

**DEVELOPMENT OF TIME AND DEPTH STRUCTURAL MAPS FOR THE ANYI  
FIELD D5000 RESERVOIR IN STATIC MODELLING**

**BY**

**Daniel EDOSOMWAN**

**LSC2003191**

**DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY**

**FACULTY OF LIFE SCIENCES**

**UNIVERSITY OF BENIN**

**BENIN CITY**

**OCTOBER, 2025.**

**DEVELOPMENT OF TIME AND DEPTH STRUCTURAL MAPS FOR THE ANYI  
FIELD D5000 RESERVOIR IN STATIC MODELLING**

**BY**

**Daniel EDOSOMWAN**

**LSC2003191**

**A THESIS SUBMITTED TO THE DEPARTMENT OF SCIENCE LABORATORY  
TECHNOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN  
CITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF  
THE DEGREE OF BACHELOR OF SCIENCE (B.Sc.) IN SCIENCE LABORATORY  
TECHNOLOGY (GEOLOGY & MINING TECHNIQUES OPTION)**

**OCTOBER, 2025.**

## **DEDICATION**

I dedicate this work to God who gave the inspiration for this work, and had also enabled this work to see the light of day.

## CERTIFICATION

This is to certify that the thesis entitled “DEVELOPMENT OF TIME AND DEPTH STRUCTURAL MAPS FOR THE ANYI FIELD D5000 RESERVOIR IN STATIC MODELLING” was carried out and authored by Daniel EDOSOMWAN. This Bachelor of Science (B.Sc.) thesis has undergone thorough evaluation and has been duly approved by:

---

**Mr. Bassey Peter**

**Project Supervisor**

---

**Date**

---

**Dr. P.O. Alonge**  
**Project Coordinator**

---

**Date**

---

**Prof. J. O. Osarumwense**  
**(Head of Department)**

---

**Date**

---

**External Examiner**

---

**Date**

## **ACKNOWLEDGEMENT**

My immense and profound gratitude to God Almighty for His marvelous help to me throughout the duration of this research. I make bold to say that Jesus began and completed this project work by Himself through me. He made available every human vessel and technological tool needed for this work to see the light of day.

Without His guidance, this accomplishment would not have been possible. The completion of this research work has been made possible through the unwavering support of my family, friends, teammates, supervisor and lecturers. I deeply appreciate all the encouragements and assistance. I want to express my heartfelt thanks to

## TABLE OF CONTENTS

<b>CONTENTS</b>	<b>PAGE</b>
TITLE PAGE .....	i
DEDICATION .....	ii
CERTIFICATION .....	iii
ACKNOWLEDGEMENT .....	iv
TABLE OF CONTENTS .....	v
LIST OF FIGURES .....	viii
LIST OF TABLES .....	ix
ABSTRACT .....	x
<b>CHAPTER ONE</b> .....	<b>1</b>
1.0 INTRODUCTION.....	1
1.1 Background to the Study .....	1
1.2 Statement of the Problem .....	4
1.3 Motivation for the Study .....	6
1.4 Aim and Objectives of the Study .....	6
1.5 Significance of the Study .....	7
1.6 Scope of the Study .....	7
1.7 Definition of Terms .....	7

<b>CHAPTER TWO</b> .....	11
2.0 LITERATURE REVIEW .....	11
2.1 Seismic Interpretation .....	11
2.2 Static Modelling of Subsurface Reservoirs .....	12
2.3 Dynamic Modelling and Fluid Flow Simulations .....	13
2.4 Geological Setting .....	14
<b>CHAPTER THREE</b> .....	17
3.0 RESEARCH METHODOLOGY .....	17
3.1 Regional Setting .....	17
3.2 Materials Employed .....	17
3.3 Method Employed .....	18
3.3.1 Data Preparation .....	18
3.3.2 Data Availability, Data Gap and Mitigation Measures .....	19
3.3.3 Well – to – Seismic Tie .....	21
3.3.4 Fault Interpretation .....	22
3.3.4.1 Major or Bounding Faults .....	23
3.3.4.2 Minor (Small) Faults within the block .....	23
3.3.5 Horizon Interpretation .....	24
3.3.6 Velocity modelling .....	24
3.3.7 Time to Depth Conversion/Time Map and Depth Map Generation .....	25

<b>CHAPTER FOUR</b> .....	26
4.0 DATA PRESENTATION AND ANALYSIS .....	26
4.1 Preliminary Check for Dimensions on Semblance .....	26
4.2 Seismic Volume Processing.....	28
4.3 Well-to-Seismic Calibration.....	29
4.4 Structural Interpretation of Study Area .....	31
4.4.1 Fault Interpretation .....	31
4.4.2 Horizon Interpretation .....	33
<b>CHAPTER FIVE</b> .....	37
5.0 SUMMARY, CONCLUSION AND RECOMMENDATION.....	37
5.1 SUMMARY .....	37
5.2 CONCLUSION .....	38
5.3 RECOMMENDATION.....	38
<b>REFERENCES</b> .....	40

## LIST OF FIGURES

FIGURES	PAGE
<b>Figure 1.1:</b> A Play Map showing the Niger Delta and its Depo-Belts	16
<b>Figure 1.2:</b> 3D Background Map, Semblance Volume & Seismic Volume Log Suite	19
<b>Figure 1.3:</b> Raw Seismic before Application of Semblance Attribute at Time Slice -1772 ms	20
<b>Figure 1.4:</b> Application of Fault Enhancing Attribute – 1572 ms	21
<b>Figure 4.1:</b> Semblance 2D View of Study Area at -1808 ms before Fault Interpretation	26
<b>Figure 4.2:</b> Semblance 3D View of Study Area at -1808 ms before Fault Interpretation	27
<b>Figure 4.3:</b> MADCOW Bandpass Filter Application	28
<b>Figure 4.4:</b> Well-to-Seismic Tie	29
<b>Figure 4.5:</b> Fault Interpretation on Seismic Volume	31
<b>Figure 4.6:</b> Semblance Fault Depiction in the Xline at Time Slice -1772 ms	32
<b>Figure 4.7:</b> Semblance Fault Depiction in the Inline at Time Slice -1782 ms	33
<b>Figure 4.8:</b> Polygon Build on Semblance	34
<b>Figure 4.9:</b> Time Structure Map	35
<b>Figure 4.10:</b> Depth Map	36

## LIST OF TABLES

TABLE	PAGE
<b>Table 1:</b> Showing Seismic Log Suites for 3 Wells	19

## ABSTRACT

The purpose of this study was to evaluate the Anyi field's seismic volume in order to provide the best structural frameworks for the D5000 reservoirs, which would be utilized to create precise static models. Using fault representations and depth-converted surface maps, the reservoir's structural model was built. There are two main East-West oriented faults that define the reservoir's structural structure. The Amosi growth fault borders it to the north, while the Klin boundary fault borders it to the south. It is structurally an elongated rollover anticline that is oriented east-west. Channels and shorefaces make up the majority of the reservoir. The data was revalidated and quality-checked, and a thorough literature study was carried out. A MADCOW bandpass filter was used to reduce both coherent and random noise in the seismic data. Well-to-seismic calibration was then performed utilizing Anyi-001's sonic log. They interpreted the fault and horizon. Checkshots from Anyi-006, from which the time and depth map was constructed, were used to simulate velocity. Amplitude extraction was then used to improve seismic visualization and find characteristics or anomalies associated with reservoir characteristics, including fluid connections, channels, fractures, and changes in porosity. The results of this investigation indicate that the D5000 reservoir has a limited potential for hydrocarbon recovery and accumulation in the Anyi field (Anyi-006) but a high potential in the Okoko field (Okoko-001). In order to maximize gas recovery from this significant reservoir, the results provide a better knowledge of the stratigraphic disposition of the reservoir, which will aid in better interpretation, lower drilling risk, and well-informed economic decisions. Additionally, this study's results confirm that seismic interpretation, velocity modeling, and attribute analysis techniques are trustworthy and efficient means of evaluating the Niger Delta's reservoir features and volumetric analysis.

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background to the Study

The interpretation and identification of sub-surface structural targets should always be supported by a thorough understanding of the regional tectonic framework of the area, being aware of structural variability through space and time. The application of structural geological concepts to the interpretation of seismic data is essential for accurately reconstructing sub-surface structures and for comprehending their geometric and kinematic development, which has significant impacts on the exploration and generation of drilling prospects.

The Niger Delta Basin has continuously maintained a thick sedimentary cover and prominent petroleum geological features that are conducive to petroleum generation, expulsion, and trapping, from the onshore areas through the continental shelf to the deepwater zones, according to geophysicists and geologists (Ameloko and Omali, 2013). Building up reserves from stratigraphic prospects is currently the upstream petroleum industry's biggest problem. Thus, rigorous and comprehensive planning is required for the discovery and exploitation of these opportunities. In order to create a reservoir model, reservoir characterisation necessitates the integration of many data types. In order to give a precise geometric description of the reservoir's structural and stratigraphic features, seismic data in particular might be quite important.

Since the fundamental geophysical seismic data is first captured in time, a detailed interpretation of the seismic data must be supplied in order to achieve this. Constructing contour seismic maps that depict the two-way travel time (TWT) to a reflector, as shown on the seismic sections, is the primary objective of geophysical seismic interpretation. The seismic time-depth conversion procedure must then be used to transform these time (isochron) data into depth (isodepth) maps.

In order to facilitate tasks like evaluating the hydrocarbon movable index, estimating reserves, developing field development strategies, forecasting future production trends, optimizing well placement, investigating alternatives, and managing reservoir resources, Oyelayo and Akinyemi (2023) explained that reservoir modeling comprises the creation of a computerized representation of a petroleum reservoir. Each discrete cell in the model's three-dimensional grid has characteristics including porosity, permeability, water saturation, net-to-gross ratio (NTG), and facies. Dynamic models replicate fluid flow during production using finite difference techniques, whereas geological models provide static representations of the reservoir inside a field.

With considerable oil and gas deposits, the Niger Delta province of Nigeria is a geologically significant region. The Tertiary Niger Delta Akata and Agbada Petroleum System, which is mostly in Nigeria but may perhaps extend into Cameroon and Equatorial Guinea, is part of this area. Creating a geological reservoir model entails describing the reservoir in detail using the information that is already accessible, such as 3D seismic data and well logs that include density, gamma-ray, sonic, and resistivity logs.

The Anyi field is a complex geological environment with a variety of lithologies, extensive fault systems, and substantial hydrocarbon potential. It is situated in the fertile Niger Delta region. For optimal hydrocarbon recovery, efficient reservoir management, and well-informed field development decision-making, a precise 3D static model of this field must be built. To develop a trustworthy static model and obtain a thorough grasp of the subsurface properties, geophysical, petrophysical, and geological data must be integrated (Aldahash et al., 2019).

Mostly obtained via seismic surveys, geophysical data offers a comprehensive picture of the stratigraphy and underlying structures. This information is crucial for defining reservoir borders,

locating fault systems, and mapping the structural framework (Al-Khulaifi et al., 2016). Seismic inversion and amplitude versus offset (AVO) analysis are two sophisticated seismic interpretation methods that improve the lithology and fluid content of the reservoirs.

Core samples and well logs provide petrophysical data that provides important information about the reservoir's characteristics, such as fluid saturation, permeability, and porosity. As stated by Azzam et al. (2017), precise petrophysical analysis is essential to comprehending the quality and distribution of the rocks in the reservoir. Strong petrophysical property estimate is ensured by combining core measurements with well log data, which is crucial for reservoir modeling and characterisation.

Understanding the field's depositional environments, stratigraphic sequences, and structural geology requires a contextual framework that is provided by geological data. In order to create a comprehensive 3D static model, geophysical and petrophysical data are combined with a coherent geological model that is built through detailed geological mapping and sedimentological studies (Bachmann *et al.*, 2006).

Advanced modeling software is used to integrate these disparate facts, enabling the creation of an accurate and comprehensive static model. This model is a fundamental tool for reservoir simulation, production forecasting, and development planning, claim Aldahash et al. (2019). The 3D static model of the Anyi field offers a comprehensive perspective of the subsurface by integrating geology, petrophysical, and geophysical data, facilitating more effective and efficient exploitation of its hydrocarbon resources.

In order to provide the best structural frameworks for the E8000 reservoirs, which will be utilized to create precise static and dynamic models, this study attempts to perform seismic interpretation of the Anyi field.

## **1.2 Statement of the Problem**

For effective and sustainable natural resource exploitation, it is essential to comprehend the subsurface characteristics of hydrocarbon reservoirs. Reservoir characterization is a multifaceted process that combines geological, geophysical, petrophysical, and engineering data to produce a detailed model of the reservoir; among the many approaches employed, geophysical and seismological techniques are essential for supplying high-resolution images and comprehensive details about the subsurface structures.

Accurate reservoir characterization is essential for optimizing hydrocarbon extraction and managing resources effectively. Complex subsurface lithologies, which involve diverse rock types, fluid contents, and intricate geological structures, pose significant challenges to traditional characterization methods. Production seismology, which involves continuous monitoring and analysis of seismic data during the production phase, offers a promising approach to enhance understanding and characterization of these complex subsurface environments. However, several challenges need to be addressed to fully harness the potential of production seismology in building static and dynamic reservoir models.

One of the primary challenges is the accurate acquisition and interpretation of seismic data in environments with complex lithologies. These subsurface complexities can lead to highly variable seismic responses, making it difficult to distinguish between different rock types and fluid contents. Traditional seismic methods often fall short in resolving such complexities, leading to uncertainties in the static and dynamic models of the reservoir. Furthermore, the dynamic nature of reservoirs during production adds another layer of complexity. Changes in pressure, temperature, and fluid saturation can alter the seismic properties of the reservoir,

necessitating advanced time-lapse (4D) seismic techniques to monitor these changes over time. However, the implementation of 4D seismic surveys is often constrained by high costs, logistical challenges, and the need for sophisticated data processing and interpretation techniques.

Another significant challenge is the integration of production seismology data with other reservoir characterization methods. Creating coherent and accurate static and dynamic models requires the seamless integration of seismic data with geological, petrophysical, and engineering information. Discrepancies between different datasets can arise due to their varying scales and sensitivities, complicating the construction of reliable reservoir models. Effective integration demands advanced computational techniques and interdisciplinary collaboration, which are often limited by current technological and methodological constraints. Additionally, the heterogeneity and anisotropy of reservoir rocks further complicate the interpretation of seismic data. Variations in rock properties, such as porosity, permeability, and fluid saturation, can significantly impact seismic wave propagation, creating complex seismic signatures that are difficult to analyze. The presence of fractures, faults, and other structural features adds to this complexity, requiring specialized approaches to accurately characterize their influence on reservoir performance.

The goal of this research is to perform seismic interpretation of the Anyi field in order to provide optimal structural frameworks for the D5000 reservoirs that will be used to build accurate static and dynamic models. Through the improvement of resolution and reliability of reservoir characterization, this work will support more effective and sustainable resource management practices, which will ultimately contribute to the efficient exploitation of hydrocarbon resources. Given these challenges, there is a pressing need for innovative approaches and advanced

technologies in production seismology to improve the understanding of complex subsurface lithologies.

### **1.3 Motivation for the Study**

Effective hydrocarbon extraction and resource management are hampered by the complexity of subsurface lithologies. With the help of production seismology, which provides a dynamic method of continuously monitoring and interpreting seismic data, this study aims to improve both static and dynamic models by combining them into a coherent framework that enhances reservoir characterization and volumetrics. Traditional static models by themselves frequently fall short of providing a comprehensive understanding, while dynamic models can provide a more thorough understanding but necessitate constant data input.

### **1.4 Aim and Objectives of the Study**

#### **Aim:**

The primary aim of this study is to carry out seismic interpretation of the Anyi field with a view to providing optimal structural frameworks for the D5000 reservoirs that will be used to build accurate static and dynamic models.

#### **Objectives:**

1. to carry out literature reviews, data gathering, quality-check and revalidation;
2. to carry out well-to-seismic tie so as to identify which seismic loop corresponds to the reservoir of interest;
3. fault and horizon interpretation that may act as potential conduits or barriers to fluid flow;
4. velocity modeling;
5. time and depth map generation.

## 1.5 Significance of the Study

The outcome from this research work via integrated approach, will help to build a more robust field development plan endowed with enhanced reservoir management and reduced uncertainty that enable more precise predictions of reservoir behavior, more efficient resource utilization, identify and mitigate potential risks, leading to more informed decision-making to the company and its joint venture partners.

## 1.6 Scope of the Study

The scope of this work is to carry out the interpretation of the seismic volume and structural modelling of ANYI D5000 reservoir using 3D seismic data.

## 1.7 Definition of Terms

- **Production Seismology:** production seismology involves the continuous monitoring and analysis of seismic data during the production phase of a reservoir. It provides real-time information about changes in subsurface conditions, such as pressure, fluid saturation, and stress fields, enabling the dynamic assessment of reservoir properties over time. This approach enhances the understanding of reservoir behavior and supports the optimization of hydrocarbon extraction processes.

- **Static Models:** static models are detailed representations of the reservoir at a specific point in time, capturing the initial geological, petrophysical, and structural properties of the subsurface. These models are built using various data sources, including seismic surveys, well logs, and core

samples. Static models provide a foundational understanding of the reservoir's architecture, including the distribution of rock types, porosity, permeability, and fluid contacts.

- **Dynamic Models:** dynamic models simulate the temporal changes in reservoir properties and behavior due to production activities. These models integrate time-dependent data, such as production rates, pressure changes, and fluid movements, to predict how the reservoir will respond over its lifecycle. Dynamic models are essential for optimizing production strategies, forecasting future performance, and managing reservoir pressure and fluid flow.

- **Subsurface Lithologies:** subsurface lithologies refer to the various types of rock formations found beneath the Earth's surface. These lithologies can include sandstones, shales, carbonates, clays, and other rock types, each with distinct physical and chemical properties that influence their behavior and response to seismic waves. Understanding the composition, distribution, and properties of these lithologies is crucial for accurate reservoir characterization and modeling.

- **Reservoir Characterization:** reservoir characterization is the process of creating detailed, comprehensive models of the subsurface, integrating geological, geophysical, petrophysical, and engineering data. The goal is to understand the reservoir's structure, properties, and behavior to optimize hydrocarbon recovery. This involves analyzing seismic data, well logs, core samples, and production data to construct static and dynamic models that guide exploration, development, and production strategies.

- **Volumetrics:** volumetrics involves estimating the volume of hydrocarbons present in a reservoir. This includes determining both the total volume of hydrocarbons in place (STOOIP - Stock Tank Oil Initially In Place, GIIP - Gas Initially In Place) and the recoverable volume that

can be economically extracted. Accurate volumetric analysis is critical for resource evaluation, development planning, and economic assessment of reservoir projects.

- **Integrated Approach:** an integrated approach in reservoir characterization involves combining multiple disciplines and data sources to create a cohesive and accurate model of the subsurface. This approach leverages the strengths of different methods, such as geological mapping, seismic interpretation, petrophysical analysis, and engineering simulations, to address the complexities of reservoir behavior. Integration ensures that all available data are used synergistically to reduce uncertainties and improve decision-making.

- **Heterogeneity:** refers to the variation in rock properties within a reservoir. This can include differences in porosity, permeability, lithology, and fluid saturation, which can significantly affect fluid flow and reservoir performance. Understanding heterogeneity is crucial for accurate reservoir modeling and efficient hydrocarbon recovery.

- **Anisotropy:** refers to the directional dependence of rock properties, meaning that properties such as permeability and seismic velocity can vary depending on the direction of measurement. Anisotropy can be caused by factors such as layering, fracturing, and stress fields, and must be accounted for in reservoir characterization and modeling to accurately predict reservoir behavior.

- **Seismic data:** the processed seismic volume or section that covers the area of interest.

- **Well log data:** Density, Sonic and Checkshot logs. Other logs such as GR, Resistivity, Neutron are needed but not compulsory.

- **Wavelet:** the mathematical function that represents the shape and characteristics of the seismic source wavelet.

- **Well Markers:** this data indicates the top of our reservoir in depth.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

The study of subsurface reservoirs is essential for the exploration, development, and management of oil and gas fields. The seismic interpretation, static modeling, and dynamic modeling of reservoir properties are critical for understanding the subsurface structure and behavior. This literature review presents a synthesis of recent studies in the field of seismic interpretation and subsurface modeling, examining the methodologies used and findings reported by various authors in addressing the challenges of seismic data interpretation and the creation of both static and dynamic models.

#### 2.1 Seismic Interpretation

Accurate seismic interpretation is fundamental to understanding the subsurface structure, identifying faults, and delineating the stratigraphy of reservoirs. Seismic data provides insights into the geological framework, yet its interpretation remains challenging due to issues such as poor resolution, complex geology, and noise (Aldahash *et al.*, 2019). The primary goal is to convert seismic data into interpretable geological models that can inform reservoir development strategies.

Oluwajana *et al.* (2017) conducted a study on the application of advanced seismic imaging techniques, including frequency filtering and multi-azimuth acquisition, to improve the resolution and clarity of seismic data in areas with complex subsurface structures. They identified that while traditional seismic techniques often fail to resolve small-scale geological features, the new imaging methods significantly enhance the detection of fault systems and

stratigraphic boundaries. Their findings indicate that high-frequency seismic data improves the identification of shallow reservoirs and provides a more accurate structural framework.

Al-Khulaifi *et al.* (2016) focused on the integration of seismic and well log data for more accurate interpretation of subsurface structures. They used time-to-depth conversion techniques to reconcile seismic reflection times with the actual depth of subsurface features. Their approach included applying sophisticated inversion methods to combine seismic amplitudes with well data, thereby providing a more refined understanding of reservoir boundaries and subsurface stratigraphy. The authors found that this integrated approach allowed for better identification of subsurface layers, enhancing the reliability of static models.

## **2.2 Static Modelling of Subsurface Reservoirs**

Static modeling involves the construction of time-independent geological models that reflect the physical properties and structures of a reservoir. These models are critical for understanding the distribution of rock properties such as porosity and permeability, and they serve as the foundation for dynamic simulations (Bachmann *et al.*, 2006).

Beydoun and Hossain (2003) explored the static modeling of subsurface reservoirs using a hybrid approach that combined seismic interpretation with geological constraints and petrophysical data from well logs. They demonstrated that grid-based modeling could effectively capture reservoir heterogeneity when high-quality seismic data and well data were integrated. Their study found that the inclusion of geostatistical methods allowed for better spatial distribution of key properties, such as porosity and permeability, improving the accuracy of the static model. Furthermore, they highlighted that incorporating uncertainty analysis into the static

modeling process could provide more reliable predictions of reservoir behavior, particularly in heterogeneous reservoirs.

In a similar vein, Ijasaan *et al.* (2013) investigated the role of seismic inversion in static reservoir modeling. Their study used post-stack inversion techniques to improve the resolution of the seismic data and to generate better estimates of subsurface lithology. By inverting seismic amplitudes into impedance, they were able to map out variations in lithology and porosity across the reservoir. Their findings underscored that seismic inversion, when combined with geological modeling, enhances the prediction of reservoir properties such as fluid saturation and rock heterogeneity. This method proved especially valuable in reservoirs with complex depositional histories and uncertain geological interpretations.

### **2.3 Dynamic Modelling and Fluid Flow Simulations**

Dynamic modeling involves simulating the behavior of the reservoir over time, taking into account factors such as fluid flow, pressure, and temperature changes. This process is crucial for optimizing reservoir management and improving recovery techniques. However, dynamic modeling is highly sensitive to the accuracy of the underlying static model, as well as the quality and quantity of the input data (Li *et al.*, 2020).

Wei *et al.* (2014) explored the integration of dynamic simulation with static geological models to simulate fluid flow and reservoir performance. They used a coupled model that integrated geological, geophysical, and engineering data to simulate the flow of oil and gas within a subsurface reservoir. Their study applied reservoir simulation software, such as Eclipse and Petrel, to model the pressure and saturation distribution over time. The results showed that

dynamic modeling can accurately predict fluid migration and recovery factors, provided that the static model is well-calibrated and incorporates realistic boundary conditions. This study emphasized the need for continuous monitoring of reservoir performance to update the dynamic model and improve predictive accuracy.

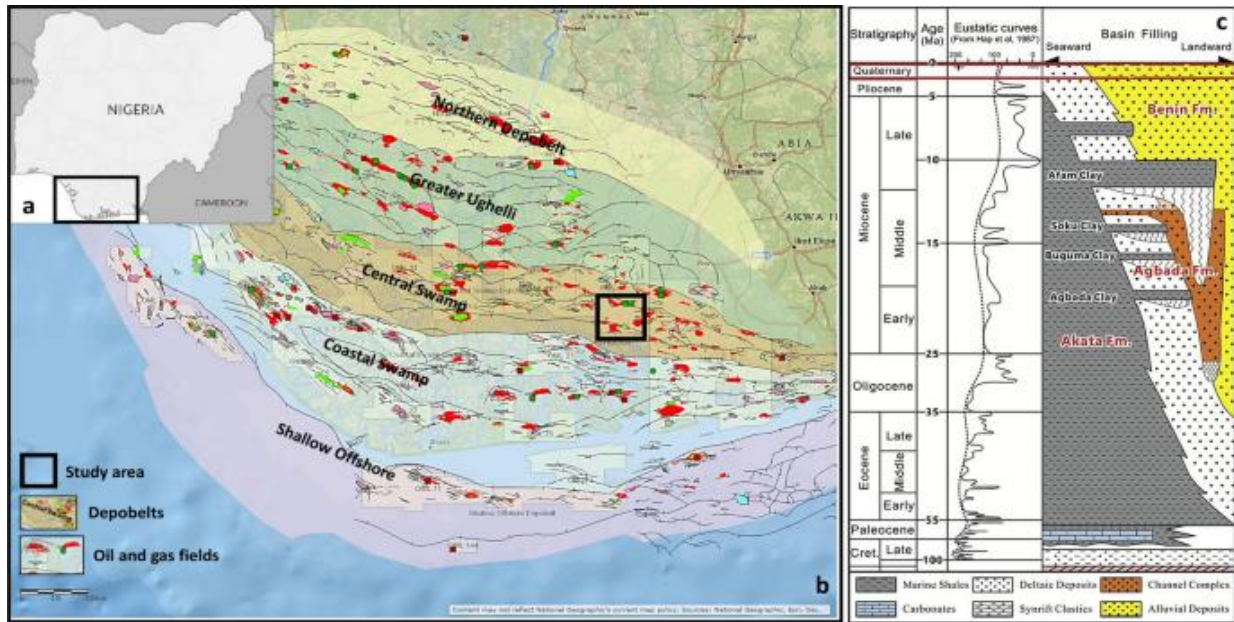
In their research, Yi *et al.* (2021) examined the effect of various reservoir management strategies on fluid flow and recovery rates using dynamic reservoir simulation. They applied a range of operational scenarios, including water flooding and gas injection, to assess the long-term performance of a reservoir. Their findings suggested that dynamic models are highly effective in predicting how different management techniques impact recovery and reservoir pressure. The study also emphasized that dynamic modeling helps identify the optimal timing and placement of wells, improving recovery efficiency.

## **2.4 Geological Setting**

The study area is OML 11, which is 8km x 3km in dimension and located about 43km East of Port Harcourt, within the Greater Port Harcourt Land Area. It is located in the Central Depobelt of Niger Delta (Fig. 1.1). Structurally, it is an elongated rollover anticline, oriented in an E-W direction, bounded to the North by the Amosi growth fault and to the South by the Klin boundary fault. The Reservoir comprises mostly of channels and Shorefaces.

The Niger Delta is situated in the Gulf of Guinea along the West African Margin, spanning the Niger Delta province from longitude 5°E to 8°E and latitude 4°N to 6°N (Tuttle et al., 1999). The basin consists of three primary formations: the marine Akata, the paralic Agbada, and the continental Benin formations (Table 1). The Akata Formation, composed of marine shale, serves

as the primary source rock (Doust and Omatsola, 1990). The Agbada Formation's reservoir rock consists of sandstone with intercalated shale. According to Kulke (1995), during the delta's formation, there was a balance between subsidence and sedimentation rates. The sediment deposition pattern was influenced by the tectonic setting and structural features of the region. From the Eocene to the present, the delta has prograded southwestward, creating five depositional belts at different stages (Doust and Omatsola, 1990). The Niger Delta's main structural features include rollover structures, multiple growth faults, antithetic faults, and collapsed crest structures (Fig. 2) (Tuttle *et al.*, 1999). Structural traps formed during the synsedimentary deformation of the petroleum-bearing Agbada paralic sequence, as noted by Evamy *et al.* (1978) and Stacher (1995). These structures become increasingly complex to the south due to the gravitational instability of the over-pressured, under-compacted Akata Formation (Tuttle *et al.*, 1999). Doust (1989) mentions that hydrocarbons are trapped within the growth fault structures, with approximately 4 billion cubic meters present in existing fields. The Niger Delta's seal rock primarily consists of interbedded marine shales within the Agbada Formation. Three seal types are found: clay smearing along faults, vertical seals, and interbedded sealing layers, which are juxtaposed against subsurface reservoir sands due to faulting (Doust and Omatsola, 1990).



**Fig. 1.1:** A Play Map showing the Niger Delta and its Depo-Belts

## CHAPTER THREE

### 3.0 RESEARCH METHODOLOGY

#### 3.1 Regional Setting

There are four major fault blocks of interest within the study area and they include the following: Amosi main fault block, Isim fault block, Anyi fault block and Klin fault block. The Amosi main fault block is separated into the Main, West and East blocks. The Eastern block is the area of Isim field.

The Anyi field is located in OML-11, some 42 km north east of Port Harcourt. It constitutes part of the Elem – Ajo – Bang - Anyi North – Isim – Klin- Mirie megastructural trend. The Anyi block is bounded to the north and south by growth faults separating the field respectively from Isim and Klin accumulations. The Anyi gas field (Anyi-006) was interpreted as a simple fault dependent dip closure separated from the oil accumulation to the northeast by a saddle. At the extreme southwestern corner of the Anyi block is the Okoko discovery. It is some 3 km south west of the gas field and is separated from it by another saddle.

#### 3.2 Materials Employed

Materials used for the seismic interpretation and building of the static model include the following:

- i. Petrel software (2023 model)
- ii. 3D Seismic Volume
- iii. MADCOW Bandpass filter
- iv. Well tops (inputs from Production Geologist)
- v. Well logs such as Density, Checkshots, Sonic etc (inputs from Petrophysicist).

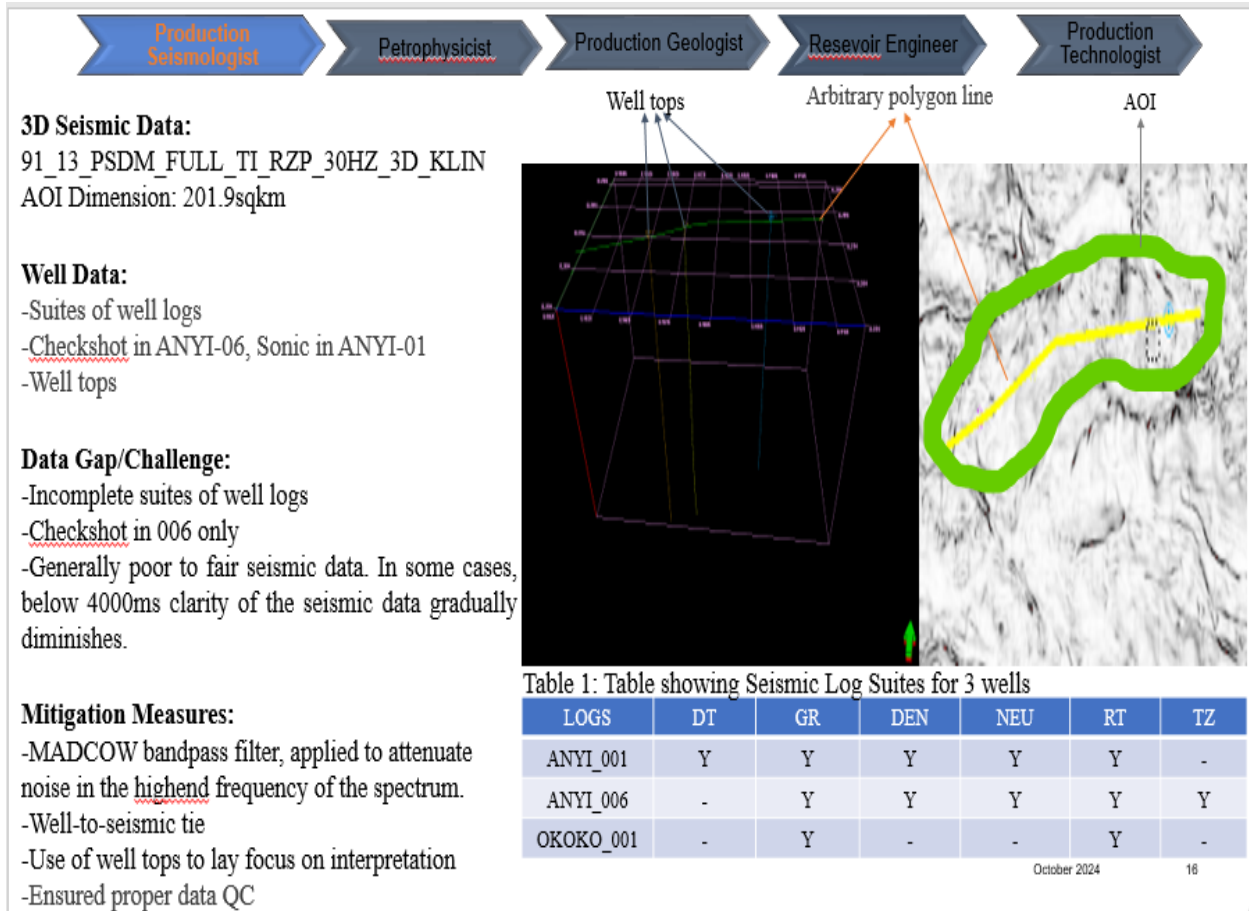
### **3.3 Method Employed**

#### **3.3.1 Data Preparation**

An integrated approach to reservoir appraisal begins with data preparation, which entails gathering, processing, and organizing numerous data types from several sources, including production data, seismic data, well logs, and pressure data (Stacher, 1995). This earthquake was of low quality, particularly in the deep section. In certain instances, the seismic data's clarity decreases below 4000 ms. Following the reflectors on the traverse parts becomes difficult as a result. As a result, some structural elements have a tendency to disappear, making continuity difficult to detect.

To draw attention to the fault, a voice semblance was applied to the seismic data. Additionally, a MADCOW filter of roughly 30–40 hertz was used to improve the seismic and lower the noise in order to raise the signal to noise ratio. To determine if the seismic data phase was in SEG or reverse SEG polarity, a polarity check was performed. In order to acquire various time slices, the seismic volume was also realized. To make sure the right units or standards are used for each parameter, the data was also quality-checked for correct calibration on the Petrel program.

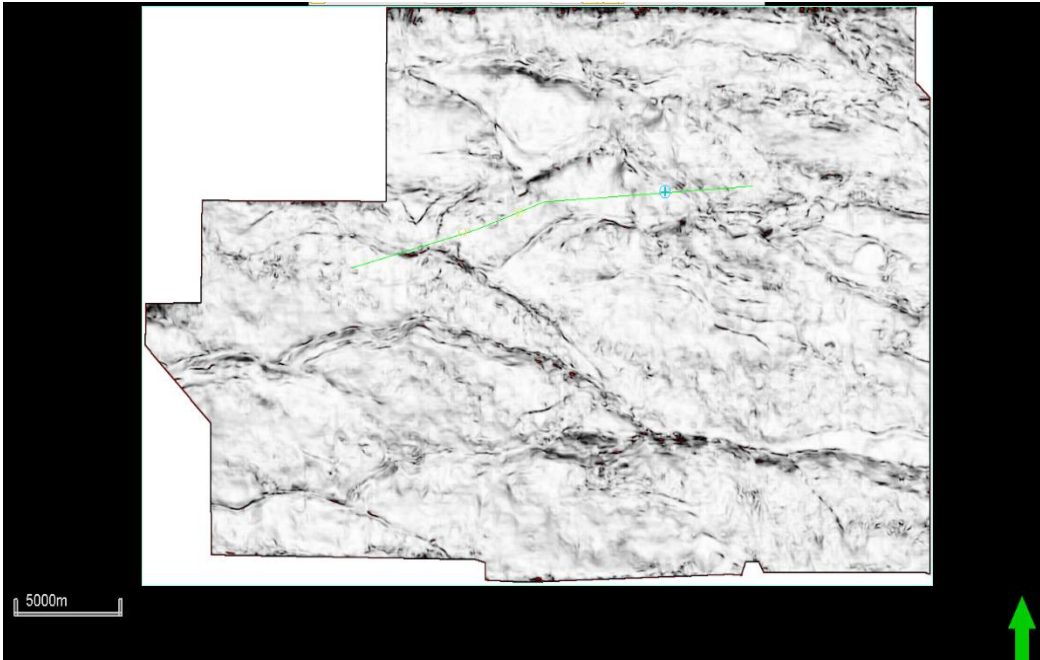
### 3.3.2 Data Availability, Data Gap and Mitigation Measures



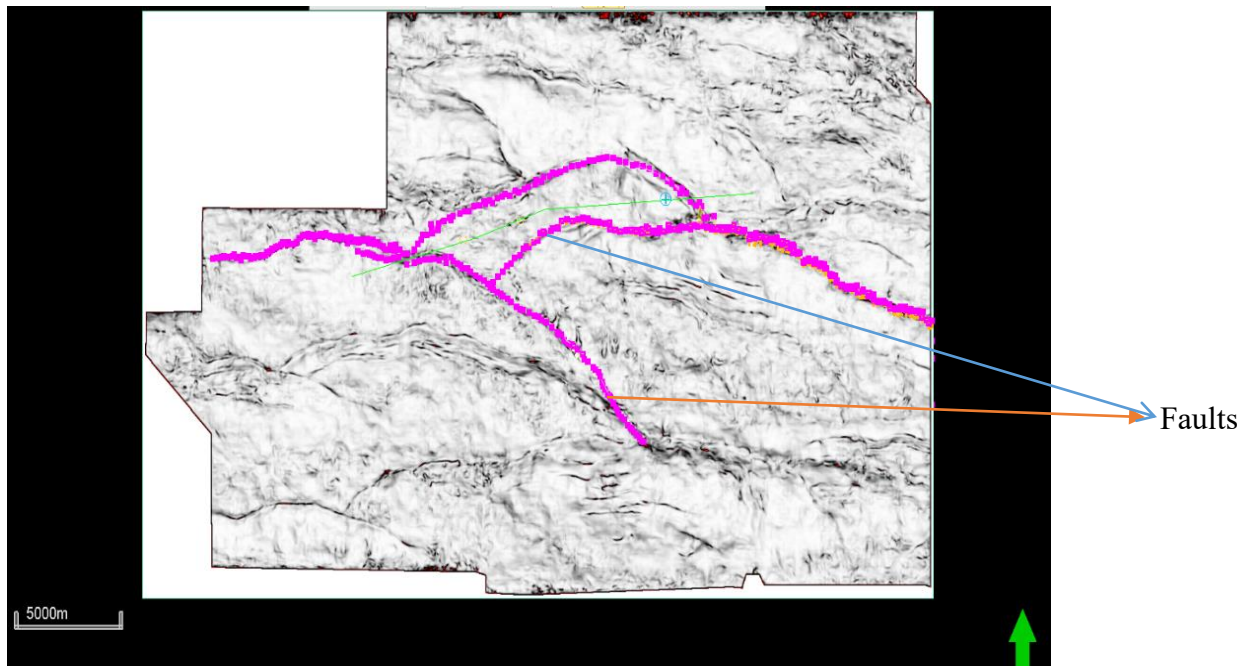
\*\*\*AOI: Area of Interest, DT: Sonic log, GR: Gamma ray log, DEN: Density log, NEU: Neutron log, RT: Resistivity log, TZ: Checkshots

**Fig. 1.2:** 3D Background Map, Semblance Volume & Table Showing Available Log Suite

Semblance analysis was employed to depict major and minor fault at particular time slices.



**Figure 1.3:** Raw Seismic before application of semblance attribute at time slice 1772 ms



**Figure 1.4:** Application of fault enhancing attribute @1572 ms

### 3.3.3 Well – to – Seismic Tie

Walk-through for Seismic to Well calibration

- i. Calibration of the sonic with the checkshot
- ii. Generate wavelet
- iii. Calculation of Acoustic Impedance log from the Sonic and Density log
- iv. Generation of the reflectivity coefficient from the acoustic impedance log
- v. Convolution of the wavelet with reflectivity to generate synthetic seismogram. The synthetic seismogram was calibrated to the PSI seismic data, and a time shift of about 12ms was applied. The well marker was displayed and the sand of interest was identified as a blue loop, which was an indication that the sand is a soft sand. From the above workflow, the updated checkshot derived was set as the active Time - Depth relation.

Anyi-001 well data was used for the well-to-seismic tie because this well was the only well in the vicinity of Anyi that had GR log, sonic and density logs. This was used to tie to the seismic data. All other wells had only GR logs but lack sonic logs that can be used to synthesize the seismic trace along the well path. The production seismologist used the Anyi-001 well to generate the synthetic seismogram utilising petrel software which was used to tie the well-to-seismic. The synthetic was found to conform reasonably on the seismic.

### **3.3.4 Fault Interpretation**

Variance edge detection or attribute analysis methods were employed to enhance the visibility and continuity of the faults in the seismic data (Tuttle *et al.*, 1999). The fault interpretation was carried out using manual picking, and was carried out every 16ms. A major synthetic fault was mapped, separating the Amosi field from Anyi. The Anyi field was also found to be separated from Klin field with a major growth fault.

The approach employed included dividing the interpretation into three scales because the Anyi and Amosi structure is dependent on the faulting configurations. In this method, a sub-regional evaluation of the structures was conducted first, followed by a field-scale inquiry and the incorporation of well data specifically for the horizon calibration and picking. The filtered (MADCOW) volume was coupled with the semblance data at the sub-regional scale in order to identify and pick boundary faults. The unique structural differentiating characteristics of the semblance volume made it extremely helpful in the fault interpretation process. When shown in greyscale, the lateral fault lines are visible and can be traced on the seismic sections of the entire variable volume.

The main faults were identified and picked. These faults are characterised with large throws between the blocks. There was also an establishment of the key reflectors and seismic sequences within the region of interest and assessment of the reflector/horizon continuity within same area.

#### **3.3.4.1 Major or Bounding Faults**

Major boundary faults were located and selected in the area of interest. The Eastern boundary fault has a minor throw, while the Northern, Southern and Western border faults have large throws. Such faults are typical of the growing faults of the Niger Delta. Typically, deep-seated and continuous down to 4500 ms, these faults cut across seismic sections starting at around 1000 ms and have characteristic East-West orientations. There have been notable fault throws across these significant faults. In several of the observed occurrences within the region of interest, these throws are as high as 250 ms.

#### **3.3.4.2 Minor (Small) Faults within the block**

After effectively distinguishing the Anyi and Amosi fields from the nearby fields, including the Klin on the south and the Isimiri on the west, the difficulty was in comprehending the fault structure inside the Amosi field. The study shed light on the likelihood of several minor mistakes with little throws in this field. Indeed, the clarity and confidence of the geological structures were improved by this method with a striking resemblance to the MADCOW seismic volumes. As a result, several subtle flaws and the tiny throws that go along with them were found and selected.

There are numerous minor faults, which are not deep seated, and mostly antithetic resulting from collapsed crest of the rollover anticline. Some of the other minor faults steps from the major faults and are in the same orientation with the major faults but have shorter lateral spans.

### **3.3.5 Horizon Interpretation**

To locate and map the seismic reflectors that match geological horizons or boundaries, horizon picking was used. Depending on where they came from and how they relate to the nearby rocks, geological horizons can be categorized as unconformities, disconformities, paraconformities, etc. (Stacher, 1995). Both automatic and manual interpretation were used to interpret Horizon. Beginning at inline -1782 ms, the interpretation was carried out every 16 ms. The convergent interpolation approach was used to grid the interpreted horizon. A surface map in time is the result of the horizon interpretation process.

Horizons were regularly selected on the positive loops and interpreted on a cross-line and a regular seed grid with every 16th line. Horizon choosing was done in normal mode. The Anyi block was not the only place where horizon interpretation was possible at the E8000 levels. The nearby fault blocks were included in the interpretation. Petrel software was used to automatically track the interpreted seed grids. Because the quality of the seismic data along the loop varied, the E8000 horizon was interpreted as a trough using a combination of human and auto-tracking methods. The loops transform into doublets and have amplitudes ranging from high to medium. Moderately continuous loops with a finer 2 x 2 grid surrounding the hydrocarbon concentration were selected every 4 Inline and Xline.

### **3.3.6 Velocity modelling**

Since real-time drilling can only be done at depth, velocity modeling is crucial because seismic data is obtained in real-time, and velocity illustrates the relationship between depth and time. The speed at which seismic waves move through fluids and rocks is measured by a physical characteristic called velocity. For geological interpretation and reservoir characterisation, it

makes it possible to convert seismic data from the time domain to the depth domain, which is more precise and realistic (Kulke, 1995).

For this work, checkshots from Anyi-006 was employed to derive the velocity of seismic waves at various depths. This was used as input into the velocity models and was tested to arrive at a fit for purpose velocity model.

### **3.3.7 Time to Depth Conversion/Time Map and Depth Map Generation**

In order to obtain an accurate representation of the subsurface, i.e for the time-to-depth relationship (TDR), the interpreted E8000 horizon and the mapped faults were converted from time to depth, using the velocity model built from Anyi-006 checkshots. The time interpreted seed grid for the E8000 was loaded into PETREL and the seed grid in time used to build a velocity model. The time structure shows the reservoirs to be shallower to the south while progressively becoming deeper towards the north of the structure. A time structural model was constructed in PETREL incorporating the major faults and the minor fault for structural framework model. The grids were tied to the well tops in time. This time structural map was generated from the interpretation by applying fault and boundary polygon to the seeded grid. 3 major boundary fault and 1 minor fault was identified for the D5000.

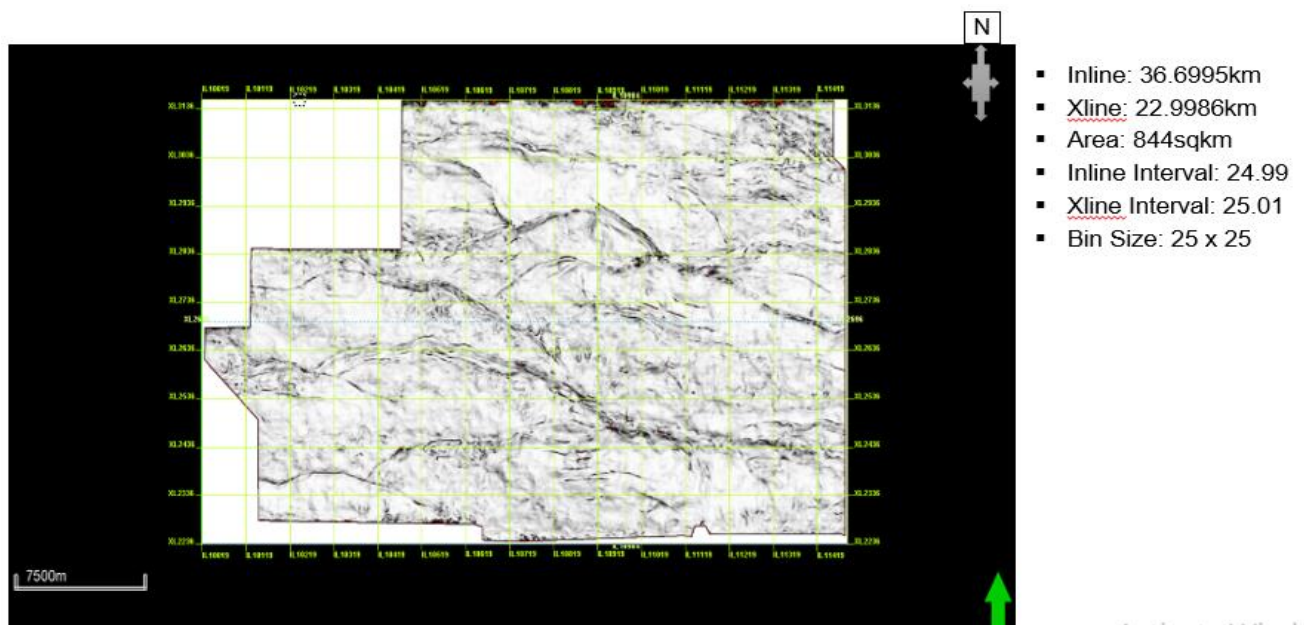
The time structural model was depth converted using the velocity model built from check shots data from well ANYI-006. The surfaces in depth represent the top structural maps for our reservoir of interest. These surfaces were transferred to the Production Geologist as an input for the static model.

## CHAPTER FOUR

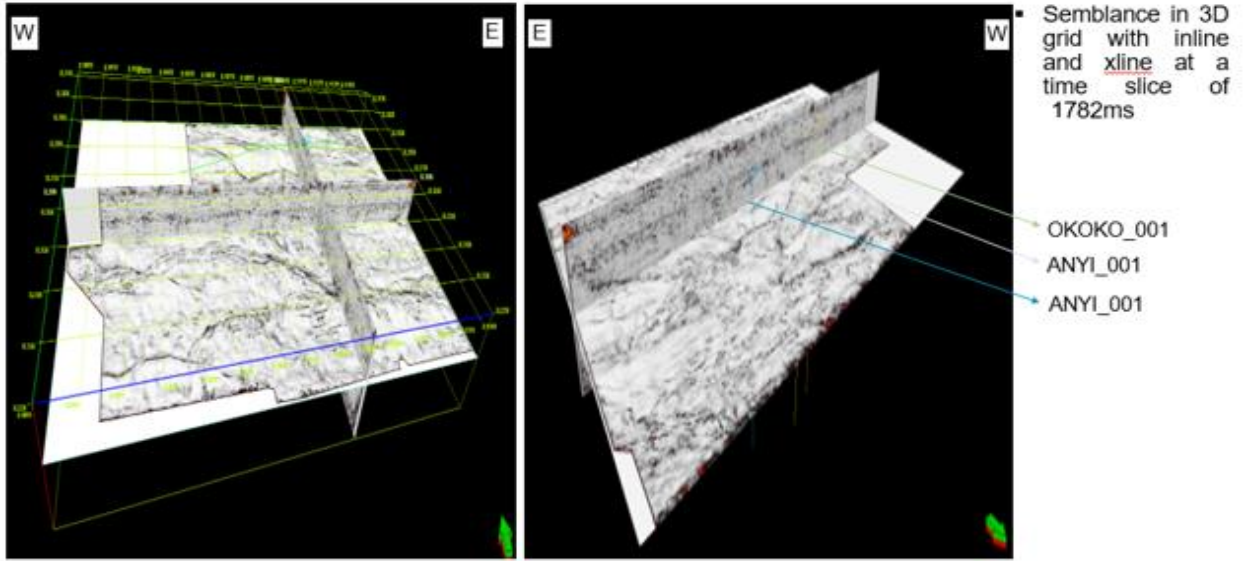
### 4.0 DATA PRESENTATION AND ANALYSIS

#### 4.1 Preliminary Check for Dimensions on Semblance

A preliminary check was conducted to delineate the dimension of the study area in both 2D and 3D view at specified time slices before fault interpretation was done.

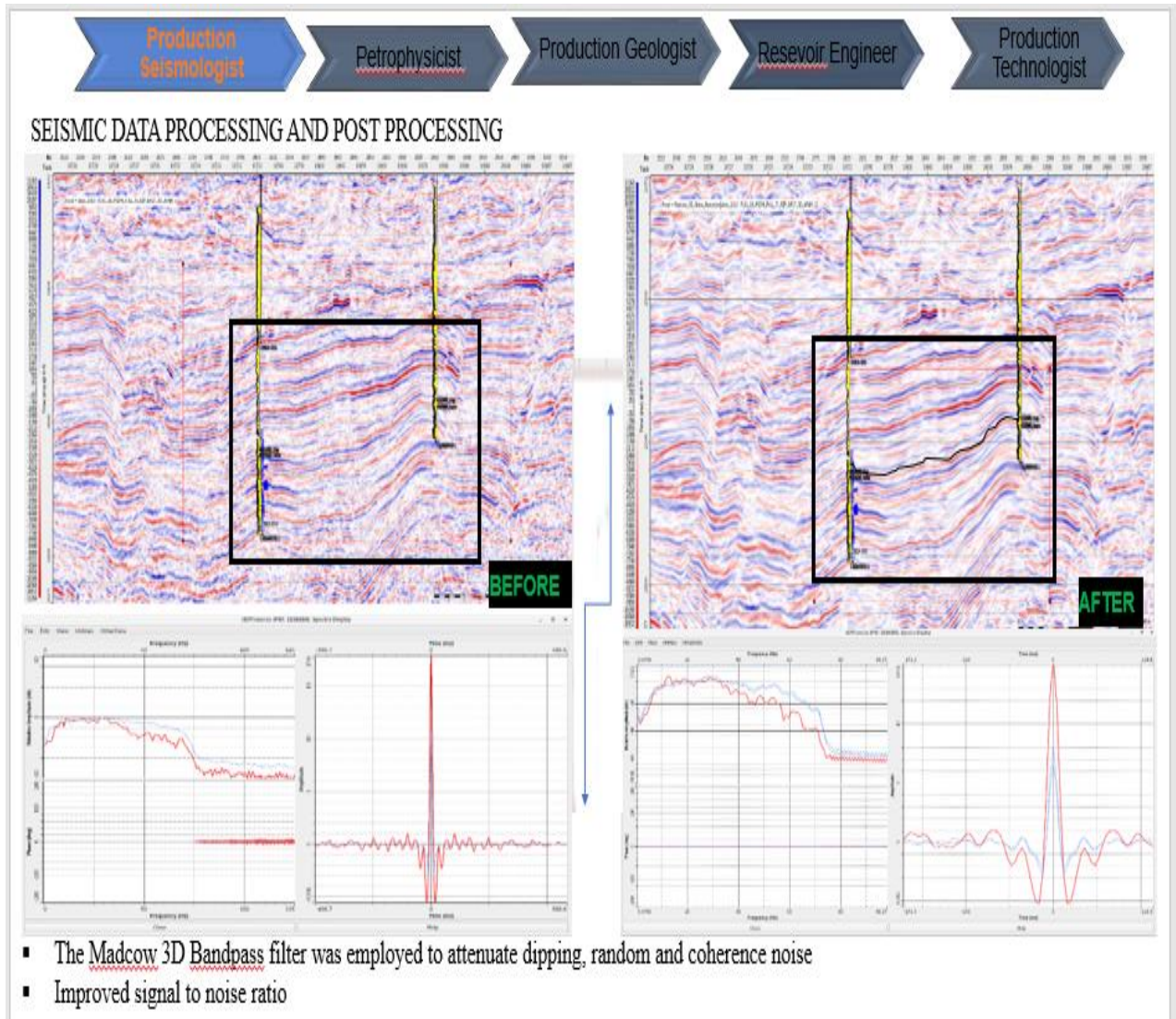


**Fig 4.1:** Semblance 2D view of Study Area at 1808 ms before fault interpretation



**Fig 4.2:** Semblance 3D view of Study Area at 1808 ms before fault interpretation

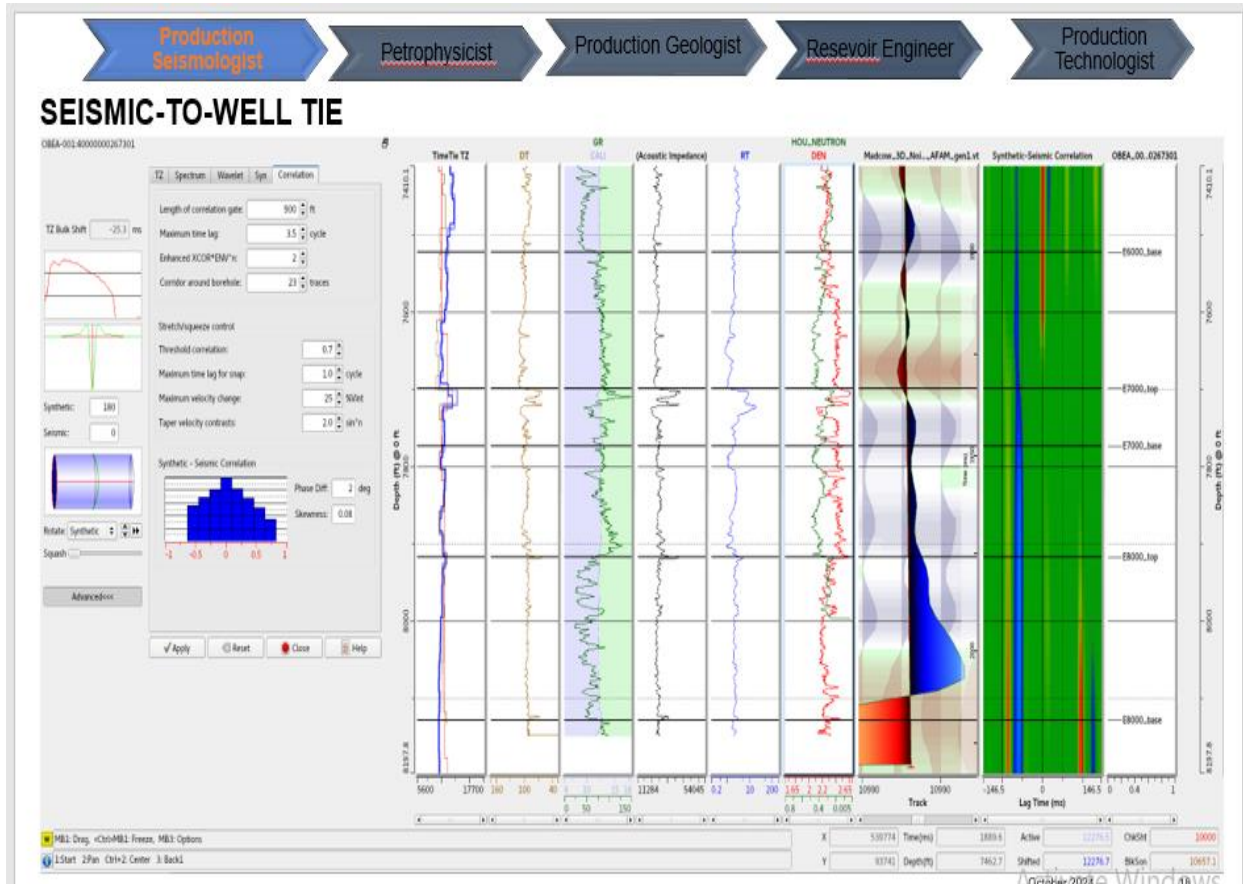
## 4.2 Seismic Volume Processing



**Fig. 4.3:** MADCOW Bandpass filter application

The 3D seismic data was first quality-checked for compliance and then revalidated before applying the MADCOW bandpass filter to attenuate dipping, random and coherence noise, thereby improving the signal-to-noise ratio.

### 4.3 Well-to-Seismic Calibration



**Fig 4.4:** Well-to-Seismic Tie

Figure 4.4 shows the representation of the well-to-seismic calibration employed to integrate well log data with seismic data, so as to improve the seismic interpretation and analysis. In this study, well to seismic calibration was performed using the Anyi-001, because it has the sonic log needed for generating the synthetic seismograms.

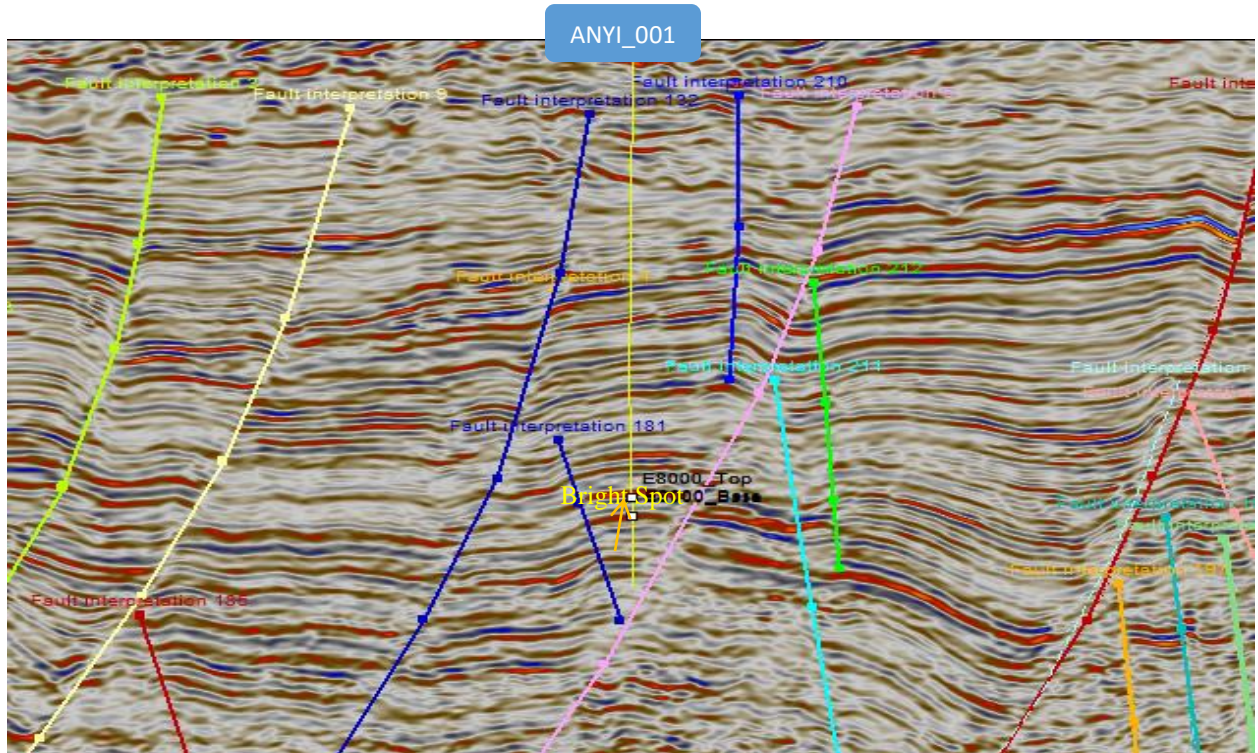
Database and polarity critically determine seismic character. The Shell standard employed is the reverse polarity i.e the anti-SEG convention, in which face and polarity of seismic data are zero phases of European polarity, where the trough is the hard kick while the peak is the soft peak.

Oyelayo and Akinyemi (2023) suggest that the over-red characteristic indicates low impedance and is associated with a potential reservoir of younger sediments, similar to those found in the Niger Delta. The sonic log data was corrected for borehole effects, such as washouts and rugosity, before being converted from time domain to depth domain and then calibrated with the checkshot data (Evamy *et al.*, 1978). The sonic log data were then used to generate synthetic seismograms using a 180-phase Ricker wavelet with a dominant frequency of 20 Hz. Bulk shift was -25.2 ms while the phase drift was 2 degrees.

The synthetic seismogram match was fair with the seismic traces at the reservoir section and very well at the shallower part of the well. The seismic marker was thereafter used as the basis for the seismic interpretation and analysis.

## 4.4 Structural Interpretation of Study Area

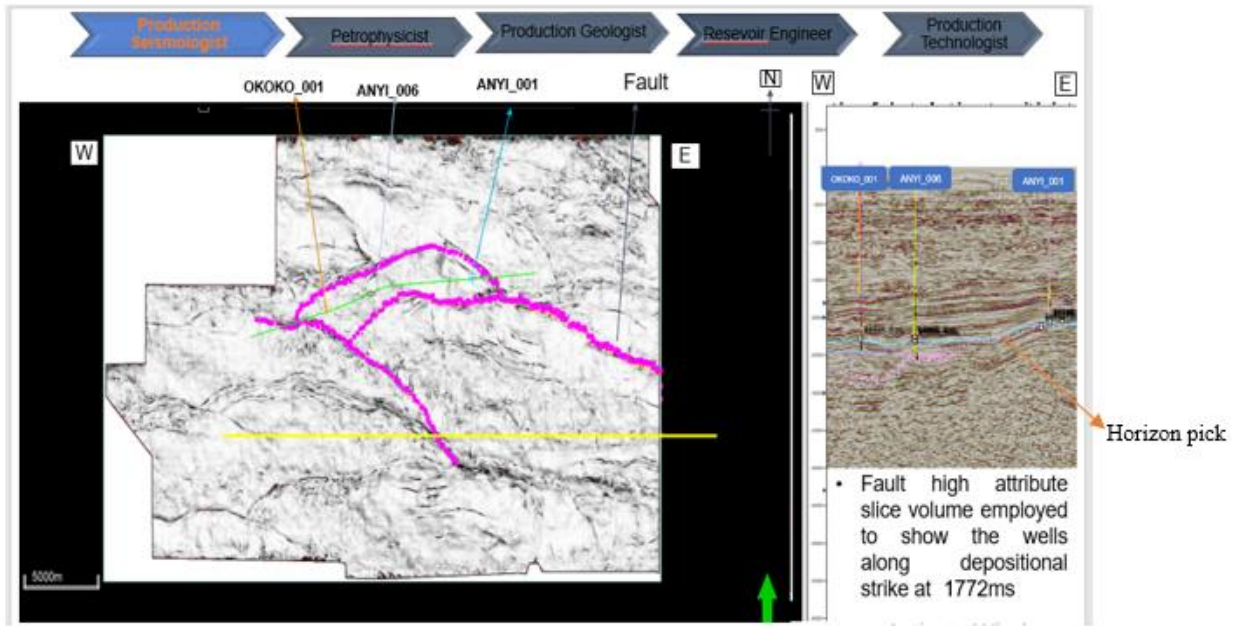
### 4.4.1 Fault Interpretation



**Fig. 4.5:** Fault interpretation on Seismic Volume

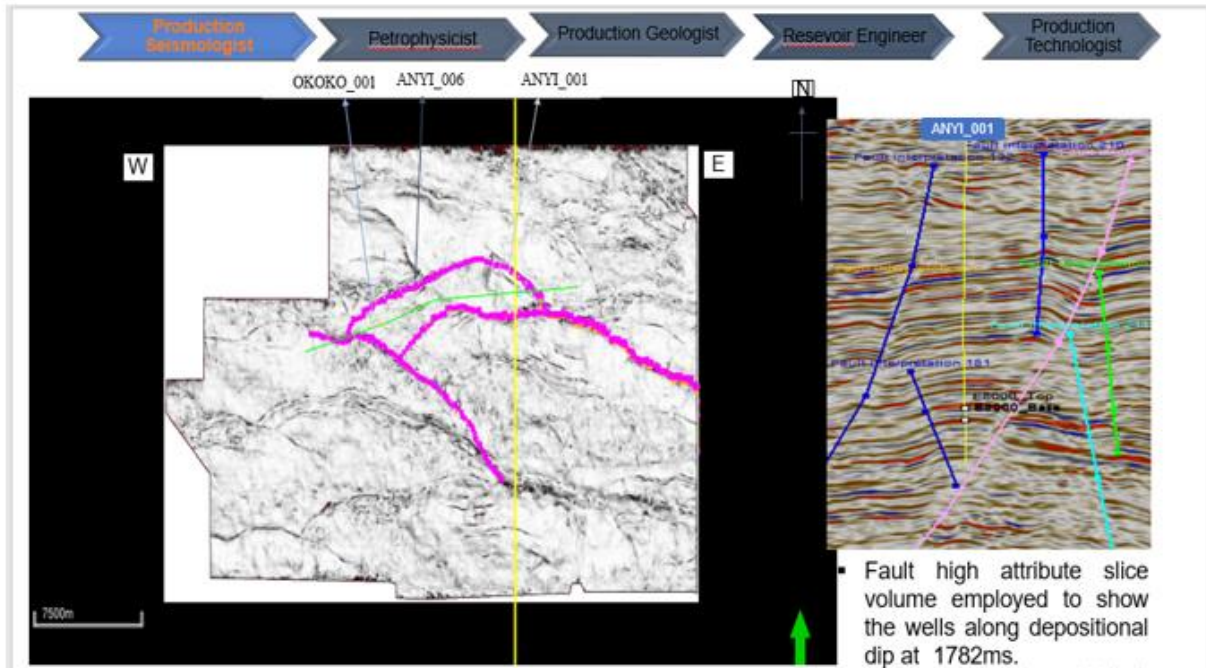
As progradation takes place from inboard to outboard, rapid deposition takes place which creates a depobelt boundary fault, and the faults were interpreted using 4, 8 and 16 geospatial traverse. The Anyi field is separated from the Amosi field and Okoko field by major faults. Generally, the study area stands out as a distinct domain characterized by a prevalence of fault-related structural formations. This structural configuration gives rise to a notable potential for fault-assisted processes. A dominant influence on deposition is attributed to the significant presence of listric normal faults, a salient feature extracted from the 3D data utilized. The field's structural makeup takes the form of an elongated anticline, confined within the expanse defined by the major structure-building fault trending in a west-southeast direction to the north – acting as the

principal zone of displacement. Within the field, the landscape is marked by the presence of numerous synthetic and antithetic faults. These smaller-scale intra-field faults vary in length, with many closely aligned parallel to the major fault that defines the northern boundary of the structure.



**Fig 4.6:** Semblance fault depiction in the Xline at time slice 1772 ms

The semblance analysis which served as a guide/QC for fault interpretation was employed to help depict fault zones at specified time slices. A few shallow faults were observed at about 64 ms, while some extends to the deep and could serve as a conduit for hydrocarbon migration. However, penetrating the faults could also lead to borehole instability within the shallow intervals.



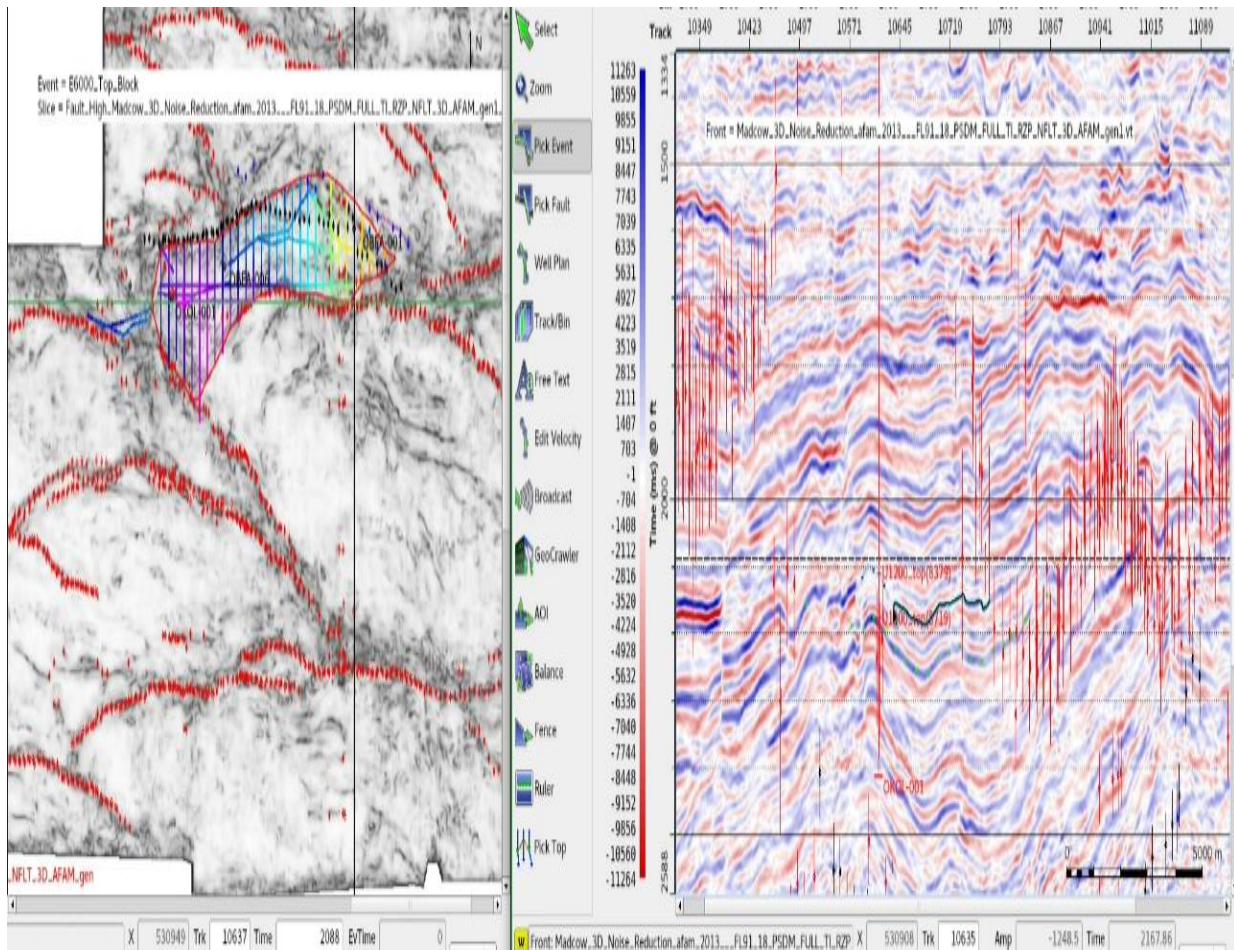
**Fig 4.7:** Semblance fault depiction in the Inline at time slice 1782 ms

#### 4.4.2 Horizon Interpretation

Horizon interpretation was carried out using synthetic processing on both inline and cross-line seismic data. Prominent seismic reflections, which mark the highest points of the main reservoir sands, were identified in the seismic data for mapping purposes.

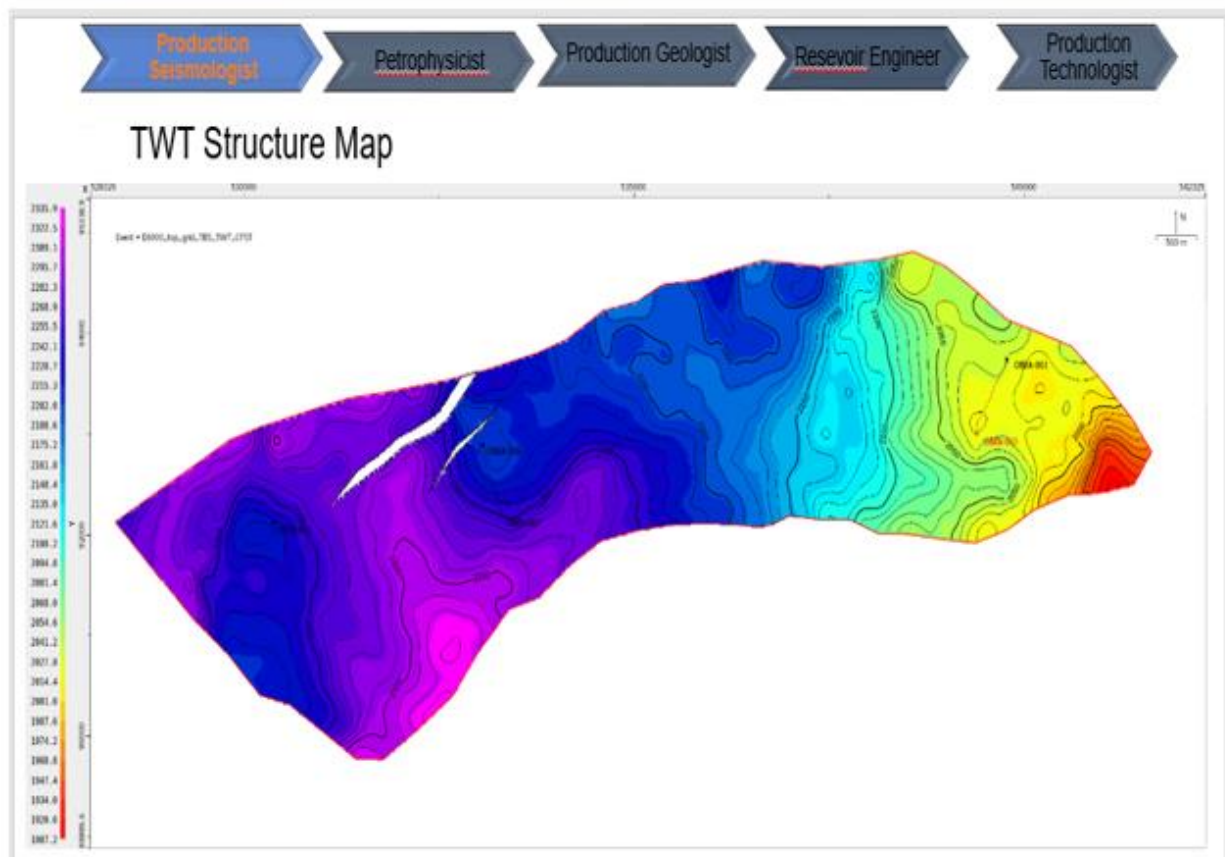
The check-shot function was utilized to generate temporal structure maps using the interpreted horizons. A map function window that use color to depict structural elements displays the depth structural maps for the horizons that were created. The primary fault's direction is plainly seen on the map. In the survey area, the Northeast region exhibits the structure high, while the South and Southwest regions exhibit the structural moderate and low, respectively. The same characteristic

is found over the whole horizon, according to the time and depth structural map observations. On the whole horizon, the structural highs remained nearly in the same location.



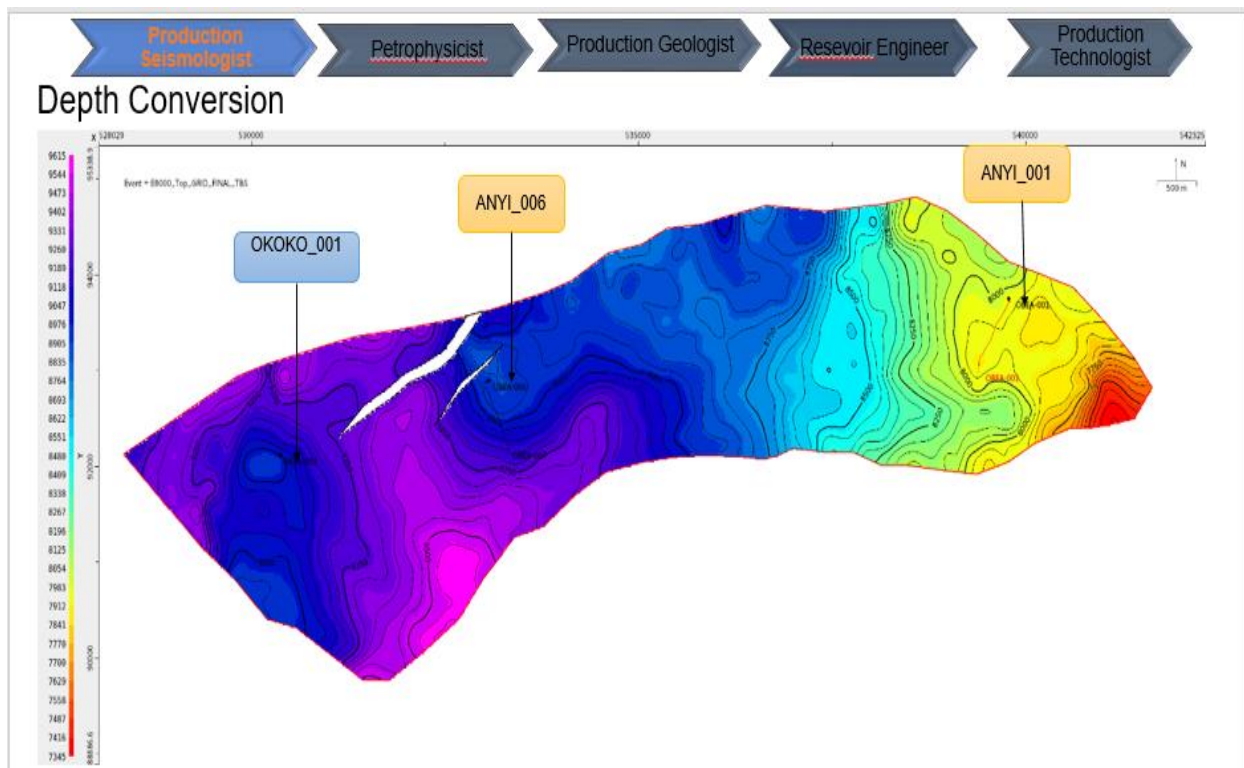
**Fig 4.8:** Polygon build on semblance

#### 4.4 Map Generation (Time and Depth)



**Fig. 4.9:** Time Structure Map

The D5000 reservoir was mapped as peak with Horizon is around (1945-2350) msec. Manual interpretation was done in picking the grids after every 16 lines.



**Fig. 4.9:** Depth Map

D5000 reservoir is around (7920-8135) ft, and a saddle exist between OKOKO\_001 and ANYI\_006

Structural time maps and depth maps were generated at the top of four reservoirs. This was done in order to delineate the orientation of the fault and zone of structural high and low. The effectiveness of sealing is not influenced by the quantity of throws or the presence of shale/clay distributed along fault planes (Bush, 1975; Weber and Daukoru, 1975). Weber and Daukoru (1975) suggest that fault sealing may occur when the fault throws are less than 492 feet (150m) or when the shale/clay content along the fault plane exceeds 25%.

## CHAPTER FIVE

### 5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

#### 5.1 SUMMARY

This investigation was conducted to assess the Anyi field's gas supply. With Klin Power Station as the primary client, the Eastern Division Gas market's anticipated demand rise made this necessary. Anyi field should supply the medium-term (starting in 2007) extra gas needed. OML 11 is home to this established field, which is around 45 kilometers east of Port Harcourt. It was found by Anyi well -001 in October 1975.

There have been ten (10) drainages and seven (7) wells drilled in the field thus far. Amosi growth fault to the north and Klin boundary fault to the south define its structural characteristics as an extended rollover anticline that is oriented east-west. The majority of the reservoir is made up of shorefaces and waterways.

The data was revalidated and quality-checked, and a proper literature study was carried out. To reduce both random and coherent noise, the seismic data was filtered using a MADCOW bandpass filter. After that, well-to-seismic calibration was performed utilizing Anyi-001's sonic log. The horizon and fault were interpreted. Anyi-006 checkshots were used for velocity modeling, and the time and depth map was constructed from them. The next step was amplitude extraction, which was done to improve seismic visualization and find features or anomalies associated with reservoir characteristics such fluid connections, channels, fractures, and changes in porosity.

## **5.2 CONCLUSION**

The process of seismic interpretation for volumetric analysis and D5000 reservoir characteristics is complex and requires integrating several data sources and methodologies. The importance of a methodical approach to data preparation, interpretation, calibration, and analysis in the context of reservoir appraisal is highlighted by this work. Based on the results of this investigation, the D5000 reservoir has a low potential for hydrocarbon recovery and accumulation in the Anyi field (Anyi-006) but a high potential in the Okoko field (Okoko-001). Seismic interpretation, velocity modeling, attribute analysis, and contact prediction techniques are efficient and trustworthy approaches for evaluating reservoir features and volumetric analysis in the Niger Delta, according to the study's findings.

## **5.3 RECOMMENDATION**

Based on the results and conclusions of this study, the following suggestions are put forth for further investigation and real-world implementation in the area of seismic interpretation for reservoir characteristics and volumetric analysis:

1. The improvement of time-to-depth conversion and velocity modeling approaches should be the focus of ongoing work, particularly in complicated geological environments like the Niger Delta.
2. To minimize uncertainty and improve decision-making, reservoir management processes should incorporate ongoing quality control and validation of seismic interpretation results.
3. Further research should explore advanced techniques for data integration, interpretation, and calibration to enhance the accuracy and reliability of reservoir evaluation.

4. Geoscientists, reservoir engineers, and data scientists must work together to study reservoir continuity utilizing seismic interpretation in a more thorough and integrated way. By putting these recommendations into practice, the industry may be better equipped to manage and evaluate reservoirs, particularly in challenging geological environments like the Niger Delta.
5. To expedite analysis procedures, research should be done on the creation of automated attribute extraction methods and machine learning techniques for feature identification in seismic data.

## REFERENCES

- Aldahash, A., Clinton, M.A. and Kraig, L.L. (2019). *Static Reservoir Modeling: Integration of Seismic and Well Data*. Journal of Petroleum Science and Engineering, 179: 314-324.
- Al-Khulaifi, M., Calvin, D.F. and Salman, G. (2016). *Seismic Inversion for Reservoir Characterization and Fluid Flow Simulation*. Geophysics, 81(2): B47-B56.
- Alvarez, G., Mann T. P., Vargas, C.A. and Wood, L.J. (2021). Gravity, Seismic Reflection, and Tomographic Constraints on the Subduction-to-Strike-Slip Transition at the Southeastern Caribbean Plate Boundary Zone Memoir 123: South America-Caribbean-Central Atlantic Plate Boundary, 469-512.
- Ameloko, A.A. and Omali, A.O. (2013). *Reservoir Characterization and Structural Interpretation of Seismic Profile: A Case Study of Z-Field, Niger Delta, Nigeria*. Petroleum & Coal, 55(1): 37-43.
- Azzam, R., Heffman, U.A. and Wrangler, Z.D. (2017). *Dynamic Reservoir Modeling: Challenges and Advances in Fluid Flow Simulation*. Journal of Petroleum Technology, 69(5): 82-89.
- Bachmann, R., Viem, E.E. and Dough, M. (2006). *Structural Modeling in Reservoir Management: A Practical Guide*. Geophysical Journal International, 164(2): 482-495.
- Beydoun, Z., and Hossain, M. (2003). *Seismic Inversion and Reservoir Characterization*. Geophysics, 68(5): 1629-1636.
- Brown, A.R. (2002). *Interpretation of Three-Dimensional Seismic Data*. Society of Exploration Geophysicists. 2: 89-101

- Bush, K. (1975). Fault Sealing Properties. In: Weber, K. J., and Daukoru, E. (1975). Petroleum Geology of the Niger Delta: 9th World Petroleum Congress, Tokyo, Proceedings. Cambridge University Press. Cambridge, UK. 2: 209-221.
- Doust, H. (1989). The Niger Delta Hydrocarbon Potential, a Major Tertiary Niger Province. In: Proceedings of KNGMG Symposium, Coastal Lowstands, Geology and Geotechnology, The Hague. Kluiver Academic Publishers, Dordrecht, 1: 22–25.
- Doust, H. and Omatsola, E. (1990). Niger Delta. In: Edwards, J.D., Santogrossi, P.A. (eds) Divergent/Passive Margin Basins. American Association of Petroleum Geology Memoir 48: Tulsa, American Association of Petroleum Geologists. 1: 239–248.
- Evamy, B.D., Haremboure, J., Kamerling, P., Knaap, W.A., Molloy, F.A. and Rowlands, P.H. (1978). Hydrocarbon habitat of Tertiary Niger Delta. Am. Asso. Petrol. Geol. Bull. 62: 277–298.
- Hindawi. O.O. (2017). Tectonic Evolution and Petroleum System of the Niger Delta Basin, Nigeria. Journal of Geosciences and Geomatics, 5(1): 1-13, 63.
- Ijasan, O., Torres-Verdín, C. and Preeg, W.E. (2013). Interpretation of Porosity and Fluid Constituents from Well Logs Using an Interactive Neutron-Density Matrix Scale. *Interpretation*. 2(2): 34-52.
- Kulke, H. (1995). Regional Petroleum Geology of the World. Part II: Africa, Australia and Antarctica. Berlin, *Gebruder Bogrntraeger*. 143–172.
- Li, J.Y., Zhou, B.G. and Li, T.M. (2020). Seismogenic Depths of the Anninghe-Zemuhe and Daliangshan fault zones and their seismichazards. *Chinese J. Geophys.*, 63(10): 3669-3682.
- Martínez, G., Núñez, A., Jara, J.M., and Olmos, B.A. (2024). Expected Seismic Performance of the San Agustín Church at Morelia, Mexico. *Journal of Building Pathology and Rehabilitation*, 10(1): 4.

- Oluwajana, O.A., Ehinola, O.A., Okeugo, C.G. and Adegoke, O. (2017). Modeling Hydrocarbon Generation Potentials of Eocene Source Rocks in the Agbada Formation, Northern Delta Depobelt, Niger Delta Basin, Nigeria. *J. Pet. Exp. Product Technol.* 7: 379–388.
- Oyelajo, J.A. and Akinyemi, D.H.S. (2023). Reservoir and Structural Analysis Through Modeling using Well Logs and 3D Seismic Data in OY-1 Field, Onshore Niger Delta, Nigeria. *International Journal of Innovative Science and Research Technol.* 8(8): 2705-2723.
- Stacher, P. (1995). Present Understanding of the Niger Delta Hydrocarbon Habitat. In: Oti, M.N., Postma, G. (eds). *Geology of Deltas.* 23-28.
- Tan, H., Gao, X., Wang, K., Gao, J., and He, J. (2022). Hidden Roughness of Subducting Seafloor and Implications for Megathrust Seismogenesis: Example from Northern Manila Trench. *Geophysical Research Letters*, 49.
- Tuttle, M.L., Charpentier, R.R. and Brownfield, M.E. (1999). The Niger Delta petroleum system. Niger Delta province, Nigeria, Cameroon, and Equatorial Guinea, Africa, US Department of the Interior, US Geological Survey. 132-222
- Weber, K.J. and Daukoru, E.M. (1975). Petroleum Geology of Niger Delta: Proceeding of the Ninth World Petroleum Congress, 2, Geology: London, Applied Science Publishers, Ltd. 322-325
- Wei, Y., Jianbo, W., Shuai, L., Kun, W. and Yinan, Z. (2014). Logging Identification of the Longmaxi Mud Shale Reservoir in the Jiaoshiba Area. *Sichuan Basin Nat Gas Ind. B* 1(1): 230–236.
- Yao, H. J. (2020). Building the Community Velocity Model in the Sichuan-Yunnan Region, China: Strategies and Progresses. *Science China Earth Sciences*, 63(9): 1425-1428.
- Yi, G. X., Zhao, M. and Long, F. (2021). Characteristics of the Seismic Sequence and Seismogenic Environment of the MS 6.0 Sichuan Luxian Earthquake. *Chinese J. Geophys*, 64(12): 4449-4461.