



**FEDERAL UNIVERSITY OF PETROLEUM RESOURCES**  
**Effurun, Delta State, Nigeria**

**8<sup>th</sup>**

## **INAUGURAL LECTURE**

**Titled:**

**DE-RISKING "SEARCH" FOR THE BLACK GOLD:  
GEOPHYSICS, ANSWER TO QUESTIONS UNKNOWN**

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**20<sup>th</sup> November, 2024**



**DE-RISKING "SEARCH" FOR THE BLACK GOLD:  
GEOPHYSICS, ANSWER TO QUESTIONS UNKNOWN**

**8<sup>TH</sup> IN THE SERIES OF INAUGURAL LECTURE OF THE  
FEDERAL UNIVERSITY OF PETROLEUM RESOURCES,  
EFFURUN, DELTA STATE**

**By**

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## **DEDICATION**

To:

**God Almighty** and His beloved Son, **Jesus Christ** our Lord, Saviour and Giver of Life and Knowledge.

To my late lovely parents

**Chief Gabriel Erhianor Ogagarue**  
**Alice Unuavwokpan Ogagarue**

Also to:

My dear elder brother, now my father: **Godwin Erhianor Ogagarue**

And to:

My dear lovely wife, **Dr. (Mrs.) Rita Ogagarue** and my precious children, **Oghenevovero Emmanuella Ogagarue** and **Oghentejiri David Ogagarue**

## PREAMBLE

I give the Almighty God and His beloved Son, Jesus Christ, our Lord and Saviour, the glory as I humbly stand before you this day to deliver the 8<sup>th</sup> in the series of Inaugural Lecture of this great, unique and premier University of Petroleum Resources in Africa. I most respectfully welcome you to the lecture, and sincerely thank you for the honour of your presence.

Our dear, sagacious Vice-Chancellor, Sir, I want to unreservedly thank you for responding to the call by the Almighty God to be used as a vessel to actualize my dream of delivering my inaugural lecture. I have always pondered over when and how it would come. Today therefore, is the appointed time for me to cross over the Rubicon into the galaxy of esteemed Professors of this great University. Permit me to pay homage to the predecessors in the University who presented the first seven inaugural lectures: Professors J.B. Arubayi, C. Onosemuode, A. Rim-Rukeh, O. Damisa, D.F. Ogeleka, E.O. Agabalagba and G. Ofualagba. I humbly stand on their shoulders to keep this lofty academic exercise flying. As I present my inaugural today, I remember the contributions of members of my Department who have transited to the great beyond: Prof. G.I. Alaminokuma, Dr. A. Omoboriwo and Mr. Anyanwu. May the Lord continue to rest their souls in perfect peace.

Mr. Vice-Chancellor, Sir, the occasion of an inaugural lecture affords the lecturer an opportunity to showcase to a mixed audience, in an understandable language, what has engaged his academic attention and its relevance or otherwise to the socio-economic development of the environment and humanity. I am prepared to do that in the lecture of today which I have titled: *De-risking “Search” for the Black Gold: Geophysics, Answer to Questions Unknown*.

During the course of this lecture, I shall attempt to explain the meaning of the “**Black Gold**”, mention something about its formation and occurrence, and then give a little background of geophysics. I will intentionally exclude the arduous theories and equations which are usually associated with the subject of geophysics, while focusing my attention on the aspect of geophysics that is concerned with my lecture. Finally, I will showcase what in my view, are some of the contributions I have made in area of the “search” for the black gold.

## 1.0 INTRODUCTION

"**Black Gold**" is another word for petroleum. Petroleum is derived from the words *petra* (rock in Greek) and *oleum* (oil in Latin). Hence, petroleum is simply **rock oil**, and more often called **crude oil**. The word "crude oil" is, however, limiting because crude oil has some natural gas in it when it is produced. For example, a single barrel of crude oil extracted from the earth may contain enough natural gas that can fill our homes. Therefore, in general terms, petroleum refers to crude oil and natural gas. Perhaps, the realization of this fact was the reason for the change of name from the Nigerian National Oil Corporation to the Nigerian National Petroleum Corporation in 1977.

Petroleum is often called **black gold** because when crude oil is extracted from the ground, it is mostly black in colour, and because of the oil and gas in it and due to their value, it is often described as gold. Please permit me henceforth to use the words **Black Gold, Petroleum, Crude Oil and Natural Gas**, or simply **Oil and Gas** interchangeably.

Mr. Vice-Chancellor, Sir, by the grace of God, I forayed into diverse areas of Geophysics such as solid mineral and groundwater exploration, air pollution and soil contamination studies and made significant research contributions as I traversed the ranks to reach the pinnacle of my career. However, my interest in the "**Search for the Black Gold**", which forms the subject of my lecture today, stems from the value attached to crude oil and natural gas as the panacea for wealth in nations endowed with them. Nations can fight avoidable wars if the supply chain of this gold is threatened. For example, over the years, Nigeria has become heavily dependent on oil and gas as a major source of revenue, with oil and gas accounting for more than 90% of the country's export earnings (Ukpo, 2023).

The search for oil and gas is fraught with high risks and uncertainties. The reason is that operators are faced with several unknown questions and how to find correct answers to them. Yet, operators that are successful in the end receive high reward. Today in this lecture, I shall share with you some of those unknown questions or fears, and how we used the instrumentality of geophysics to provide answers to them.

### 1.1 Formation and Occurrence of the Black Gold

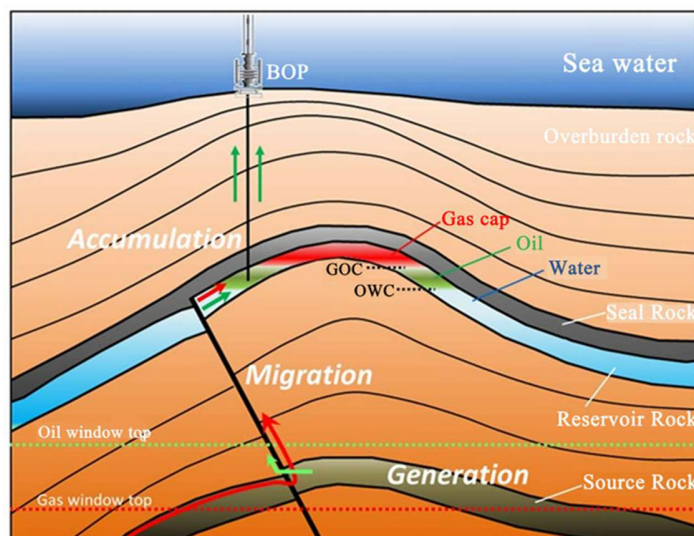
Mr. Vice-Chancellor Sir, scientists believe that this important substance, the *black gold* is produced from decomposed plant and animal matter which have died long ago, and have become slowly buried by thick layers of sediments. After being subjected to a persistent increase in heat and pressure in the deep over a long period of time, they become converted into petroleum.

Having highlighted the meaning of petroleum and how it is formed, let me now mention briefly, something about its occurrence and accumulation in the subsurface. In my formative years as a young student of Geophysics, I used to think that petroleum is found in big pools in the underground rocks. Some people still live in this delusion today. In reality, petroleum is found in tiny spaces between the grains of sediments in the subsurface. The sediments are called reservoir rocks and the spaces between the rock grains are called pores. The pores could sometimes be so small that they are not visible to the naked eye.

In its natural state, oil and gas always looks for a way to escape to the surface. Therefore, when petroleum is generated from a source rock, it moves up through permeable strata or openings in rocks and is lost at the earth's surface unless it is trapped and prevented from escaping. The trap is where petroleum is barred from further movement. Therefore, for petroleum to accumulate in the subsurface rocks, there must be:

- i. A mature source rock, which is an organic material that transforms into petroleum under intense heat and pressure;
- ii. A porous and permeable reservoir rock, which holds the accumulation and is able to release it during extraction;
- iii. A sealing rock, which is a rock that has the capacity to prevent oil gas from escaping to the surface.

The search for oil and gas bothers on identifying suitable locations in the subsurface which satisfy the above conditions (Fig. 1). Unfortunately, less than 1% of the earth is prospective to these conditions, and this further increases the risk and uncertainty associated with petroleum exploration.



**Figure 1: Elements and processes of a petroleum system (JOGMEC, 2013)**

## 2.0 GEOPHYSICS IN THE “SEARCH” FOR THE BLACK GOLD

### 2.1 What is Geophysics?

In general, Geophysics is the science that applies the principles of physics to study the earth (usually the subsurface of the earth). The subsurface geology is not directly visible and as such, for the geophysicist to see through the surface of the earth, he must employ an indirect approach.

The approach is by making measurements on or near the surface of the earth to obtain data arising from variations in the distributions of the physical properties of the rocks and minerals that constitute the subsurface of the earth. When the data are analyzed and interpreted, it could lead to the detection of local or regional features that are of economic importance to the explorationist.

The physical properties of the earth materials (rocks and minerals) which can be measured in order to study the earth include:

- i. The density (which determines gravitational acceleration)
- ii. Magnetic susceptibility and remanence (which determine magnetizability)
- iii. Density and elastic parameters (which determine the velocity of seismic waves in the earth)
- iv. Electrical potential (which determines conductivity or resistivity)
- v. Electrical capacitance (which determines the quantity of voltage that can develop)
- vi. Electrical conductivity and magnetic induction
- vii. Natural radioactivity
- viii. Dielectric constant

The type of physical property desired to be measured determines the geophysical method employed to study the earth. The geophysical methods are grouped into two subdivisions, which are:

- i. Those that derive their source from the natural field of the earth. These are called *passive or natural field geophysical methods*, and include gravity, magnetic, self potential, radiometric (natural radioactivity), magnetotelluric and geothermal methods;
- ii. Those that use artificial sources to incite measurements. These are called *active or artificial geophysical methods*, and include seismic, electrical resistivity, electromagnetic and radiometric methods that utilize the excitation of a suitable source.

Generally, the natural field methods can provide information on the earth's physical properties to significantly greater depths and are logistically simpler to carry out than the artificial methods. However, the artificial methods can produce more detailed and better resolved image of the subsurface than the natural methods.

## **2.2 Geophysical Methods in the “Search” for the Black Gold**

Mr. Vice-Chancellor, Sir, in the “search” for the black gold, the focus of the geophysicist is to be able to obtain an image of the subsurface where the structures with the highest potential for the accumulation of commercial quantity of oil and gas can be located with the least geologic uncertainty.

There are three types of rocks which are formed within the earth. They include the sedimentary, metamorphic and igneous rocks. The sedimentary rocks overlie the metamorphic and igneous rocks which are formed deep within the earth. Sedimentary rocks constitute the essential elements of a petroleum system and as such, the search for petroleum is targeted at sedimentary basins.

In a virgin area where the subsurface geology is completely unknown, the first questions the operator would likely ask are: *where is the sedimentary basin? how thick are the sediments?* These questions would have to be answered first before we begin to look into what lies beneath.

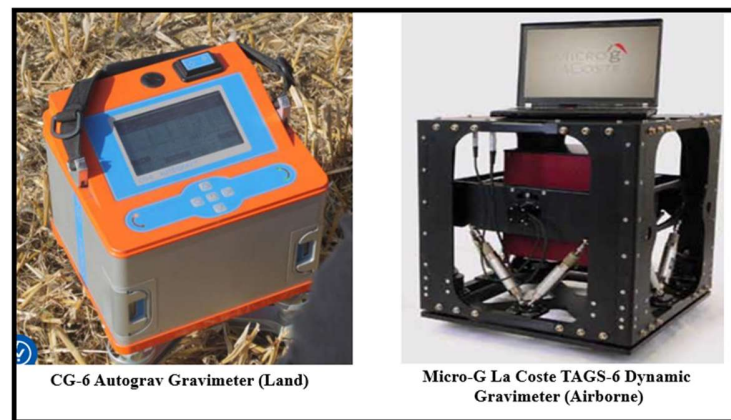
The answers to these unknowns are provided by two branches of geophysics which include the gravity and magnetic methods. In the search for petroleum, these methods are often employed as reconnaissance surveys mainly from the air where the measuring instruments are mounted on an aircraft programmed to fly along predetermined grids, or on a ship in offshore areas. Permit me at this point, Sir, to review their processes as it pertains to the search for crude oil and natural gas, without the boredom of the associated theories and equations.

### **2.2.1 The Gravity and Magnetic Methods**

The gravity method is a passive geophysical method. This is because, it derives its source from the earth's gravity field. The method measures the spatial variations in the earth's gravitational field over an area of interest. Interpretations made from gravity measurements are based on the mutual attraction between any two masses; this has been explained in physics by the Newton's Law of Universal Gravitation. The law adduces that any two bodies in the universe attract each other with a force whose magnitude depends on the product of their masses and the inverse square of the distance between them.

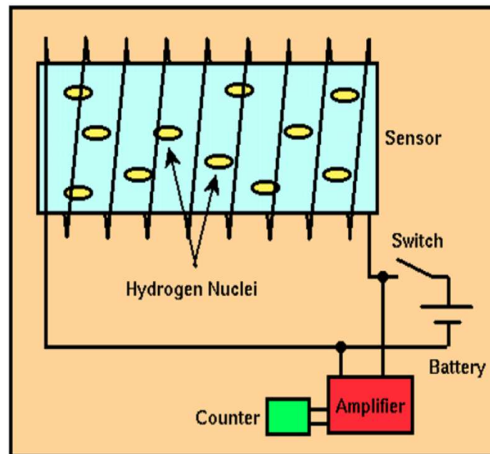
In geophysics, however, we are interested in the force exerted on a body by the earth, called the force of gravity. The force of gravity produces acceleration on all objects on, or near the surface of the earth. This force is called acceleration due to gravity, and has an average value of approximately  $9.8 \text{ m/s}^2$ . Variations in the earth's gravity field are therefore caused by departures from the average value of the gravitational acceleration.

In gravity surveying, we measure the acceleration due to gravity on a unit mass at the surface of the earth at any location where the measurement is desired, using highly precise equipment called the gravimeter (Fig. 2). The physical property of rocks we measure using this method is the density of the rocks. Different rocks in the subsurface have different densities. The higher the density of a rock, the higher is the gravity value measured at a location. This way, we are able to measure the spatial variations in the density of the subsurface rocks. Sedimentary rocks have much lower density than the basement rocks which lie beneath the sediments.



**Figure 2: Gravity measuring instruments**

The magnetic method is also a passive geophysical method, like the gravity method. In magnetic surveying, we measure variations in the magnetic field of the earth. These variations are caused by contrasts in the magnetic susceptibility and remanence which determine the magnetizability of the rocks in the presence of an applied (or external) magnetic field. The magnetic susceptibility of sedimentary rocks is much lower than that of igneous and metamorphic rocks. Hence, interpretations from magnetic surveys in the search for petroleum enables us to determine the depths to the igneous and metamorphic basement underlying the sequence of sediments in the area. Proton Magnetometer, an instrument used for magnetic survey data acquisition is shown in Fig. 3.



**Figure 3: Proton Precision Magnetometer**

Mr. VC Sir, geophysical methods are often used in combination to derive a better understanding of the subsurface geology. In the search for petroleum, interpretations from the gravity survey shows the lateral extent of sediments in the area while information on the thickness of the sediments is provided by the magnetic survey. Combining these two surveys would enable us delineate the sedimentary basin overlying the basement and identify areas of main sediment accumulation within the basin, which would thereafter become the target for further geophysical investigations using the seismic method.

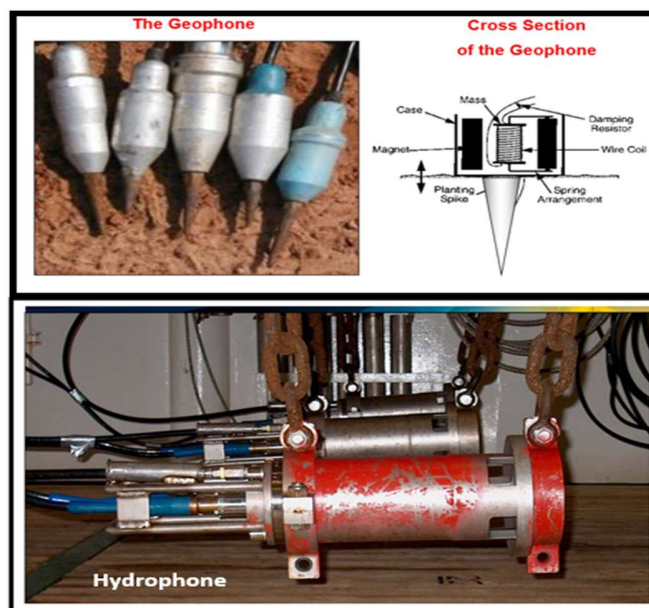
The initial round of surveys using the seismic method normally involves 2-D seismic acquisition along widely-spaced profile lines, carried out mainly to delineate the major structural or stratigraphic elements of the regional geology in the sedimentary basin. With this done, a detailed, follow-up 3-D seismic reflection survey would then be planned and executed in selected areas within the basin containing the main prospective targets.

### **2.2.2 The Seismic Method**

Unlike the gravity and magnetic methods, the seismic method is an active geophysical method because it uses an artificial source to incite measurements. In seismic exploration, a sound wave is introduced into the earth from an energy source such as an explosive charge, a hammer blow or weight drop mechanism. This generates elastic waves, called seismic waves, which propagate at different velocities through the earth's interior, away from the source in hemispherical divergence. The product of the velocity at which the seismic wave propagates through a particular rock in the subsurface and the density of that rock gives what is known as **acoustic impedance**.

As the seismic waves travel through the earth, they can be reflected, refracted or transmitted whenever they encounter a rock surface or geological boundary where there is contrast in acoustic impedance. The seismic waves which are reflected or refracted from such boundaries

eventually return to the surface where their travel times are measured by special sensors or detectors (Fig. 4) placed at or near the earth's surface. Thus, the seismic method is classified into two types – seismic refraction method which is designed to measure the refracted waves, and seismic reflection method which is designed to measure the reflected waves. In either case, the measured travel times constitute the seismic data that are acquired during seismic surveys, and their magnitudes depend on the distance from the source to the detector and the elastic properties of the rocks through which the waves have traveled. From the measured travel times, information on the depths to the various subsurface boundaries and the velocities with which the waves have traveled through the rocks are derived. These are thereafter used to produce an image of the subsurface which is used to study the earth.

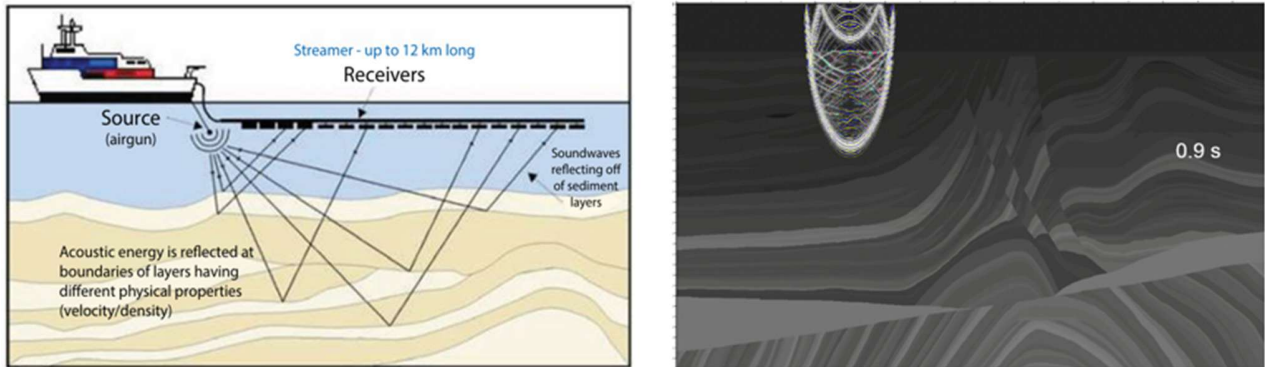


**Figure 4: Seismic sensors – Geophone and Hydrophone**

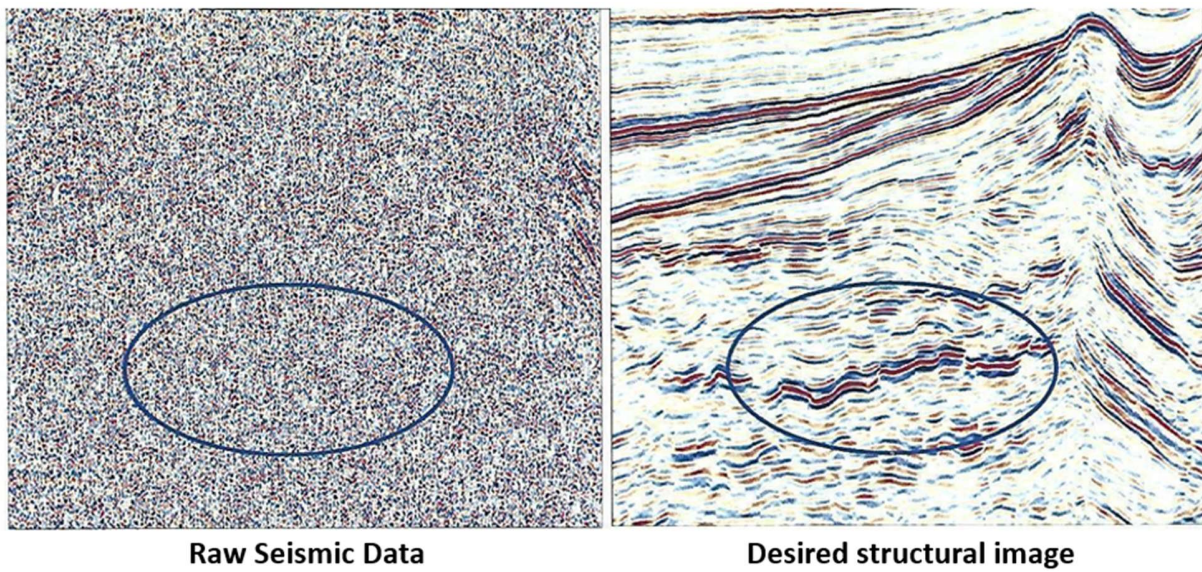
The seismic reflection method (Fig. 5) is the preferred seismic exploration method in the search for oil and gas. This is because of its ability to produce a more detailed, well resolved image of the subsurface from which we can identify geological structures suitable for the accumulation of petroleum.

Mr. Vice-Chancellor, Sir, a seismic image is like an ultrasound of the earth (Allison and Mandler, 2018). It is the tool the Geophysicist produces to provide a detailed information about the structure of the subsurface, including buried faults, folds, salt domes, and the size, shape and orientation of rock layers (Fig. 6). It is this image that helps to pinpoint the location of oil and gas in the subsurface. The creation of a good seismic image which can help to de-risk the location of oil and gas in the subsurface requires a well-researched use of the principles of physics to **manipulate** the seismic data that have been recorded in order to provide answers to

several unknown questions that are inherently associated with the recorded data. This is the main area which my research contributions in this lecture will showcase.



**Figure 5: A typical setup for offshore seismic survey and wave propagation schematic – Image credit: U.S. Bureau of Ocean Energy Management**



**Figure 6: Raw seismic data and final subsurface structural image**

### **3.0 RESEARCH CONTRIBUTIONS TO THE “SEARCH” FOR THE BLACK GOLD**

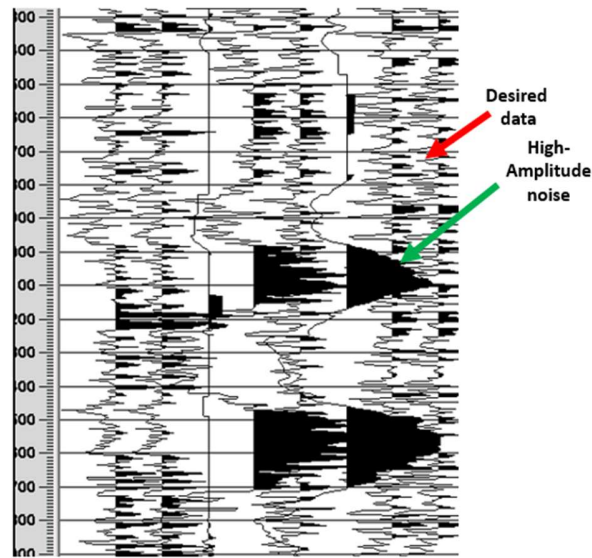
Mr. Vice-Chancellor, Sir, the search for petroleum is capital intensive yet, there is no guarantee of success due to its high risks and the uncertainty of locating it. Apart from the enormous cost of acquiring, processing and interpreting the data to locate the petroleum, its extraction from the subsurface reservoir for economic purposes is also very expensive. For example, the drilling of a single well may cost an average of \$5-8 million in onshore and \$100 – 200 million or more in deep water. This underscores the need for continued research and development aimed at eliminating or reducing known and unforeseen risks, both in the search for, and exploitation of the oil and gas.

In view of the above, some of the research contributions I believe I have made in our adventures to eliminate or reduce some of the associated risks can be categorized into two parts, with special focus on the Niger Delta sedimentary basin. They include:

- i. Research contributions aimed at manipulating the seismic data to obtain the ideal image of the subsurface to de-risk the correct location of oil and gas.
- ii. Contributions which aim to provide solutions to the safe and cost effective extraction of oil and gas from the subsurface for economic purposes.

#### **3.1 Noise Attenuation Studies**

The acquired seismic data is mostly a combination of the primary reflections which we desire to measure and a whole lot of unwanted signals which usually find their way into the record to corrupt the measurement. We do not often have the privilege to avoid these unwanted signals from being recorded. We generally refer to the unwanted records as noise, and they include, among several others, signals generated from bad weather conditions during the acquisition, such as lightning and heavy wind. Others include signals generated by moving vehicles, sparks from overhead cables, human and instrumental errors, and cable bites by sharks in marine and offshore acquisitions. Some of these noise have very low or high amplitudes in comparison to the primary reflections (Fig. 7), and the first challenge to the seismologist is how to answer questions regarding where they are in the data, their source and how to model and remove them.

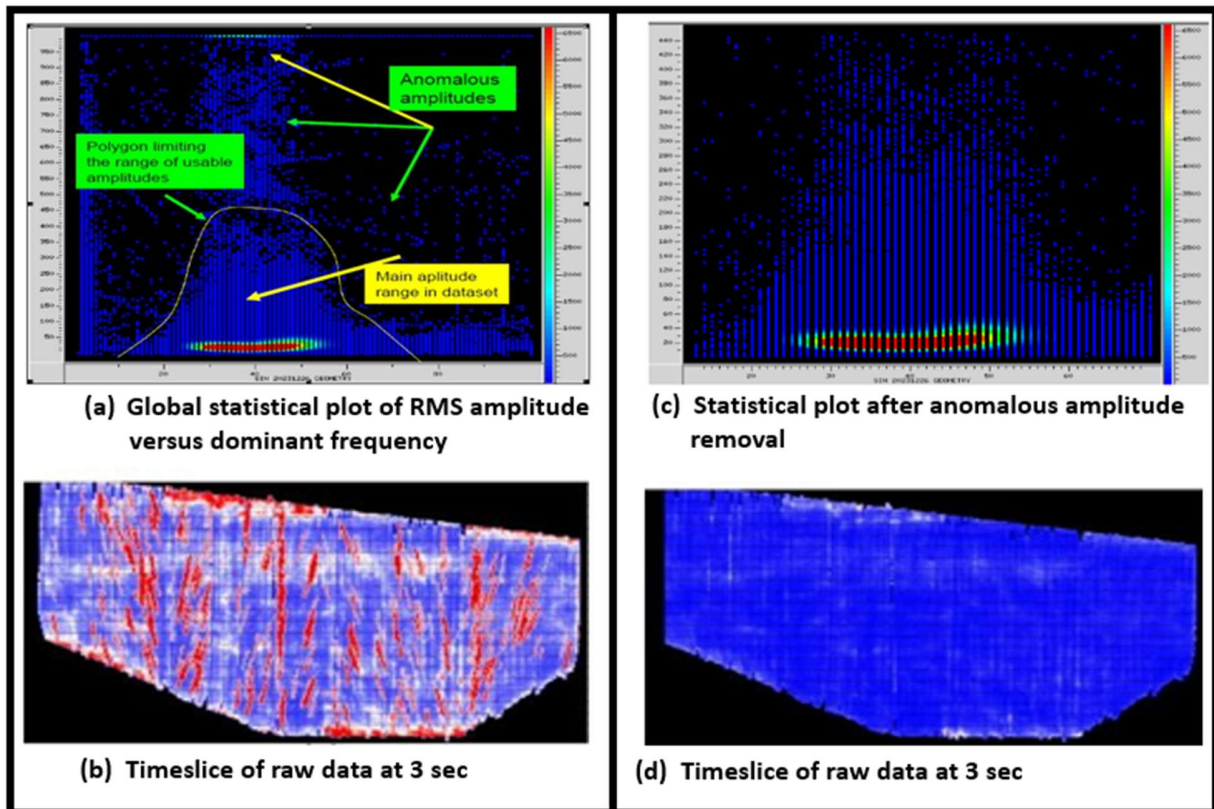


**Figure 7: Seismic record with spikes**

Some noise in the data, such as the one above, require to be detected and removed at the early stage of the data manipulation, which I will subsequently refer to as processing. They tend to suppress the information we desire to obtain from the primary reflections and cause a lot of problems if we fail to detect and remove them early in the processing. These kinds of noise are random and lack coherency between different seismic traces.

The conventional practice of detecting these kinds of noise is to manually inspect the data from trace to trace during which time, any identified bad trace is removed either by zeroing its amplitude or directly throwing it away from the record. This practice can take several weeks or even months to conclude and due to human error, it is often not possible to identify all bad or unwanted signals from the record, especially when dealing with a large volume of data having several millions of traces to inspect. Therefore, spurious amplitudes are retained in the dataset which cause imaging problems. This eventually results in a false image of the subsurface and therefore, a false location of the structures suitable for petroleum accumulation.

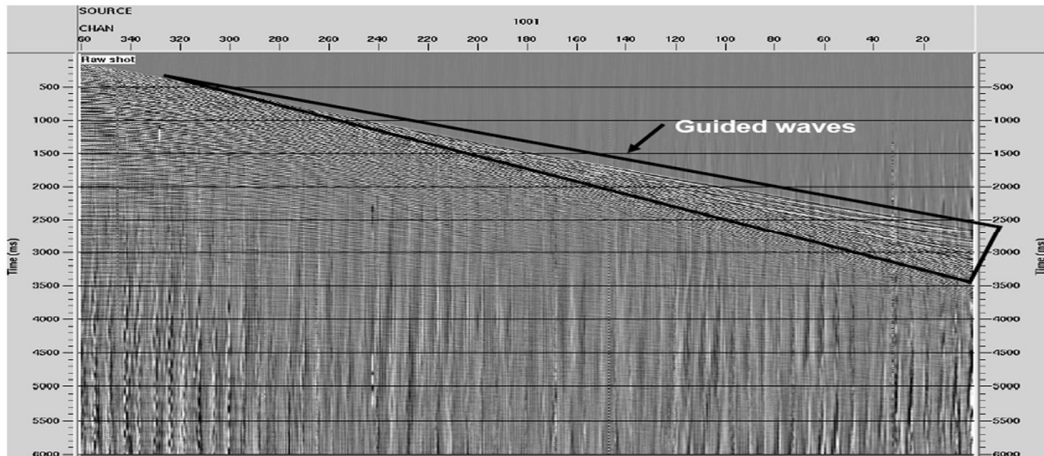
**Ogagarue** and Nwankwo (2016) developed a novel approach which utilizes a global statistical amplitude analysis window to try to resolve this industry problem. The procedure calculates the Root Mean Square (RMS) amplitude and dominant frequency of every trace in the window and outputs them as a header information into a database which when plotted, gives a global display of the amplitudes of all the traces in the entire dataset on the fly (Fig. 8).



**Figure 8: Global amplitude analysis for automatic trace editing**

The result shows that the technique is able to reveal areas within the whole data volume where amplitudes are abnormally high or low in the seismic record. We can then quickly select such areas with a polygon and eliminate them from the record. Thus, the manual exercise which, in some cases, could take months to carry out, with probable residual errors due to the failure to identify all of the problematic records, can be done in a matter of a few hours with the highest level of fidelity.

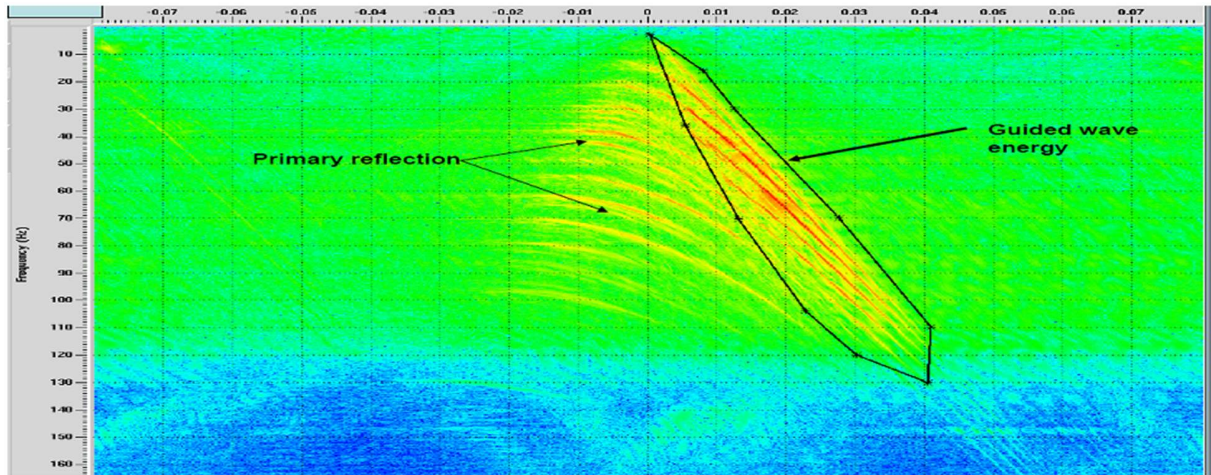
Mr. Vice-Chancellor, Sir, in addition to the seismic waves which propagate into the earth when a source is initiated, there are other waves which are generated at the same time as the seismic waves, but they prefer to travel along or near the earth's surface. They occur more in marine seismic acquisitions, especially where the sources are buried very shallow within the water layer. When the seismic velocity of the rocks below the water layer is very high compared to the velocity of seismic waves in water, some of the waves generated by these sources are trapped and guided laterally within the water layer. Therefore, instead of traveling to deeper depths into the subsurface rocks, they travel along or near the surface of the earth. Hence, we refer to them as guided waves (Fig. 9).



**Figure 9: Raw seismic shot record with heavy presence of guided wave energy**

The waves have very high amplitudes (which decay exponentially with depth) and very low velocities when compared to the seismic waves. These waves are recorded along with our targeted data, but they are noise and we need to detect and eliminate them from the seismic record in order to obtain a meaningful picture of the subsurface. Eliminating the guided waves is a serious challenge to the processing geophysicist since the waves have features that make them look similar from trace to trace, i.e., they are coherent noise. Targeting them for elimination sometimes impacts the amplitudes of the primary reflection which we want to preserve. There is thus the question of how best to remove them in order not to degrade the quality of our final image.

**Ogagarue (2010)** carried out a study which shows that guided wave energy can be eliminated from shallow marine seismic data acquired in the Niger Delta with a high level of success, if we transform the data from the original travelttime-offset ( $t-x$ ) domain, where they are recorded, to a form where they are represented in terms of frequency and wavenumber, called the F-K domain. The results show that the energy of the guided waves are well separated from the primary data on account of their low velocities in the F-K domain. Whereas the primary reflections are concentrated around  $K = 0$ , the guided wave energy has much higher positive dip (Fig. 10), and on this account, their separation becomes easier to deal with before transforming the data back to the  $t-x$  domain.



**Figure 10: F-K analysis plot with LMO + trace interpolation: The primary data is concentrated around  $K = 0$  in the transformation (Ogagarue, 2010)**

Mr. Vice-Chancellor, Sir, seismic data acquisition in the “search” for petroleum in the marine or offshore environment is particularly interesting, but it has its challenges. The sources and receivers are tied to a ship and recordings are made as the ship moves along pre-determined sail lines. This means that the sources and receivers must be at some depth within the water column while the recordings are made. This is the conventional towed streamer seismic acquisition method, and has proven effective over the years for 3-D subsurface imaging.

In areas where water depths are too shallow for the ship to sail, or where there are too many obstacles for streamer operations, seabed seismic sensors have, in some cases, been employed as an alternative to image the subsurface. We call this ocean bottom cable (OBC), 4-C or multicomponent seismic acquisition. The sensors comprise a hydrophone which records the pressure field, and a 3-component geophone, oriented in the X, Y and Z directions to record ground motion in those directions, respectively. That way, it is possible to measure the full waveform. The processing of this dataset is very challenging, just as its acquisition is challenging and expensive.

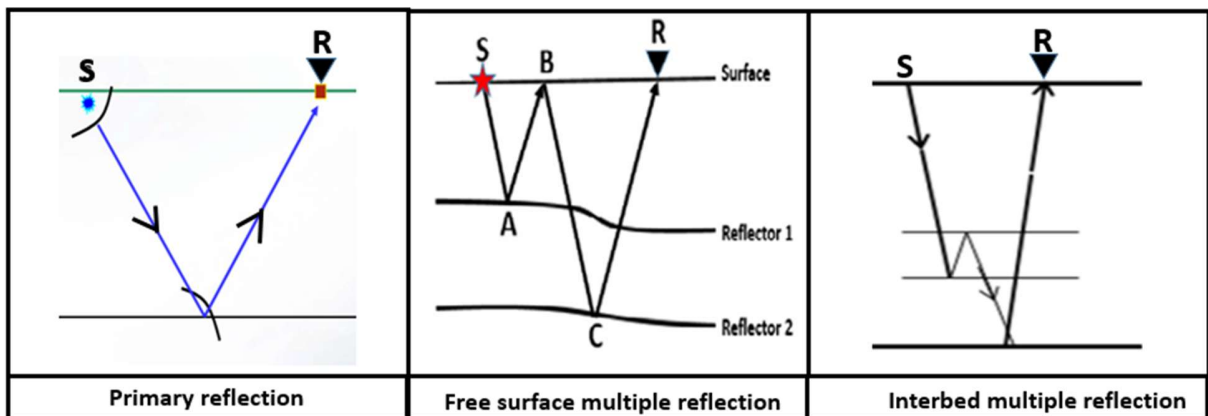
In the “search” for petroleum using compressional (P-wave) data alone, only the data recorded by the hydrophone and vertical (Z-component) geophone are of interest. The two records can be summed up to give a much clearer picture of the subsurface if the challenges associated with their processing are surmounted. A very big challenge in the manipulation of these datasets is that the Z-component geophone data can be significantly noisier than the hydrophone data. The vertical geophones are supposed to be buried vertically at the water bottom (seafloor). If this happens, then they would only record ground motions due to compressional waves alone. The level of noise in both the hydrophone and geophone would thus be comparable and their attenuation would be much easier. When its position is not totally vertical, it would measure some shear waves in addition to the compressional waves. This

makes the record to be much noisier than the hydrophone record and summing both records becomes more problematic for the geophysicist. The vertical geophone records are always noisier because it is not practically possible to bury the geophones vertically throughout the acquisition exercise.

**Ogagarue et al. (2010)** investigated coherent noise attenuation with application to 4-C Ocean Bottom Cable seismic data acquired in the Niger Delta shallow offshore. The study highlights the importance of applying a well selected low-cut frequency filter and time-variant exponential gain function to remove very low frequencies and correct the data for amplitude loss due to spherical wavefront spreading, respectively, and thereafter model shear leakage from the Y-component geophone and apply it to further suppress the vertical geophone data, thereby effectively reducing the noise to the level of noise in the hydrophone data.. This procedure allows for a high level of confidence in further attempts to eliminate the noise in the F-K domain.

### 3.2 Multiple Suppression Studies

Mr. Vice-Chancellor, Sir, seismic waves which have been reflected only once from a geologic boundary before being recorded by a sensor placed at or near the earth's surface are called primary reflections, and they are the energy we desire to measure in seismic operations. In addition to the primary reflections, because we are dealing with a multilayered earth, some seismic waves are reflected more than once from various subsurface boundaries before being recorded. These are called multiples, and they are of varied forms (Fig. 11).



**Figure 11: Primary and multiple reflections recorded during seismic operations**

The multiples are generated mainly at seismic boundaries within the earth where there are large reflection coefficients, arising from large acoustic impedance contrasts, such as the free water surface and water bottom in marine operations, and the base of the weathering layer in land operations. They destructively interfere with primary reflections in the seismic records and

give rise to false geologic structures in the subsurface. Therefore, their removal from the seismic record is expedient because our aim is that our final image of the subsurface does not contain any geologic structure that is a false structure. The oil and gas business is an expensive one. There are no room for chances. Several questions associated with multiples include: *Where are the multiples in the data? What is giving rise to them? How do we model, and then eliminate them from our record without impacting our targeted structures?*

Multiple removal has been a longstanding problem to the seismic processing geophysicist, especially because the multiples are of varied types and each type presents its unique problems.

**Ogagarue and Ebeniro (2014)** carried out a study that successfully eliminated water bottom multiples from a 3-D seismic dataset acquired in the Niger Delta offshore, using an adaptation of the parabolic radon transform method first introduced by Dan Hampson (Hampson, 1986). The procedure involves a transformation of the entire data from the t-x to the time-moveout domain, called the tau-P domain, where the primaries may be well separated from the multiples on the basis of their moveout, which depends largely on seismic velocity. Moveout is the difference in the traveltime of seismic waves at two different offsets. We tested the applicability of the procedure on a synthetic seismic dataset (Fig. 12) we generated using parameters similar to those used in the acquisition of the real seismic data dataset. The results show that the method is effective in eliminating seismic multiples generated at the seafloor in offshore seismic operations in the Niger Delta (Fig. 13), but highlights the importance of a priori knowledge of accurate seismic velocities for an effective primary-multiple separation in the radon space.

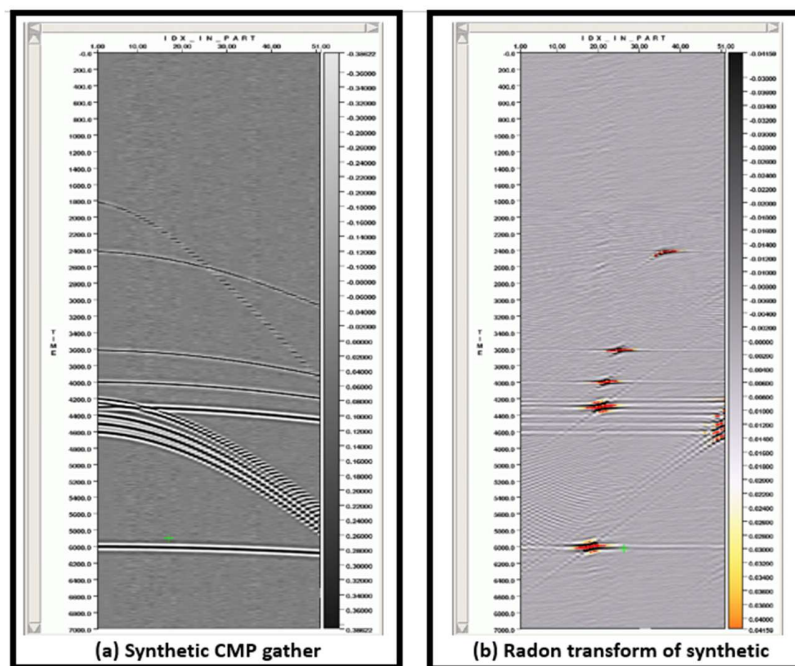
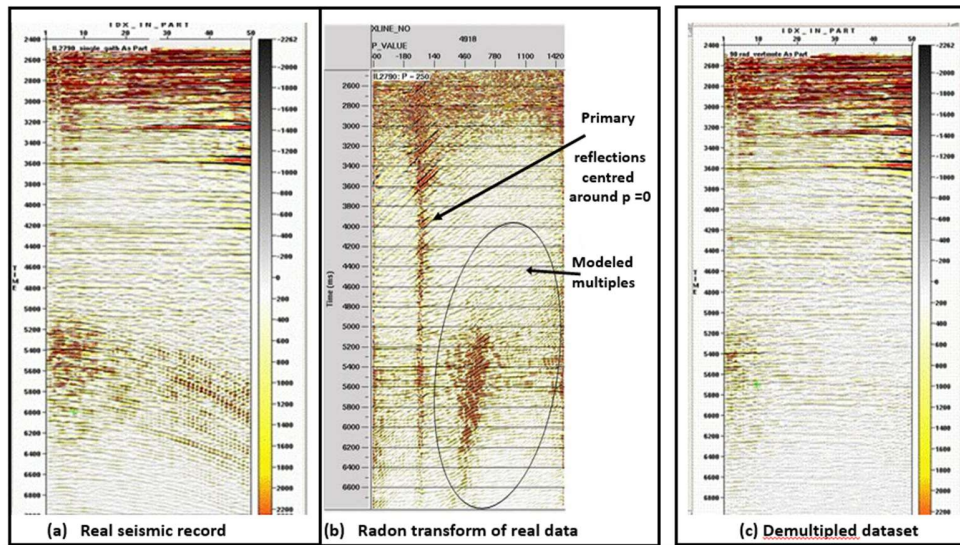
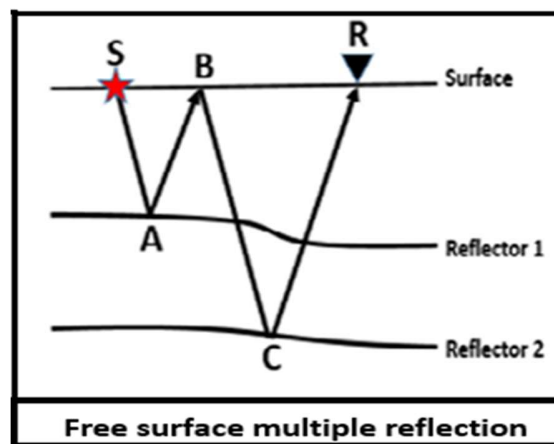


Figure 12: Modeled seafloor synthetic multiples for radon demultiple



**Figure 13: Applicability of radon transform for seafloor multiple elimination in offshore seismic operations in the Niger Delta**

The success of the above study in eliminating multiples generated at the water bottom in seismic datasets acquired in the Niger Delta encouraged me to further study multiples and their characteristics, particularly focusing on the elimination of multiples generated at the air-water interface. These multiples have at least one downward reflection at the free air-water surface (Fig. 14), and their effect is very dominating in seismic records.



**Figure 14: Free surface related multiple**

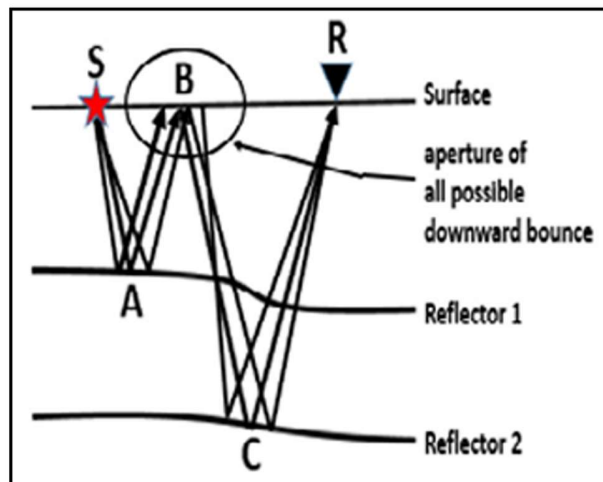
One of the problems faced in dealing with these kinds of multiples is that the position of the rebound at the free surface, i.e., position **B** in the figure, is not known. Position **B** must be known in order to be able to remove the multiple **SABCR** from the recorded data. Since we cannot directly know the position **B**, all conventional techniques to remove the multiple predict

the multiple **SABCR** by convolving all sub-events in the data, such as **SAB** and **BCR** in the figure shown. Thus, we would have: **P (SAB) \* P (BCR) = mult (SABCR)**

The success of the above procedure requires the seismic data to be densely sampled in both the in-line and cross-line directions so that we can possibly have a source at every receiver location. The data may need to be interpolated to obtain missing contributions from the multiple model to achieve this. This makes the elimination process highly compute intensive. On the other hand, seismic data is often inadequately sampled in the cross-line direction. This introduces frequency aliasing in the dataset which causes additional problems for the geophysicist to deal with, after his efforts to eliminate the multiples.

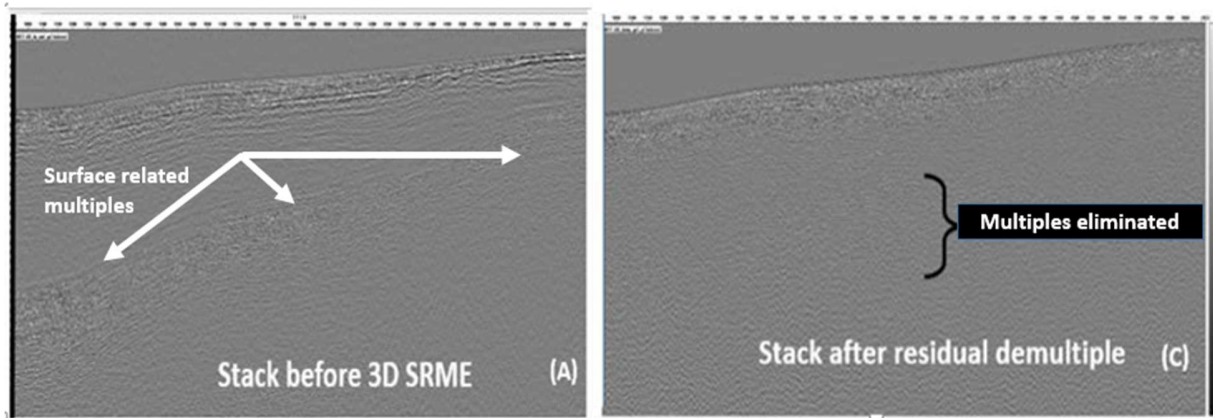
**Ogagarue** and Nwankwo (2019) carried out a study targeted at the removal of free surface multiples without interpolating the data in the cross-line direction. Our approach follow the method of Matson *et al*, (1999), but with modification to map an aperture for all possible downward bounce locations on the free surface over which the convolution process is carried out (Fig.15). Using this method, the predicted multiple becomes the summation of the convolution of all possible sub-events within the pre-determined aperture, i.e.:

$$\sum P (SAB) * P (BCR), P (SAB)^I * P (BCR)^I, P (SAB)^{II} * P (BCR)^{II}$$

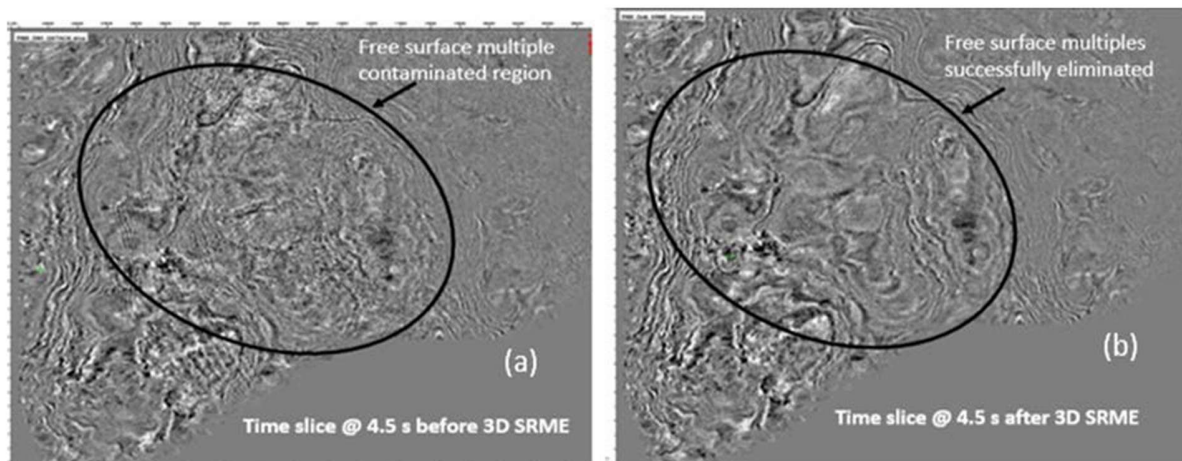


**Figure 15: Free surface multiple SABCR with inclusion of aperture of all possible free bounces, modified from Matson *et. al.*, 1999.**

The procedure requires far less compute time, and is very effective in eliminating surface related multiples from 3-D seismic data acquired in the Niger Delta offshore (Fig. 16).



**Figure 16 a: Surface multiple elimination quality check on stacks**



**Figure 16 b: Surface multiple elimination quality check on time slice at 4.5 sec**

Please permit me at this point, to mention that in an OBC seismic acquisition, both the hydrophone and 3-component geophones measure up- and down-going wavefields. The up-going wavefields are those that are recorded at the ocean floor after reflection from the subsurface rocks below the seafloor. Even after being recorded, these waves move through the water column, get totally-internally reflected at the water surface, move downward through the water layer and are recorded again at the seafloor. This series of recordings go on and on, causing several multiples (preferably called “ghosts”) and reverberations in the seismic record. We are interested only in the up-going wavefields that return to the seafloor after reflection from the subsurface boundaries. So, the geophysicist is again faced with how to separate the up- and down-going wavefields, eliminate the down-going, and retain only the up-going wavefields.

In 2014, **Ogagarue and Ebeniro (2014)** carried out a dual sensor summation study on an OBC dataset acquired in the Niger Delta shallow marine environment. The objective was to

implement the dual summation method of Hoffe *et al.* (2000), investigate its applicability to datasets acquired in the Niger Delta and suggest possible ways of improving the summation method. The summation is based on the fact that the up- and down-going wavefields have opposite polarity.

The novel approach in our study was the calibration of the hydrophone data through the derivation of amplitude scalars which we carried out upon the realization that the RMS amplitudes of the hydrophone data were significantly higher than those of the vertical geophone data (Fig.17). The Hoffe *et al.* (2000) implementation had suggested upscaling the vertical geophone data rather than the hydrophone data. Our study shows that process would cause a significant mismatch in amplitudes of the two datasets and would further degrade the summation output. Consequently, we derived amplitude scalars which effectively matched the amplitudes of the two datasets to enable their summation. Conclusively, the procedure is effective in eliminating receiver-side ghosts (Fig. 18) which constitutes serious problems to the seismic processing geophysicist in his search for petroleum using OBC datasets acquired in the Niger Delta.

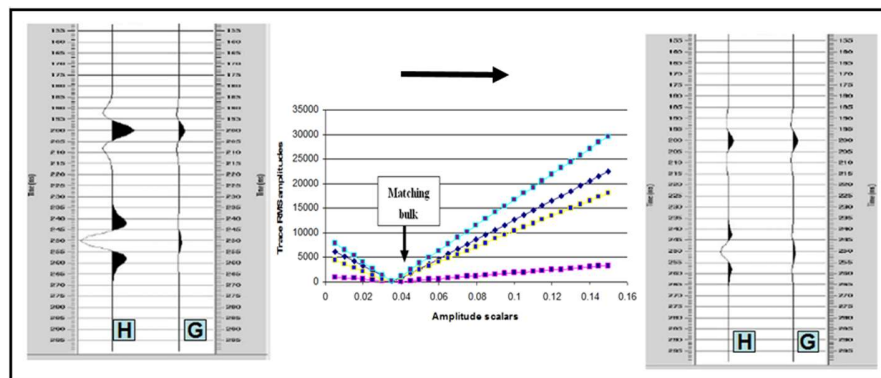


Figure 17: RMS amplitude levels before scaling, amplitude scalars and amplitude levels after scalar application

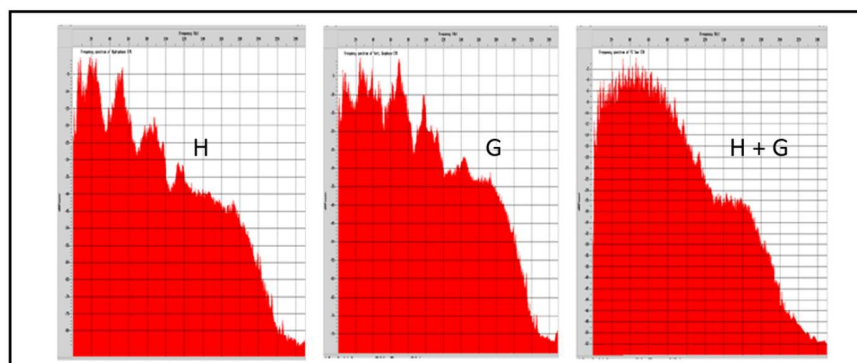


Figure 18: Frequency spectrum of the Hydrophone, vertical geophone and summed stacked datasets

### 3.3 Velocity Studies

Mr. Vice-Chancellor, Sir, having dealt with issues relating to noise and multiples in the seismic record, another very important task for the geophysicist in the “search” for petroleum is the determination of seismic velocities of the subsurface rocks. The velocity must be accurate to be able to accurately determine the exact depths and lateral extents of the structures in the subsurface. The accurate position and extent of the structures must be known to de-risk the presence of petroleum.

My initial research efforts to aid the accurate determination of seismic velocities was through the application of cross correlation. Cross correlation is a standard method of determining the similarity between two signals as a function of time delay applied to one of them (Yilmaz, 2001; Sheriff, 2002 and Ikelle and Amundsen, 2005).

(Ogagarue and Asor, 2010) developed a novel procedure which utilized the method of cross correlation to determine areas within a seismic volume where already estimated seismic velocities are either correct and require no further correction, or incorrect and therefore require correction. We carried out the study by cross correlating near ( $5^{\circ} - 18^{\circ}$ ) and far ( $30^{\circ} - 42^{\circ}$ ) angle limited CDP gathers generated from 3-D marine seismic dataset obtained from OML 100/102 in the Niger Delta. The result shows that where the estimated seismic velocity is optimum and require no further correction, the cross correlation peak lag time is zero or near zero. Very high peak lag times indicate areas where the estimated velocity is incorrect and require further work to correct the velocity (Fig. 19).

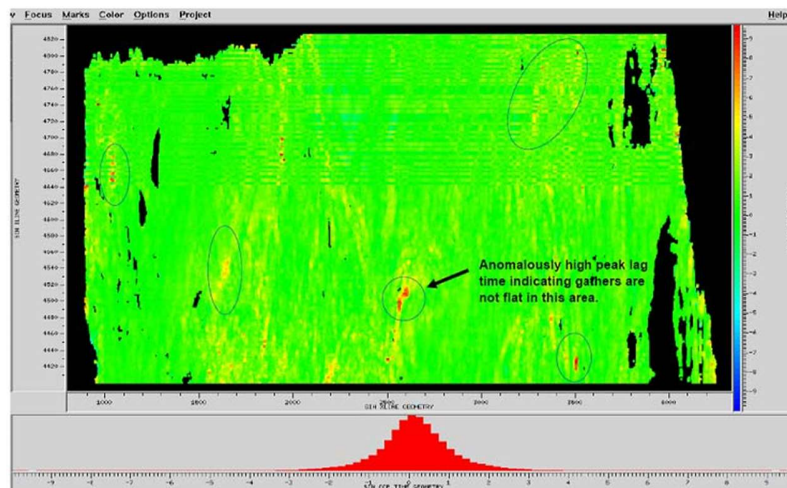
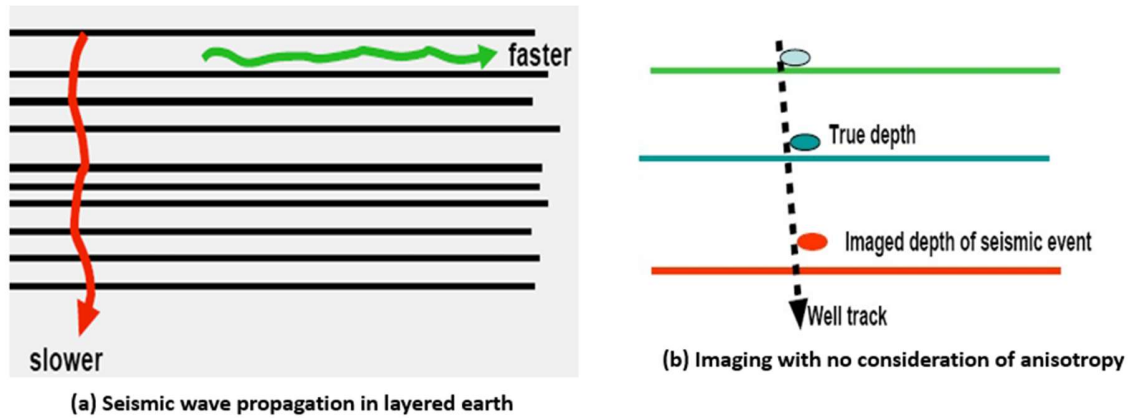


Figure 19: Global plot of cross correlation peak lag time for velocity QC

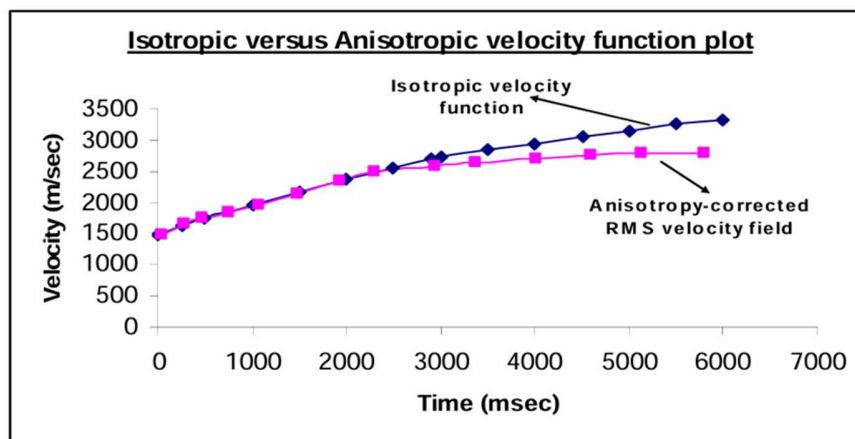
Another area of research for the improvement of seismic velocity in the Niger Delta is velocity anisotropy. In seismology, we say a layer is anisotropic if seismic waves propagate through it at different velocities in different directions. In a layered earth, seismic waves propagate faster along the layers than across layer boundaries (Fig. 20a). The preferred orientation of clay

minerals in shales cause similar behavior to seismic wave propagation. As a result, velocities derived from seismic data are faster than they should be. The overall result is that structural depths interpreted from seismic data are deeper than the true subsurface depths of those structures (Fig. 20b). It is therefore imperative that we incorporate velocity anisotropy in imaging algorithms if we do not want to de-risk the presence of petroleum.



**Figure 20: Velocity anisotropy and imaging considerations**

By incorporating velocity anisotropy into imaging algorithm performed on long offset seismic data acquired in the Niger Delta, **Ogagarue et al., (2010)** developed a more accurate velocity modeling technique which takes into consideration the anisotropic nature of the Niger Delta sediments (Fig. 21).



**Figure 21: Comparing isotropic and anisotropic velocity functions at a CDP location along a seismic survey**

The results of this study show that velocity anisotropy should be a concern to the oil and operator only if the operator desires to explore the deeper horizons in the Niger Delta. The deeper structures are seen to be imaged with higher velocities, and this places those structures at depths even much deeper than their true positions if anisotropy is not accounted for. This

results is very important since most of the exploration interests in the Niger Delta are now in the offshore areas where long offset seismic data acquisition would soon become the order of the day. The long offset acquisitions are designed to probe the much deeper targets.

Mr. Vice-Chancellor, Sir, away from locating the structures suitable for the presence of oil and gas in the subsurface, geophysics also answers a number of questions regarding the fluid(s) present in those structures, such as: *is it gas or oil?; is the accumulation, of commercial quantity?; are the structures such that it would be possible for us to extract the fluid(s) from them easily?*

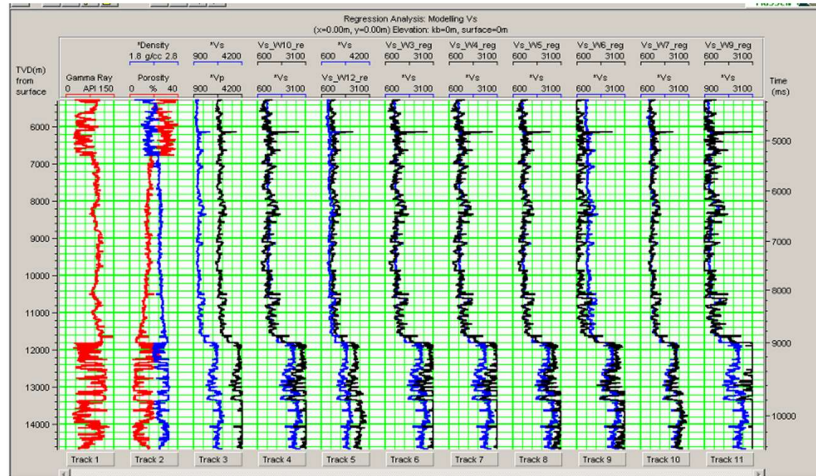
Among others, the geophysicist relies on the tool of **Rock Physics** to provide answers to the majority of these questions and more, in order to de-risk the exploration for oil and gas. Rock physics seeks to establish the link between rock properties and the observed seismic response over the rocks. In addition to *density* and the *compressional seismic velocity* ( $V_p$ ), another important rock property that we can relate to the presence of petroleum is the *shear velocity* ( $V_s$ ).

Shear wave acquisition, whether through surface or borehole geophysics, is very expensive. On the other hand, exploration for oil and gas is mainly dependent on the use of the compressional seismic velocity which most conventional seismic acquisition surveys are designed to acquire. Using data obtained from the Gulf of Mexico sedimentary basin in the North American continent, Castagna *et al.* (1985) obtained a widely accepted empirical relationship between compressional and the shear wave velocity. Through a detailed regression analysis of dipole sonic log data acquired in some petroleum wells between 2000 and 2002 in the Niger Delta sedimentary basin, Nigeria, **Ogagarue (2008)** obtained an adaptation of the Castagna's  $V_p - V_s$  relationship (**Egn. 1**) for the Niger Delta sediments (Fig. 22 ). The results show that the Castagna's relation under estimates shear velocity to between 6% and 10% in all the wells studied (Table 1). The **Ogagarue's (2008)** relationship has been widely used by a number of industry professionals and authors in relating compressional and shear wave velocities in the Niger Delta sedimentary basin (e.g. Abbey *et al.*, (2018); Adeniran and Aizebeokhai (2019); Abbey *et al.*, (2020); Ajah *et al.*, (2020); Chollom *et al.* (2021).

$$V_p = 1.11702 V_s + 1279.08$$

**Equation 1**

(where the units are in m/s).



**Figure 22: Regression Analysis for Vs Prediction.**

*In this figure, the regression lines obtained for all of the wells were used to predict Vs for one particular well. The figure shows that the Vs was best predicted with the linear regression for **Well 7**.*

**Table 1: Comparison between Localized Vp – Vs model and Castagna’s Relation**

Depth (ft)	GR API	Poro %	RHOB G/CC	Vp m/s	Vs m/s	Vs Predicted	Vs Castagna	Vs_diff Predicted	% prediction error	Vs Cast Castagna	% Castagna error
10040	95	13.4	2.441	2699	1254	1271	1154	-17	-1.4	100	8
10045	94	13.46	2.44	2655	1218	1232	1116	-14	-1.1	102	8.4
10049	93	12.82	2.45	2674	1211	1249	1133	-38	-3.1	78	6.4
10053	96	13.27	2.443	2674	1196	1249	1133	-53	-4.4	63	5.3
10058	97	12.63	2.453	2665	1200	1240	1125	-40	-3.3	75	6.3
10062	95	13.46	2.44	2659	1207	1235	1120	-28	-2.3	87	7.2
10066	95	13.4	2.441	2664	1200	1240	1124	-40	-3.3	76	6.3
10071	93	13.14	2.445	2685	1220	1258	1142	-38	-3.1	78	6.4
10075	91	12.82	2.45	2672	1224	1247	1131	-23	-1.9	93	7.6
10080	90	13.27	2.443	2751	1285	1317	1199	-32	-2.5	86	6.7
10084	89	13.08	2.446	2782	1325	1345	1226	-20	-1.5	99	7.5
10089	91	13.21	2.444	2772	1323	1336	1217	-13	-1	106	8
10093	89	14.17	2.429	2755	1317	1321	1203	-4	-0.3	114	8.7
10098	87	13.78	2.435	2747	1294	1314	1196	-20	-1.5	98	7.6
10102	90	14.29	2.427	2720	1283	1290	1172	-7	-0.5	111	8.7
10107	94	13.53	2.439	2672	1253	1247	1131	6	0.5	122	9.7
10111	92	14.49	2.424	2636	1214	1215	1100	-1	-0.1	114	9.4
10115	88	15.32	2.411	2617	1204	1197	1084	7	0.6	120	10

### 3.4 Pore and Fracture Pressure Prediction Studies

Mr. Vice-Chancellor, Sir, on January 16, 2012, there was a blowout at K.S. Endeavor, a drilling rig operating on behalf of Chevron Nig. Limited at the Funiwa Field, off the coast of Nigeria. Two (2) crew members were killed in the blowout. Again, on August 15, 2023, the Majestic rig belonging to Seplat Energy collapsed while operating in Ovhor, Delta State. One (1) crew member was reported killed in that incident. Away from Nigeria, on January 22, 2018, a

blowout occurred in the Pryor Trust drilling rig in Oklahoma, USA, killing all five (5) members of the crew (Fig. 23 ).

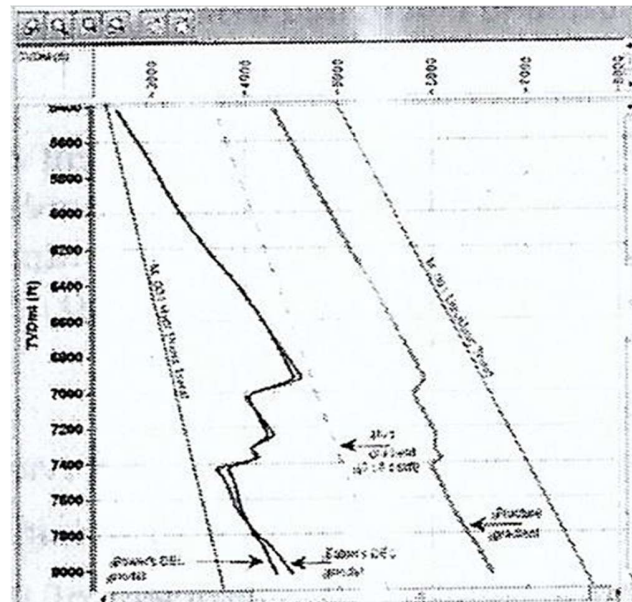


**Figure 23: January 22, 2018 Pryor rig blowout (U.S. Chemical Safety and Hazard Investigation Board).**

The desire of every oil and gas producing company, after exploring and finding the petroleum, is to be able to drill safely to target reservoirs and exploit the petroleum. One factor that controls the safe and cost effective drilling of petroleum wells is a foreknowledge of the pressure of fluids in the pore spaces of the sediments. This has to be accurately predicted along the trajectory of a proposed well before drilling can take place. The well engineer makes use of the information to design a safe and cost effective drilling of the well. Accurate prediction of the pore fluid pressure is significant because if the predicted values are lower than the actual, fluids, especially gas may flow from the formation into the well, causing kicks and blowouts in severe cases. This could have been the cause of the catastrophic incidences of January 16, 2012 and January 22, 2018 mentioned above. On the other hand, over-prediction can lead to formation damage during drilling, resulting from mud invasion into the formation due to over-engineering of the well. In my opinion, this could have been the cause of the Seplat Energy rig collapse of August 15, 2023.

Geophysics is the answer to several questions leading to the accurate knowledge of pore and fracture pressure pre-drill. My quest for knowledge in pore and fracture pressure prediction started in 2017, when I carried out a geopressure and sediment compaction study of the structurally complex Biafra-Qua Iboe members of the Southeastern part of the Niger Delta offshore (**Ogagarue, 2017**). The objectives were to delineate the shallowest indication of the onset of overpressure in the area, determine its magnitude, including the associated fracture pressure using established relationships, and offer explanation on the mechanism(s) generating the overpressure. The result (Fig. 24) shows that the onset of overpressure is fairly constant at 6,300 ftss (*ft. sub-sea*) across the area, and is well pronounced between 6,400 ft ss and 7,000 ftss. Geopressure in the area is mild to high, and ranges from 2,062.54 psi to 5,593.05 psi. The predicted values are higher farther south in the study area, where the thickness of shale is much

higher. Overpressure in the area is caused by disequilibrium compaction and tectonic activities. A mud weight of 0.7 psi/ft was estimated to be optimum to drill safely through the overpressured zone in the area.



**Figure 24: Pore/fracture pressure regime in the Biafra-Qua Iboe area.**

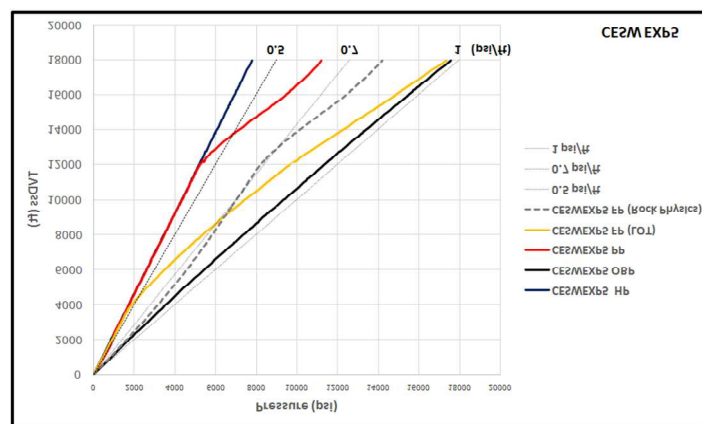
Emudianughe and **Ogagarue (2018)** also investigated the subsurface pressure regime of the Ada Field in the Niger Delta onshore, and reported pressure gradients of 0.6 psi/ft at depths 12,000 ft TVDml and deeper. Previous studies have reported the likelihood of higher pressures in the deep. We therefore concluded that overpressured fluids may have been remobilized through the numerous fault systems and connected channel complexities in the area. This can cause serious unexpected challenges during drilling. Thus, we recommended a robust geomechanical modeling prior to further development and production stages in the field and similar fields in the Niger Delta with structural complexities.

Mr. Vice-Chancellor, Sir, in addition to the pore fluid pressure in the rocks, the *in situ* fracture pressure is another important information that guarantees the safe and cost effective drilling of a petroleum well. This is the pressure that is enough to cause the formation to fracture while drilling. The pressure in the drilling mud must be kept reasonably lower than the fracture pressure (and reasonably higher than the pore fluid pressure) at all times to prevent the formation from fracturing during drilling.

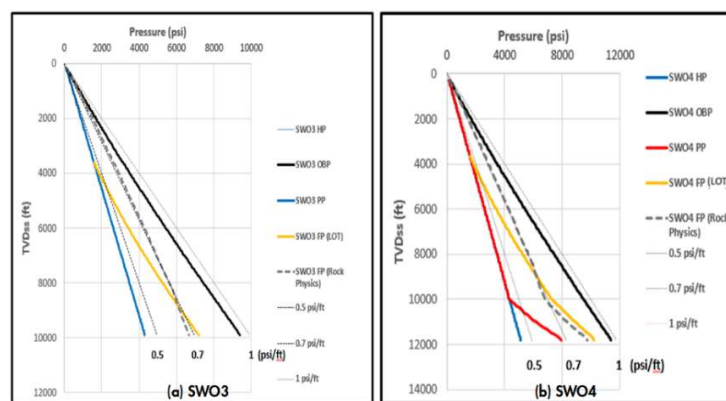
The main sources of *in situ* fracture pressure data include the Repeat Formation Test (RFT), Drill Stem Test (DST), Minifrac Tests, Leak-off Test (LOT) and the Extended Leak-off Test (XLOT), the Leak-off tests being the most common and perhaps accurate. Unfortunately, measured fracture pressure data are not available in the majority of wells in the Niger Delta,

and most of the available data are mainly limited to the onshore and shallow water wells in the Niger Delta (Ajayi *et al.*, 2021).

In our quest to provide industry solution to the fracture pressure challenges, **Ogagarue and Ogbe (2018)** investigated the use of rock physics modeling for fracture pressure prediction as an alternative to *in situ* fracture pressure measurements, focusing on petroleum wells in the central and shallow offshore areas of the Niger Delta where LOT data are available. The study shows that rock physics modeling is a viable alternative to fracture pressure measurements in the deep offshore areas of the Niger Delta where measured fracture pressure data are lacking, provided an average of 11% is added to the modeled values to obtain a reasonable estimate of the fracture pressure (Figs. 25 and 26; Tables 2 and 3).



**Figure 25: LOT-derived (gold) and rock physics-derived (dashed grey) fracture pressure profiles for Central swamp well 1. The fracture pressures are plotted together with hydrostatic, overburden and pore pressures at the well. Pressures gradients are also indicated for 0.5psi/ft, 0.7 psi/ft and 1 psi/ft.**



**Figure 26: LOT-derived (gold) and rock physics-derived (dashed grey) fracture pressure profiles for Shallow offshore wells SWO3 and SWO4. The fracture pressures are plotted together with hydrostatic, overburden and pore pressures at the wells. Pressures gradients are also indicated for 0.5 psi/ft, 0.7 psi/ft and 1 psi/ft.**

**Table 2: Comparison of LOT and rock physics-derived (RKP) fracture pressure in overpressured section of CESW EXP5 well. These are shown together with percentage difference in the values. Overburden pressure (OBP), hydrostatic pressure (HP) and pore pressure at the well is also shown.**

TVDSS (ft)	OBP (psi)	PP (psi)	HP (psi)	FP (LOT, psi)	FP (RKP, psi)	FP_diff	% Diff
14670.00	14116.72	7954.77	6381.45	13168.54	10945.35	2223.18	16.88
14675.89	14122.83	7961.74	6384.01	13176.23	10952.21	2224.03	16.88
14851.00	14304.64	8170.52	6460.19	13405.10	11157.17	2247.93	16.77
14861.00	14315.03	8182.65	6464.54	13418.18	11169.05	2249.13	16.76
14946.97	14404.37	8284.82	6501.93	13530.21	11269.38	2260.83	16.71
15132.00	14596.85	8503.61	6582.42	13770.65	11484.36	2286.29	16.60
15217.55	14685.92	8604.50	6619.63	13881.54	11583.52	2298.02	16.55
15254.00	14723.89	8646.38	6635.49	13928.60	11624.83	2303.77	16.54
15300.00	14771.82	8699.53	6655.50	13988.00	11677.21	2310.79	16.52
15310.00	14782.24	8711.26	6659.85	14000.92	11688.74	2312.18	16.51
15400.00	14876.06	8815.51	6699.00	14117.04	11791.46	2325.58	16.47
15432.00	14909.43	8852.80	6712.92	14158.31	11828.16	2330.15	16.46
15487.88	14967.72	8917.62	6737.23	14230.31	11892.01	2338.30	16.43
15758.26	15250.07	9221.06	6854.84	14576.76	12192.29	2384.47	16.36
15928.00	15427.58	9401.83	6928.68	14792.70	12372.57	2420.14	16.36
16029.00	15533.29	9508.85	6972.61	14921.01	12479.39	2441.62	16.36
16170.00	15680.99	9652.56	7033.95	15099.43	12623.70	2475.74	16.40
16187.00	15698.81	9669.72	7041.35	15120.92	12640.96	2479.96	16.40
16230.00	15743.88	9713.05	7060.05	15175.26	12684.55	2490.71	16.41
16292.00	15808.89	9775.67	7087.02	15253.61	12747.53	2506.08	16.43
16300.40	15817.69	9784.26	7090.67	15264.23	12756.15	2508.08	16.43
16396.00	15917.99	9877.96	7132.26	15384.75	12850.84	2533.91	16.47
16460.00	15985.17	9939.55	7160.10	15465.33	12913.27	2552.05	16.50
16572.80	16103.62	10047.86	7209.17	15607.30	13023.09	2584.20	16.56

**Table 3: Comparison of LOT and rock physics-derived (RKP) fracture pressure in overpressured section of SWO3 well. These are shown together with percentage difference in the values. Overburden pressure (OBP), hydrostatic pressure (HP) and pore pressure at the well are also shown.**

TVDss	HP	OBP	PP	FP (LOT)	FP (RKP)	FP_Diff	%Diff
10120.00	4389.74	9614.07	4524.25	7463.98	6969.34	494.64	6.63
10200.00	4427.71	9706.47	4693.64	7610.86	7103.27	507.60	6.67
10280.00	4459.07	9782.80	4841.71	7738.66	7218.58	520.08	6.72
10360.00	4496.69	9874.43	5017.86	7886.21	7355.95	530.26	6.72
10440.00	4529.23	9953.89	5141.39	8004.31	7460.25	544.05	6.80
10520.00	4564.88	10040.99	5275.80	8130.81	7573.99	556.83	6.85
10600.00	4599.35	10125.18	5406.18	8253.40	7685.72	567.68	6.88
10680.00	4633.09	10207.64	5539.20	8375.45	7803.01	572.44	6.83
10760.00	4669.50	10296.82	5705.07	8513.80	7940.93	572.87	6.73
10840.00	4701.28	10374.71	5852.11	8637.18	8063.42	573.76	6.64
10920.00	4739.64	10468.72	6028.44	8780.98	8208.53	572.45	6.52
11000.00	4771.00	10545.61	6174.31	8901.84	8329.46	572.39	6.43
11080.00	4808.24	10637.11	6363.96	9047.48	8479.42	568.07	6.28
11160.00	4841.16	10718.05	6535.55	9178.88	8614.78	564.10	6.15
11240.00	4876.42	10804.73	6718.07	9317.08	8761.14	555.93	5.97
11320.00	4911.28	10890.43	6897.82	9452.77	8906.75	546.02	5.78
11400.00	4944.63	10972.61	7075.00	9584.43	9048.44	535.99	5.59
11480.00	4981.43	11063.36	7271.08	9727.45	9202.97	524.48	5.39
11560.00	5012.82	11140.77	7435.63	9849.87	9334.41	515.46	5.23
11640.00	5051.56	11236.32	7635.38	9995.54	9491.32	504.22	5.04
11720.00	5082.95	11313.90	7798.26	10115.91	9620.34	495.57	4.90
11800.00	5105.04	11368.54	7912.86	10204.06	9714.17	489.89	4.80

Mr. Vice-Chancellor, Sir, my major research breakthrough in pore pressure prediction was when I was offered sabbatical placement in SPDC in 2018 as a Senior Research Advisor to the Exploration Department. The company was preparing to spud three (3) new wells in the shallow waters in that year. I was given a project to **investigate velocity anisotropy in the area and thereafter model pore pressure in readiness for the drilling campaign**. Leading a team of four (4) geophysicists, some of whom were based in The Hague, we developed a technology which utilizes gridded velocity inversion technique to automatically derive a regional geologically sensitive seismic interval velocity depth reversal surface within an input seismic interval velocity field, below which overpressure rapidly builds (**Ogagarue, et. al., 2018**). We thereafter employed this surface to guide regional 3D pre-drill pore pressure prediction away from well control.

Conventional practice of regional pore pressure prediction often relies on interpreted seismic horizons, especially regionally extensive seismic horizons, to guide pressure predictions away from well control. Mechanisms that control pore pressure can vary subtly or abruptly in depth or lateral extent, especially in areas of complex pressure regimes. As a result, the conventional methods are often not able to capture all cases of seismic velocity reversals which reflect changes in pore pressure in the pre-drill model. This has often caused pressure surprises during drilling activities, some of which have been catastrophic.

Analysis of the result of our study at a blind well location within the survey where *in situ* pore pressure measurements have been made shows that the predicted pore pressure is accurate, with an error margin of **0.2%**. The technology was approved as *novel not only to SPDC, but the entire Shell Group for a field-wide pre-drill pore pressure prediction*. It is noteworthy to mention that the technology has been deployed successfully to steer a safe and efficient drilling campaign by Brunei Shell Petroleum, Shell Malaysia and SPDC. Other Shell Groups may have keyed in by now. The beauty of the technology is that once a seismic interval velocity function is extracted from a proposed well trajectory, the accurate pore fluid pressure along that trajectory can be output automatically. That way, a number of wells can be drilled simultaneously.

***Amidst the plan for a copyright of the technology in the name of Ogagarue and SPDC at the time, below is a commendation letter from SPDC management on the outcome of this research.***



Dr Difference Odeyowwi Ogagarue  
Department of Earth Sciences (Geophysics Option)  
Federal University of Petroleum Resources  
Effurun, Delta State

**The Shell Petroleum Development Company of  
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Internet [www.shellnigeria.com](http://www.shellnigeria.com)

15 October, 2019

Dear Dr Ogagarue,

**LETTER OF COMMENDATION**

On behalf of The Shell Petroleum Development Company of Nigeria Limited (SPDC), I hereby commend you for your research contributions to SPDC during your time in the company on Sabbatical leave.

We particularly wish to commend you on the outcome of your research project titled: **"Velocity Anisotropy and Pore Pressure Prediction in The  $\Delta$  Area, Shallow Offshore, Niger Delta."** It is gratifying to note that the results of your research work here in Nigeria were quality-checked and approved as having met global standards.

SPDC deeply appreciates your contribution to her business during your one-year sabbatical leave and wish you success in your future academic pursuits.

Yours Faithfully,



Igo Weli

General Manager, External Relations

The highlights of the technology is shown in Fig. 27 and Fig. 28.

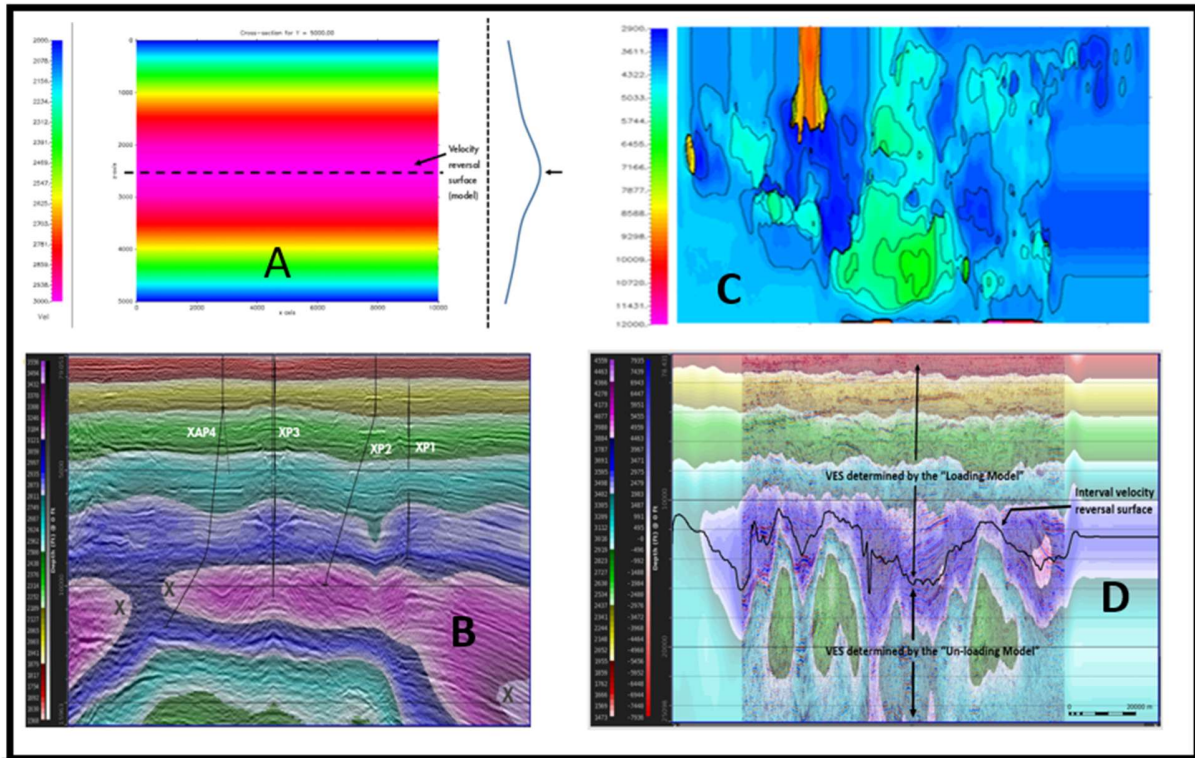


Figure 27: 3-D pore pressure prediction using gridded velocity inversion: Development steps are A, B, C and D.

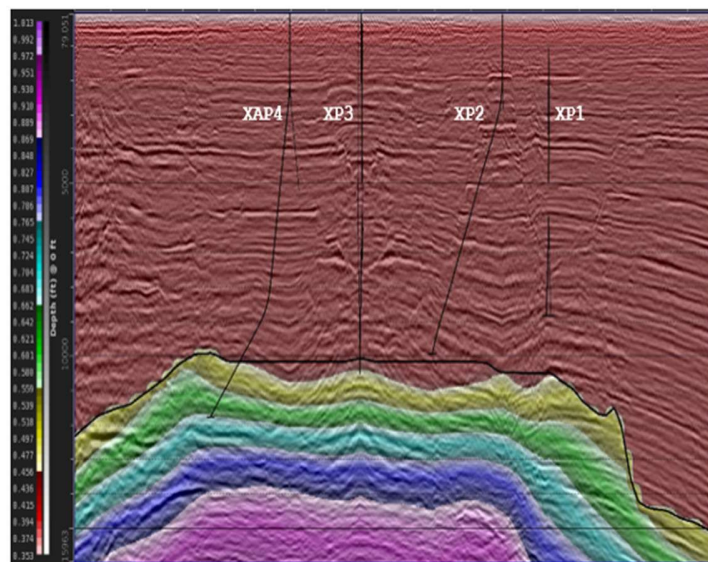
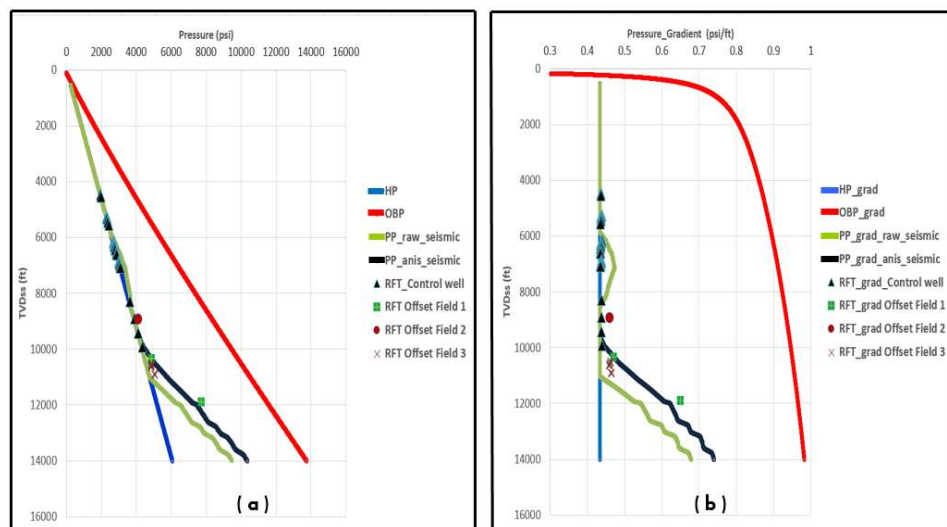


Figure 28: Predicted 3-D pore pressure gradient along an arbitrary seismic line in the survey.

Another aspect of the above work was our quest into the application of velocity anisotropy in pore pressure prediction (Ogagarue and Uko, 2018). Working on a recently acquired seismic volume covering an area of 122 sq. km. in the Niger Delta shallow offshore, we carried out a well-based pore-pressure modeling in a number of wells in the area, extracted a seismic velocity function at a control well location and corrected it for anisotropy and then integrated the results to predict regional pore pressure in the area. Pore pressure predicted using the anisotropy-corrected seismic volume compared reasonably well with measured pressure data at a blind well location, with a standard deviation of 0.45 in contrast to 50.82 standard deviation obtained from regional pore pressure predicted without consideration of velocity anisotropy.

Very interestingly Sir, in addition to predicting much lower pressures in the overpressured zones in the area, the uncorrected seismic velocity also predicted the onset of overpressure at 10.58% deeper than the depth of the onset obtained from the measured pressure data (Fig. 29; Table 4). The predicted depth error compares well with the 10.30% degree of maximum anisotropy obtained in this dataset. Therefore, pore pressure volume predicted with a velocity cube without the consideration for velocity anisotropy would likely introduce a depth error equivalent to the degree of maximum anisotropy in a seismic velocity volume. This result further corroborates the results of our previous work on velocity anisotropy (Ogagarue *et. al.*, 2010)



**Figure 29: Pore pressure and pressure gradient profiles extracted at blind well, including RFT offset data. (Green: profile from raw seismic velocity; Black: profile from anisotropic volume). The measured pressure data clearly align with the prediction from the corrected volume.**

**Table 4: Comparison of measured and predicted pressures at Blind well location in overpressured section (RFT data pulled from offset fields)**

<b>TVDss (ft)</b>	<b>RFT (psi)</b>	<b>PP (psi) (Raw vel)</b>	<b>PP (psi) (Anis. vei)</b>	<b>PPG RFT (psi/ft)</b>	<b>PPG (psi/ft) (Raw vel)</b>	<b>PPG (psi/ft) (Corr. vel)</b>
10340	4860.41	4477.12	4875.68	0.4701	0.4330	0.4715
10501	4856.07	4546.82	4901.72	0.4624	0.4330	0.4668
10934	5068.91	4734.75	5161.21	0.4636	0.4330	0.4720
11890	7727.57	6204.98	7566.68	0.6499	0.5219	0.6364

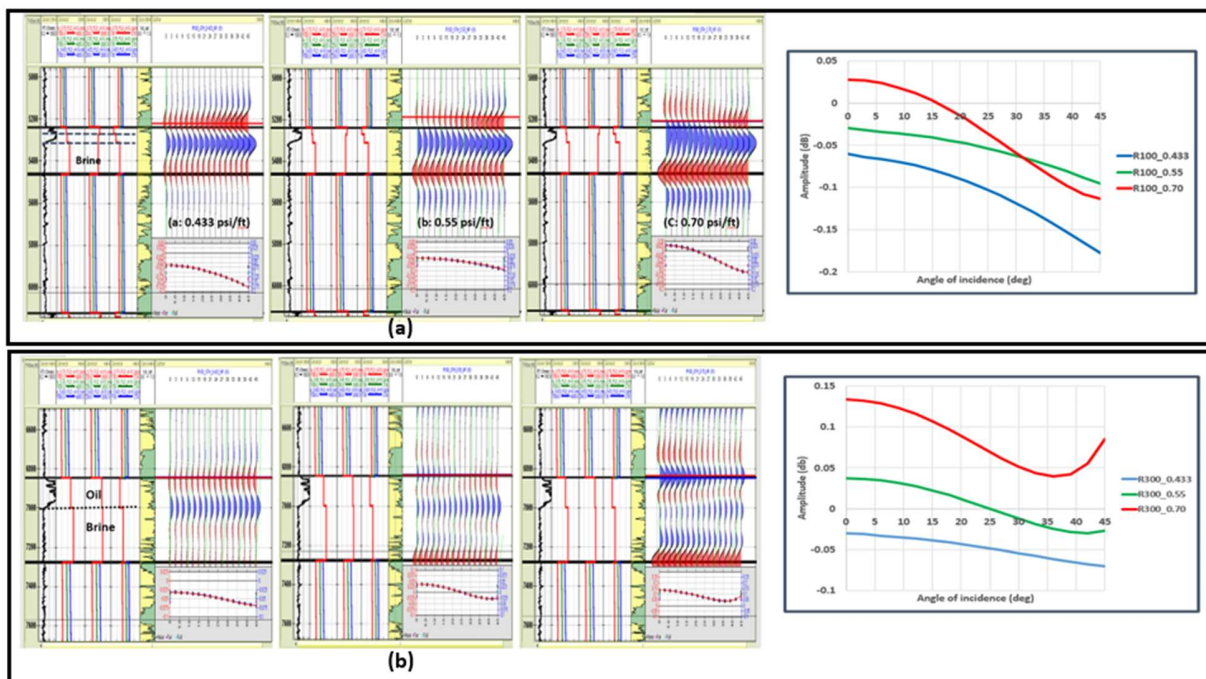
Mr. Vice-Chancellor, Sir, people often say that the Niger Delta is in the waning days of its oil production. This assertion is largely untrue. According to the pioneer Group Managing Director of Conoil Producing, Ebi Omatsola, reported in Oil Patch Sub-Sahara of June 28, 2013, only 2% of wells in the Niger Delta have penetrated deeper than 15,000 ft (4.572 km) TVD. 70% of the wells have not gone deeper than 9,000 ft (2.743 km) TVD. According to him, this is like scratching the surface. The Niger Delta basin has productive zones up to 20,000 ft (6.096 km) deep. He accused oil and gas operators of being afraid to take risks in their search for oil and gas in the Niger Delta.

Now, what is this risk, if I may ask? The risk is the fear of the unknown in running into a shale sequence as they try to exploit potential targets in the deep. Shale sequences are potentially overpressured, and operators usually have heart attacks when they run into shale while drilling a well. For example, in the mid 90's, Shell attempted a deep drilling campaign, with mixed results. A decade after, ExxonMobil and TOTAL jointly spudded a well, targeted to drill deeper than 15,000 ft, but pressure problems forced them to stop, even though they were using a High Temperature, High Pressure rig at the time (Akinosho, 2013). Therefore, Mr. Vice-Chancellor, with the 3-D pore pressure modeling solutions we have developed for the oil and gas industry in the aforementioned works, this fear of the unknown related to overpressure, is now a thing of the past. Drillers would become fully armed with all pore pressure information required to drill into any target, and through any sequence. Nearly all cases of pressure surprises that are likely to be encountered would have been accommodated. I therefore call on oil companies to leave their comfort zones exploring for oil and gas at shallow targets, to leverage the opportunity of our solutions to seek pay opportunities at deeper targets. This is particularly important as the country is seeking ways of increasing the reserve base for oil and gas, to increase the national wealth.

In our quest to further de-risk the search for oil and gas in the deeper plays in the Niger Delta, we also conducted a research on how seismic amplitudes change at reservoir tops in response to varying pore pressure regimes. In the study, we performed an end-member shale elastic parameter substitution in which we subjected the shales (non-reservoirs) to progressively

increasing pore pressure regimes while keeping the sands (reservoirs) at *in situ* (hydrostatic) condition. The aim was to examine how seismic amplitudes change with offset in the presence of gas, oil or brine at varying pore pressures.

The results show that in the presence of gas at the reservoir top, the reservoir exhibits a typical CLASS III AVO response at *in situ* pressure condition, but the gas sand gradually changes to CLASS II and finally CLASS I sands at mild and hard overpressures, respectively (Fig. 30a). The reflection coefficients are weakly positive at the near offsets, with evidence of polarity reversal and large negative reflection coefficients at the far offsets in the presence of a hard overpressure regime. For oil sand, the AVO response is typically CLASS I with large positive reflection coefficients at the near offsets at hard overpressure (Fig. 30b). These findings are useful for providing better risk assessment of the deeper plays in a prospect area which are below true vertical depth of petroleum wells, which lack well control (Ogagarue, 2019).



**Figure 30. Seismic response modeling for different pore pressure regimes in the Niger Delta Shallow offshore area: (a) gas reservoir (b) oil reservoir - Pore pressure regimes used are: hydrostatic pressure regime (0.433psi/ft); mild overpressure regime (0.55psi/ft); hard overpressure regime (0.70psi/ft)**

In another study (Ogagarue and Emudianughe, 2019), well log data were used to model rock bulk density and vertical stress across the Niger Delta depobelts which include the Northern, Greater Ughelli, Central Swamp, Coastal Swamp and Offshore (Shallow and Deep) depobelts (Fig. 31). The aim was to investigate how these properties vary across the Niger Delta basin, with an underlying implication for proper well planning, exploratory and developmental

drilling specific to the respective depobelts. Our findings show that vertical stress gradient varies between 0.40 and 0.94 psi/ft in the northern delta depobelt, and between 0.40 and 0.90 psi/ft in the deep offshore depobelt, indicating a slight overall decrease in the gradient from the onshore towards the Niger Delta deep offshore (Fig.32).

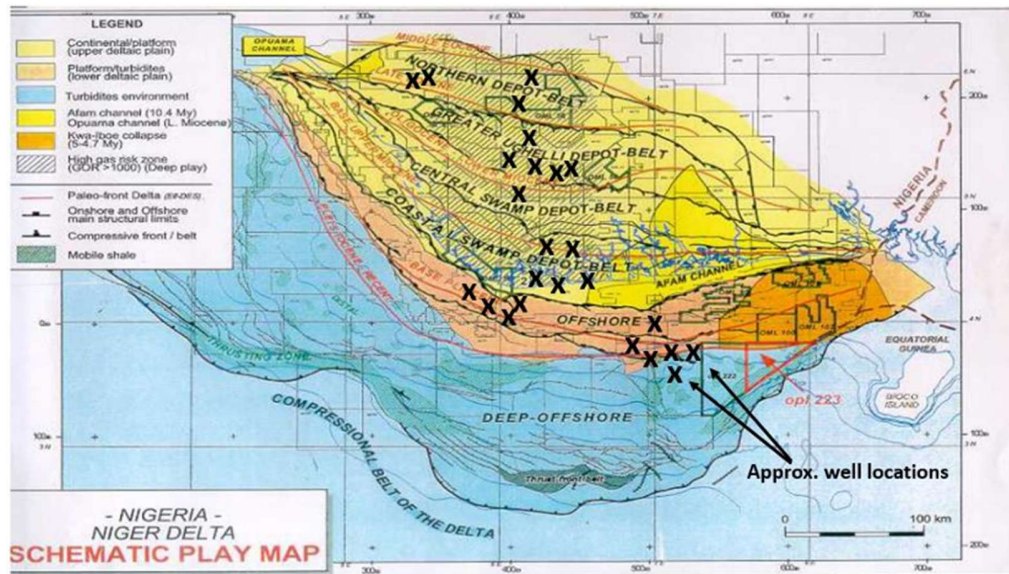


Fig. 31: Niger Delta schematic play map showing depobelts and the well locations used in the study

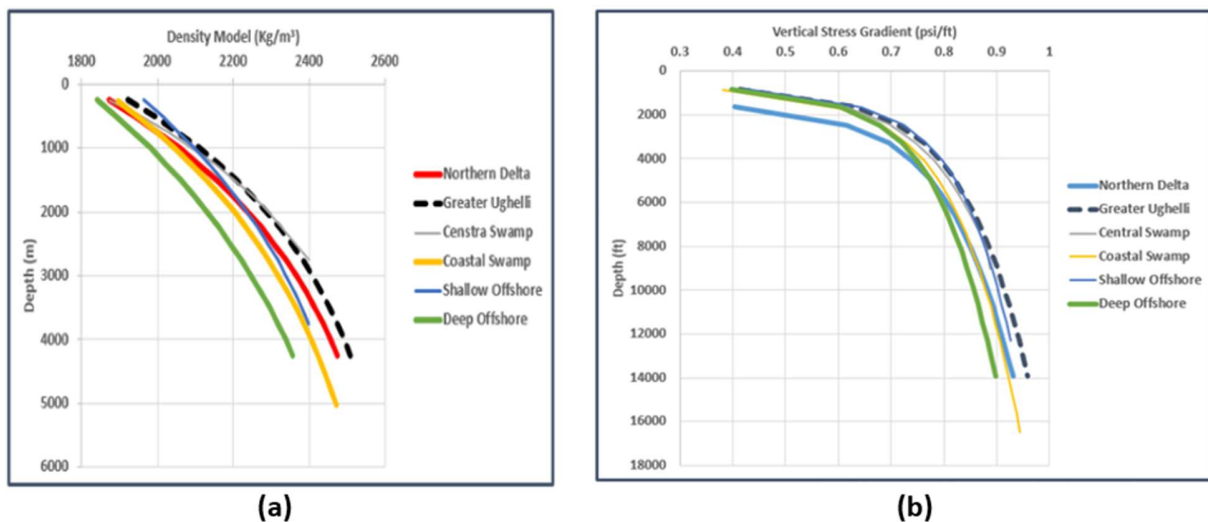


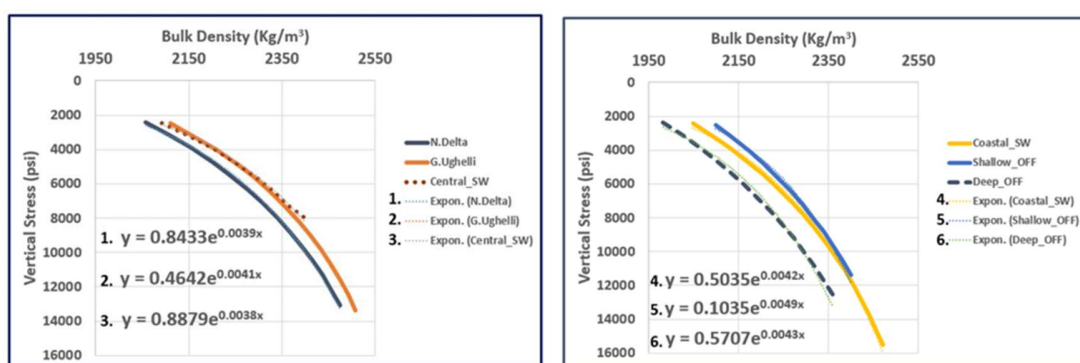
Fig. 32: Variation in bulk density and vertical stress gradient across the Niger Delta basin

The variation is attributable to lithologic changes resulting from changes in the rate of sediment compaction which, on the average, is higher in the onshore areas where porosity reduction with depth is expected to be much faster, probably due to the significant thickness of the continental sands in those areas (Fig. 33). The result agrees with Weber and Daukoru (1988) that sediment compaction in the Niger Delta varies from one depobelt to another.



**Figure 33: Variation in sediment compaction coefficient across the Niger Delta.**

Average vertical stress gradient across the Niger Delta is 0.94 psi/ft ±0.02 psi/ft. Bulk density varies with depth from 1.87 to 2.48 g/cm<sup>3</sup>, and 1.84 to 2.36 g/cm<sup>3</sup> in the northern delta and deep offshore depobelts, respectively. With this understanding, we derived analytical models between bulk density and vertical stress for the respective depobelts (Fig. 34) to aid future real-time pore and fracture pressure predictions specific to the depobelts. This is important to create stability in the prediction, especially in areas with lack of suitable data or where data quality is in doubt.

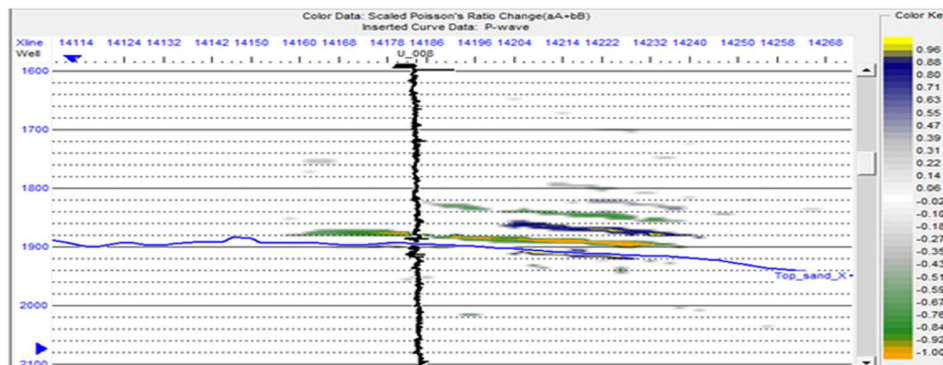


**Figure 34: Analytic models between the formation bulk density and vertical stress across the Northern Delta, Greater Ughelli and Central Swamp depobelts; and between the Coastal Swamp, Shallow Offshore and Deep Offshore depobelts, respectively**

Other contributions to pore pressure, velocity and seismic amplitude-related issues in the Niger Delta include an inquest into constrained data-driven velocity model building to improve exploration potential in shallow gas-charged channels in the Niger Delta basin, a well-based pore pressure validation study in a producing field in the Niger Delta and an anisotropic geomechanical characterization of a shallow offshore field in the Niger Delta. The conclusions drawn from these studies have already been published in diverse literature (Ogagarue, 2018; Emudianughe and Ogagarue, 2019 and Ogagarue and Olowokere, 2019).

### 3.5 Quantitative Seismic Interpretation Studies

In our effort to further contribute to the reduction of risks in the search for oil and gas, we took a step to move away from interface-based seismic to what happens at the reservoir itself. In the first instance, following Russell *et al.*, (2003), we carried out a Direct Hydrocarbon Indicator (DHI) study in which we integrated rock physics, AVO modeling and analysis to characterize reservoir fluids and lithology using well and seismic data (Ogagarue and Anile, 2016). The result reveals amplitude anomalies that helped to identify the lateral extent of the reservoir, clearly showing the fluid accumulation within the reservoir away from the wellbore (Fig. 35). The approach is useful for locating by-passed oil and gas in a depleted field, or possible new exploration interests away from the wellbore or in unpenetrated zones. This can possibly result in an increase in the oil and gas reserves base in the Niger Delta.



**Figure 35: AVO analysis result showing Scaled Poisson's Ratio (aA+bB). Prospective exploration zones can be identified from the AVO attribute volume away from the wellbore.**

Other DHI studies carried out in the Niger Delta include “*Lateral Rock Property Prediction by Post Stack Acoustic Impedance Inversion*”; “*A Comparative Study of Acoustic and Elastic Impedance Seismic Models for Rock Property Prediction*” and “*Lithofacies Discrimination using Model Based Post Stack Seismic Inversion in ‘STD’ Field*”. The interesting results from these studies, which have been published in the contemporary literature (Ogagarue, 2016; Ogagarue and Alaminokuma, 2016; Enaughe *et al.*, 2023), have further stressed the importance of DHI in lithology and reservoir fluid discrimination away from the wellbore or in unpenetrated zones.

## 4.0 CONTRIBUTIONS IN ALLIED AREAS OF RESEARCH

Mr. Vice-Chancellor, Sir, as stated earlier in my introduction, we have been involved in what I call allied areas of research which are interwoven with the topic of my inaugural lecture. In this regard, we have interrogated issues that bother on efforts to integrate all available data and utilize technologies to mitigate exploring and exploiting oil and gas. For example, in **Ogagarue and Asor (2005)**, we carried out “*in situ* thermal conductivity estimates of sedimentary rocks in the western Niger Delta using sonic and continuous temperature logs. The study reveals thermal conductivity variation of  $1.1 \text{ Wm}^{-1} \text{ }^{\circ}\text{C}^{-1}$  to  $6.2 \text{ Wm}^{-1} \text{ }^{\circ}\text{C}^{-1}$  across the western Niger Delta, with an average of  $3.1 \text{ Wm}^{-1} \text{ }^{\circ}\text{C}^{-1}$ . The north-central part of the western Niger Delta have the highest thermal conductivity values, which are seen to decrease eastwards and seawards. Thermal conductivity data are important in heat flow determination.

In a similar study (**Ogagarue, 2007**), we investigated the present day heat flow in the Niger Delta sedimentary basin, using well log data obtained from petroleum well spanning the basin. Results obtained from this study show isoflux in the Niger Delta basin varies from  $27.6 \text{ mWm}^{-2}$  to  $68.3 \text{ mWm}^{-2}$ , with an average of  $43.92 \text{ mWm}^{-2}$ . This is comparable to average world heat flow value of  $64. \text{ mWm}^{-2}$  (Chapman and Pollack, 1975), continental margin basins of  $62 \text{ mWm}^{-2}$  (Sclater *et al.*, 1981), and  $65 \text{ mWm}^{-2}$  for the Nigerian continental margin (Chukweke *et al.*, 1992). Akpabio *et. al.*, (2007) had estimated an average heat flow of  $45 \text{ mWm}^{-2}$  for the paralic section of the Niger Delta basin. Heat flow data are important for information regarding sand percentage, hydrocarbon (oil and gas) maturation, migration and accumulation.

Other contributions in the allied area include “*Integration of 3D Seismic and Well log Data In the Optimal Reservoir Characterisation of EMI Field, Offshore Niger Delta Oil Province, Nigeria*” and “*Sequence stratigraphic approach to hydrocarbon exploration in Bobsaa field, onshore Niger Delta*”. Findings from these studies have potential implication for ascertaining the presence of oil and gas at the reservoir level (Oyedele *et. al.*, 2012, Oyedele *et. al.*, 2013).

## 5.0 ACKNOWLEDGEMENTS

I have been obsessed with being addressed with the title of “Professor” ever since my undergraduate days. Then, I regarded a Professor as a demi god, and even during my short stint in the industry, I was still dreaming of the day I would be addressed a Professor. Therefore, to the Almighty God our Father, His only begotten Son, Jesus Christ our Lord and Saviour, and the Holy Spirit, be all the glory, honour, praises and adoration for making it possible for me to attain this height, and also to be alive to deliver this lecture.

I now fully understand the dilemma of inaugural lecturers who talk of how difficult it is to attend to the section on Acknowledgements in their lecture. I agree with them because the making of a Professor is a herculean task. Many would have made contributions through their care, guidance and mentorship, whether through physical contact or their research reports, publications and books.

In view of the above, I want to first, sincerely and wholeheartedly thank our dear, transformational Vice-Chancellor, Prof. Akpofure Rim-Rukeh, for giving me the platform to deliver this lecture. Thank you for all you have been to me and my family, and all your administration has done to take FUPRE to the current height. I thank also, other Principal Officers: Prof. (Mrs.) D.F. Ogeleka (DVC Admin.), Engr. (Prof.) Godswill Ofualagba (DVC Acad), Dr. (Mrs.) J. Omoyine (Madam Registrar), Mr. Garuba Nabayi (Bursar) and Prof. M. Anyaegbu (Librarian), including other members of the University Administration for their efforts in assisting the Vice-Chancellor to actualize his vision for the University.

I am deeply and immensely grateful to my beloved parents, Chief Gabriel Erhianor Ogagru and Madam Alice Unuavwokpan Ogagarue, of blessed memory, for the immense love and physical, financial and spiritual support they gave to me during their lifetime. May the Lord continue to rest their souls in His bosom. I most sincerely thank my elder brother, now my father, Mr. Godwin Erhianor Ogagarue, who stood firm to ensure we all acquired University education. May the Lord make you to reap the fruits of your good works. I also thank Indian Ogagarue, Engr. Emmanuel Ogagarue, Mr. Patience Akhuaghare, Sosorobia Oghenevwgaga, Omonigho, Esther and Vero for their love. I am grateful to my beloved sister, Enameguono Ikporikpo (blessed memory) for her encouragements. I sincerely acknowledge my amiable in-laws here present. My mother in-law, Patricia Oniomo is like a mother to me. Thank you for giving me a good wife, and your presence here today.

I will remain eternally grateful to my beloved brother, uncle and friend, Mr. Lucky Awobasivwe, of blessed memory, for giving the platform to fly. His positive impact in my life will remain indelible for ages. Rest in peace my dear brother Lucky.

I sincerely appreciate the contributions of previous administrations of the University for giving me an opportunity to serve in different capacities thereby enriching my academic and administrative potentials. I particularly thank the pioneer Vice-Chancellor, Prof. Babatunde Alabi (blessed memory) for employing me, and Profs. J.O. Etu-Efeotor and A.O. Akii Ibadode (FAS) for their positive impacts in my life.

I acknowledge with gratitude my former Principal at Ovu Grammar School, Rev. Fr. Daniel Cashman who instilled the virtues of academic discipline, integrity and hard work in us (the students). May God continue to rest his soul.

I owe a debt of gratitude to Profs. J.O. Ebeniro, M.O. Olorunfemi and late Profs. J.S. Ojo, S.L. Folami and A.S. Ekine for their mentorship. They demystified the subject of Geophysics and made me to fall in love with it. In particular, a full page would not be enough for me to adequately appreciate Prof. J.O. Ebeniro. I really appreciate all that you did for me, Sir. In the words of the former Vice-Chancellor, University of Port Harcourt, Prof. Don Baridam in his book - Raising the Bar, he said “Prof. Ebeniro is one man who believes that great feats could be accomplished without necessarily mystifying simple issues. A man of immense knowledge and versatility, Prof Ebeniro wears a highly deceptive casual surface that hides a serious-minded public officer with a knack for great accomplishments”. This is truly who Prof. Ebeniro is. Thank you very much, Sir. I want to use this opportunity to also thank Prof. G.O. Avwiri for his contributions. I fondly refer to him as the man “with the good heart”. I benefited greatly from my association with you.

Let me now appreciate the contributions of my colleagues in the Department of Earth Sciences and College of Science in particular, and University in general. At the Departmental level, I thank Prof. W.N. Ofuyah (current HOD), my brother indeed), Prof. Juliet Emudianughe (my partner in research), Prof. A.N. Asadu, Assoc. Profs. O.O. Omo-Irabor, J. Osokpor and M.S. Chaanda, Dr. E. Onovughe, Dr. B.O. Ogbe, Dr. (Mrs.) C. Ekeoma, Dr. P.U. Kragha, Dr. O. E. Izeze, Dr. D.P. Okomoko, Dr. S.E. Odumoso, including J. Omigie, B.T. Ikporukpo, S. Utah, B. Overare, S. Daniya, E. Eduviere, R. Ogbon, C. Ukaegbu, K. Eruogi and J.A. Odubu. I will not forget my protégé, Dr. L. Nnorom. I thank you all.

I sincerely appreciate my colleagues in the College of Science. I thank the Dean, Prof. E.O. Agbalagba for building on the successes of past administrations of the College. I remain loyal to my senior colleagues in the College: Profs. M.O. Edema, P. Tawari-Fufeyi, K.O. Abiola, I.E. Agbozu, C. Onosemuode, T. Egbuchunam, O. Adeyem and E.A. Enaibe, having also acknowledged the Vice-Chancellor. I thank Profs. K.A. Ibe and A.M. Okedoye, as well as Profs. A.A.P. Ojugo, D. Allenotor, L.E. Tudararo-Aherobo and W. Iwurie. I appreciate Assc. Profs. D.A. Oyemade, E.E. Elemike, G. Asibor, O. Adeyemi and J.I. Mbonu, my good friend. I do not forget the other members of staff in the College of Science, academic and non-academic. Please, I appreciate you all for your various contributions and encouragements. I specifically thank all the HODs and staff in the College of Science that assisted me in one way or the other, to key into the Vice-Chancellor’s vision to successfully create six (6) new B.Sc. and one (1) new M.Sc. programmes during my tenure as Dean. Thank you all.

I have enjoyed unwavering support, encouragement and friendship from colleagues across the University community. For lack of space, I wish to sincerely thank Profs. C.N. Owabor, I.C. Ajuwa, C.O. Izelu, I. Emovon, F.I. Ashiedu, C.O.Mgbemena, J.E. Okhaifo, G.O. Uzedhe, D.U. Onyishi, A.O. Okewale, T.C. Nwaoha, C. Nwokolo, J. Agbakwuru and Assc. Profs. O.B. Otanocha, U. Money, Rev. Fr. J. Ukutsemuya and O.E. Ohimor. My sincere thanks to Dr. Benson

Adogbeji, my childhood friend, Arc. O. Ekwerhare, J. Otolu, Dr. (Mrs.) Ogundeji, J. Eruteya and C. Izu. Thank you all.

I am immensely grateful to my spiritual Fathers: Rev. Dr. G.B. Bagudu, Rev. Dr. T.O. Adeleke, Rev. Benjamin Oghenekaro, Rev. Dr. Akhere Aisiri, Rev. Jonathan Avwadjuyo, Rev. Fr. Dr. Oghenejode Abaka and Rev. Fr. J. Anara for their prayers and guidance.

I appreciate all members of Ovu Foundation (an NGO involved in providing educational support). Dr. Isreal Imide, Engr. R. Ohre, Dr. R. Edjedegba, Dr. E. Oniyama, Mr. P.A. Okokoyo, J. Ogbevire, O. Ate, E. Akpoveta, G. Demede, P. Ukeseraye, Prof. A. Isara, C. Omodafe, G. Obuareghe, M.S. Oghenemiderhi, Barr. N. Ohre, J. Emunefe, T. Okumakube, S. Okotie, J. Avwioroko, V. Ukpeseraye, E. Akpoveta, Chief P. Abolor, E. Ojuederie and K. Unuero. Thank you for all you do to give hope to the needy.

I must sincerely thank the vivacious Vice-Chancellor, University of Benin and Chairman, Committee of Vice-Chancellors, Prof. Lilian I. Salami and her management team for their positive impacts in my life. I thank Prof. E.E. Ukpebor, Prof. D. Omorogbe, Prof. B.A. Chokor, Prof. S.M. Ogbonmwan, Prof. R. Edokpia, Prof. P. Oviawe, Prof. S.A. Aliu, Prof. F. Okieimen, Prof. E. Ogujor, Prof. J.O. Osemwenkhai, Prof. S. Adewole, Prof. A. Dosunmu, Prof. J.A. Ajienka, Prof. A.W. Mode, Emeritus Prof. W. Iledare, Prof. G. Ikpi, Prof. O. Aremu, Prof. K. Bello, Prof. F.O. Ezomo, Prof. E.O. Aiyohuyin, Prof. C.O. Aigbogun, Prof. O.D. Osahom, Prof. O.I. Imasuen, Dr. I. Ohenhen and Dr. O.O. Olamigoke for their support.

I am most grateful to the GM, Corporate Relations, SPDC, Igo Weli, Pastor (Dr.) Gloria Udoh, Emmanuel Anyim, Prof. Kenneth Nweke, Victor Hart, Dr. Bart Tchelaar, Dr. A. Adesida, Afolabi Fatunmbi, Dr. S. Maxwell-Amgbaduba, Dr. Linda Dennar, Dr. J. Osimobi, Dr. Obinna Chudi, Ifekelunma Umeogu, Dr. Meshach Omudu and Nedo Osanyande for their support.

Special thanks to Prof. C.N. Nwankwo, Vincent Akpojivi, Onajite Omughele, Sunny Irighwefere, Stephen Igbereyivwe, Dr. Ian Jones, Charles Ugueze, and Assc. Prof. Kunle Sofolabo.

I appreciate my former students, especially the post graduate students with whom I have had the privilege of sharing my research experiences and challenges. I appreciate you for the honour of being your mentor, especially Dr. Stanley Eze who incidentally became the first indigenous PhD graduate of the University.

I appreciate my immediate family for their love, understanding and care. I sincerely, wholeheartedly, effusively, sagaciously thank my spiritually confirmed DNA and beloved wife, the very dear Dr. (Mrs.) Rita Ogagarue. I appreciate you for giving me a peaceful home to pursue my dream and attain this height, and our beloved children, Oghenevovwero Emmanuella Ogagarue and Oghenetejiri David Ogagarue. I thank you, Hope Oniomu Obotenu, for your position in the immediate family.

Finally, my most respected, beloved, venerated audience, I must sincerely thank you for your presence here today. Thank you for your precious time. God bless you for coming and listening.

## 6.0 CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusion

Mr. Vice-Chancellor, Sir. Oil and gas accounted for only 2.7% of Nigeria's total export in 1960 (CBN, 2007). By Quarter 4, 2023, this figure had risen to 89.23%, comprising 81.23% crude oil and 8.00% natural gas export (NBS, 2024). It may be higher by Q4, 2024. You would thus agree with me that Nigeria has enjoyed enormous wealth from the abundance of its petroleum resources. It is left for us to decipher if the petroleum wealth has been used justifiably or not.

The wealth derived from petroleum would not be possible without the ingenuity of the geophysicists who are the first to go into the bushes, deserts, marine, offshore and other harsh environments to radiograph the earth and look for this hidden treasure underneath. The geophysicist is akin to the radiographer who x-rays the human body to study the internal organs.

Crude oil and gas reserves currently stand at 37.5 billion barrels and 209.26 trillion cubic feet of associated and non-associated gas (NURPC, 2024). Nigeria is desirous of increasing these reserves. The figures can be increased if oil companies would leave their comfort zones and explore new ways to explore and exploit the petroleum. Geophysics will be at the center of the deployment of new techniques and innovations for de-risking the "search" for the "Black Gold", and extracting it in a safe and cost effective manner. Therefore, geophysicists will continue to be in high demand because it is through their efforts we are able to see the unseen, something he makes possible by constantly researching for *what is new, what can be done, the best way to do it*, to improve efficiency without necessarily re-inventing the wheel.

### 6.2 Recommendations

It is no gainsaying that there is a recent surge towards renewable technologies and ongoing commitments by different nations to limit global warming to 1.5<sup>0</sup>C due to the climate challenges associated with the use of fossil fuel. Nigeria has set a target of 2060 for net-zero gas emission in its commitment to limit global warming, and other countries are setting different targets for achieving net zero to prevent global warming from crossing to a dangerous threshold.

Phasing out oil and gas completely, whether now or in the future is a mere fantasy due to the realities of today's fossil fuel-dependent economy, especially in developing nations. The demand for fossil fuel will continue to grow in the coming years (CNBC, 2024), and oil and gas will remain in the energy mix for decades to come.

Alternative energy sources have not been able to displace fossil fuels despite the huge investments the world has made on alternative energy sources in the past two decades. In fact,

when most people think of energy, they think of electricity, which is only about 20% of energy for the end user. Alternative energy sources mainly provide electricity. Certain sectors within the economy require extremely high temperatures to operate, such as iron, plastic, cement and steel; they rely on the use of fossil fuels to operate.

In view of the aforesaid, I recommend the following:

- i. In addition to renewable sources, nations should invest massively in research that would result in the development of low-carbon options for the fossil fuel to improve its friendliness to the environment.
- ii. Governments should be committed to, and enact long-term policies that would foster gas utilization as a transitional fuel, in addition to the low-carbon options..
- iii. Oil and gas will remain an important component of the global energy mix for ages to come. Nigeria as a fossil-fuel dependent country cannot stop the development of fossil fuel projects. Rather, it should continue to seek ways to increase its reserves to meet local needs as well as make it competitive in the global market. GEOPHYSICS, through concerted efforts, will continue to seek improved ways of finding and exploiting these reserves to consolidate the economic prosperity of the country. Oil and gas companies should leverage the myriads of solutions we have provided to de-risk their “search” for the Black Gold” in their comfort zones, and to seek pay opportunities at hitherto unexplored targets in the effort to increase the national reserve.

Mr. Chairman, Sir, my most respected, beloved and venerated audience, I thank you all for listening.

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Difference Ogagarue has over fourteen (14) years of University teaching, research and administrative experience, in addition to twenty eight (28) years of oil industry experience, comprising fourteen (14) years of active service and fourteen (14) years of consultancy in oil and gas operations in the areas of well log database management, seismic reconstruction/vectorization services, seismic data processing, seismic amplitude variation with offset modeling and analysis, inversion and pore pressure prediction.

He has over forty (40) research publications in reputable local and international journals. Some of his research outputs have led to the development of several novel technologies which are currently being deployed by major oil and gas operators. Notable among these technologies is the novel technology which utilizes gridded seismic interval velocity inversion to derive depth surfaces below which overpressure builds, within a seismic interval velocity cube. This technology has been successfully deployed for 3D pore pressure prediction campaigns in Nigeria and internationally by major international oil and gas giants.

His University administrative experience is robust and varied, some of which include Coordinator and Ag. Head of Department; Desk Officer, TETFund; Sub-Dean, Postgraduate School; Dean, College of Science; Chairman and member of several Committees at the Departmental, College and Central Management levels.

He has a good relationship with the oil industry and academia, and has attracted several cash, equipment, facilities and software donations to the Earth Sciences Department to aid Geological/Geophysical Field work, and improve teaching and learning in the Department. He chaired a Committee that attracted an expatriate, the Society of Exploration Geophysicists (SEG) Distinguished Instructor, Dr. Ian Jones, to deliver the maiden edition of the College of Science Annual Lecture Series in 2017.

Over the years, he has acquitted himself as a consummate teacher, researcher and mentor to many students and younger colleagues. He has supervised four (4) Masters Projects, and the maiden indigenous FUPRE PhD Dissertation. He currently has four (4) PhD supervisees. He has served as an External Examiner and professorial assessor to the University of Port Harcourt and Obafemi Awolowo University, as well as the Delta State College of Education for assessment to the rank of Chief Lecturer.

Difference Ogagarue has rendered professional services in Nigeria, the United Kingdom (UK) and United States of America (USA). He has served as a Senior Research Advisor to the Exploration Department, SPDC during his 1-year Sabbatical placement with the company in 2018. He has attended a number of Workshops in Nigeria and USA, and delivered noble papers at local and international Conferences. His paper, which he co-authored with his mentee, a

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