a few million to tens of millions of years Figure 19.

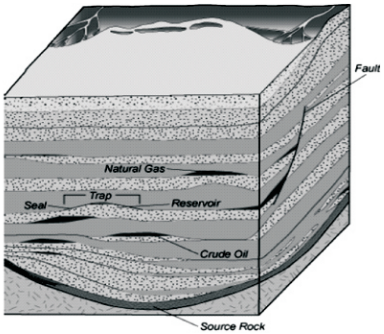

Figure 19: Continued burial of sediment and rock layers in subsiding basin

The organic matter within the organic-rich rock layer begins to cook during this period of heating and portions of it thermally decompose into crude oil and natural gas (thermogenic gas). This overall process of cooking petroleum out of an organic-rich rock layer involves the appropriate combination of temperature and time. Organic-rich rock layers that have undergone this process of petroleum generation are considered to be thermally mature and referred to as source rocks.

Oil and gas are formed from the decomposed remains of ancient plants and animals (the Organic Theory). Through a sequence of geologic events that occurred over millions of years, organic material was deposited in **basins**, together they were gradually buried to greater depths under layers of sediments and became what geologists refer to as **source (**Source rock refers to the formation in which oil and gas originate).

As they subsided deeper and deeper in the basin Figure 23, both the **temperature and pressure increased** and, over time and through a series of chemical reactions, some of the organic material got transformed into petroleum.

This transformation is illustrated in **Figure 20**. As the organic-rich source rock is buried deeper into a basin, the temperature increases and the transformation of the organic matter to petroleum takes place.

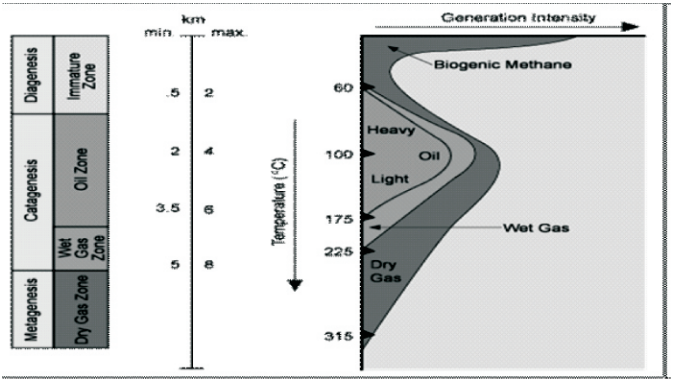

Figure 20: Organic matter in source rocks is transformed into petroleum at deeper depths of burial as the temperature increases.

2.4 Petroleum System

Oil and gas fields are geological features that result from the coincident occurrence of five types of geologic features: (1) Oil and gas source rocks, (2) Migration, (3) reservoir rocks, (4) Reservoir seals, and (5) traps.

2.4.1 Oil and Gas Source rocks:

In petroleum geology, source rock refers to rocks from which hydrocarbons have been generated or are capable of being generated(Stefan, M.L1990) Figure 21.

When temperatures of the organic-rich sedimentary rocks exceed 120o C (250o F) the organic remains within the rocks begin to "cook" and oil and natural gas are formed from the organic remains and expelled from the source rock.

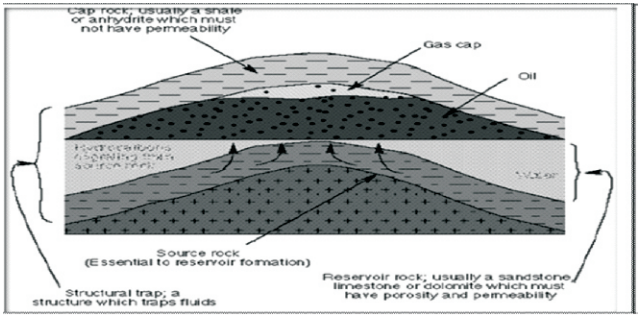

Figure 21: Source Rocks: Maturation and expulsion

2.4.2 Migration

Migration is the process of the oil and gas moving away from the source rock. Migration is caused by burial, compaction, and increase in volume and separation of the source rock constituents. There must be space 'porosity' within the rocks to allow for movement. In addition, there should be “permeability' within the rocks Fig. 27 and 28.

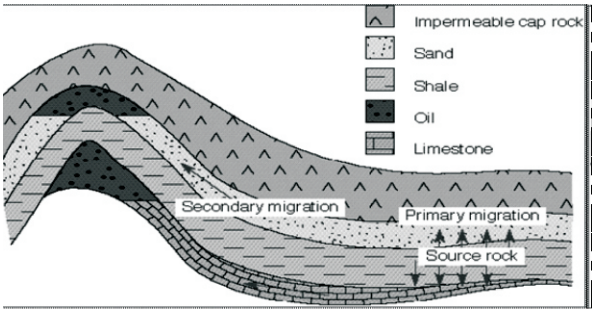

Figure 22: Source Rock, Primary and Secondary Migration

Evidence for Migration: Oil Seepages

Visual evidence of migration is seen as oil and gas seepages (Plate 1) and Figure 23.

Plate 1: Migration Evidence: Oil Seepages

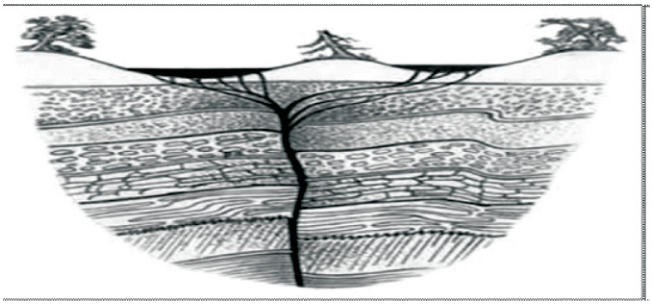

Figure 23: Evidence of Oil Seepage: The La Brea Tar Pits in Los Angeles.

The La Brea Tar Pits in Los Angeles are puddles of asphalt that seeped to the surface from young (Miocene) source rocks through faults Fig 23.

2.4.3 Petroleum Reservoirs

A petroleum reservoir is a porous, permeable rock formation, in which oil and gas are contained in the empty spaces between the rock grains (Figure 24).

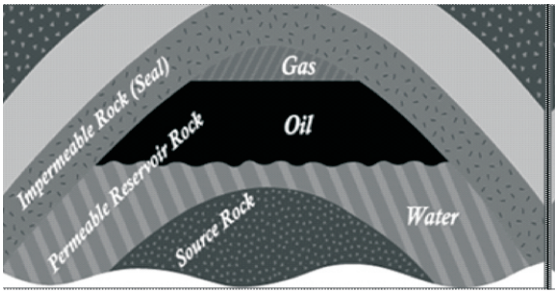

Figure 24: A petroleum reservoir

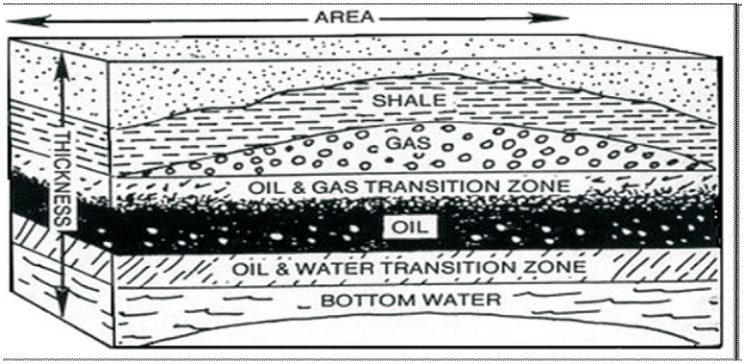

Figure 25: Some Reservoir Properties: Thickness, Area, Depth etc.

2.4.4 PETROLEUM TRAPS.

Trapping is the mechanism by which migration of oil and gas is stopped such that an accumulation of these liquids occur Fig. 26. Traps are combinations of physical factors that promote the

accumulation and retention of Oil and Gas in one location (**Adiela** & Ayodele, 2018). Traps can be structural, stratigraphic, or a combination of the two.

1. Structural Traps

S**tructural traps** are caused by tectonic deformations such as folding, faulting and other post-depositional activities. Fig 26, Plates 2 and 3.

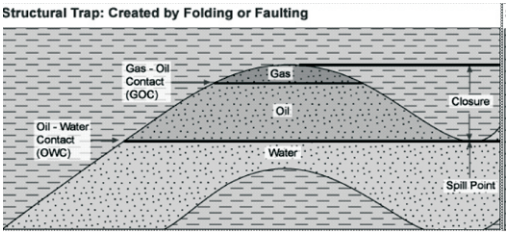

Figure 26: Structural Traps: Created by Folding or Faulting.

***Plate 2**: Faulted Outcrop*

***Plate 3**: Folded Structure*

1. Stratigraphic Traps

Stratigraphic traps are caused by depositional differences between adjacent rock types Fig 27, 28, 29 and Plate 4.

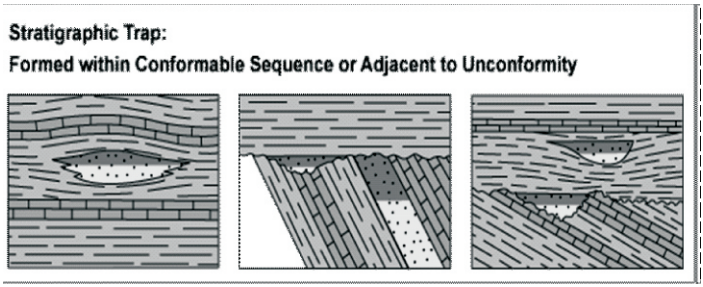

Figure 27: Stratigraphic traps are formed by subtle changes in rock type.

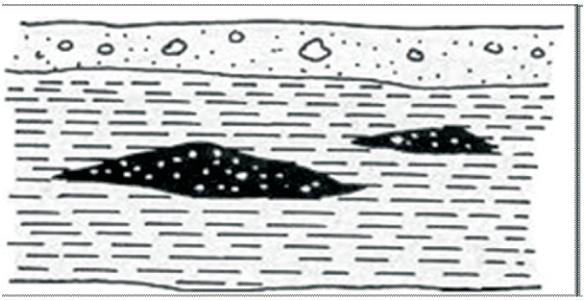

Figure 28: Lens trap

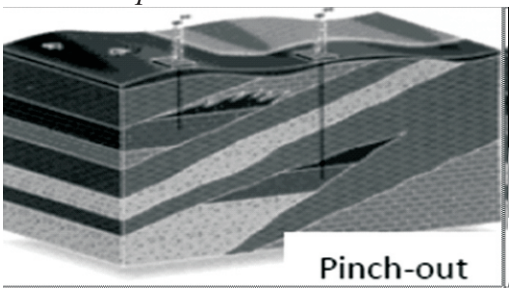

Figure 29: Pinch-out trap

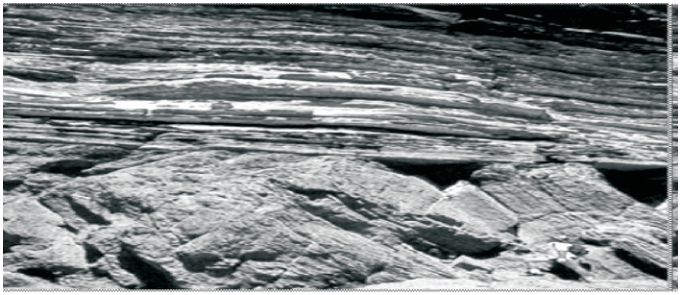

Plate 4: Angular unconformity

3 Combination Traps:

A combination trap contains both structural and stratigraphic features. Figure 30

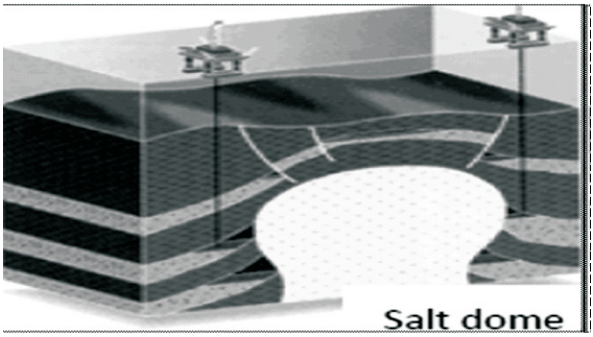

Fig 30: Combination Traps formed as a result of both structural and stratigraphic traps

2.4.5 Reservoir Seal (Cap Rock):

A seal is an impermeable rock unit that overlies a trap and prevents the hydrocarbons from further upward migration

(Figure 31). It is a relatively impermeable rock that forms a barrier, cap or seal above and around reservoir rock so that fluids cannot migrate beyond the reservoir(**Adiela**, 2018). The most common seal is a shale layer.

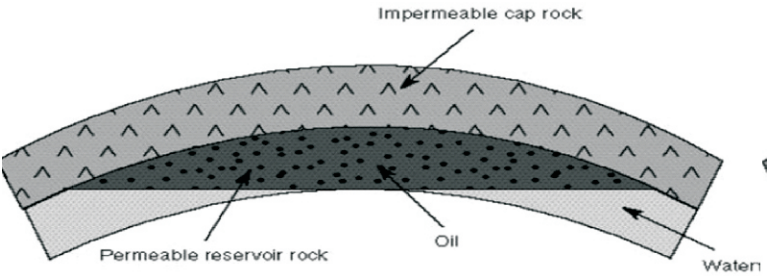

Figure 31: An impermeable cap rock (Seal)

The term petroleum system therefore refers to the combination of the main geological attributes which have led to the accumulation of hydrocarbons (Fig.32).Therefore the main geological attributes of a Petroleum System includes: The Source Rock; a porous and permeable reservoir rock; an impermeable cap rock, a trap and a succession of geological events (favourable timing).

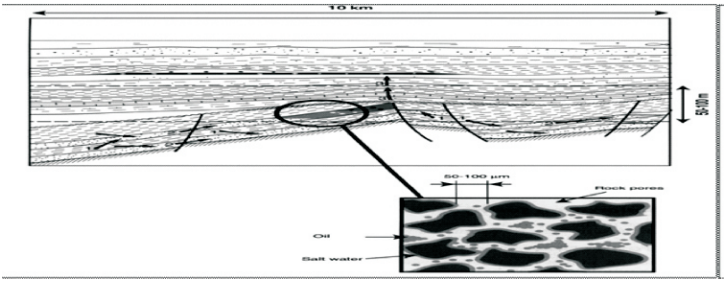

Figure 32: A Petroleum System

2.5 The Niger Delta Petroleum System / Basin

The delta is formed at the site of a rift triple junction related to the opening of the southern Atlantic starting in the Late Jurassic and continuing into the Cretaceous. The delta proper began developing in the Eocene, accumulating sediments that now are over 10 kilometers thick. The Niger Delta is situated in the Gulf of Guinea (Figure 33) and extends throughout the Niger Delta Province (Doust & Omatsola, 1990). The Niger Delta is one of the largest regressive deltas in the world with an area of 300,000 km2 (Evamy & others, 1978), a sediment volume of 500,000 km3 (Reijers, Petters, & Nwajide, 1997) and a sediment thickness of over 10 km in the basin depocenter (Evamy,& others, 1978).

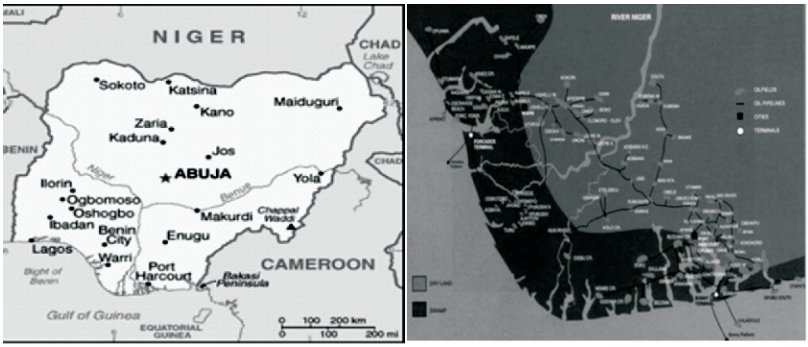

Figure 33: Map of Nigeria and the Map of the Niger Delta.

The Niger Delta Province contains only one identified petroleum system (Ekweozor and Daukoru, 1994) referred to as the Tertiary Niger Delta (Akata –Agbada) Petroleum System (Figure33). The Niger Delta province is the twelfth richest in

petroleum resources (Michael, Roland, & Michael, 1999).

The Tertiary section of the Niger Delta is divided into three formations, representing prograding depositional facies that are distinguished mostly on the basis of sand-shale ratios Figure 34. The type sections of these formations are described in Short and Stäuble (1967). The Akata Formation at the base of the delta is of marine origin and is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt (Figure 34). The primary source rock is the upper Akata Formation(Michael, Roland, & Michael, 1999).

Deposition of the overlying Agbada Formation, the major petroleum-bearing unit, began in the Eocene and continues into the Recent. The formation consists of paralic siliciclastics over 3700 meters thick and represents the actual deltaic portion of the sequence. The Agbada Formation is overlain by the third formation, the Benin Formation, a continental latest Eocene to Recent deposit of alluvial and upper coastal plain sands that are up to 2000 m thick (Avbovbo, 1978). Figure 34

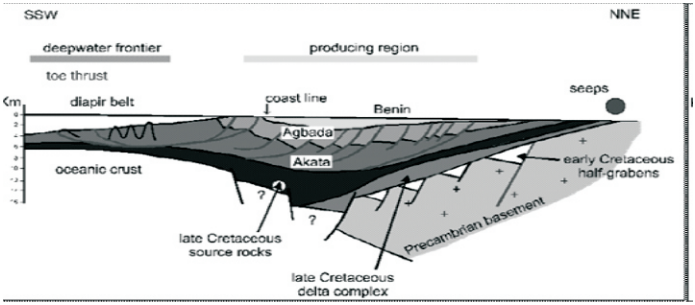

Fig 34: The three formations of the Niger Delta: from Doust and Omasola (1990).

Most known traps in Niger Delta fields are structural although stratigraphic traps are not uncommon. The structural traps developed during syn-sedimentary deformation of the Agbada paralic sequence. Doust and Omatsola (1990) describe a variety of structural trapping elements, including those associated with simple rollover structures(Fig. 35).

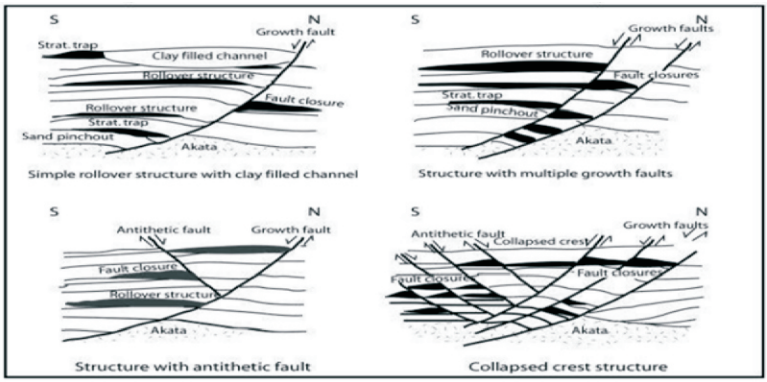

Fig. 35:Niger Delta Oil Field Structures and trap types: Doust and Omotsola (1990).

3.0 THE EXPLORATION TO PRODUCTION PROCESS

3.1.0 Exploration Techniques, Tools and Equipment

Petroleum exploration is essentially a search process that can be represented by a funnel (Figure 36). It starts with broad surveying techniques designed to gather information over the full extent of an entire basin.

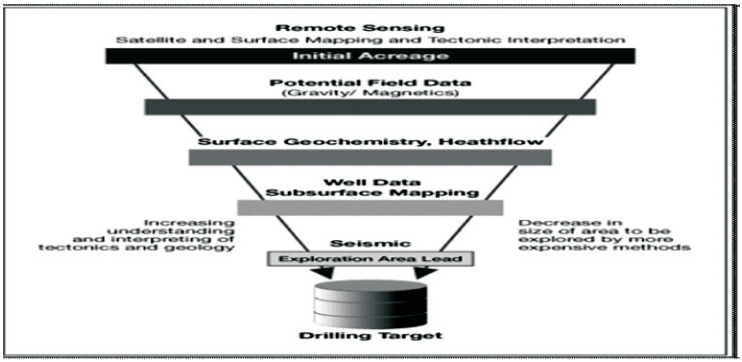

Figure 36: The "funnel process" illustrates the petroleum exploration search approach.

3.1.1 Broad Surveying Techniques: Basin-wide search techniques, which include the application of remote sensing and surface mapping techniques, are used.

3.1.1.1 Remote sensing involves the acquisition, processing and interpretation of images from aircraft and satellites (Plate 5) using Aerial photography.

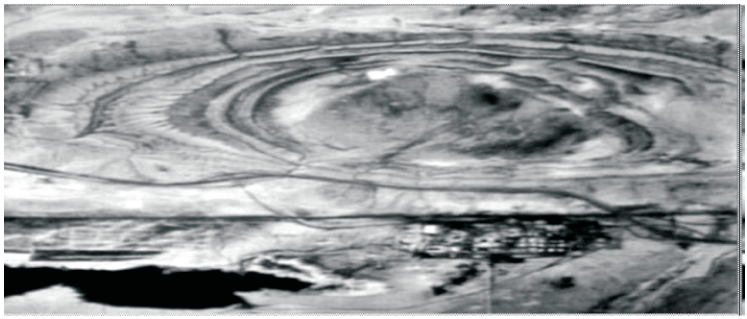

Plate 5: *Remote sensing via satellite of rocks suggests that a structural trap has been uplifted and eroded at the surface.*

3.1.1.1 Surface mapping involves mapping of surface outcrops that the geologists use to infer the location and structure of the formations below the surface.

3.1.2 Geophysical Surveys

Geophysical techniques such as magnetic, gravity and seismic surveys provide a way of measuring the physical properties of a subsurface formation.

3.1.2.1 Magnetic Surveys

A magnetometer is used to measure local variations in the strength of the earth's magnetic field and, indirectly, the thickness of sedimentary rock layers where oil and gas might be found.

3.1.2.2 Gravity Surveys

The gravity survey method makes use of the earth's gravitational field to determine the presence of gravity anomalies (abnormally high or low gravity values) which can be related to the presence of dense igneous or metamorphic rock or light sedimentary rock in the subsurface.

3.1.2.3 Seismic Surveys:

Tools and Equipment

Some equipment's used in Seismic survey include the following: Weight drops with different weights, Sledge hammers, Seismic guns, Geophones, Accelerometers, Seismographs, Hydrophones, Trucks, etc (Plate 6).

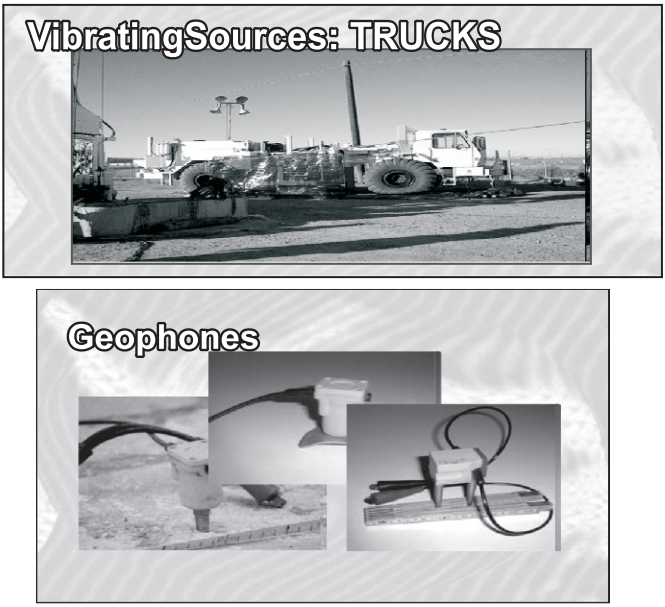

Plate 6: Some Geophysical Tools and Equipment

Principles of Seismic Surveys

The geophysical method that provides the most detailed picture of subsurface geology is the seismic survey (Coffeen, 1986). This involves the generation and propagation of seismic waves down into Earth until they encounter a discontinuity (any interruption in sedimentation) and are reflected back to the surface Figure 37. On-land, seismic "shooting" produces acoustic waves at or near the surface by energy sources such as dynamite, a "Thumper" (a weight dropped on ground surface), a "Dinoseis" (a gas gun), or a "Vibroseis" (which literally vibrates

the earth's surface). Electronic detectors called geophones then pick up the reflected acoustic waves. The signal from the detector is then amplified, filtered to remove excess "noise", digitized, and then transmitted to a nearby truck to be recorded on magnetic tape or disk.

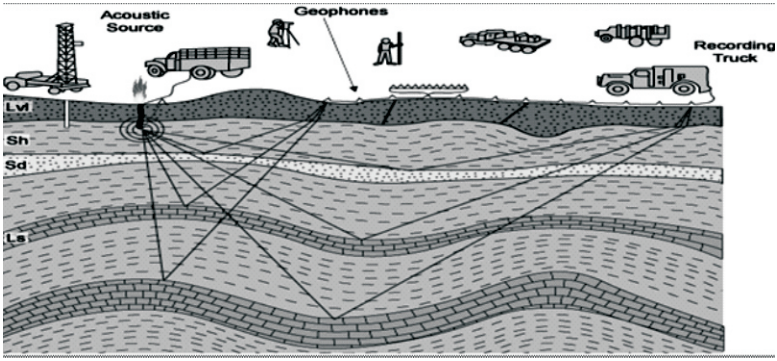

Figure 37: A land-based seismic survey.

In petroleum exploration we generate an acoustic signal at the surface and record how long it takes to be reflected back from a subsurface horizon (the "two way travel time").The acoustic source in a marine survey consists of air guns located just below the water's surface, while the receivers or hydrophones are contained in streamers behind the vessel Figure 38. The air guns emit a vibration, while the hydrophones pick up the reflected acoustic signal. These signals are then captured in computers on the seismic vessel and converted to seismic traces.

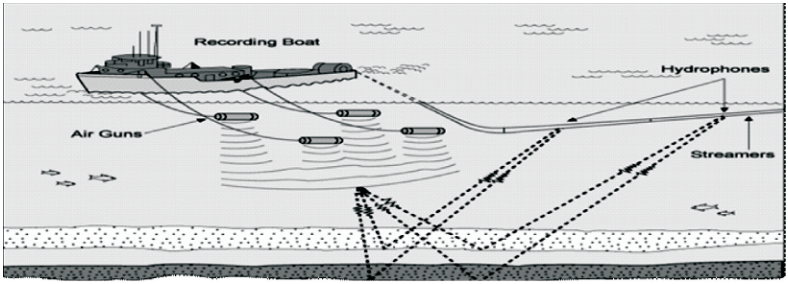

Figure 38: An offshore based seismic survey

For a land-based survey, a receiver, or **geophone (Figure 39)**, records the vibrations transmitted back from the subsurface. When the reflection arrives at the geophone, the earth vibrates a magnet and the time of arrival is recorded in the truck (Plate 7) or boat.

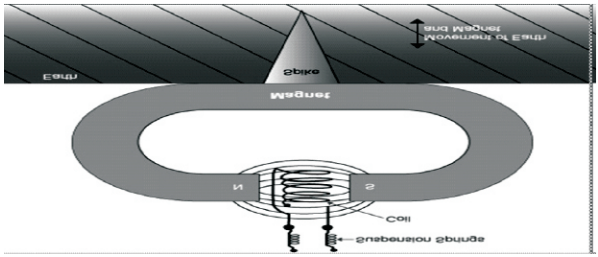

*Figure 39**:** The geophone picks up the vibration of the reflected signal within the magnet and coil and conveys it to the recording instruments.*

***Plate** 7: Thumper Trucks*

In an actual survey, multiple sources and receivers are deployed at equal spacing along a line at the surface. The recorded signals are then-processed to improve the clarity of the reflections, and the results are then displayed in the form of a seismic section for each survey line (Fig 40).

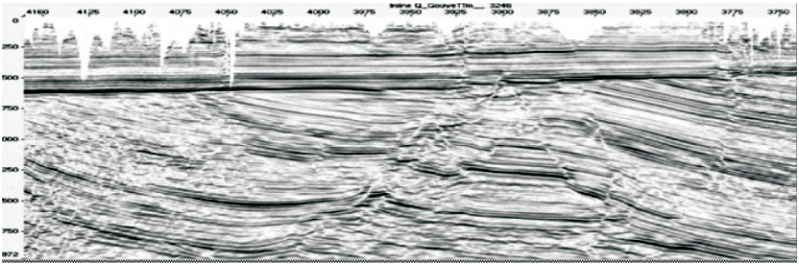

Figure 40: Seismic line

Once the data are processed and interpreted, the geoscientists provide us with a picture of subsurface geologic features (**Figure 41**). Today this interpretation is done on multiple computer screens with the opportunity to "view" the results in special rooms (Workstation rooms) **Plate 8**.

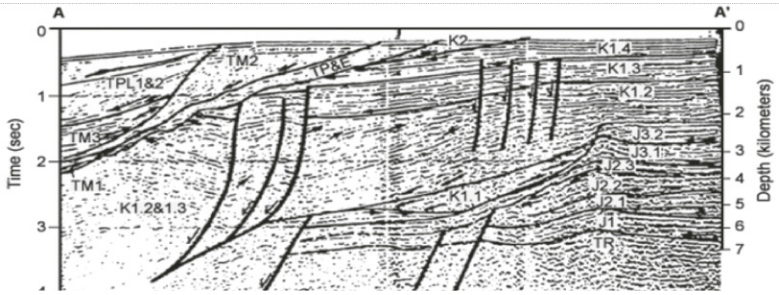

Figure 41: The interpretation of the seismic section

***Plate 8**: Interpreting seismic data on multiple computers*

3.2 Subsurface Mapping

Geologic maps are a representation of the distribution of rocks and other geologic materials of different lithologies and ages over the Earth's surface or below it. Subsurface mappingis a valuable tool for locating underground features that may form traps or outline the boundaries of a possible reservoir. Some examples of subsurface geological maps used for exploration and production include; Structural contour maps,structural amplitude maps, isopach maps, lithofacies maps etc.

3.3 Subsurface Geology and Formation Evaluation

Another source of subsurface data within the basin is available from wells that have been drilled in the area. Well data provides information on formation rock and fluid properties (Etu-Efeotor,

1997).Well logs are one of the most valuable sources of subsurface data, and are available from virtually every well that has been drilled (Schlumberger, 1985)(Figure 42)

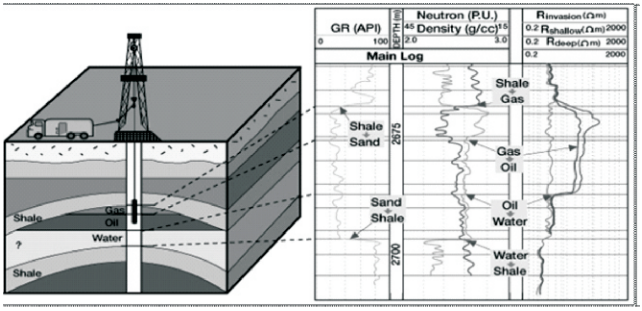

Figure 42: Well logs measure rock properties in the wellbore.

In the well log of Figure 42, we see that the depth from datum (usually feet or meters below sea level) is noted in the middle of the strip. On the left is the recording of the natural Gamma radiation (GR) of the rocks. Shales have a naturally high value and sandstones do not. So this recording allows us to identify the depth and type of rocks we have drilled. We can thencorrelate and connect the subsurface rock layers between wells and make the preliminary interpretation shown in Figure 43.

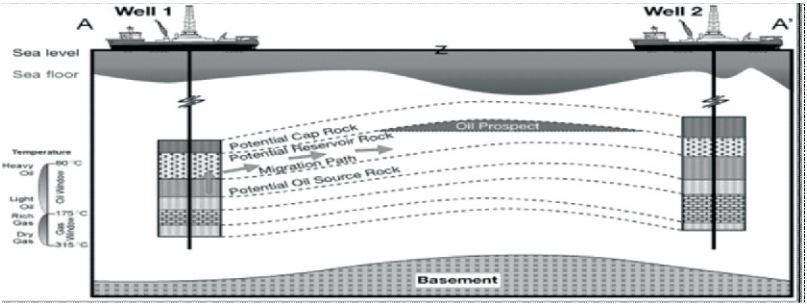

Figure 43: The well log for Well 2 allows us to expand our interpretation of the basin on the eastern side through correlation.

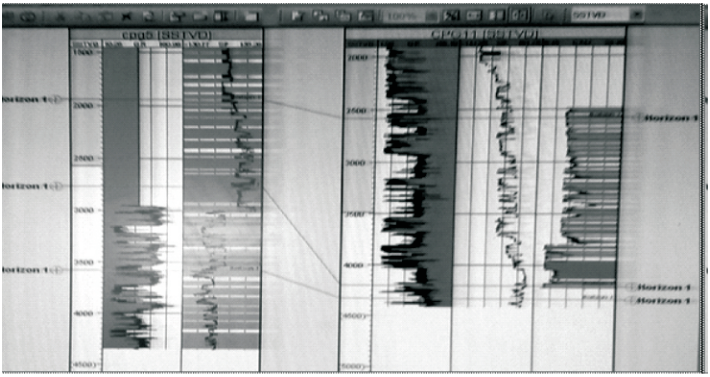

Figure 44: Cross-section constructed from correlated well logs

Subsurface correlation is based primarily on stratigraphic continuity, or the premise that formations maintain the same thickness from one well to another.

Logs can provide a direct measurement of: Porosity, Permeability, Water saturation and hydrocarbon movability, Hydrocarbon type (oil, gas, or condensate), Lithology,

Formation dip and structure, Sedimentary environment, Travel times of elastic waves in a formation etc.These parameters can provide good estimates of the reservoir size and the hydrocarbons in place (Hyne, 2001).

3.4 Drilling Methods - Exploration Drilling

Drilling is the final stage and the supreme arbiter of the exploration process. Drilling an exploration well can take several (2 to 6) months, and on average one drilling in five results in the discovery of an economically feasible hydrocarbon reservoir.

The objective of drilling is to create a link between the surface and the target formation by penetrating the various geological strata down to a depth of up to ten kilometres (35000 ft). The most widespread technique involves attaching the rock with a rotating drilling bit (Fig. 45).

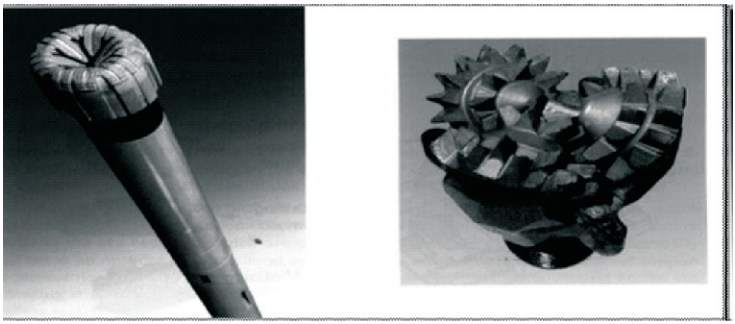

Figure 45: Drill Bits

The drilling bit is attached to a drill string (Fig. 46).

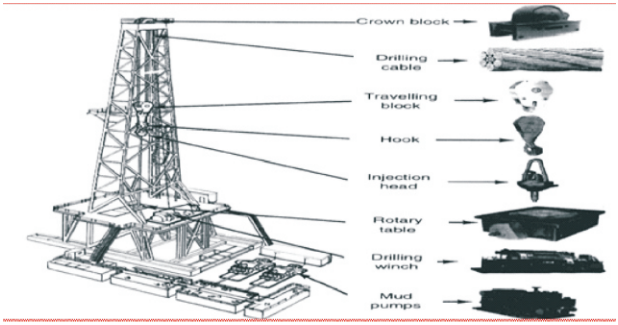

Figure 46: Main Components of a Rig.

Drilling starts with a large bit, for example of 26 in. (66 cm) in diameter attached to a drill-collar and a drill-pipe. When drilling has reached a certain depth a new drill-pipe is added to the drillstring.

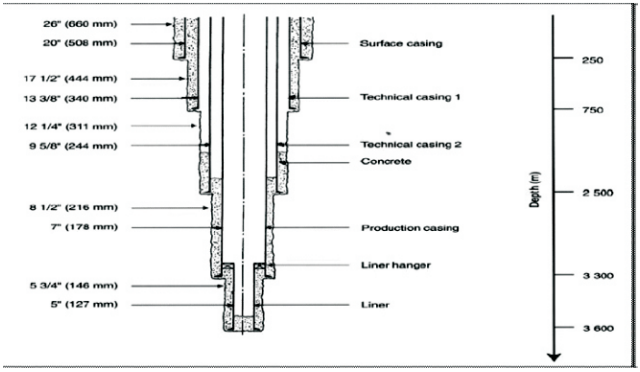

Figure 47: Cased Wellbore

As drilling progresses, successively smaller drill bits are used and the diameter of the cased hole decreases, as shown in (Figure 47).

CHOICE OF DRILLING EQUIPMENT

The main difference between onshore and offshore drilling is related to the way in which the rig is supported. Offshore operations are conducted from platforms which either float or are fixed to the sea bed, and which are capable of performing all the functions normally carried out at an onshore drilling site as well as certain other services such as diver support and a meteorology station. The platforms may be either fixed platforms resting on the sea bed, floating structures or semi-submersibles. Self-raising or jackup rigs are generally used in shallow waters. Barges and semi-submersibles with dynamic positioning tend to be kept for deeper waters. These mobile units only remain stationary during drilling (Fig. 48).

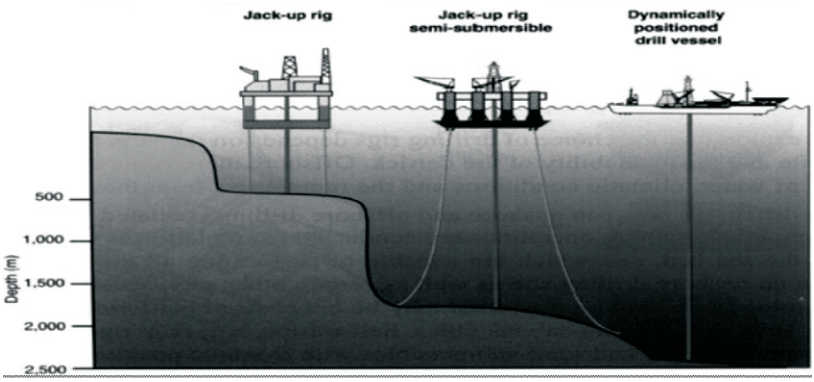

Figure 48: Mobile Platform for Offshore Drilling

Appraisal Well

If an exploration well leads to a discovery, it is necessary to prospect further in order to delineate the reservoir and evaluate

its potential. This appraisal stage essentially involves carrying out the following tasks: Mapping; Reservoir simulation; and the drilling of additional wells several metres away in order to obtain more data.

When these tasks have been completed, a decision will be taken, based on the available information, whether to develop the field and put it into production or to shut it in until economic prospects become more favourable or whether to abandon it.
Several vital questions have to be answered at this stage: Is the field commercial? Should it be developed? And if so, what should be the development scheme?

Development and Production
If the appraisal stage shows that the characteristics of the reservoir are sufficient to justify production then the development stage begins. The development stage involves drilling the future production wells and installing all the associated equipment required for production. Capillary forces within the reservoir make it impossible to recover all of the hydrocarbons from the field. It is estimated that an average of 80% of the gas and 30% of the oil can be recovered.

Recovery Mechanisms
There are two recovery mechanisms: Primary and Enhanced recovery mechanisms.

A. Primary recovery
After the wells have been completed hydrocarbons can be produced at the surface. They flow from the reservoir into the

well under the effect of the pressure gradient between the reservoir and the well bottom (Fig. 49). As production proceeds the pressure in the reservoir falls, thus reducing the natural flow rates of the hydrocarbons.Primary recovery typically allows 25-30% of the oil to be recovered.

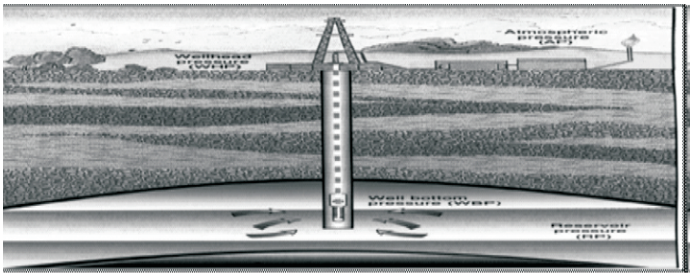

Figure 49: Primary Recovery

B. Enhanced recovery

The volume of crude oil extracted under primary recovery is not economically viable. It is therefore often necessary to resort to mechanisms for enhancing the recovery rate of hydrocarbons. We have secondary recovery and tertiary or enhanced recovery mechanisms.

Secondary recovery is effected by means of water injection and gas injection, water injection being largely used. It involves either drilling injection wells or converting production wells into injection wells. Water is then introduced into these wells under pressure. This both maintains the pressure in the oilfield by taking the place of the produced oil in the pores of the reservoir rock and flushing out the oil remaining in the producing rock, driving it towards the production wells (Fig.

49). The injection of water or immiscible gas into an oilfield leads to recovery rates which are higher (40-60%).

Tertiary recovery processes, known as EOR (enhanced oil recovery), make use of chemical and thermal techniques, They can improve recovery by a further 5-10% of the total oil resources in the oilfield (Fig. 50).

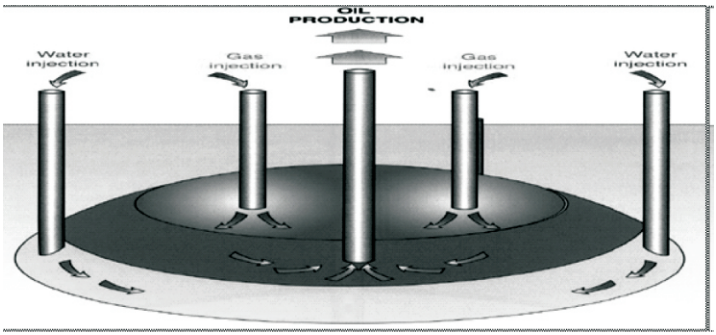

Fig. 50: Secondary recovery – Maintaining pressure by injecting water into the aquifer

3.5 TYPES OF DEVELOPMENT DRILLING:

The principles underlying development drilling are the same as those for exploration drilling, but more specific use is made of directional and horizontal drilling, and multi-drain systems.

3.5.1 DIRECTIONAL DRILLING

Directional drilling can be carried out on a J or an S configuration Fig. 51. It is normally used when the drilling zone is inaccessible or urbanized; To circumvent a subterranean

obstacle such as a salt dome and to deal with a well in which there has been an accident.

3.5.2 HORIZONTAL DRILLING:

Horizontal drilling is a special case of directional drilling in which the borehole is horizontal, parallel to the reservoir strata Fig 51. It is used when the production zone is a long way from the drilling rig; this technique can even be used to access resources under the sea bed from an onshore location, thus avoiding the need for offshore equipment.

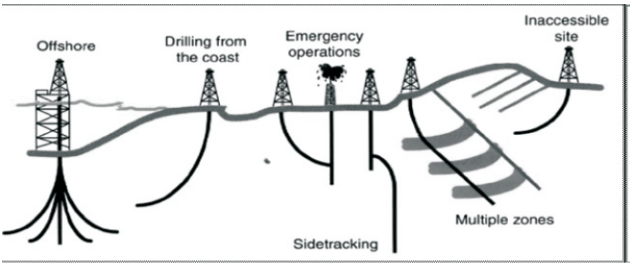

Fig 51: Horizontal and Directional drilling

3.5.3 MULTI-DRAIN DRILLING STSTEM

Multi-drain wells allow production from different parts of a reservoir with a single well Figure 52. During production, multi-drain systems multiply the number of wellbores and therefore increase production.

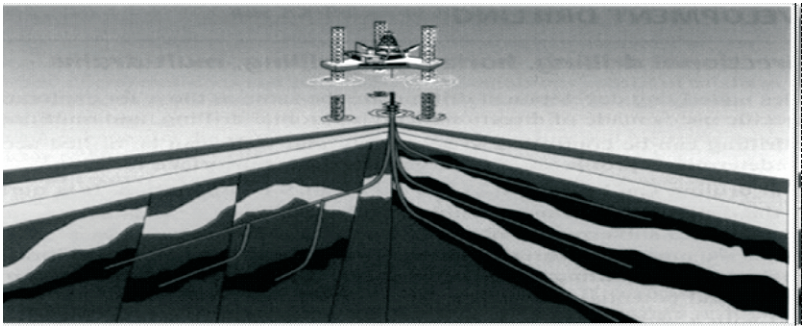

Figure 52: Multi-drain Wells

3.6 WELL COMPLETION

Completion involves making the well ready for production. A connection has to be made between the wellbore and the reservoir, by drilling into the reservoir, treating it, equipping the well and putting it into production.Once the well has been completed, the wellhead is attached to the top so as to control the flow of fluids (Fig. 53).

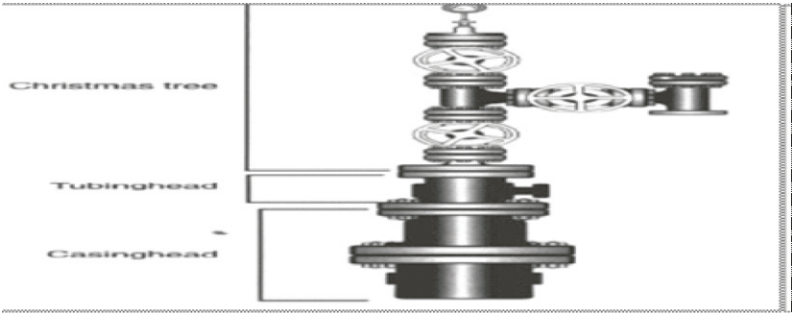

Figure 53: The Well Head

3.7 THE PRODUCTION FACILITY - PROCESSING OF EFFLUENTS

The production facility includes: the effluent processing units; the storage, metering and dispatch facilities (Fig 54). In the case of oil production, The function of the processing plant is to bring the oil or gas up to the specifications required for export. Figure 54

Figure 54: Production Facility

In offshore production these installation have to be located on platforms with a restricted surface area (Fig. 55).

Figure 55: Offshore Production Platform

THE PETROLEUM INDUSTRY TODAY

Today's modern oil business is quite organized and broadly arranged into three main segments known as the Upstream, Midstream and Downstream Sectors Figure 56.

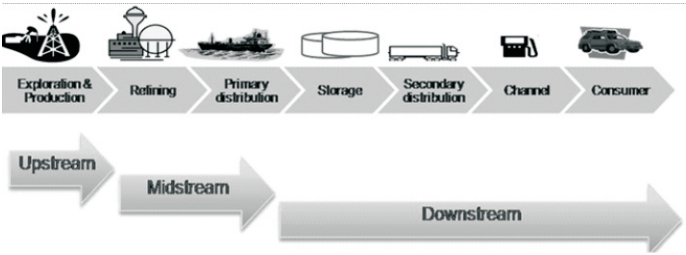

Figure 56: Upstream, Midstream and Downstream Sectors

4.1 UPSTREAM SECTOR:

Companies in the **Upstream** oil business are involved in exploring for oil (prospecting and exploration), drilling of oil and getting it out of the ground (production). When the oil is out of the ground, it is processed, stored and transported to the refineries. Fig. 56

4.2 MIDSTREAM SECTOR

The midstream sector consists of the operational activities which connect the upstream operators to the downstream markets. It involves the transportation (by pipeline, rail, sea barge, or truck), storage, and wholesale marketing of refined petroleum products.

4.3 DOWNSTREAM SECTOR

The Downstream segment involves everything from refining the crude oil and it covers storage and transportation of all the refined products until it ends up in your car's petrol tank or in your kitchen stove as kerosene Figure 56.

4.3.1 CRUDE OIL REFINING

Crude oil from the ground is a mixture of hydrocarbons which are subjected through a refining process to segregate the different components Figure 57.

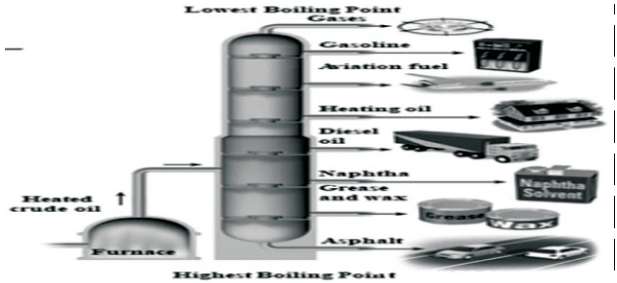

Figure 57: The Crude Oil Distillation Column

Nigeria has 3 refineries namely Port Harcourt Refining Company (PHRC) (Plate 9); Warri Refining and Petrochemical Company Limited (WRPC) and Kaduna Refining and Petrochemical Company Limited (KRPC). This is in addition to one privately owned by Mr. Aliko Dangote.

Plate 9*: The Port Harcourt Refinery*

The 4 major oil and gas products in Nigeria:

There are 4 major products that are in high demand and most popular with everyday consumers in Nigeria: Petrol, Diesel, Kerosene and Cooking Gas.

4.4 Other Energy Sources: Non-Renewable and Renewable Energy Resources

4.4.1 Non-RenewableEnergySources

Non-renewable resources are energy sources with limited supply and cannot be replaced in a short period of time. Examples are Coal, Oil and Natural gas {World Energy council (WEC, 2010)} Figure 58. They are known as Fossil Fuels because of their organic origin (compounds of Carbon and Hydrogen – Hydrocarbons).

75% of global energy is from fossil fuel, 6% nuclear and the rest 19% is from renewable energy Figure 58. International Energy Agency (IEA)(2007).

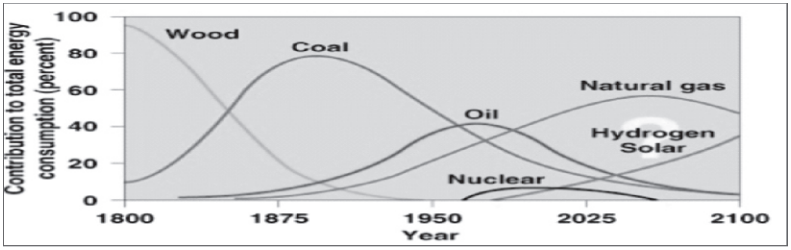

Figure 58: Contribution to total energy consumption over time.

Fossil fuels area valuable source of energy. However, burning fossil fuel is harmful to the environment. It releases hazardous gases into the air that we breathe.There is also the possibility of an oil spill. Carbon pollutes the environment and is responsible for global warming. Climate change, acid rain and change in seasons are some other effects that have been observed by many people. With so many problems, scarce resources and rising prices, these resources cannot be used for life time. The need of the hour is to look for some alternative sources of energy (Renewable energy sources).

4.4.2 Renewable Energy Resources

Renewable energy resources are energy sources that can be re-used or readily replaced naturally within a human lifetime (Akpan & Akubue, 2014). Examples are Solar, Wind, Water, Geothermal and Biomass (Plate 10).

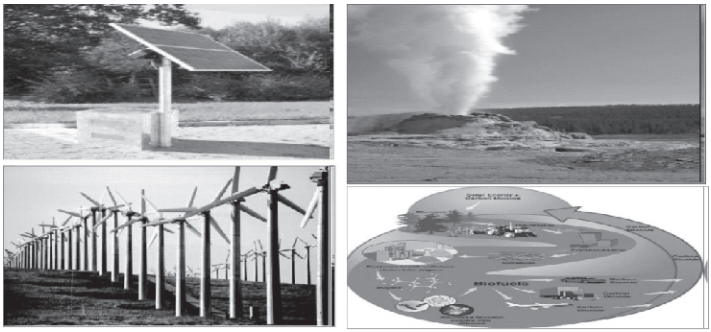

***Plate 10**: Some Renewable Energy Sources: Solar; Geothermal; Wind; Biomass.*

Nigeria is blessed with rich renewable energy resources (Table 1).

Table 1: Nigeria's Renewable Energy Resources (Energy Commission of Nigeria (1998))

Resource	Reserve Estimate	Reserve Estimate (billion toe)	Comments
Solar	3.5–7.0kW/m^2/day	1.082	Annual average increasing from South to North
Wind	3.0–7.0m/s		Moderate; Annual average increasing from South to North
Small Scale Hydro	734.2MW		In the 7 River Basins

Fuelwood	43.3MillionTonnes	1.6454	Over 100Years
AnimalWaste and Crop Residue	144MillionTonnes/Yr	4.032	Over 100Years
WaveandTidal			Not Yet Developed
Geothermal			Not Yet Developed

Presently, the potentials of some of the resources like geothermal, waves, tidal and ocean energy sources remainunquantified in Nigeria (Iloeje,2004) and {International Institute for sustainable Development, IISD (2008)}.

CHALLENGES OF THE OIL AND GAS INDUSTRY IN NIGERIA - OIL EXPLORATION AT THE BOTTOM.

5.1 Crude Oil Theft, Illegal Refineries and Pipeline Vandalism.

Crude Oil Thief: Oil theft is the illegal appropriation of crude oil products from the pipelines of multinational oil companies. Nigeria loses about 150,000 barrels of oil per day which translates to more than 4 billion dollars a year (Plate 11). There is a massive disruption to oil operations. Recently in October, 2022, NNPC uncovered 4KM illegal Oil Pipeline from Forcados to the Sea and a loading port operating for 9 years in Delta State. This has brought down production to levels as low as we have never seen.

***Plate 11**: Crude Oil theft through illegal oil refinery*

Illegal Refineries: From Abonnema to Ahoada town, Bodo City to Bonny, Omoku to Oyigbo, artisanal refining and distribution of kerosene and diesel are well known and the operators operate with reckless abandon. In Ikwerre local government area of Rivers State, no fewer than 184 illegal refining sites were uncovered in the area since the clampdown on illegal refineries began across the state (Plate 12).

But Crude Oil is flammable. Nigeria drew global attention as 100 people died because of an explosion at an illegal refinery in the Abaezi Egbema forest of Imo State.

***Plate 12**: Illegal refinery where crude oil is "cooked" by Locals*

Pipeline Vandalism: This involves the breaking of pipelines with the intention of getting the fluid content of the pipeline for economic gain(Plate 13). Suspected crude oil thieves reportedly attacked and vandalized the 24-inch Ogboinbiri/OB-OB gas pipeline, disrupting the gas export schedule of Nigerian Agip Oil Company (NAOC) from oilfields in Bayelsa.

Plate 13*: Pipeline Vandalism*

5.2 Gas Flaring

Gas flaring is the wasteful industrial practice of burning natural gas during oil production. It releases pollutants into the atmosphere, and emits about 380 million tonnes of carbon dioxide and black carbon (soot), contributing significantly to global warming(Plates 14 and 15).

***Plate 14**: Gas flaring at an industrial gas plant*

***Plate 15**: Community dwellers going about their chores with gas flaring in the background*

Oil and gas firms operating in the country's onshore and offshore oilfields flared 73 billion standard cubic feet (SCF) of gas in three months, between January and March 2022, translating to a loss of $256 million to the country (N106 billion).

According to gas flare data released by the National Oil Spill Detection and Response Agency (NOSDRA), the 73 billion SCF of gas flared between January to March 2022.

5.3 Environmental Pollution (Oil Spills).

An Oil Spill is the release of liquid petroleum hydrocarbon or distilled products into the environment(Plate 16). Data from the National Oil Spill Detection and Response Agency (NOSDRA)

showed that Nigeria recorded a total of 4,486 cases of oil spills, amounting to 242,193 barrels of oil, from 2015 to 2021.

Plate 16 *: The pollution of rivers in the Niger Delta as an example of Oil Spill.*

According to the 2011 UNEP Reports, 273 Oil Spills with a volume of 115,000 barrels of Oil was lost annually due to faulty or abandoned pipelines, Oil bunkering by criminals and lack of maintenance of Oil facilities. In 2021, companies reported 388 incidents, resulting in 23,956 barrels of oil.Oil spills have continued to threaten the sanctity of the ecosystem, especially in the Niger Delta pervading lands, mangroves, creeks, and rivers (Plates 16 and 17).

Plate 17*: Oil Spills destroy ecosystems in the Niger Delta.*

5.4 Insecurity and Kidnappings

Nigeria is characterized by lawlessness and this is heightened by the day as refined petroleum pumps through our communities. Open demonstrations pervade the length and breathe of the nation. Kidnappings, Protests (Plate 18) and insecurity have become the hallmark of the Nation. Protesting Itsekiri host communities of Ugborodo in Warri Southwest Local Government Area of Delta State shut down operations of 15 crude oil well heads within the Ogidigben flow station.The oil wells are operated by Shell.

Plate 18: Protesting Youths (Source: The Nation Newspaper)

Kidnappings

Kidnapping started with the kidnap of expatriates working in the Oil and Gas sector (Plate 19). Today anybody can be kidnapped.

Plate 19*: Kidnaping in the Niger Delta by MEND*

5.5 Poor State of Refineries:

One key challenge in the refinery sector is the poor state of the refineries and the huge cost involved in the rehabilitation of the 3refineries in Nigeria (Plate 20).

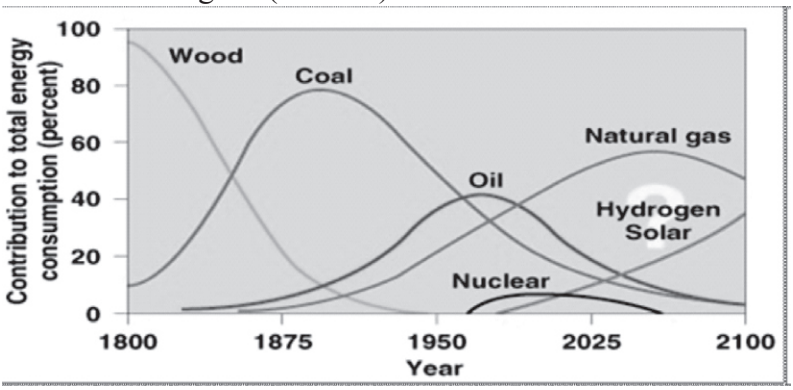

Plate 20*: PH refinery awaiting rehabilitation*

Our Refineries are dead and they need oxygen. The Nigerian National Petroleum Corporation (NNPC) spent N18.22 billion

on refinery rehabilitation between January and March 2022. Of this amount, N9.11 billion was expended on the refineries in January 2022, while another N9.11 billion was spent in March.

It is very laughable that Nigeria borrowed $1 billion from Afrexim bank to rehabilitate the Port Harcourt refineries while vandals are breaking the pipelines. The pipelines that would feed crude to the refineries are at the mercy of vandals - a development that could create fresh challenges for rehabilitated refineries.

5.6 Lack of Funding, Reduced Investments and Divestment of Assets.

Nigeria is heavily reliant on foreign funding for oil and gas exploration and production and the Nigerian oil and gas sector is currently facing liquidity squeeze as global financial institutions are reluctant in providing funds for hydrocarbon exploration. However the increasing rate of oil theft and vandalism especially in the Niger Delta region is highly responsible for most of the huge losses incurred by operators in the oil and gas industry. As a country, Nigeria has lost $1.5billion so far in 2022 because of escalated acts of vandalism.

Nigeria is experiencing lowest oil output ever. Today we are producing less than 1.5 million barrels per day because of the disruptive activities of vandals and criminals along our pipelines in the Niger Delta area that has brought down oil production levels.

Divestment of Assets

International oil companies are leaving Nigeria. Texaco sold off its assets to Chevron in 2000 while Chevron sold its OMLs 83 and 85 in 2015.In the last one year, two foreign oil companies have sold their assets and discontinued business in Nigeria. The first was UK - based Royal Dutch Shell in July 2021, just one month before the PIB was signed into law by President Muhammadu Buhari. Seven months after it was signed, Exxon Mobil Corporation (Exxon Mobil) joined Shell to quit the Nigerian oil market, by taking out its investment in Mobil Producing Nigeria Unlimited. Exxon sold its asset to Seplat although the deal is still subject to Ministerial Consent and regulatory approvals.

5.7 Subsidy:

The amount spent on fuel subsidy monthly rose from N60.39bn in March 2021 to N245.77bn in March 2022, indicating an increase of 306.97 per cent in one year. In 2022, NNPC has spent N210.38bn, N219.78bn, and N245.77bn as the subsidy on petrol in January, February, and March 2022 respectively.

Nigeria will spend as much as N4 trillion on petrol subsidies in 2022. Paying such huge sums for petrol subsidies is bad economics for Nigeria.

The issue of subsidy on premium motor spirit, otherwise called fuel, is a bone in the federal government's throat. The petrol

subsidy is like a cancer on the Nigerian economy which must be removed for the economy to breathe and survive. Subsidy is a burden to the federal government as revenues that should have been used for critical infrastructure are spent on subsidies. The rationale for subsidies had long been defeated as it has failed to achieve the goal for which it was established.

There is fraud going on in the management of fuel subsidy giving the fact that the country has not been able to ascertain the amount of fuel being consumed by the country. There is a cartel benefitting from the subsidy which the government has not been able to unveil.

We cannot ascertain what the real consumption is as far as these products are concerned in Nigeria. We still believe that there is a lot of cross-border transfer of this product. Once it comes to Nigeria, it goes through the border more than what we even consume in Nigeria.

There are doubts over Nigeria's daily petrol consumption figures filled with questionable figures as released by concerned authorities. Nigeria's subsidy regime has for decades remained a subject of controversy, with the figures from the authorities ranging from between 50 million litres per day to around 103 million litres.

5.8 Dearth of Human Capital

Nigeria has not been serious with her human capacity development because she has not been taking education as a priority. UNESCO approved that the educational sector should be given 26% of the annual budget, but Nigeria gives only less than 8% for the past years {UNDP, 2002}

The key challenges here are: Aging and retiring workforce, Industry – Academia mismatch, Employability and Inadequate industry specific institutions

6.0: OPPORTUNITIES IN THE NIGERIAN OIL AND GAS INDUSTRY - OIL EXPLORATION AT THE TOP

We should be very passionate about Nigeria and believe that with focus and clear targets, the country can make progress despite challenges. There are latent opportunities in the Oil and Gas Sector:

6.1 Opportunities in the Nigerian Content Act 2010.

The Nigerian Oil and Gas Industry Content Development (NOGICD) Act, otherwise known as the local content law was enacted in 2010. It is a legislation meant to improve indigenous participation in the oil and gas industry. The Nigerian Content Act is for the development of local skills, the use of local manpower and resources designed to change the policy thrust of the nation's oil and gas industry through indigenous participation (Olsen, 2010).

Some Key legislative highlights and provisions of the Nigerian Content Act include:
SECTION 3(1): Nigerian independent operators shall be given first consideration in the award of oil blocks, oil field licenses, oil lifting licenses and in all projects …….

SECTION 3(2): There shall be exclusive consideration to Nigerian indigenous service companies which demonstrate ownership of equipment's, Nigerian personnel and capacity to execute such work …..

On a positive note, the Nigerian Content Act has helped save the country outrageous sums of money in capital flight as well as jobs. This has also led to more government revenue, more jobs, more skills, and less dependency on foreign countries with the resultant gains for national security.

The Nigerian Content Development and Monitoring Board (NCDMB) has grown Nigerian content in the oil and gas sector to 42 percent. Presently Nigerian-owned oil companies produce 15 percent of the country's daily oil output and account for some 60 percent of domestic gas supply. On ownership of oil and gas industry equipment, 40 percent of vessels deployed in the sector are owned by Nigerians.

6.2 Opportunities in the Petroleum Industry Act.

The Petroleum Industry Act (PIA) 2021 is a game-changer for

the oil industry. An essential part of the PIA is the Host Communities Development Fund (HCDF).

Host Community Development Fund: Oil companies operating in Nigeria are expected to incorporate a host community trust (Plate 21) aimed at fostering sustainable prosperity within the host community. The Host Community Development Trust - HCDT ("the Trust") will oversee all Social, Environmental, and Infrastructural projects in the communities where oil and gas assets are located.

***Plate 21**: Oil and Gas Host Community Board of Trustees Meeting*

Funding: The Trust will be funded by 3% of the actual annual operating expenditure of the preceding financial year in the upstream petroleum operations. The HCDT Fund would come directly to the oil bearing communities, in addition to the existing 13% Derivation, the NDDC funds, the budgetary provisions for the Federal Ministry of Niger Delta and the Amnesty Programme of the Federal Government, hence the need for host communities to take keen interest in the management of the Fund.

6.2 Asset Divestment Opportunities.

Most International Oil Companies (IOCs) are selling their assets and leaving the shores of Nigeria. Asset divestment presents opportunities for indigenous players. With the recent spate of divestments in the Nation's Oil and Gas sector, we believe that indigenous companies can take charge.

Divestments have resulted in the emergence of indigenous companies playing major roles in exploration and production activities such that companies like First E&P, Eroton, Aiteo and others have acquired assets and are now responsible for the production of about fifteen percent of the nation's oil and more than sixty percent of domestic gas.

Using the instrumentality of the Nigerian Content Act, indigenous companies shouldn't play small. We should aim at becoming international champions as against becoming local champions.

6.3 Oil and Gas Sector Refining Opportunities.

As long as the demand for more energy continues to grow in Nigeria, the oil and gas business will continue to boom and become more lucrative. Notable Oil and Gas Investment Opportunities include: Oil Refinery Business, Fuel Importation, Oil Servicing Business, Petrol Filling Station etc. Other investment Opportunities in the downstream sector are: Domestic Production and Marketing of Liquefied Natural Gas (LPG), Domestic Manufacturing of LPG cylinders, valves, and

development of simple, flexible and less expensive gas burners, NLNG Projects etc.

Case 1: Cooking gas: Nigeria needs $750m for 5MMT annual consumption' (5 Million Metric Tonnes)

Plate 22: Cooking gas cylinders

Nigeria requires about $750m investment in the transportation and retailing infrastructure for Liquefied Petroleum Gas, popularly called cooking gas (Plate 22), to achieve the target of five million metric tonnes of annual consumption.

Case 2: The Nigerian LNG and the Opportunities within the NLNG.

Nigeria LNG Limited (NLNG) is considered one of the most important economic projects in Nigeria. Since it began

operations in 1999 when it shipped its first LNG cargo, NLNG has brought significant economic benefits to Nigeria (www.nigerialng.com). The NLNG is the fastest growing LNG Company in the world. It has delivered over 5,000 LNG cargoes to buyers around the world. NLNG Train 7 Project will increase our production capacity by 35% and increase our revenue and it is anticipated to create more than 12,000 new jobs during the construction stage, and on completion. Over USD10 billion is expected to be invested in Train 7 and boost Nigeria's Foreign Direct Investment (FDI) profile. The Project will support the development of local engineering and fabrication capacity.

6.5 Recent Funding Opportunities in the Oil and Gas Sector.

To transit seamlessly from fossil fuels to zero-carbon, funds are needed. There are several funding opportunities in the Oil and Gas sector (Nzekwu,2004):

1. **Institutional funds**: Financial institutions such as Afreximbank, African Development Bank AfDB, African Union (AU), World Bank, IMF, and others have put in place programmes through which the Nigerian nation can access funds for energy and other related activities.

2. The Nigerian Content Act provides for the funding of contracts in the Oil and gas sector to enable local contractor's access funds for the execution of various projects. The

Nigerian Content Intervention Fund is accessible to community contractors as it addresses the persistent funding challenges that have hindered the capacity and growth of local service providers in oil and gas industry.

3. **N250bnNationalGas Expansion Programme** by the Central Bank of Nigeria: The CBN issued N250bn National Gas Expansion Programme to stimulate economic activities byfast-tracking the developmentofgas-basedproducts. This fund is capable of creating more than 3 million jobs in this country but only 77 companies and start-ups have applied to this fund.

6.6 Digital Transformation Opportunities in the Oil and Gas Industry.

Artificial intelligence, Virtual reality, blockchain (Plate 23) etc. are solutions that can streamline downstream oil and gas supply chains thereby cutting costs as well as emissions in the process. Digitization therefore plays prominent roles in the Oil and gas sector (Buba,2005&Deskus,2014).

a. Artificial Intelligence and its application in the oil and gas industry:

1. **Defect Detection and Enhance Quality Assurance**: If defected oil pipeline or machine is installed into production, this could result in losses and severe damages. Deploying a Computer-vision based AI

system can verify the quality of production and provide deep insights of defects in analytics. AI powered Defect Detection solutions are cost-effective and is extremely economical. Plate 23

2. **Ensure Safety and Security Standards**

Employees in oil plants work under different temperature conditions and are sometimes exposed to toxic environment. An AI-powered computer-vision solution can monitor the work site to ensure workers are following safety procedures without any deviations. AI solutions can alert management even for the smallest deviations in compliance.

3. **AI Reduces Production and Maintenance Cost**

Pipeline Corrosion problem can result in catastrophic damages halting the entire production process. This is one of the biggest concerns of the industry. AI solutions can prevent incidents like this (Pipeline corrosion, leakages, oil spills etc.) from occurring. AI and IoT technologies can detect signs of corrosion by analyzing various parameters using knowledge graphs and predictive intelligence to approximate the corrosion occurrence probability and raise alerts to pipeline operators.

4. Uncover New Insights in Oil and Gas Exploration

AI helps Oil and Gas companies resolve the problem of resource availability. Adopting autonomous AI-powered robots for exploration is a great solution. Top oil and gas companies are using drones to gather seismic images while image processing algorithms extract information. Based on this analysis, explorations are carried out. This process minimizes human risk and ensures accurate data.

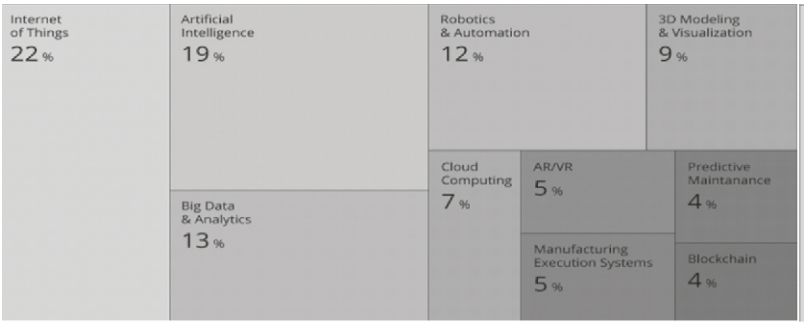

Plate 23: *Top 10 Oil and Gas Industry Trends and Innovations in 2021*

6.7 Renewable Energy Opportunities in the Era of Energy Transition.

Building more fossil fuel driven power plants is not the most environmentally favourable option because of emissions of pollutants, global warming effects and the finite nature of its fuel supply (Sambo, 2009) and (Nwosu, et.al 2013).The most

feasible solution would be a complete mix of all the renewable energy sources.

6.8 Human Capital Development Opportunities - Nigeria's Biggest Asset.

The Oil and gas value chain comprises the downstream, midstream and upstream. All these involve Exploration, production, field development etc. We must focus on people. Not just value chain but value network. The people and the environment: The stakeholders, communities, the social networks etc.

Taking our gas products from where they are produced to where they are to be used will involve marketing, transportation, safety, technology etc. and all these involve human beings. Transportation of gas, LPG involves use of ships that must be manned by human beings and the question is who will train them in the use of Exploration techniques, Seismic data interpretation, LPG Cylinder productions etc. Therefore we must think about creating a niche in terms of building human capacity for the future.

It is the human capital investment that drives all the processes and achievements in the new economy. To achieve modern growth and development, we must break off from the shackles of the old economy.

There is need for training and retraining of oil and gas

professionals in the country. This is the only way for the sector to cope and remain relevant. Our educational systems need to do more as skills, not degrees, are the realities of the future.

7.0 GOING BEYOND AND EXCEEDING EXPECTATIONS: WAY FORWARD FOR NIGERIA.

In order for Nigeria to come tops in the comity of developed nations, we must take a holistic look at the following:

7.1 Implementation of the Petroleum Industry Act (PIA):

There is need for the Federal Government to fully implement the Petroleum Industry Act (PIA), which was suspended in January 2022 as a result of Federal Government's inability to remove fuel subsidy. If this PIA works, Nigeria will see less pipeline vandalism as the host communities will have a direct stake in the oil and gas sector, and consequently, this will increase the nation's oil production and enhance revenues flowing to the federation account.

There is need for oil bearing communities to commence the selection of credible persons to populate the Board of Trustees of their respective Host Communities Development Trust (HCDT) as provided for under the Petroleum Industry Act (PIA).

7.2 Creation of an Oil Jackpot Committee (OJC)

As a result of the Russia-Ukraine War, global crude oil prices pushed above $100 a barrel thereby creating a bull run, which Nigeria is currently benefiting from. Nigeria has got to treat the Russia - Ukraine War as her last oil windfall and thus make it a major national priority by setting up a special crude oil jackpot/committee to prepare for the eventuality of a spike in petroleum prices. It should put together a list of investment projects that would generate significant income immediately, target spending in infrastructures like power and transport that will boost growth and obviously make economic diversification its primary objective.

7.3 **Establishment of a National Strategic Oil Reserve (NASOR).**

This is the right time for Nigeria to build a strategic crude oil reserve, with massive storage capacity that could hold at least a year's worth of Nigeria's OPEC (Organisation of Petroleum Exporting Countries) production capacity.

The global oil market continues to suffer from the vagaries of the coronavirus pandemic and other eventualities. Yesterday, it was COVID-19, today it is Russia – Ukraine war; tomorrow, it will be something else. It is time for Nigeria to protect her economy from being tossed to and fro by circumstances beyond her control.

If we build large crude Oil storage infrastructures as National Strategic Oil Reserves, we will not have to sell our crude at a production loss. We will be in a position to stockpile the product in our reserve until such a time as prices improve.

7.4 Development of a Comprehensive Divestment Policy

The reality is that we cannot stop the International Oil Companies in Nigeria from divesting but the process must follow international standards. During asset divestment, the inclusion of a preemptive clause in oil and gas operating agreements is very necessary. Preemptive right allows the partners to a joint venture maintain control of the venture. This is to ensure that the NNPC sustains a prosperous business environment for Nigeria and enable the National Oil Company pay more attention to abandonment and relinquishment costs; severance of operator staff; and third-party contract liabilities among others.

Curiously, many of the oil and gas assets sold to Nigerians, mostly by the International Oil Companies, are rarely decommissioned or properly abandoned, a development that clearly breaches existing laws regulating the industry.

All issues and obligations related to abandonment and decommissioning must be fully addressed in line with global best practices, regulations, conventions, and laws. With the exit wave expected to continue, Federal Government is expected to draft a divestment criteria or guideline to ensure Nigeria is not at the losing end when more firms announce their exit from the country's oil market.

The Federal Government should ensure that Nigeria's National strategic interest is safeguarded, by developing a Comprehensive Divestment Policy to ensure a win – win situation for Nigeria and exiting IOCs.

7.5 Elimination of Crude Oil Theft

a. The government has not for one moment considered rehabilitating the thousands of young people involved in illegal refineries, pipeline vandalism and crude oil theft most of them geniuses at what they do. In the West, even innovative criminals are not left to rot; the government co-opts them into governance – to redesign their law-enforcement strategies and prepare for emerging criminal trends. Here we have talented young people – many of them unemployed graduates – who have innovated ways of distilling crude oil. They know how to refine. They are more afraid of hunger than they are of the Nigerian military.

VC Sir, with a country that still depends on foreign countries to refine its own crude oil; it is absolutely nonsensical and unjustified to be wantonly destroying illegal refineries. These are mushroom refining industries that could be mainstreamed, upgraded and regulated. It is a crime against Mother Nature to burn them. The pollution from their wanton destruction is more of a threat to society than the crime they are trying to stop.

I am of the view that the government should stop the burning of artisanal refinery sites because it is increasing

environmental damages in the region. Again, **the** building of modular refineries is capital intensive and beyond the reach of artisanal refiners, the FG should assist in establishing Modular Refineries in the Niger Delta and integrate the artisanal refiners into the mainstream by creating a Niger Delta - Presidential Artisanal Crude Oil Refining and Development Commission (ND - PACORDEC) to cater for the teeming unemployed youths in the region.

b. Accurate data Inventory. There should be a proper documentation mechanism to monitor and evaluate the quantity of crude oil explored and the volume sold as export or refined locally. As a country we don't have metering systems. There have been screaming headlines with information distortions that between 80 per cent and 95 per cent of Nigeria's crude oil is lost to oil thieves.

c. Setting up of special independent courts to try cases related to oil theft.

Nigeria must have the courage to set up independent special courts to try cases related to oil theft. This will ensure that cases are dealt with on time. Government must develop and have a strong political will. The Federal Government should speedily ensure that the economic saboteurs in and outside government are named, shamed and prosecuted for deterrence purposes.

d. For us to succeed, government must build a strong political will. The government officials saddled with the responsibility of catching oil thieves must be people with integrity that are not ready to compromise. And for this to work, they must be subjected to integrity test, sign up to code of conduct and as well as go through EFCC, NSA and DSS scrutiny's.

e. Use Technology to curb oil theft.
The use of technology (Robotics, Al, digital transformation, block chain, drone technology, and other electronic monitoring gadgets) would help a lot. For us to move from the bottom to the top and go beyond, we must deploy technology and stop the act of using ex-militants to protect our Pipelines. Artificial Intelligence (AI) will help to ensure pipeline safety and reduce theft and vandalism through its highly precise and accurate system. It will identify intrusion scenarios accurately with high identification precision, and quick response. We should be digital ready. Technology rules the world.

7.6 End Gas flaring

Nigeria is one of the top 10 global gas flaring nations.The government should be more committed to ending gas flaring with the development of the National Gas Policy and setting up of the Nigerian Gas Flare Commercialization Programme (NGFCP) which is designed as the strategy to eliminate gas flares from Nigeria's oil and gas fields.

Gas flaring can be mitigated through the demonstration of leadership and political will.

7.7. Rehabilitate all our Refineries.

All our 3 refineries are dead. Government should rehabilitate our refineries and make them function optimally. The Federal Government says the Port Harcourt Refining Company(PHRC) would begin operations by the first quarter of 2023, the refinery is expected to refine 60,000 barrels of crude oil per day when it commences operations and the issue of fuel scarcity would be adequately addressed and this will facilitate the removal of fuel subsidy in the Country.

7.8. Champion Investments in Renewable Energy.

The energy transition is a reality that we must embrace. The Oil and Gas companies should do more for the Country in terms of energy transition by contributing to a net-zero future in a number of ways:

1. Oil and gas companies should help in delivering climate solutions by reducing emissions. Our National Oil Company NNPCL is poorly positioned to adapt to changes in global energy dynamics.

2. Oil and Gas Companies should increase their investments in renewable energies. So far, investment by oil and gas companies outside their core business areas has been less than 1% of total capital expenditure. A key vector for energy transitions is via technologies that have relatively small unit sizes and are capable of

being mass-produced, such as solar panels, EV batteries and heat pumps.

7.9. Increase Investments in Human Capital Development

Attracting and retaining young Geoscientists is essential for our future. Technology and the people who develop and deploy it will ensure that the quantity of hydrocarbons recovered will increase. Therefore we need:

- New training methods (Simulation);new ways of working (Augmented Reality) and new ways of communicating (Social Networks).

- There is need for Industry Academia linkages to address the global short supply of skilled manpower in the Petroleum Industry. We started this by been the first to introduce wig to gown lecture in the Department and the first University in Nigeria to use Petrel and Eclipse softwares for reservoir characterization.

- Oil Companies should adopt colleges/schools/Departments. Department of Geology should be adopted by SHELL or AGIP.

8.0 MY CONTRIBUTIONS TO KNOWLEDGE.

Vice Chancellor Sir, my career in Petroleum Geology and Exploration Geophysics started first as a Pupil Geologist in the Oil Industry and later as a Lecturer in the University. Therefore my contributions to knowledge shall be in two parts namely Oil Industry contributions and academic contributions to knowledge.

8.1 Oil Industry Contributions

In my years of service in the Oil Industry, I have contributed to and reviewed several technical reports in the Oil Mining Leases of Nigerian Agip Oil Company. Results from these Fields demonstrated that the OML's are rich and are supportive of petroleum accumulations.***80% of the above Fields are Hydrocarbon bearing.***

Vice Chancellor Sir, while working in the Oil Industry as the District Coordinator of Rivers and Bayelsa States in Nigerian Content Department of Nigerian Agip Oil Company, I was privileged to present a paper (**Adiela, 2011)** at the Rivers State Oil and Gas Conference 22-23rd June, 2011 held at the Rivers State House of Assembly Complex, Port Harcourt, Rivers State with the theme: Nigerian Content Act: Facts and Issues. In the paper, I highlighted key issues affecting the implementation of the Nigeran Content Act: Difficulty in attracting investors to do business in Nigeria; Security and safety issues; Lack of power, good roads and infrastructures and Lack of funding to execute major contracts.

The paper proffered solutions on what Nigeria must do to succeed as a Nigerian Content Compliant economy:

1. The Nigerian Content strategy must look beyond the oil and gas sector so as to have an impact beyond the oil and gas sector through the encouragement of economic diversifications, promoting policies and fiscal regimes which prevent market distortions, strengthening human, technical and institutional capacities and Designing investment policies with incentives to attract investors.

2. For Nigerian to be relevant economically, the human capital, the financial capital and a strong infrastructural base are the necessary ingredients needed to position Nigeria as an economic hub of West Africa and beyond. Nigeria must identify and address all the existing gaps in human resources, facilities and infrastructures, Materials, institutions and systems.

3. Nigeria must create an attractive environment and an enabling investment climate made up of a good legal and judicial framework, fiscal incentives, protection of contractual rights, culture opposed to corruption, support to small and medium sized enterprises.

The paper pointed out that Gas flaring in Nigeria; oil bunkering and illegal refining of crude oil are definitely not what will take Nigeria to the top. The paper therefore recommended more concerted efforts by the Government to actualize the Nigerian Content in the oil and gas sector and in other sectors of the Nigerian economy with the belief that we have started a good journey and our collective dream of getting to the top can be achieved.

8.2 Academic Contributions:

In my service to the University System as a teacher, supervisor and mentor, I have had the honour and privilege of teaching and supervising numerous undergraduate and postgraduate students who obtained B.Sc. and MSc degrees in Geology and Petroleum Geology. Through research and development, I have made

several academic contributions to knowledge and in recognition of the quality and the global impact of my research in academics and industry; my published papers are frequently cited by other researchers locally and internationally.

Vice Chancellor Sir, I am privileged to have written three textbooks published by reputable foreign publishers.

Vice Chancellor Sir, I have carried out research work in Reservoir characterization, Petrophysical studies of fields in Niger Delta, Sedimentological Studies, Seismic Attributes analysis, Environmental Geology, Geochemistry, Fault seal analyses etc. and I have contributed to knowledge with over 170 academic/research publications in referred journals with high impact within and outside this country.

Today, I will limit my contributions to Field Geology and Reservoir Studies alone.

8.2.1 Contributions to Knowledge in Field Geology

Vice Chancellor Sir, I have travelled to several parts of the Country to carry out Field Mapping Exercises aimed at determining the different rock types in Nigeria. In these studies, Nigeria was divided into 4 regions namely: Southern, Eastern, Western and Northern regions.

In 2017, Ayodele, M.I; Omoboriowo,A.O & **Adiela, U.P,** carried out "A Geologic Field Report on the Geology of Part of the Oban Massif and Calabar Flank, South Eastern Nigeria" as published in the *International Journal of Scientific Engineering*

and Science. 1(5):29-34, 2017. The study locations are all along the Calabar Ikom highway and Calabar-Itu road (Fig. 59).

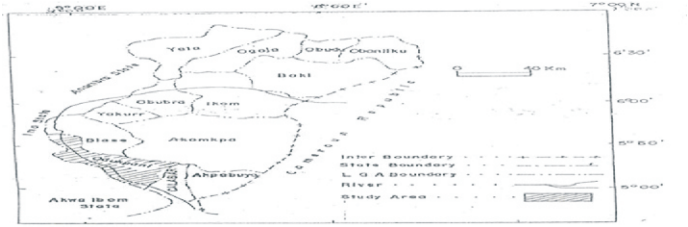

Figure 59- Map of Cross River State showing study area.

A total of six locations were mapped to obtain key Geologic features:

Location 1

Situated along the Calabar–Odukpani Road; about few metres from the main road. The location's formation is Nkporo shales (Plate 24). These diments are characterized by dark grey carbonaceous, friable fissile shale with occasional thin bands of marl stone and gypsum. The formation is rich in borrows and ammonite's for a mini fera assemblages have also been formed in abundance.

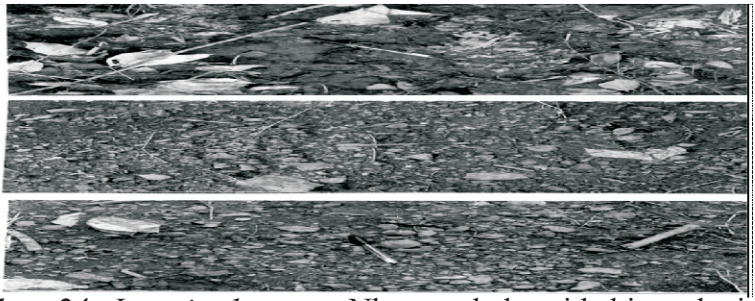

Plate 24*: Location1outcrop*:Nkporo shale with bio-turbation and burrow organisms.

Location2

Situated along the Calabar–Odukpani, New Netim Road; about few metres from the main road. It is composed of Marl out crops described as the New Netim marls (Plate 25).These marls form extensive ridges and consist of impure limestone (marl) and shale intercalations. They are highly burrowed and have been found to contain large quantities of ammonites and assemblages of echinoids. The marls are deposited in a wide variety of near shore marginal marine settings.

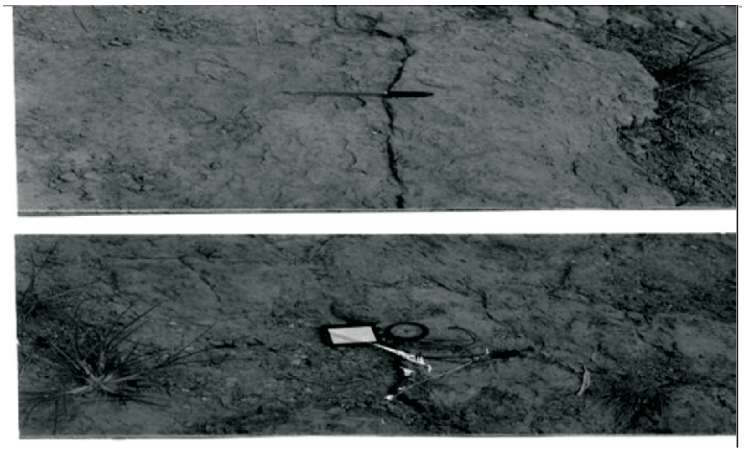

Plate 25- *Location2outcrop:NewNetimmarl*

Location3

Situated along the Calabar–Odukpani Road about 2m away from the main road. The major geologic feature found is a cave. The cave is imbedded inside New Netinmarls (Plate 26).

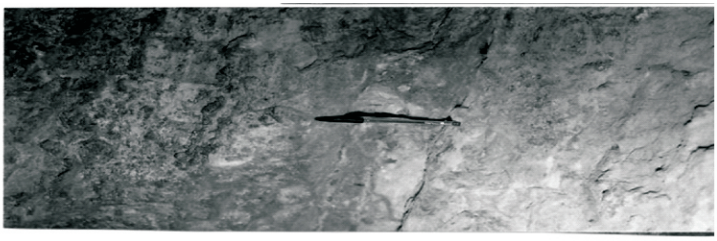

Plate 26 - *Location 3 outcrop*: Cave imbedded in new Netimmarl

Location 4

The formation of location 4 out crop is known to be Ekenkpon shale. This formation is exposed a ta road section in Ekenkpon village (Plate 27). It is a sequence of pyritic and organic rich sediments. About 0.3m of shale formed the first bed at the top followed by 0.6m bed of limestone, then followed by massive intercalation of limestone and shale.

Plate 27 - *Location 4 outcrop*: Ekenkpon shale (limestone inter bedded with shale) at the Ekenkpon village.

Location5

Situated at some few kilometres from Awi main town. It is a type section of the Awi formation. It consists of a sequence of sand

stone grading into siltstone with clay intercalations (Plate 28). They are fluvio-deltaic and non-marine deposits of early cretaceousage. They mark the beginning of sedimentation in the Calabar Flank

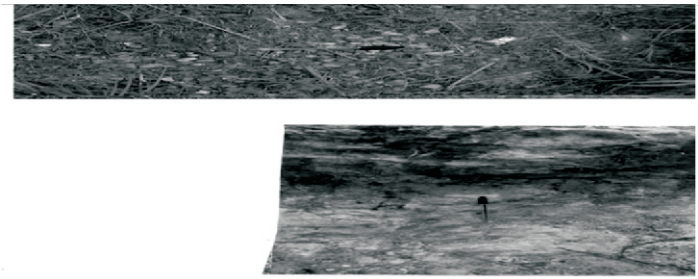

Plate 28 -*Location 5 outcrop*: Top picture shows Awi Formation along Calabar-Odukpani Road and The picture under it shows the contact between sedimentary rock (Awi Formation) and the bedrock mapped at opposite side of the top outcrop in the same Area.

Location6

The out crop of location 6 is located at some few kilometers from Ikom-Ita road and it is about 5m from the main Calabar–Ikom road at Uyanga (Plate 29). It is a massive, strongly banded outcrop consisting of light and dark coloured minerals. The rock name is Biotite-gneiss; the gneisses are all quartz-felds pathic and medium to course grained. Foliations are present.

Plate 29 - *Location 6 outcrop*: Top picture shows massive gneiss mapped along Uyanga-Akamkpa road and down picture shows quartz vein intrusion ingneiss in the same area

We found that the study area has a heterogeneous geology. The Obanmassif is affected by metamorphic an digneous activities while the Calabar Flank is basically composed of cretaceousse diments.

To determine the rock types in Southern Nigeria, **Adiela, U.P** & Omoboriowo, A.O, 2015 carried out the "Biostratigraphic Study of Outcrops along Port Harcourt – Enugu Expressway, Ozalla Junction, Anambra Basin, Nigeria. This research was published in the *International Journal of Research for Science and Computational Engineering* (IJRSCE), 1(1):5-11, Dec. 2015.

To determine the rock types in Eastern Nigeria, **Adiela, U.P,** 2016examined the "Biostratigraphical and Paleo environmental Analysis of Enugu Area, Anambra Basin, Nigeria" and published in the *International Research Journal of Interdisciplinary and Multidisciplinary Studies*: 2(2):58-64. Further studies by **Adiela, U.P**; Maduaka, P.I and Omoboriowo,

A.O examined the "Biostratigraphical Interpretation of Upper Cretaceous Outcrop along Enugu – Amagu Ibite Road, South East Nigeria" and published in the *International Journal of Research for Science and Computational Engineering (IJRSCE)*, 2(2)1:35-42 Jan. 2016.

To assess the rock types in Western Nigeria, **Adiela, U.P**& Ofuyah, W.N 2017 studied "The Structural Geology of Eshiawa in Igarra Area, Southwestern Nigeria as published in the *Journal of Scientific and Engineering Research,* 2017, 4(4), 273 – 282 and again in 2017**,** Ayodele, M.O; **Adiela, U.P**& Yikarebogha, Y, examined the "Geophysical Studies for Foundation Investigation in Basement Complex: A case study of Iloko, Osun State, Nigeria" as published in the *International Journal of Scientific Engineering and Science:* 1(5):24-28, 2017.

In determining the rock types in Northern Nigeria,Elias, P; Omoboriowo, A &**Adiela, U.P.** 2017 assessed "The Geology of Part of Paiko Sheet, North West Nigeria as published in the *International Journal of Scientific Engineering and Science* 1(5):35.

The Paiko sheet 185 Northwest covers an approximate area of 80km^2 in Paikoro Local Government Area of Niger State. The study are characterized by the rocks of the Nigerian basement complex. These rocks are mainly granites of different types which includes Leucocratic granite, granodiorite and biotitegranite (Plates 30, 31 and 32).

Plate 30 - *LeucocraticGranite*

Plate 31 - *Granodiorite*

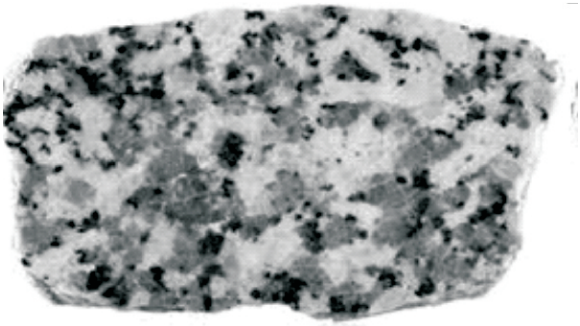

Plate 32 - *Biotite Granite*

From the investigations and analysis of several field mapping exercises carried out in different parts of Nigeria, results revealed that Nigeria has all the three types of rocks namely: Sedimentary rocks, Igneous rocks and Metamorphic rocks. We found that Cross River State has all 3 types of rocks but is predominantly made up of the Basement Complex Rocks. Rivers state and the entire Niger Delta States are predominantly made up of Sedimentary rocks which contain Hydrocarbons and this is why the Niger Delta is prolific and Hydrocarbon bearing.

8.2.2 Contributions to Knowledge in Reservoir Studies

Iidentified the reservoirs that are capable of holding significant amount of Oil and Gas in the Niger Delta. I carried out a study in the Obor Field, Offshore Niger Delta (Fig 60) in 2018 to determine if geological structures support the entrapment of Oil and Gas.

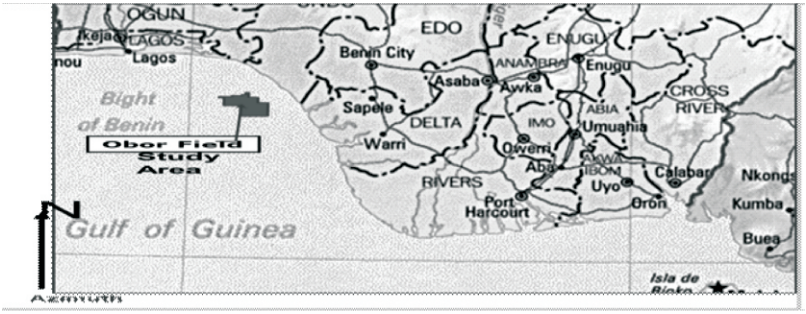

Figure 60: Location Map of the Obor Field Study Area

The Obor Field has an area of 330sqkm. I delineated the Seismic

map with lines and traces. Three Seismic Horizons of interest representing sand reservoir bodies were selected and both major and minor faults were delineated and interpreted. Fig 61

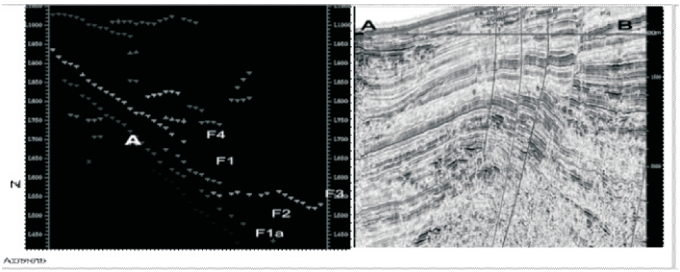

*Fig.61: Horizon and Fault Interpretations in Obor Field, Niger Delta. (**Adiela**,2018)*

I generated structural maps ranging from amplitude maps, depth maps, Lithofacies maps etc. and I observed the presence of increased sedimentation at the edge of the faults showing that the faults assisted in the hydrocarbon entrapment process Fig 62.

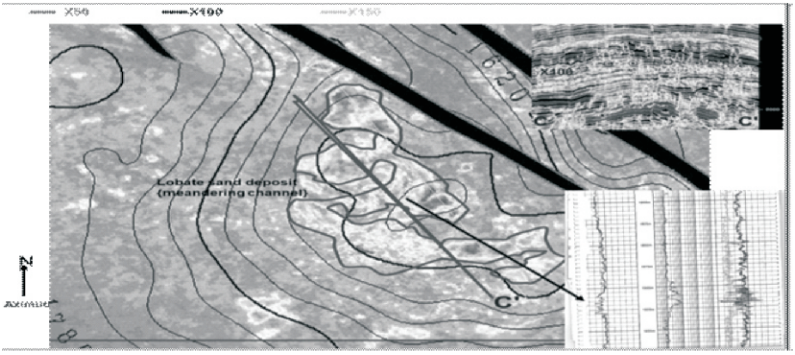

Figure 62: Ampitude Map Extraction (Adiela, U.P: 2018)

Further in-depth analysis on the depositional history of the Obor

Field revealed a stacked multi-channel deposition above a mud-filled channel along the B –B' profile and along the C – C' direction highlighting the presence of a high sinuosity channel from the depositional lobe structures. Fault polygons were captured and the total area of the polygons as calculated stood at 162.15sqkm (Table 2) which is the possible area where Oil and Gas has accumulated in the Obor Field.

Table 2: Area of Anomaly Polygons

AREA OF ANOMALY POLYGONS			
S/N	Horizon Names	Polygons	Area(km2)
1	X50	X50_Pol 1	9.71
	X50	X50_Pol 2	31.04
2	X100	X100_Pol 1	11.1
	X100	X100_Pol 2	58.46
3	X150	X150_Pol 1	6.61
	X150	X150_Pol 2	45.23
TOTAL AREA OF POLYGONS			162.15

8.2.2.1 Studies on Depositional Environments

Adiela, U.P &Jackson, C.A (2018) examined the "Depositional Environments and reservoir Studies of 'Sasa' Reservoir sandstone, Niger Delta, Nigeria" and published it in the *International Journal of Scientific Research and Management*. Several other studies on depositional environments such as: **Adiela, U.P**; Omoboriowo, A.O & Acra, E.J (2016): Depositional environments and Reservoir Characterization of MM Sand, 'Olo" Field in Niger Delta Nigeria as published in the *International Journal for Innovative Research in Multidisciplinary Field*; **Adiela, U.P**; Jackson, C.A & Ayodele, M (2018): *Depositional Environments of ENO Oil*

field reservoir sands, Niger Delta. International Journal of Scientific and Technology Research ***etc.*** The above studies investigated different depositional environments based on the integration of welllogs, coredata and lithofacies analysis and we found that the environment of depositions in the Niger Delta are made up of distributary channels, mouth bars, point bars, tidal channels, tidal flats, lower shoreface, middle shoreface and Upper shoreface. We concluded that the Niger Delta basin is characterized by depositional environments that are supportive of hydrocarbon accumulation.

8.2.2.2 **Studies on Niger Delta Structures**

In trying to determine the structures that can aid the entrapment of hydrocarbons in the Niger Delta, Studies on Reservoir Sand Body Continuity in the Niger Delta were carried out in 2018 by Opatola, A.O; Ogbe, O.B. &**Adiela, U.P**: "Establishing Sand Body Continuity Using High Resolution Sequence Stratigraphic Analysis in Agbada Field, Niger Delta, Nigeria" and published in the *FUPRE journal of scientific and Industrial Research*, 2(1), 2018. Our findings were used for the development of the sequence stratigraphic framework for the Agbada Field and the Field wide correlation gave an insight into stratigraphic succession of the typical sand/shale alternation of the Agbada Formation.

To determine if Petroleum Systems have permeability barriers that prevents the flow of Petroleum which acts as seal to the migration of crude oil, **Adiela, U.P**; Jackson, C.A & Ayodele, M, 2018 assessed the Reservoir and Paleoenvironmental Studies of

the BOFI Sand, BOFI Field, Niger Delta, Nigeria as published in the *International Journal of Scientific and Technology Research*, 7(8):45-48, August 2018. In this study, we examined the reservoir and paleo-environments of the Bofi sand and established that Shales / mudstones act as permeability barriers to the vertical flow of hydrocarbon for all the reservoirs in the Niger Delta.

In 2016, we tried to determine the variability of rock properties by establishing the different components of reservoir sands and shales. **Adiela, U.P**. & Yikarebogha, Y. (2016) examined the "Petrophysical and Seismic Analysis of 'TUGA' Field, Niger Delta Basin Nigeria" as published in the *International Journal for Innovative Research in Multidisciplinary Field*, 2(12):414-420, Dec, 2016. In this study, we evaluated the seismic attributes of Tuga Field, Onshore Niger Delta, using 3D-seismic data in which six shale and five reservoir sand units were identified. All of these units were penetrated by three wells. The results revealed that the rock properties are variable. The Shales had high acoustic impedances, high transmission coefficients and low reflection coefficients compared to sands. The Seismic attributes analysis also revealed rock properties in terms of fluid content and depositional environments with moderate - high amplitude and strong reflection strength with seismic continuity being continuous to chaotic and truncated by faults.

To highlight the importance of Petroleum Traps in Petroleum Systems, in 2017, Nwiado, J.K; Acra E.J & **Adiela, U.P** investigated the Seismic and Reservoir Characterization of the

"Olumo" Field, Niger Delta Basin, Nigeria. In this study, ***S****eismic attributes were used to characterize two reservoirs in Olumo field located onshore Niger Delta. 3-D seismic data and well logs were integrated to unravel complex field subsurface traps associated with hydrocarbons and to gain more insight on reservoir architecture. In this study, two horizons; A001 and B00l were identified and mapped on the 3D seismic data using correlations provided in the well tops across the four wells to delineate and establish the continuity of the reservoir sand bodies.*

In these researches, we found that in order to map a hydrocarbon reservoir, studies of geologic structures that can hold hydrocarbons in place must be considered to evaluate prospects so as to determine optimal production strategies and minimize uncertainties that may be associated with hydrocarbon exploration processes.

8.2.3 Contributions to knowledge on Renewable Energy Studies:

Following the fact that Oil will go the way of coal in 40 to 50 years' time, my interest shifted to renewable energies. I enrolled for a second PhD programme at the Emerald Energy Institute with the sole aim of moving from bottom of Oil to the Top and beyond by focusing on Renewable Energies. So in 2021, **Adiela, U.P**& Agiobenebo, T(2021) carried out the "Analysis of Energy Consumption and economic growth in Nigeria: The Renewable and Non Renewable Energy Perspectives", as published in the Confluence Journal of Economics and Allied Sciences

(CJEAS), Vol.4 Issue 1, pp: 221 - 236.This study used the case of the Nigerian economy to examine the extent to which the energy–led growth hypothesis varies for renewable energy compared to the nonrenewable energy sources. In this study we found that the relative potential of renewable energy as the most appropriate energy–mix for enhancing growth process to be statistically viable only in the short run. On the whole, it is recommended that policies that encourage energy consumption led–growth should be geared towards effective utilization of the various sources of renewable energy that has been left untapped.

Again, Nigeria should continue to encourage the use of modern energy resources, namely; Solar energy, Wind energy, Hydro energy, Tidal energy etc. towards satisfying the country's total energy demand.

9.0 CONCLUSION

Vice-Chancellor Sir, the Nigerian Oil and Gas Industry is filled with challenges which can be mitigated and eliminated. The opportunities in this sector are enormous and with a strong and collective will, we can harness these opportunities to our benefit. Nigeria cannot be left behind in the pursuit for cleaner energy because God has blessed us with abundant oil and gas resources to midwife the energy transition process. Leveraging on our natural resources is one sure way to move from the bottom to the top and beyond. Let us therefore think “Natural” by moving from where we are presently to where we all want to be and going “BEYOND” by exceeding expectations.

Vice-Chancellor Sir, my distinguished audience, we can start the journey of moving from the bottom to the top and beyond from this auditorium today.

Rivers State University was established in 1980 and has done very well in creating the Department of Geology in 2016. Even though Rivers State is the "Oil and Gas Capital of Nigeria" with massive oil and gas production coming from Omoku, Ogoni, Etche, Bonny etc, the state does not have her own Oil and Gas company and therefore is not producing oil and gas at the moment. The ultimate question therefore is why has this been the case? Why is the Oil Capital of the most populous country in Africa not having an Oil Company? I shall NOT attempt to answer this question using this medium, but I shall simply call on the University management to have a rethink by starting something great in the short term. VC Sir, it is pertinent for the University Management to establish a centre of excellence called the Centre for Oil, Gas and Energy Studies (COGEST) and should be made up of Departments such as: Geology, Geography, Oil and Gas Law, Physics, Electrical, Petroleum Engineering, Gas Engineering, etc. COGEST RSU will be the first in Nigeria and through collaborative efforts of these departments we shall move this University, the State and the Country to the next level in terms of energy transition. The question is can't this University produce energy in the nearest future? Yes, we can. Can't we own our Oil Blocks and produce Oil and Gas? Yes, we can. This is the one way we can go from bottom to top and beyond.

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ACKNOWLEDGMENT

I am very grateful to God Almighty who made all things beautiful in His time.

My sincere, unapologetic and unreserved appreciation goes to the kind, peaceful. gentle and amiable Vice-Chancellor of this great "University of the year 2021", distinguished and respected erudite Prof. Nlerum Sunday Okogbule, My contact with you has been life transforming. I became a Professor in your tenure and your confidence in me made you to appoint me as the third Head of Department, Department of Geology of this great University. As Head of Department, you supported us to have the first full NUC accreditation for the Department of Geology. Again today, you graciously gave me the platform and opportunity to be the 83rd Inaugural Lecturer of this great University and the very first inaugural lecturer from the Department of Geology. May your administration get to the top and beyond in Jesus name, Amen.

I heartily appreciate the Deputy Vice Chancellor (Administration) Prof. N. S. Okoroma (Eze Chukwukere 111)

who is a father to me in this University. I specially appreciate the Deputy Vice-Chancellor (Academics), Prof. Valentine Omubo Pepple, for his friendly disposition, assistance and unflinching support. I am grateful to you Sir

I wish to express my gratitude to the former Vice Chancellor, Prof. Blessing Chimezie Didia and the former Acting Vice Chancellor, Prof. (Mrs.) Opuenebo Binya Owei. I sincerely express my undivided thanks to the Registrar of this University, Dr. Sydney C. Enyindah; the present and former University Librarians, Dr. (Mrs.) Jennifer Ngozi Igwela and Prof. (Mrs) Blessing Ahiauzu; the Acting Bursar Mr. James Orji Ebere, and the University Orator Prof. Isaac Zep Obipi for their immense contributions to the growth and development of this University.

My heartfelt gratitude goes to all members of Council and Senate, who have conscientiously supported the Management towards the sustained growth and development of this University. The giant unprecedented strides and accolades this University is associated with in recent times is traceable and attributable to your efforts..

Special thanks to my Dean, the Dean of the Faculty of Science

Prof. Confidence Kinikanwo Wachukwu, Your influence and contributions to my life are greatly appreciated. To my mentors, friends and Colleagues in the Faculty of Science:, Prof. Friday B. Sigalo, Prof. Adaobi Ugbomeh, Prof. Akuro E. Gobo, Prof. Israel Cookey, Prof. John Onwuteaka, Prof. Ndokiari Boisa, Prof. Adol Nwaoburu Prof. Felix Igwe, Dr. Nedia Akani, Prof. I. D. Essi, Prof. S. A. Wemedo, Prof. C. C. Obunwo, Prof. A. B. Nwauzoma, Prof E. Nwabueze Prof. I.K.E Ekwuozor, Prof. Fekaurhobo; Prof. E. Barthimeaus; Dr. D. Matthias; Dr. Elechi Amadi, Dr Ngozi Jane Maduelosi, Dr. Ike Anireh, Dr Iyeneomie Tamuno, Dr. Marvin Ugboma, Dr. Mrs Adline Ben Chioma, Dr. Nuka Nwaibu,, Prof. Uko, Dr. Horsfall, Dr. Holy Brown, Dr. (Mrs.) Evelyn M. Eze, Dr. A. R. C Amakiri and a host of others who impacted my life positively.

I sincerely appreciate a gentle friend and colleague, the Chairman University Lectures Committee, Prof. N. H. Ukoima and all members of the University Lectures Committee for their kind disposition and support: Prof. J.M. Jaja; Prof. John Ohaka; Prof N.A. Nwafor and Mr. Emeka Egbuchor.

I earnestly appreciate my teachers; project Supervisors and mentors notably Prof. L.C. Amajor (Late), and Prof. David Gray

for patiently guiding me through the herculean journey of my PhD programme in Petroleum Geology. It is with a grateful heart that I am thanking Dr. Mrs Ifeyinwa Olotu (Late) for painstakingly supervising my Master's degree programme and Prof. John Etu-Efeotor, my academic Daddy and mentor who supervised my Undergraduate work diligently and for bringing out the best that has defined my life today. I will not fail to appreciate my University lecturers: Prof. C. Tse, Prof, V.U. Ukaegbu, Prof. F. Ukaigwe, Prof Odigi, Prof. G.J. Udom. Prof. Tamuno Agiobenebo; my Primary and Secondary school teachers notably: Mr. Peter Ben Brew, Apa Joe, Mr. Enyia, Ajekeh, Ogolo, and my Secondary School Principal Chief Anthony Egobueze (Late). I am eternally grateful to you all.

It is my honour to appreciate and thank all the foundational members of the Department of Geology notably Prof. Clifford. S. Teme; Prof. T.K.S. Abam; Prof. C. L. Eze; Prof. S. Ngah; Prof. P.Youdowei, Dr. O.D. Ngerebara and all other Lecturers and non-academic staff of the Department of Geology for working so hard in bringing our Department to an enviable height. I have received so much support and encouragement from my colleagues in the Department notably from Prof. Micheal Oden, Prof. Sokari Braide, Dr.Tammy Morrison, Dr. Bright Amechi, Mrs. Ekine Erefama, Mrs. Augustina Otto, Miss Okechukwu Okpobiri, Mrs. Agara Faith, Bright Sunday Obinna, Sally

Amadi, Enyinda Amadi, Goodluck Sunday Wasuru and Pepple Olga Sodienye.

I also acknowledge my past and present students for their numerous support and encouragement notably: Chinasa Akpelu, Angela Lolo Osuma, Azibator Jonathan, Precious Ogueri, Azubuike Queen, Benjamin Franklin, Benson Princewill, Chioma Rita Nnodi, Chisom Gospel, Damiete Jenewari, Curtis Jumbo, Victory Chukwu, Christian Chukwunenye, Dan-Nubo, Diseph Aselemi, Dorin Ifunnaya Odili, Eunice Akari, Eze Juliet, Favour Amugo, Favour Okeoghene, Faith Monday Nsubari, Fred Mahlon, Glory Akpan, John Nwankwo, Joy Dunne, Tom Afibor, Sabaina Samuel, Vincent Nwigwe, and Yabari Aborloo. Your immense contributions made this day a reality.

I appreciate the staff and students of Geology Department, Akwa Ibom State University for urging me to go higher. I am particularly grateful to: Prof Bassey Nsikak, Dr. Clement Bassey, Dr. Tom Harry, Mrs. Asuaiko, Mrs. Abia Uwem, Dr. Abraham Udoh, Ibanga Mfon, Etukudo Jackson, Adorable Akra Unyime, Akpabio Okon Uyai, Emma Horrace, Emmanuella Aidoko, Mmayen Akpabio Ita, Glory Ita, Hannah Toyo, Ini Obong, Inim, Mary Eminue, and Veronica Ibanga Effiong.

I acknowledge my university Community Friends namely: Dr. Sunny Orike, Prof. Precious Ede, Prof. Kenneth S. Ordu, Prof. L. C. Obara, Engr Dr. Isaac, Dr. Charles Orji, Barr. Blessing Timothy, Henry Onu, John Akah, Dr. Frank Amugo, Dr. Justin Odinioha, Assoc. Prof. Aduche Wokocha, Prof. Pac Odu, Prof Benneth Eke Obi, Dr. Nne Saturday, Dr. Nnamdi Ekeocha, Dr. Udinmwem Efosa, Dr. Emma Okon, Dr. Abraham Opatola, Dr. Jones Acra Edward, Prof. Iyk Agbagwa, Dr. Kingsley Okengwu, Kingsley Wordu, Dr. Lawson Jack, Dr Lilian Odelugo, and Prof. Joel Ogbonna. Your massive support is very much appreciated.
It is my honour to appreciate my friend and the Chairman of my committee of friends for this 83rd inaugural lecture, Dr Anthony Egobueze and all other members of my committee of friends for a beautiful job well done.

I acknowledge the support from the following organizations: Rubies Academy, Paddoe Energy Nig Ltd, Rivers State Government, and Petroleum Trust Development Fund. I am especially indebted to my Professional Associates and Colleagues in Nigerian Mining and Geosciences Society (NMGS); Nigerian Association of Exploration Geologists (NAPE); Oil and Gas Trainers Assoictaion of Nigeria (OGTAN); the Nigerian Content Development and Monitoring

Board (NCDMB) and all my friends in the Oil Industry for your support and encouragements. My association with you has been a wonderful blessing.

I appreciate my friends and former colleagues in Nigerian Agip Oil Company (NAOC).You have been a source of motivation. I thankfully appreciate my G20 group of friends from NAOC especially: Charles Amarame, Ashiri Victor, Babatunde Attiogbe, Brown, Cofie Emmanuel, Justin Omoku, Eddy Amgbare, Ehi Bazuaye, Ejiro Eleluwor, Emma Adewale, Ezekiel Odjegba, Tadareigha, Yibo, etc. you are part of my success story today.

I appreciate the immense contributions of all my teachers, colleagues and friends from Heriott-Watt University, Edinburgh; Aberdeen Business School, Robert Gordon University, the University of Aberdeen, Emerald Energy Institute, Centre of Petroleum Geosciences and the Institute of Petroleum Studies namely: Prof. David Gray, Anne Stevenson, Chimara Godwin, Dr. George Chinotu, Gilbert Wopara, Prof. Harcourt Wokocha, Hon. Alex Ibeh, Monday Ahiwe, Harriet Odjegba, Prince Chinda, Hon. Alex Ibeh, Prof. Chijioke Nwaozuzu, Mrs. Ekwi John-Adegbesan, Dr. Alwell Nteegah,

Dr. Engr. Edward Aigbedion, Dr. Isreal, Kazeem Isah, Micheal Ajali, Dr Obinda Gershon, Prof. Salisu Afeez, Dorcas Ihenacho and Ada Ulazi

My friends and associates are not forgotten here; Stephen Dakoru, Allen Eze, Amaechi Ordu, Omoboriowo Adeh(Late), Prof. Alex Opara, Azike Ogochukwu, Ubong Inyang, Peter Omeke, Dr Osisioma Anyamuka, Dr. Osaki Lawson Jack, IK Roberts, Chira Nwuzor, Dr. Chijioke Soronnadi Ononiwu, Arthur Kalagbo, Ayodele Moses, Zubby Emmanuel, Mr. Sunny Wama, Barr Sopakrite, Charles Wugate, Dr. Chris Jackson, Chioma Uzor, Charles Okara, Hope Nduka, Ken Nkwonta, Laurent Ordu, Nonye Agoh, Nduka Onyedibia, Mr. Iyk Oginah, Hon. Kennedy Osoh, Wari Dakoru, Chibueze Ogbuagu, Barr Ojadi Ezi, Oji Tombert, Reginald Ihedike, Temple Amachree, Udoh Ikenyiri, Solomon Dungwu, Emma Taigbenu, Emma Onuchukwu, Christain Ugorji, Dr. Chi Anderson Onughara, Dr. Ezi Tom, Emeka Eke, Emeka Ajonuwe, Christain Oreke, Lucky Ahiakwo, Obulor Oduah, Rosebury Ohia, Emeka Obulor, Stephen Ogbobula, Goodleave Ozurumba and several others who impacted my life positively.

Vice Chancellor Sir, permit me to recognize and appreciate 3

special friends: Dr Francis Egobueze, Dr. Williams Iyama and Dr. (Mrs.) Eno Victoria Gomba for their years of dedicated friendship. You are friends indeed!

I acknowledge with thanks the unquantifiable academic and moral support of my undergraduate classmates: Abiye Bamson, Anthony Naabor, Bede Izuogu, Boma Jumbo, Dorothy Menyuah, Ekpelu Kingsley, Emeka Nnani, Emma Agba, Emma Nwafor, Enyia Godswill, David Akuta, Prof. H.O. Nwankwoala, James Okuku, Jephthah Aje, Jerome Eekpa, Oke Enyiche, Nelson Kiri, Sunny Ahiakwo, Waritimi Ariye Tina, Tamfiri Masi, Lawrence Enebeli, John Okirie. You are indeed unique

I deeply appreciate my secondary school mates, Old boys of Sancta Maria High School Omoku namely Basil Ikebunnah, Dr. Innocent Abali, Paul and Peter Onita, Emeka Dike, Harcourt Otomah, James Iroro, Kingsley Ogwumike, Alex Otishi, Victor Igwe, Azubuike Adiela, Nwabugo Ogum, and several others for your love and tremendous support towards my academic success.

I appreciate immensely the contribution of my traditional rulers. I Specifically and respectfully acknowledge His Eminence, the First Class Traditional Ruler in Ogba Egbema Ndoni LGA, His

Royal Majesty, His Eminnce, The Eze Ogba of Ogbaland, The Oba Odudu, Eze Barr. Nwachukwu Nnam Obi (111), HRH Eze Uche Ogbuagu (Eze-Ali of Obor), HRH, Eze Usomini Chiefs and all the political leaders from ONELGA notably: The Former PDP Chairman and Ex-RIWAMA Boss - Hon Felix Obuah, The Chairman Ogba/Egbema/Ndoni LGA - Hon Vincent Abali, the Members representing ONELGA in the Rivers State House of Assembly-Hon Elder Christain Ahiakwo and Hon Nathaniel Uwaji, Hon, Napoleon Adah, Chief Emeka Okoroma, The former Managing Director of NDDC -Dr. Chris Oboh, The Provost Federal College of Education (Technical), Omoku - Dr. Emmanuel Ikenyiri and several others for the peace and unity existing in Ogbaland and the entire ONELGA.

I will not fail to acknowledge and appreciate all the Men of God who laboured in prayers for my family and I. Specifically I acknowledge the daily prayers, words of encouragement and spiritual support from: The Regional Pastor in Charge of Region 33 Headquarters, RCCG Pst and Pst. Mrs. David Adewuyi, Pst Soji Oni, Pst Mike Ayanbode, Edmund Oseahon, Isaac Uzormah, The Pastor in Charge of Youths and Young Adults RCCG - Pst (Dr.) and Pst. Mrs. Perez Araka, Pst. Soberekon, Pst Innocent Okafor, Elders Collins Amadi, Ibekwe, Okandu, Prof.

Pst. C. Alikor, Pst. Emmanuel Isreal, Laura Amusa, Elder Young Arney, Dr. Membere, Kalada Afiafi, Chief Mrs. Selema Nwoye. My God will surely bless you all.

It is important to appreciate all members of the Redeemed Men's Fellowship of the Redeemed Christian Church of God; The Good Women Fellowship and the Youth And Youth Adults Fellowships of the Redeemed Christian Church of God for their immense support, unrelenting encouragement and continuous prayers.

I acknowledge and appreciate with deep sense of humility the unthinkable, unimaginable and unquantifiable love and support of the Adiela's family. Most especially, I am sincerely grateful to my parents, Late Mr. Ebenezer Eke Thompson Adiela and Mrs. Evelyn Nkwoma Thompson Adiela. Your unparalleled love and unflinching commitment to my future made today a reality. You are worthy examples of what genuine parenting represented. I am glad that God gave me to you and I did not disappoint you people.

I appreciate my Siblings, in-laws, cousins, nieces and nephews for being there for me especially Mrs. Ebere Odu, Mr.and Mrs Anthony C. Adiela, Mr and Mrs. Emeka Harcourt Adiela, Mrs.

Chinyere Adiela and Gladys Adiela, Mr. Kenneth Wokoma, Mrs. Chioma R. Nyenche, Onyeka Margret Wokoma, Faith, Victor and David Wokoma, Mr. Messiah Onyige, Dele Chinedu Onyige, Jenifer Ada Opatola, Junior V. Onyige, Tina Onyige, Oby and Chinonye Onyige, Mr and Mrs. Aduche Osiagor, Emma Osiagor, Chima Osiagor, Ada Osiagor, Josephine Adiela, Bestman Adiela, Mr and Mrs. Chukwuma Adiela, Adakwu Adiela, Daniel N. Adiela, Henry Adiela, Beauty Adiela and a host of many others too numerous to be listed here.

I appreciate the love and support of other family members who are very dear to me notably, Aunty Benna, Aunty Comfort, Aunty Bida, Aunty Glory(Late); Uncle Eleanya Amadike, Chief and Mrs. Orisah Amadike, Catherine Ajie, Ify Ajie, Obi Ajie, Emeka Ajie, Eze Ajie, Charles Ajie, Goodluck Akugbo, Dr. Ndu Amadike, Ogechi Ojukwu, Engr and Mrs. Grace Ndulaka Ahiakwo and Ogor Ahiakwo.

I humbly and most respectfully appreciate my father in-law, the former Dean of the Faculty of Engineering, Engr, (Sir) Prof. Christopher Ahiakwo and his dear wife, my mother in-law, Lady Mrs. Roseline Ahiakwo. These two are my pillars of support. They are always praying for my family and I. Your unrelenting support, assistance and prayers are very much appreciated.

I fully acknowledge and appreciate all other persons especially my friends, well-wishers, students, admirers, sponsors, relations and groups who assisted and supported me in several capacities but have not been mentioned or listed.

Finally, I wish to whole heartedly express my unreserved thanks, deep appreciation and love to the woman that God gave me, a rare pillar and builder; very versatile, industrious and energetic, the wife of my youth, my precious inestimable jewel, a lady of timber and caibre, my lollipop, my Sugar, my sweet sixteen and my sweet heart Dr. Mrs Obraori Peters Adiela. God blessed us with five unique, caring, lovely and adorable children and I am grateful for your continuous support, understanding and encouragement towards my academic success.