

**SUBSURFACE MAP GENERATION OF SULU RESERVOIR IN
NIGER DELTA BASIN**

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CERTIFICATION

This is to certify that this project work was submitted by EMEKA ONUSULU, MAT NO. PSC1707636 and approved by the department of Geology in partial fulfillment for the requirements of the award of Bachelor of science of Geology, University of Benin, Benin City.

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DEDICATION

This project work is dedicated to God Almighty who gave me strength throughout this project work. My parents Pst and Mrs Polycarp Onusulu, fellow project mates and siblings for their immense support towards the fulfillment of this project work.

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My heartfelt gratitude goes to God for the gift of Life and good health to be able to accomplish this great work. I also want to appreciate my project supervisor, Dr. A Ogbamikhumi for his massive impact towards the success of this project.

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ABSTRACT

An integrated approach using seismic information was employed for subsurface mapping of Sulu reservoir of the Niger Delta basin. The aim of this study was directed towards the generation of a subsurface map, determination of the subsurface structural features for hydrocarbon and prediction of prospecting of the reservoir. The methods employed include analysis of 3D seismic data using Petrel software: faults and horizon deductions from the seismic section were used to generate structural maps which revealed different structural styles present in the studied area and extraction of amplitude. A distinct horizon was mapped. From the horizon nine faults (with five been major) were mapped for the purpose of carrying 3D subsurface structural interpretation. These were used in generating the time structure maps using the Petrel Interpretational tool. The results show that the trapping mechanisms in the field are favourable for hydrocarbon accumulation. Two principal structural trapping mechanisms presents are the rollover anticline and the simple anticline. This study has demonstrated and appreciate the importance of seismic structural interpretation in generation of subsurface maps of reservoir, understanding the structural styles present, amplitude extraction for prospect ranking.

CHAPTER ONE

INTRODUCTION

1.1 GENERAL INTRODUCTION

Petroleum is a complex mixture formed by organic matter/processes. It is a complex mixture of hydrocarbon that occur in the earth in form of liquid gaseous and solids. There are two hypothesis that supports the accumulation of hydrocarbon which is the Organic and Inorganic Hypothesis. With the evidences surrounding the both hypothesis which includes the temperature, optical properties, presence of organic debris, migration and presence of homologous series and compounds, the Organic has been proven to be true. These hydrocarbons where formed from the remains of dead plant and animals that were buried overtime by sediments. Due to the deep burial of these floral and faunal materials, leading to a formation of hydrocarbon by severally processes such as: Diagenesis; which involves all the processes that occur after deposition and burial and before metamorphism. Catagenesis; this vital process involves the conversion of kerogen to hydrocarbon. Metagenesis; this is the peak of maturity of the hydrocarbon whereby it starts further break down (cracked). All over the world Nigeria, petroleum has been a major source of economic advancement but due to the difficulty associated as a result of insufficient tool in accomplishing the task, Hydrocarbon prospecting has become more and more complex to perform.

The productive interest for hydrocarbon products since the twentieth century intensified exploration for oil and gas accumulation in reservoir rocks. This prompted an extensive study of the Niger Delta depocenters after an extended period of non productive research in the Cretaceous sediments of the Benue Trough (Doust and Omatsola, 1990). Understanding reservoir characteristics most

importantly porosity, permeability, water saturation thickness and area extent of the reservoir are vital factors in quantifying producible hydrocarbon (Schlumberger, 1989). These parameters are significant in light of the fact that they fill in as authentic contributions for reservoir volumetric analysis i.e the volume of hydrocarbon in place (Edward, 1990).

Petroleum in the Niger Delta is delivered from sandstone and unconsolidated sands predominantly in the Agbada Formation. It is important to delineate the hydrocarbon reservoirs and evaluate them since they are the zones of enthusiasm for hydrocarbon exploitation (Adewoye et al., 2013). Based on reservoir geometry and quality, the lateral variation in reservoir thickness is strongly controlled by growth faults; with the reservoirs thickening towards the fault within the down-thrown block (Weber and Daukoru, 1975). It is therefore necessary to use technologically and economically viable methods in the exploration and exploitation for hydrocarbon because geophysical survey and the subsequent exploitation via drilling of wells require large capital. In order to avert any loss or wastage of resources, there is need to properly and adequately characterize a reservoir and to determine the hydrocarbon in place. This will help to ascertain the hydrocarbon potential of the reservoirs.

1.2 BACKGROUND THEORY

1.2.1 SEISMIC DATA ACQUISITION ; seismic exploration involves three stages which are the acquisition, processing and interpretation stages. The acquisition is the first of the three distinct stages of seismic exploration, the other two being seismic data processing and seismic interpretation. Seismic acquisition requires the use of a seismic source such as dynamite, at specified locations for a seismic survey, and the energy that travels within the subsurface as seismic

waves generated by the source gets recorded at specified locations on the surface by what is known as receivers (geophones or hydrophones), this process works with the reflection of sound waves.

1.2.2 SEISMIC DATA PROCESSING; this stage is further sub divided into three main process in seismic data processing which are : deconvolution, common-midpoint (CMP) stacking and migration.

Deconvolution is a process that tries to extract the reflectivity series of the Earth, under the assumption that a seismic trace is just the reflectivity series of the Earth convolved with distorting filters. This process improves temporal resolution by collapsing the seismic wavelet, but it is nonunique unless further information is available such as well logs, or further assumptions are made. Deconvolution operations can be cascaded, with each individual deconvolution designed to remove a particular type of distortion.

CMP stacking is a robust process that uses the fact that a particular location in the subsurface will have been sampled numerous times and at different offsets. This allows a geophysicist to construct a group of traces with a range of offsets that all sample the same subsurface location, known as a Common Midpoint Gather. The average amplitude is then calculated along a time sample, resulting in significantly lowering the random noise but also losing all valuable information about the relationship between seismic amplitude and offset. Less significant processes that are applied shortly before the CMP stack are Normal moveout correction and statics correction. Unlike marine seismic data, land seismic data has to be corrected for the elevation differences between the shot and receiver locations. This correction is in the form of a vertical time shift to a flat datum and is known as a statics correction, but will need further correcting later in the

processing sequence because the velocity of the near-surface is not accurately known. This further correction is known as a residual statics correction.

Seismic migration is the process by which seismic events are geometrically re-located in either space or time to the location the event occurred in the subsurface rather than the location that it was recorded at the surface, thereby creating a more accurate image of the subsurface.

1.2.3 SEISMIC INTERPRETATION The goal of seismic interpretation is to obtain a coherent geological story from the map of processed seismic reflections. At its most simple level, seismic interpretation involves tracing and correlating along continuous reflectors throughout the 2D or 3D dataset and using these as the basis for the geological interpretation. The aim of this is to produce structural maps that reflect the spatial variation in depth of certain geological layers. Using these maps hydrocarbon traps can be identified and models of the subsurface can be created that allow volume calculations to be made. However, a seismic dataset rarely gives a picture clear enough to do this. This is mainly because of the vertical and horizontal seismic resolution but often noise and processing difficulties also result in a lower quality picture. Due to this, there is always a degree of uncertainty in a seismic interpretation and a particular dataset could have more than one solution that fits the data. In such a case, more data will be needed to constrain the solution, for example in the form of further seismic acquisition, borehole logging or gravity and magnetic survey data. Similarly to the mentality of a seismic processor, a seismic interpreter is generally encouraged to be optimistic in order encourage further work rather than the abandonment of the survey area. Seismic interpretation is completed by both geologists and geophysicists, with most seismic interpreters having an understanding of both fields.

1.3 AIM

This study is aimed at understanding and interpreting the structural framework, that would ultimately aid hydrocarbon prospecting to help determine hydrocarbon presence in the field of study from the seismic data provided.

1.4 OBJECTIVES

- i. Analyzing and Interpreting the structural configurations provided in the seismic data with the aid of petrel software.
- ii. Determination of the trap mechanism in the field of study
- iii. Identification of potential sites for hydrocarbon exploration

1.5 SCOPE AND LIMITATION OF STUDY

Seismic Data Interpretation; Seismic data interpretation of study field using petrel software, to have an idea of the structural configuration of the present in the field.

Generation of Structural map; structural maps would be produced to understand the geometry and configuration of the structures.

Prospect identification; Proposed well locations will be identified based on the interpretation made from seismic data volume.

1.6 LOCATION OF STUDY FIELD

The Sulu's field is a fictitious name given to an area on shore of Niger Delta. The exact location of the field is not given. Niger Delta region of Nigeria is approximately 85km towards the atlantic ocean lying between latitude 5⁰00 and 5⁰25N and longitudes 7⁰35 and 8⁰00E.

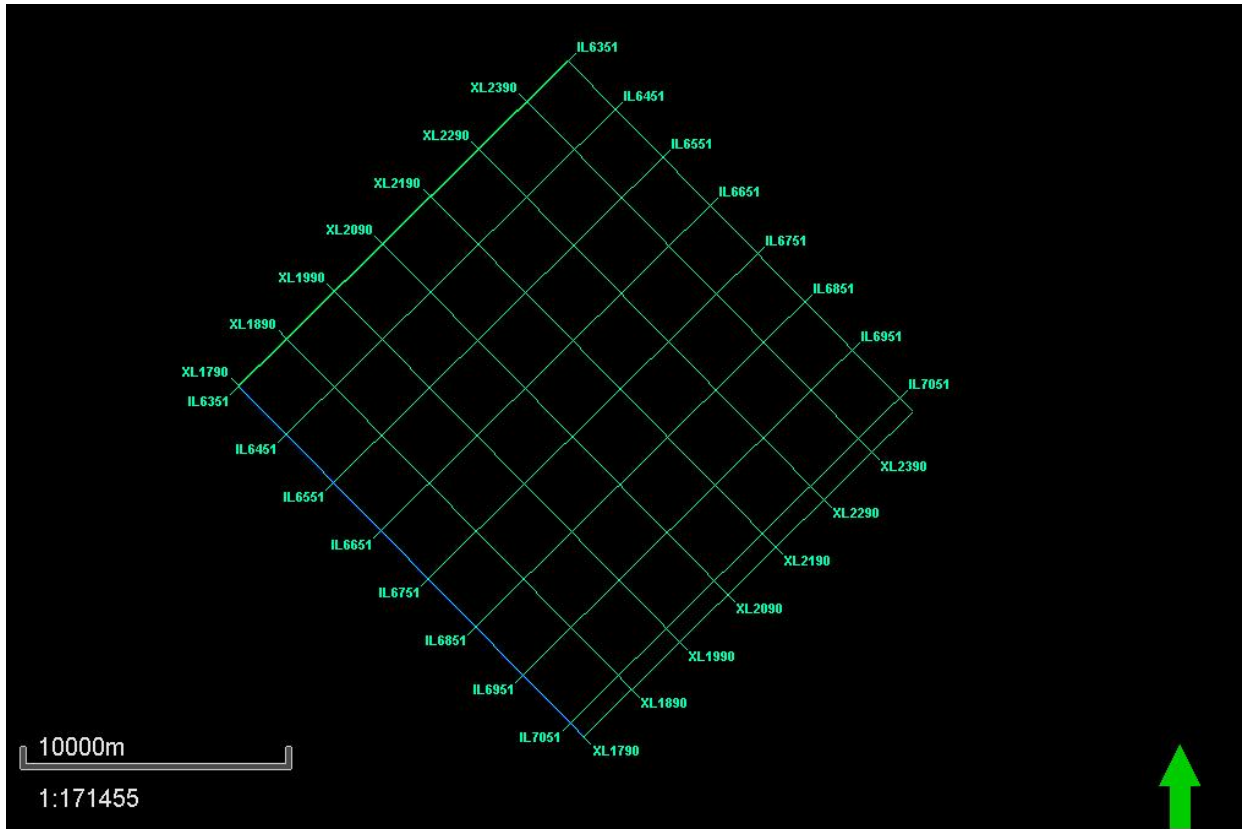


Figure 1: Survey Map

1.6.1 DEPOBELTS

Deposition of the three formations occurred in each of the five offlapping siliciclastic sedimentation cycles that comprise the Niger Delta. These cycles (depobelts) are 30-60 kilometers wide, prograde southwestward, 250 kilometers over oceanic crust into the Gulf of Guinea (Stacher, 1995), and are defined by syn-sedimentary faulting that occurred in response to variable rates of subsidence and sediment supply (Doust and Omatsola, 1990). Each depobelt is a separate unit that corresponds to a break in regional dip of the delta and is bounded landward by growth faults and seaward by large counter-regional faults or the growth fault of the next seaward belt (Evamy et al., 1978; Doust and Omatsola, 1990). Five major depobelts are generally recognized, each with its own sedimentation, deformation, and petroleum history. Doust and Omatsola (1990) describe three depobelt provinces based on structure. The northern delta province, which overlies relatively shallow basement, has the oldest growth faults that are generally rotational, evenly spaced, and increases their steepness seaward. The central delta province has depobelts with well-defined structures such as successively deeper rollover crests that shift seaward for any given growth fault.

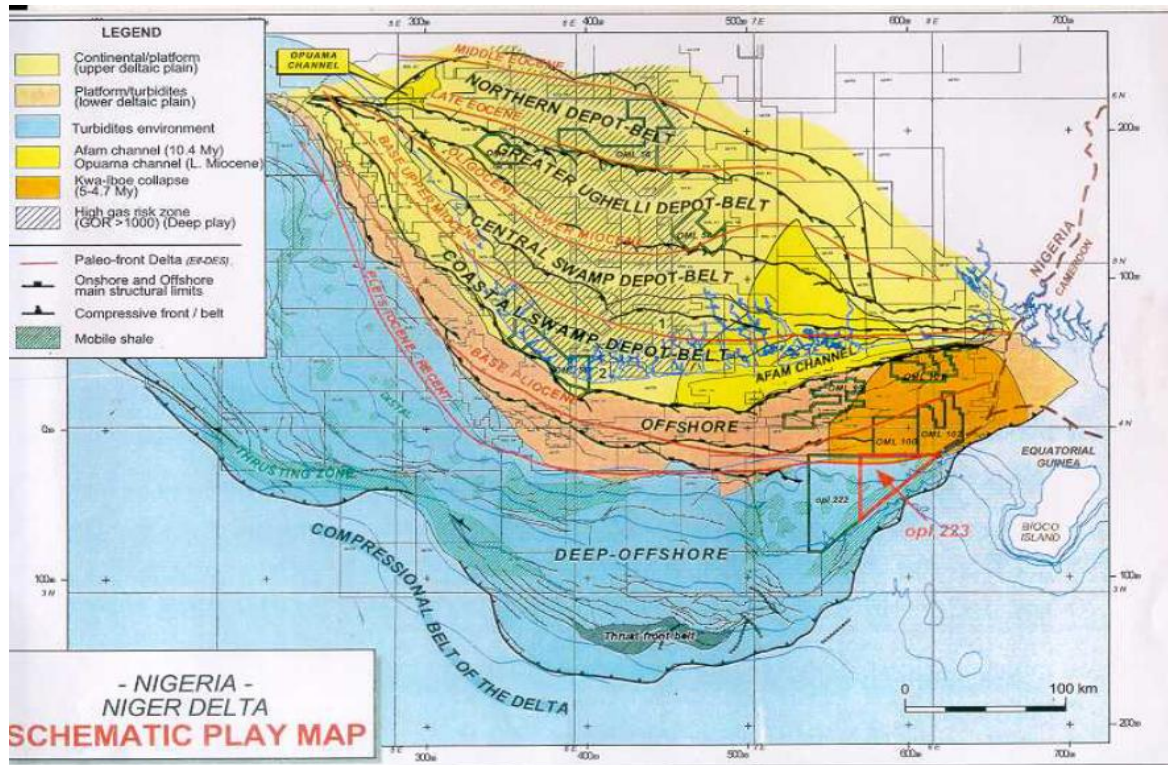


Figure 2: The map view of the different Depobelts in the Niger. (Weber, 1971)

CHAPTER TWO

LITERATURE REVIEW AND GEOLOGICAL SETTING

2.1 LITERATURE REVIEW

Geophysical studies as well as geological investigations have taken place in the Niger Delta Basin dating back some fifty years for oil and gas prospecting (Aizebeokhai and Olayinka, 2011; Cobbold et al., 2009).

Based on these investigations, Burk et al., (1972) and Whiteman (1982) described the Niger delta's tectonic setting as a clastic wedge formed along a failed arm of a triple junction system that originally developed during the break of the South American and African plates in the late Jurassic. Below are some works that are in relation; Weber, 1971; Short and Stauble, 1967; Haack and May, 2000; Evamy et al., 2000, Doust and Omatsola, 1990; Weber and Daukoru, 1975; etc.) .

The evolution of the tertiary Niger delta basin was described by Weber and Doukoru (1975) as a result of sequential paralic deposition into series of depobelts which succeeded each other in time and space leading to regular step like southward progression of the Niger, referred to as escalator regression.

The Akata shale, Agbada formation and Benin formation are together called the tertiary sequence (Short and Stauble, 1967). The sediments deposited in the Niger Delta were derived from the drainage system of River Niger, River Benue and Cross River. However, the present-day delta is a complex fluviomarine system (Bowen et al., 1994).

Structural and isopach maps of the three lithostratigraphic sequence of the Niger delta were produced (Avbovbo, 1978). The principal structural types within the basin were described (Weber and Daukoru, 1975). Syn-sedimentary faults in the basin have little or no effect on the Benin formation (Reijers et al., 1997).

Corridor et al., (2005) divided the delta into five zones based on structural characteristics;

proximal zone of extension, dominated by regional and counterregional growth faults

- i. A diapiric zone of mud diapirs and shale ridges
- ii. An inner fold and thrust belt
- iii. A translational zone between the inner and outer thrust
- iv. An outer fold and thrust belt characterized by regional and counter-regional verging thrust faults.

Stacher (1995) showed that the Niger Delta basin consists of a series of depocenters while (Evamy et al, 1978) showed that sedimentation in the depocenter is a function of the rate of subsidence with the syn depositional growth faults upsetting the delicate balance.

Weber and Daukoru (1975) proposed that the faults serve as pathway for hydrocarbon migration from source rock.

Structural analysis in different sedimentary basins worldwide using seismic and well log data have also been carried out by various workers. Since geological and geophysical investigations on the Niger Delta started about fifty years ago (Aizebeokhai and Olayinka, 2011; Cobbold et al., 2009), authors such as Hamed and Kant, (2008); Wiener et al., (1997); Ajakaye and Bally, (2002); Morgan, 2003; Haack et al, (2000); Hooper et al, (2002) etc. have worked on structural interpretation of seismic data from different parts of the basin to determine its hydrocarbon potentials.

Detailed discussions on the history, evolution, and structural features of the Niger Delta has been carried out by Allen (1964), Stoneley (1966) and Burke (1972). They analyzed and discussed the mega tectonic setting of the Niger Delta. Evamy

et al., (1978) extensively discussed the syn-depositional tectonics of the tertiary Delta.

The Niger Delta Basin located on the passive western margin of Africa, has long been recognized as a classic example of continental margin structural collapse under sediment loading (Daily, 1976 and Morley, 1992).

Three formations were defined within the Niger Delta clastic wedge based on sand/shale ratio estimated from subsurface well logs by Short and Stauble (1967), Frank and Cordy (1967) and Avbovbo (1978). From oldest to youngest namely; Basal, offshore-marine, and pro-delta shale of the Akata formation; interbedded sandstone and shale of the dominantly deltaic Agbada formation; and the sandy fluvial Benin formation.

Past sedimentological, biostratigraphical and sequence-stratigraphic studies revealed the combined influences of eustatic cyclicity and local tectonics (Stacher, 1995 and Reijers et al., 1997).

A sequence stratigraphic framework of the western Niger Delta was developed by Ozumba (1999), using foraminifera and wire line log data obtained from four wells drilled in the coastal and central swamp depobelts. Pacht and Hall, (1993) applied the sequence stratigraphic concept to exploration in the offshore Niger Delta.

Evamy et al.,(1978), Ejedawa (1981), Knox and Omatsola (1987) and Stacher (1995) described the evolution of the Delta to be controlled by pre and syn-sedimentary tectonics. The tectonic framework of the continental margin along the west coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic. The fracture zones ridges subdivide the margin into individual basins, and in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the west-African shield.

The Niger delta is a basin whose stratigraphic and paleogeographic evolution have been controlled by southward succeeding depobelts (Benkheli, 1989; Petters 1985), post deformational displacement of depocenters westward and northward directed marine transgressions (Murat, 1972; Peters, 1981). The basin is underlain by oceanic crust which is basaltic in composition, and closer to the coast by Precambrian continental basement.

The Niger Delta Basin tectonic structures are very typical of an extensional rift setting, but the presence of shale diapirism due to overloading of the shale associated with compression distinguishes the basin. The major deformational method is due to gravitational collapse of the basin, although the older faulting and deformation of the basin are related to the continental break up and rifting of the African plate and South American plate during the formation of the Benue trough. The Niger Delta basin is divided into three zones due to its tectonic structure (Michele et al., 1999); an extensional zone which lies on the continental shelf as a result of thickened crust, a transition zone and then a contraction zone which lies in the oceanic/deep marine part of the basin.

2.2 GEOLOGICAL SETTING OF THE STUDY AREA

2.2.1 NIGER DELTA BASIN

A delta is a large accumulation of sediments deposited at the mouth of a river where it is discharged into a stable water body from several fluvial systems or channels called tributaries. It results from a stream reaching a stable body of water such as the sea and building a deposit of sediments because of the reduction of its velocity of flow.

The Niger Delta Basin, situated at the apex of the gulf of Guinea on the west coast of Africa, is one of the most prolific deltaic hydrocarbon provinces in the world. The field lies between latitude 40 20' 00''N and 40 50' 00''N and Longitude 60 30' 00'' and 70 10' 00'' Covering an approximate areal extent of 70,000 km². It is composed of an overall regressive clastic sequence, which reaches a maximum thickness of about 12km (Evamy et al.; 1978).

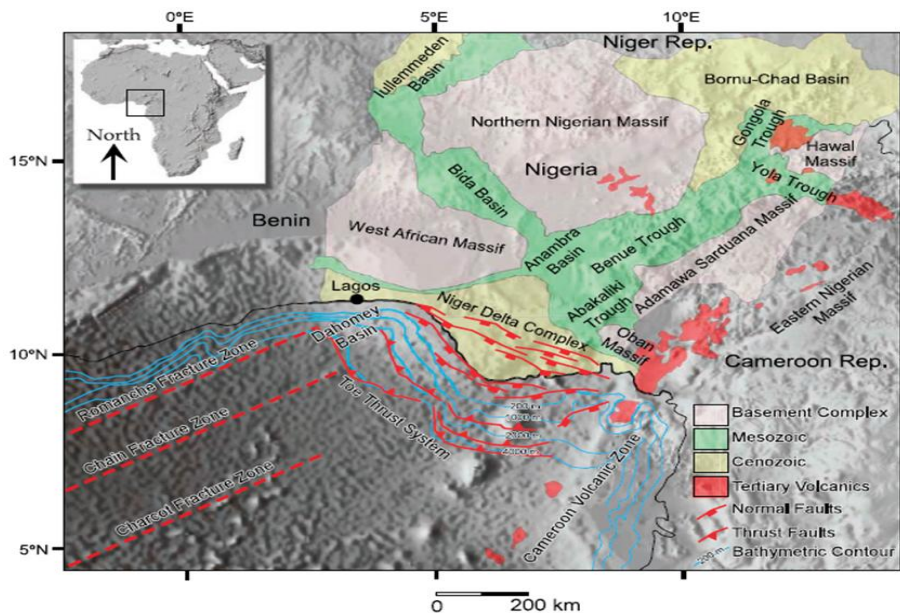


Figure 3 Map of Niger Delta showing the study area (Whiteman, 1982).

2.2.2 TECTONIC FRAMEWORK AND EVOLUTION OF THE NIGER DELTA BASIN

The tectonic framework of the continental margin along the West Coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic. The fracture zone ridges subdivide the margin into individual basins, and in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the West African shield. The trough represents a failed arm of a rift triple junction associated with the opening of the South Atlantic. In this region, rifting started in the Late Jurassic and persisted into the middle Cretaceous (Lehner and De Ruiter, 1977). Shale mobility induced internal deformation and occurred in response to two processes (Kulke, 1995). First, shale diapirs formed from loading of poorly compacted, overpressured, pro-delta and delta-slope clays (Akata formation) by the higher density delta-front sands (Agbada formation). Second, slope instability occurred due to a lack of lateral, basin ward, support for the under compacted delta-slope clay (Akata formation) (Figure 1.3). For any given depobelt, gravity tectonics were completed before deposition of the Benin formation and are expressed in complex structures, including shale diapirs, roll-over anticlines, collapsed growth fault crests, back-to-back features, and steeply dipping, closely spaced flank faults (Evamy et al., 1978; Xiao and Suppe, 1992). These faults mostly offset different parts of the Agbada formation and flatten into detachment planes near the top of the Akata formation. Taphrogenic subsidence along fundamental transform faults which had cut through the lithosphere and are the landward continuation of the Chain and Charcot oceanic fracture zones (Emery et al., 1975) initiated the Benue Trough and also latter controlled the location of the main axis of subsidence of the Niger Delta. The Niger Delta can be considered as the youngest sub-basins in the Benue Trough relative to Gongola, Yola, Abakaliki, Anambra and Afikpo sub-basin.

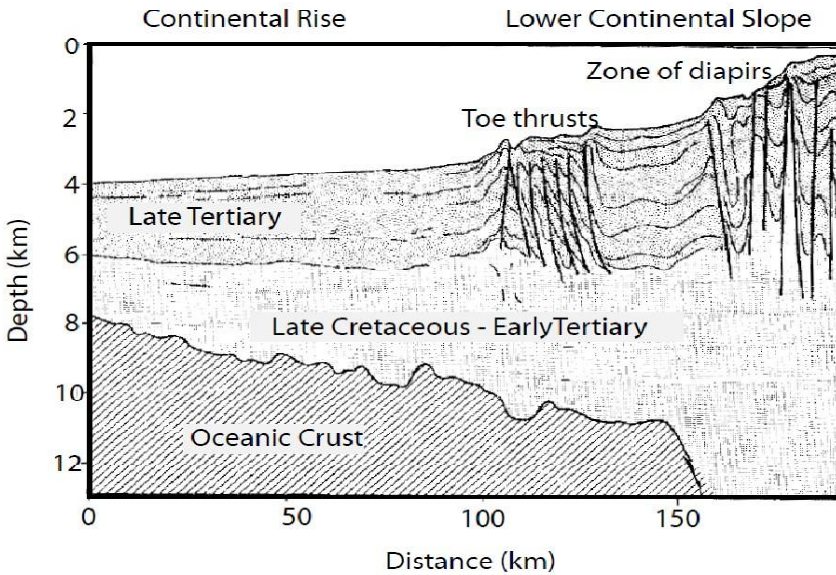


Figure 4: Schematic diagram of a cross section from the Niger Delta continental slope/rise showing the results of internal gravity tectonics on sediments at the distal portion of the depobelt. (Modified from Lehner and De Ruiter, 1977; Doust and Omatsola, 1990).

2.2.3 STRUCTURAL STYLES IN THE NIGER DELTA BASIN

The tectonic structures in the Niger Delta Basin are very typical of an extensional rift system, but the added shale diapirism due to compression makes this basin different. One of the most conspicuous geological features of the Niger Delta is its growth fault pattern. The energy responsible for their genesis is most likely to be inherent in the sediments themselves rather than in any external orogenic forces. In fact, they are believed to be gravity faults contemporaneous with rapid sedimentation and initiated by the differential loading of the underlying and mobile (laterally and vertically) under-compacted Akata shale. The sedimentation and gravity faulting has resulted in the deposition of thicker sediments on the down-thrown than on the up-thrown block. Besides, because of the large weight of sediments deposited in the delta front and the down dip subsidence accompanying this deposition, the strata have been tilted basin ward. Most of the oil accumulated

in the Niger Delta is contained in the rollover anticline structure. The oil in these structures may be

trapped in dip closures or against a Synthetic or antithetic fault.

The overall basin is divided into a few different zones due to its tectonic structure. There is an extensional zone, which lies on the continental shelf, that is caused by the thickened crust. There is a transition zone, and then there is a contraction zone, which lies in the deep sea part of the basin.

The delta sequence is deformed by syn-sedimentary faulting and folding. Evamy et al.(1978) described the main structural features of the Niger Delta as growth faults and rollover anticlines.

i. Growth Faults

Growth faults are formed as a result of rapid sedimentation along the edge of the Niger Delta, on top of clay and they are characterized by the occurrence of thicker sediments on the downthrown block relative to the up-thrown block. Growth faults are mostly termed contemporaneous fault (Weber and Daukoru, 1975; Evamy et al., 1978;Doust&Omatsola, 1990) and they are important in interpretation because they serve as major path for hydrocarbon migration from marine shale of the Akata formation to the reservoir sand of the Agbada formation of the delta. Rapids and deposition along the Delta edge on top of under-compacted clay has resulted in the development of a large number of syn-sedimentary gravitational faults. These so-called “growth faults” are also well known from U.S. Gulf coast. The spacing between successive growth faults decrease with an increase of depositional slope or an increase in rate of deposition over the rate of subsidence. Growth faults tend to envelop local depocentres at their time of formation. Their trend is thus an indication of the prevailing sedimentological pattern. The name “growth fault” derives from the fact that after their formation, the fault remains active and thereby

allows a faster sedimentation in the downthrown relative to the upthrown block. Evamy et al. (1978) classified growth faults into structure building faults, crestal flank faults. The combined effects of the growth faults are a strong rollover of the northern flank. As a result, the upper surfaces of Akata formation also become markedly curved and gravitational instability causes the shale bulge to move upward. This in turn led to the formation of antithetic faults.

a. Structure-building faults

These are the faults which define the up-dip limit of the major rollover structures. In the horizontal plane, they are essentially concave in a down-dip direction. The degree of curvature varies from being rather linear in the east to truly crescent-shaped in the western and southern part of the Delta. The curvature of the structure-building fault at their lateral extremities creates a mapping problem because of the way they repeat each other in the strike directions. In some places the structure-building faults repeat each other. Where these occur, the structure-building faults die out in the flanks of the adjacent rollover structures.

b. Crestal faults

A rollover structure may contain one or more crestal faults. They are characteristically parallel to the axis of the structure and differ from structure-building faults in that they show less curvature in the horizontal plane (Figure 1.4). They are generally steeper in the vertical plane. They display less growth, which also tends to be less continuous. In some structures, the crestal faults have very large vertical displacements. At depth, they may bring sandy marine sales, some crestal faults even cut the slip plane of the structure-building fault.

c. Flank faults

These faults as their name suggest, are located on the southern flanks of major rollover structures. Although they may show some rollover deformation at shallow levels, southerly dips are typical on either side of the fault at depth.

d. Major counter regional faults

Major counter-regional growth faults are located at the southern end of regional flanks. Antithetic faults also have counter-regional nature, but they are of secondary structural importance and display no growth, being simple compensation for extension in the overburden. K- type faults are essentially flank faults. They are considered as a separate class only because of their extremely close spacing, which gives rise to a multiplicity of narrow fault blocks. They are common (as their name implies) in shell-BP original "K" block.

ii. Rollover anticline

The rollover anticline is formed as a result of reversal of dip section such as by rotation of a block resulting from sliding along a curved fault plane usually associated with gravity faulting coinciding with deposition of sediments. These are the reversal of dip direction as produced by rotation of a curve (listric) fault plane usually associated with gravity faulting contemporaneous with deposition

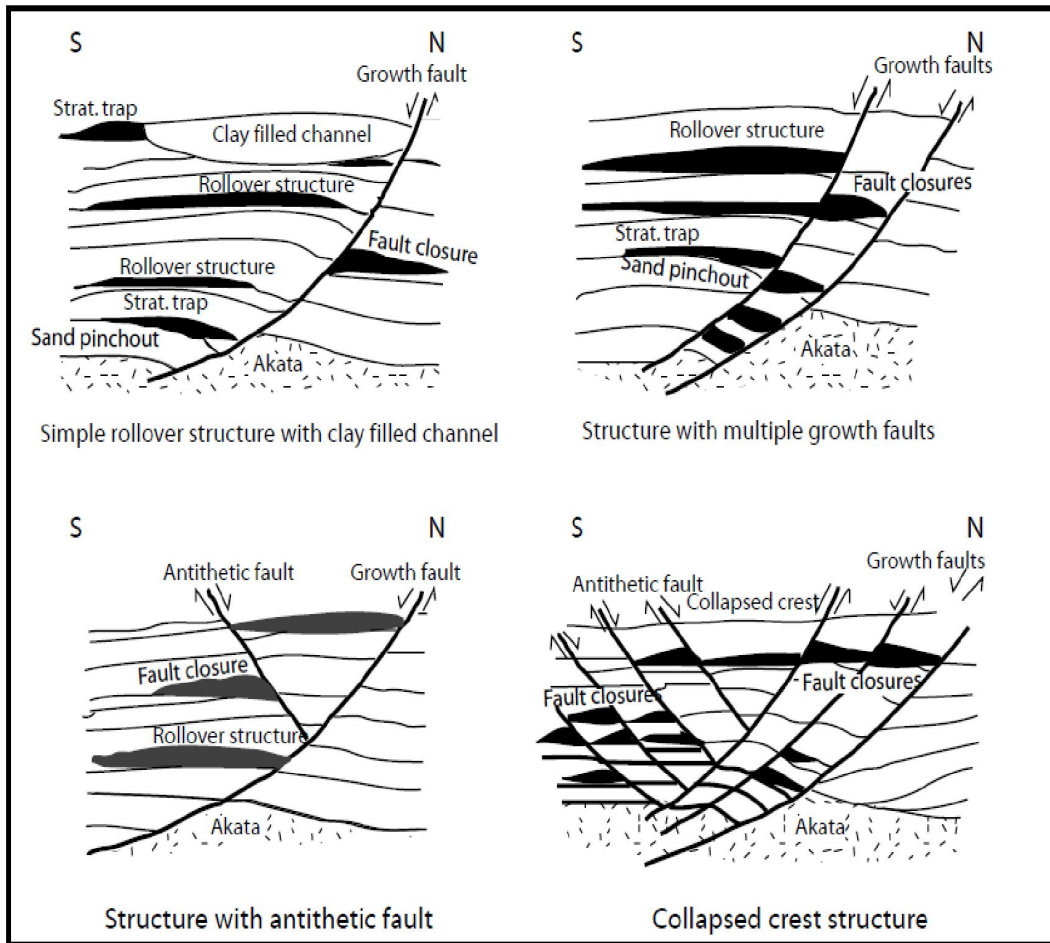


Figure 5: Niger Delta oil field structures and associated trap types. (Modified from Doust and Omatsola, 1990; Stacher, 1995).

2.2.4 SEDIMENTARY FILL OF THE NIGER DELTA BASIN

The Niger delta is built up by the tertiary sediments deposited in a high energy, constructive deltaic environment. The sediments were derived from the drainage system of River Niger, River Benue and Cross River. The present day delta however, is a complex fluvio-marine system that have succeeded one another in a step like fashion as the delta prograded south-westward, forming different depobelts that represent the most active part of the delta at each stage of deposition (Bowen et al., 1994).

The delta prograded seaward during the regressive phase while during the regional transgressive phase, the delta retreats (Evamy et al., 1978)

Weber (1971) noted that continued sediment supply, syn-sedimentary faults and relative sea level fluctuation gave rise to the continuous vertical cycle stacking of fluvio-marine interlaminated silt, sand and clay. The sedimentation mechanism in the deltaic belts was termed the “escalator regression model” by Knox and Omatsola (1989).

2.2.5 STRATIGRAPHY OF THE NIGER DELTA

In an advancing delta such as that of the Tertiary Niger delta, sediments are stratigraphically superimposed. The submarine delta fringe will encroach on sediments and will in turn, be covered by a younger lower deltaic plain.

In the Niger delta, this sequence is modified by the numerous transgressions which have occurred from time to time, breaking the continuity of the main overall regression, and becoming stratigraphically superimposed (Short and Stauble, 1967). The thick wedge of the Niger delta is considered to consist of three units Benin, Agbada and Akata formations (Figure 1.2). These formations are strongly diachronous and cut across the time stratigraphic units which are characteristically S-shaped in cross section. The typical sections of these formations are described by Short and Stauble (1967) and summarized in a variety of papers (Avbovbo, 1978; Doust and Omatsola, 1990; Kulke, 1995). These three geologic formations in the Niger Delta are discussed below:

i. Benin Formation

The Benin formation overlies the Agbada formation. The age of the formation is oligocene in the north, and becomes progressively younger southwards. To date, very little hydrocarbon deposits have been found in this highly porous and generally freshwater bearing formation (Short and Stauble, 1967). The Benin formation extends from the west across the whole Niger Delta and has been described as coastal plain sands which outcrop in Benin, Onitsha and Owerri provinces. It consists of massive continental sands; gravels with thickness ranging from 0.2 to 100metres. The sand and sandstone are coarse to fine and commonly granular in texture. In general, they appear to be poorly sorted, sub-angular to well rounded. The sand and sandstone may represent point bar deposits, channel fills and natural levees while the shale may be interpreted as black swamp deposits and oxbow fills.

ii. Agbada Formation

This is a paralic sequence of sandstone and shale underlying the Benin formation. It consists of the sandy parts, which serve as the main hydrocarbon reservoir of the Delta and shale as the cap rock. This sequence is associated with syn-sedimentary growth faulting. The Agbada formation is thickest at the center with a maximum thickness of 457.2m (Doust and Omatsola, 1990). The upper part is predominantly sandy unit minor shale intercalation and a lower shaly unit, which is thicker than the upper sandy unit. The formation was deposited beginning from the Eocene and continued into the Recent. The formation consists of paralic siliciclastics over 3700 meters thick, and represents the actual deltaic portion of the sequence. In the lower Agbada formation, shale and sandstone beds were deposited in equal proportions; however, the upper portion is mostly sand with only minor shale inter-beds. The depositional environment is therefore defined as “transitional” between the upper continental Benin formation and the marine underlying Akata formation. It is Miocene in the north and

Pliocene/Pleistocene in the south and has a maximum thickness of possibly 4600 meters. (Doust and Omatsola, 1990)

The prolific Agbada formation is divided into four distinct members:

D-1 member which is predominantly an alternating sequence of regressive sands and marine shale with minor oil and gas reservoir. Qua-Iboe consisting of thick pile of shale with thin intercalated sands that are possible oil and gas reservoir in some places The Rubble bed consisting of heterogeneous mixture of eroded Biafra sand and shale. The Biafra member is predominantly of alternating sequence of sand and shale. It contains principally oil and gas reservoir (Doust and Omatsola, 1990).

iii. Akata Formation

This unit is composed of deeper marine shale, the deepest stratigraphic unit. It is chiefly represented by plastic, low density, under-compacted and high-pressure shallow marine to deep water-shale; with only local inter-beddings of sands and/or siltstones. It is deposited as the high-energy delta advanced into deep water. In general, the shale is overpressured and this provides the mobile base for subsequent growth faulting associated with the deposition of the overlying paralic sequence. It serves as the hydrocarbon source in the Niger Delta. Majority of wells drilled in the Niger Delta only penetrated into the marine Akata Shale. Little of the formation has been drilled; therefore, not much is known about this formation. It is estimated that the formation is up to 7,000 meters thick (Doust and Omatsola, 1990).

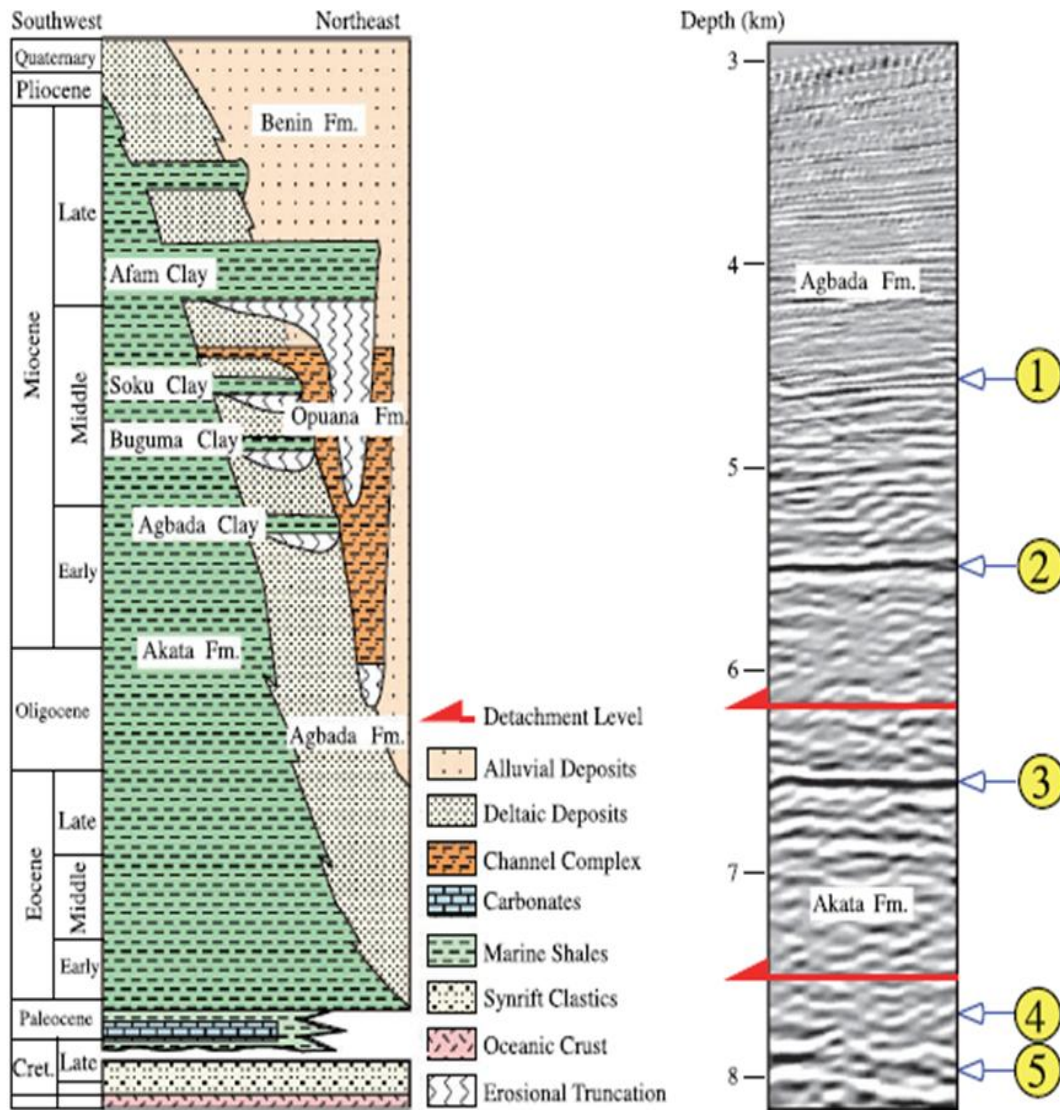


Figure 6: Stratigraphic column showing the three formations of the Niger Delta. (Modified from Shannon and Naylor, 1989; and Doust and Omatsola, 1990).

2.2.6 HYDROCARBON GENERATION AND OCCURRENCE

Hydrocarbons are compounds of carbon formed as result of breakdown of organic matter deposited alongside sediments in a reducing environment, from its original state to kerogen and then to hydrocarbon under the right temperature, pressure, and chemical conditions. Evamy et al. (1978) set the top of the present-day oil window in the Niger Delta at the 240°F (115° C) isotherm. In the northwestern portion of the delta, the oil window (active source-rock interval) lies in the upper Akata formation and the lower Agbada formation, to the southeast, the top of the oil window is stratigraphically lower (up to 1220 m) below the upper Akata/lower Agbada sequence (Evamy et al., 1978). Although there are arguments over the effects of the ratios of sand/shale overburden on the depth to top of the oil window, it is believed that the depth increases southwards as reported Beka and Oti(1995)The process through which hydrocarbons migrate from the source to reservoir rocks was examined by Hunt (1990). He related this process to the case of the Gulf of Mexico under the assumption that the phenomenon is plausible in the Niger Delta. Beka and Oti(1995) predicted a bias towards lighter hydrocarbons (gas and condensate) from the over-pressured shale as a result of down-slope dilution of organic matter as well as differentiation associated with expulsion from over pressured sources.

Petroleum occurs throughout the Agbada formation of the Niger Delta. However, several directional trends form an “oil-rich belt” having the largest field and lowest gas/oil ratio(Ejedawe, 1981; Evamy et al., 1978; Doust and Omatsola, 1990). The belt extends from northwest offshore area to southeast offshore and along a number of north-south trends in the area of Port Harcourt. It roughly corresponds to the transition between continental and oceanic crust, and is within the axis of maximum sedimentary thickness. Ejedawe(1981) states that the two factors controlling the distribution of petroleum are; an increase geothermal gradient

relative to the minimum gradient in the delta centre and the generally greater age of sediments within the belt relative to those further seaward. Weber (1987) indicates that the oil-rich belt (“golden lane”) coincides with a concentration of rollover structures across depobelts having short southern flanks and little paralic sequence to the south. Doust and Omatsola (1990) suggest that the distribution of petroleum is likely related to heterogeneity of source rock type (greater contribution from paralic sequences in the west) and/or segregation due to remigration.

A) SOURCE ROCK

Based on the volume, organic-matter content and type of the Akata shale, it is believed to be the source rock. However, there has been much discussion about the source rock for petroleum in the Niger Delta (Evamy et al., 1978; Ekweozor et al., 1979; Ekweozor and Okoye, 1980; Lambert-Aikhionbare and Ibe, 1984; Bustin, 1988; Doust and Omatsola, 1990). Possibilities include variable contributions from the marine interbedded shale in the Agbada formation and the marine Akata shale, and Cretaceous shale (Weber and adaukoru, 1975; Evamy et al., 1978; Ejedawe et al., 1979; Ekweozor and Okoye, 1980; Ekweozor and Daukoru, 1984; Lambert-Aikhionbare and Ibe, 1984; Doust and Omatsola, 1990; Stacher, 1995; Frost, 1977; Haack et al., 1997).

The Agbada formation has intervals that contain organic carbon contents sufficient to be considered good source rocks (Ekweozor and Okoye, 1980; Nwachukwu and Chukwura, 1986). The intervals, however, rarely reach thickness sufficient to produce a world-class oil province and are immature in various parts of the delta (Evamy et al., 1978; Stacher, 1995). The Akata shale is present in large volumes beneath the Agbada Formation and is at least volumetrically sufficient to generate

enough oil for a world class oil province such as the Niger Delta. Based on organic-matter content and type, Evamy et al.(1978) proposed that both the marine shale (Akata formation.) and the shale interbedded with paralic sandstone (lower Agbada formation) are the source rocks for the Niger Delta oils.

B) RESERVOIR ROCK

Petroleum in the Niger Delta is produced from sandstone and unconsolidated sands predominantly in the Agbada formation. Characteristics of the reservoirs in the Agbada Formation are controlled by depositional environment and by depth of burial (Tuttle et al., 1999). Known reservoir rocks are Eocene to Pliocene in age, and are often stacked, ranging in thickness from less than 15 meters to 45 meters thickness (Evamy et al., 1978). The thicker reservoirs likely represent composite bodies of stacked channels (Doust and Omatsola, 1990). Based on reservoir geometry and quality, Kulke (1995) describes the most important reservoir types as point bars of distributary channels and coastal barrier bars intermittently cut by sand-filled channels. Edwards and Santogrossi (1990) describe the primary Niger Delta reservoirs as Miocene paralic sandstones with 40% porosity, 2 darcys permeability, and a thickness of 100 meters. The lateral variation in reservoir thickness is strongly controlled by growth faults; the reservoir thickens towards the fault within the down-thrown block (Weber and Daukoru, 1975). The grain size of the reservoir sandstone is highly variable with fluvial sandstones tending to be coarser than their delta front counterparts; point bars fine upward, and barrier bars tend to have the best grain sorting. Much of this sandstone is nearly unconsolidated, some with a minor component of argillo-silicic cement (Kulke, 1995). Porosity only slowly decreases with depth because of the young age of the sediment and the low temperature regime of the delta complex (Tuttle et al., 1999). In the outer

portion of the delta complex, deep-sea channel sands, low-stand sandbodies, and proximal turbidities create potential reservoirs (Beka and Oti, 1995).

C) TRAPS AND SEALS

Most known traps in Niger Delta fields are structural, although, stratigraphic traps are not uncommon (Figure 1.5). The structural traps developed during syn-sedimentary deformation of the Agbada parallel sequence (Evamy et al., 1978; Stacher, 1995). The structural complexity increases from north (earlier formed depobelts), to the south (later formed depobelts) in response to increasing instability of the under compacted overpressured shale. Doust and Omatsola (1990) describe a variety of structural trapping elements, including those associated with simple rollover structures; clay filled channels, structures with multiple growth faults, structures with antithetic faults, and collapsed crest structures. The primary seal rock in the Niger Delta is the interbedded shale within the Agbada formation. The shale provides three types of seals-clay smears along faults, interbedded sealing units against which reservoir sands are juxtaposed due to faulting, and vertical seals (Doust and Omatsola, 1990). On the flanks of the delta, major erosional events of early to middle Miocene age formed canyons that are now clay-filled. These clays form the top seals for some important offshore fields (Doust and Omatsola, 1990).

ii. Stratigraphic traps

These are traps formed due to lateral variation in the lithology of the reservoir rocks, or a break in its continuity. It is due to the character of the material in the reservoir rock and the condition under which it was being deposited. It could be formed when a permeable reservoir rock changes to a less permeable or to an impermeable rock. Stratigraphic traps could also be formed when a reservoir rock is truncated by an unconformity or by original deposition of the strata-like channel sandstone or lift bar, leading to lithologic and stratigraphic variation of the reservoir rock. This changes cause local variation in porosity or termination of reservoir rock up-dip. Stratigraphic traps are not as conspicuous as structural traps on seismic sections due to insufficient acoustic impedance contrast between elements forming the trap.

iii. Combined structural and stratigraphic traps

These are sometimes regarded as the third type of traps. These traps are formed by both structural and stratigraphic trap forming mechanisms. They exhibit both structural and stratigraphic features. Instances include a faulted diapiric stratigraphic trap, salt dome overlying domes and faults compaction anticlines and salt dome-cap rock in reservoir. They are in most cases complex and best trap system.

D) MIGRATION

The process of primary migration is the movement of oil and gas out of the source rocks into the permeable reservoir rocks. Secondary migration is a process by which fluids move within a porous reservoir rock or from one reservoir rock to another. Faults in this case are highly relevant as means by which the fluids can migrate. In Niger delta, the best evidence for the vertical conductivity of major boundary faults is the fact that in most cases the fault intersection with the upper bedding plane of the reservoir functions as the spill point of the accumulation. At the level of the Akata formation, the major growth faults offset a thickness of up to several thousand meters of overpressured shale against paralic sediments in the downthrown block. A plausible migration may thus be from the overpressured shale into and through the fault zone.

CHAPTER THREE

MATERIALS AND METHODS

3.1 AVAILABLE DATA

The available data is the seismic data gotten from Shell Petroleum Development Company under the permission of the Department of Petroleum Resources.

Schlumberger Petrel software E&P platform was used to load and interpret the seismic data.

The objective of seismic data interpretation is to extract all available subsurface information from the processed seismic data, after which structure maps are generated.

3.2 WORKFLOW

The processes involved in the completion of this project work are shown by the flowchart below and further discussed in detail.

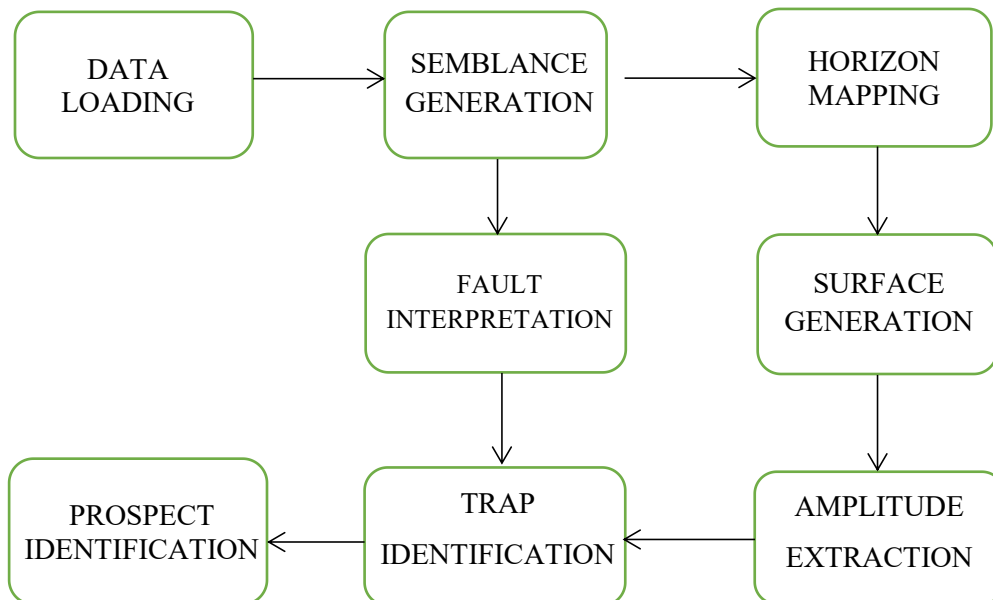


Figure 6: Project workflow

3.2.1 DATA LOADING AND QUALITY

The seismic data obtained from Shell Petroleum Development Company under the permission of the Department of Petroleum Resources was loaded onto Petrel software, after which semblance volume attribute was generated and viewed on a 2D and 3D window before interpretation was done and maps were generated (figure7). The quality of the seismic data used in this project is of satisfactory quality.

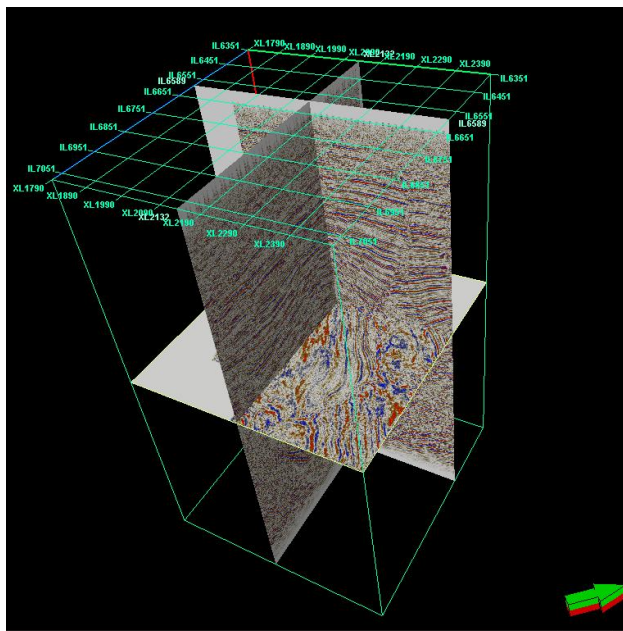


Figure 7: 3D view of study field when data was loaded

3.2.2 SEMBLANCE GENERATION:

This is a process used in the refinement and study of seismic data. The use of this technique along with other methods makes it possible. The volume attribute is usually easier to interpret when trying to deduce the underground structure of an area. The weighted semblance can be used to increase the resolution of traditional

semblance or make traditional semblance capable of analyzing more complicated seismic data.

3.2.3 FAULT MAPPING

Major structures of interest are the faults. Faults can be easily recognized and mapped on the dip lines (rather than strike). A number of factors come into play when fault mapping. These are;

- Discontinuity of events
- Change in dip configuration of horizons not related to stratigraphy
- A change in amplitude across fault
- Distorted dips or inflection of linear structures

3.2.4 HORIZON MAPPING

Horizons: Unlike Faults Horizons are best mapped out on strike lines and dip lines since they are more continuous and lack the frequent discontinuities of faults on the dip line.

On the strike line a good continuous reflector was picked to map out the horizon and give an insight to the structural framework of the area. The choice of strike line is dependent on the degree of noise data, as the noise tends reduce the resolution of the data.

3.2.5 SURFACE GENERATION:

This step involves generating a structured map that shows the selected marker horizon. Using the make and edit tool in the utilities section of the petrel software, structural maps were generated with the horizon interpreted surface.

3.2.6 AMPLITUDE EXTRACTION:

A seismic attribute need in conjunction with the structural map for prospect identification. This is a very important seismic attribute that is usually reported as the maximum (positive or negative) amplitude value at each sample along a horizon picked from a 3D volume..

This is a very important seismic attribute that is usually reported as the maximum (positive or negative) amplitude value at each sample along a horizon picked from a 3D volume. They are generated along a single seismic trace or across multiple traces within a defined window.

3.2.7 TRAP IDENTIFICATION:

Faults were interpreted using the shlumbeger attribute and camera linked 3D and interpretation window on petrel. Trap identification is based on elevation values gotten from the surface. It is a product of both fault and horizon interpretation.

3.2.8 HYDROCARBON PROSPECT IDENTIFICATION

Potential hydrocarbon traps were identified from the contoured map of the horizons (occurring as closures) and amplitude map.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 PRESENTATION OF RESULTS AND DISCUSSION

The interpretation of the 3D seismic data results obtained from SULU field of the Niger Delta led to the identification of potential prospect. The interpretation of the 3D seismic data involved the interpretation of fault and horizon mapping which led to the generation of the surface map for trap identification and amplitude extraction to finally identify a potential prospect. The horizon of interest has been accurately traced continuously across all the strike lines and the dip lines and generated on the map window. The structural map generated clearly highlights the structural configuration as well as the trapping mechanism for hydrocarbon accumulation existing in the field.

4.1.1 FAULT INTERPRETATION

With the use of schlumberger-petrel software nine faults was identified out of which; Fault 1, Fault 2, Fault 3, Fault 4 and Fault 5, Fault 6, Fault 7, Fault 8, Fault 9, were observed, with Fault 1, Fault 2, Fault 3, Fault 4 and Fault 5 being the major faults (figure 7). In interpretation both the 3D window and interpretation window were used to ensure proper delineation of these faults. The 3D window contained the semblance map showing the faults which are continuous thick lines and the interpretation window contains both the Inline and Xline which represents the dip line and strike line (these can be used interchangeably).

interpretation window with the help of a cursor tracker on the semblance map on the 3D window form the interpretation window. As observed, fault 10 is the only antithetic fault in my field of study dipping northwards as shown in figure 9.

4.1.2 HORIZON INTERPRETATION

In interpreting horizon, a continuous reflector was picked on the strike line (since it contains less faults) and traced also traced on the dip line. The quality of the reflection character determines the reliability of such time maps as an indication of the true geologic section. Although the Horizon was interrupted at certain points due to noise recorded during acquisition. It was traced at intervals of fifteen. The structural map of the horizon that was picked is presented in figure 9 below.

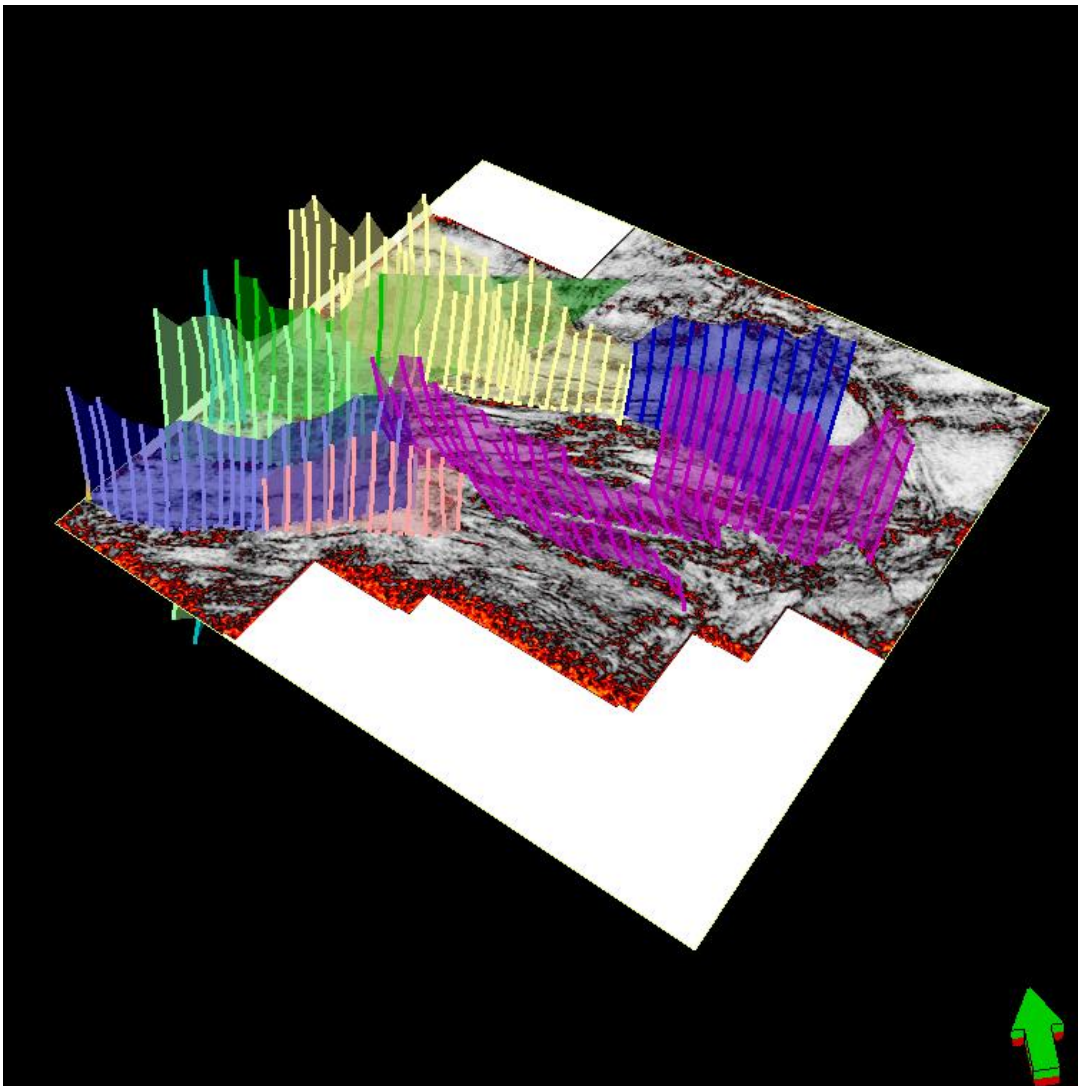


Figure 8: Faults

tracked on semblance map

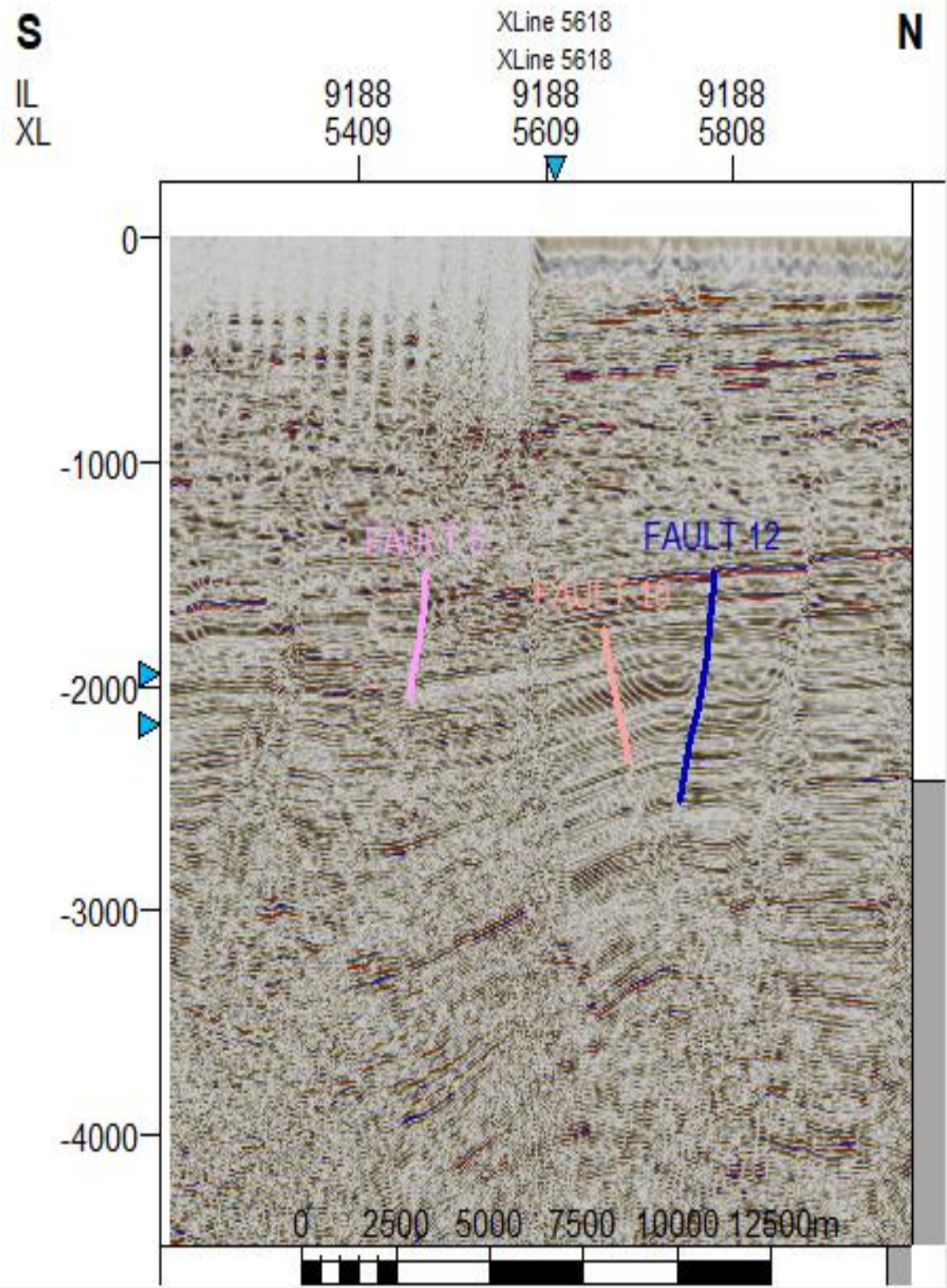


Figure 9 : Antithetic fault (fault 10) on interpretation window

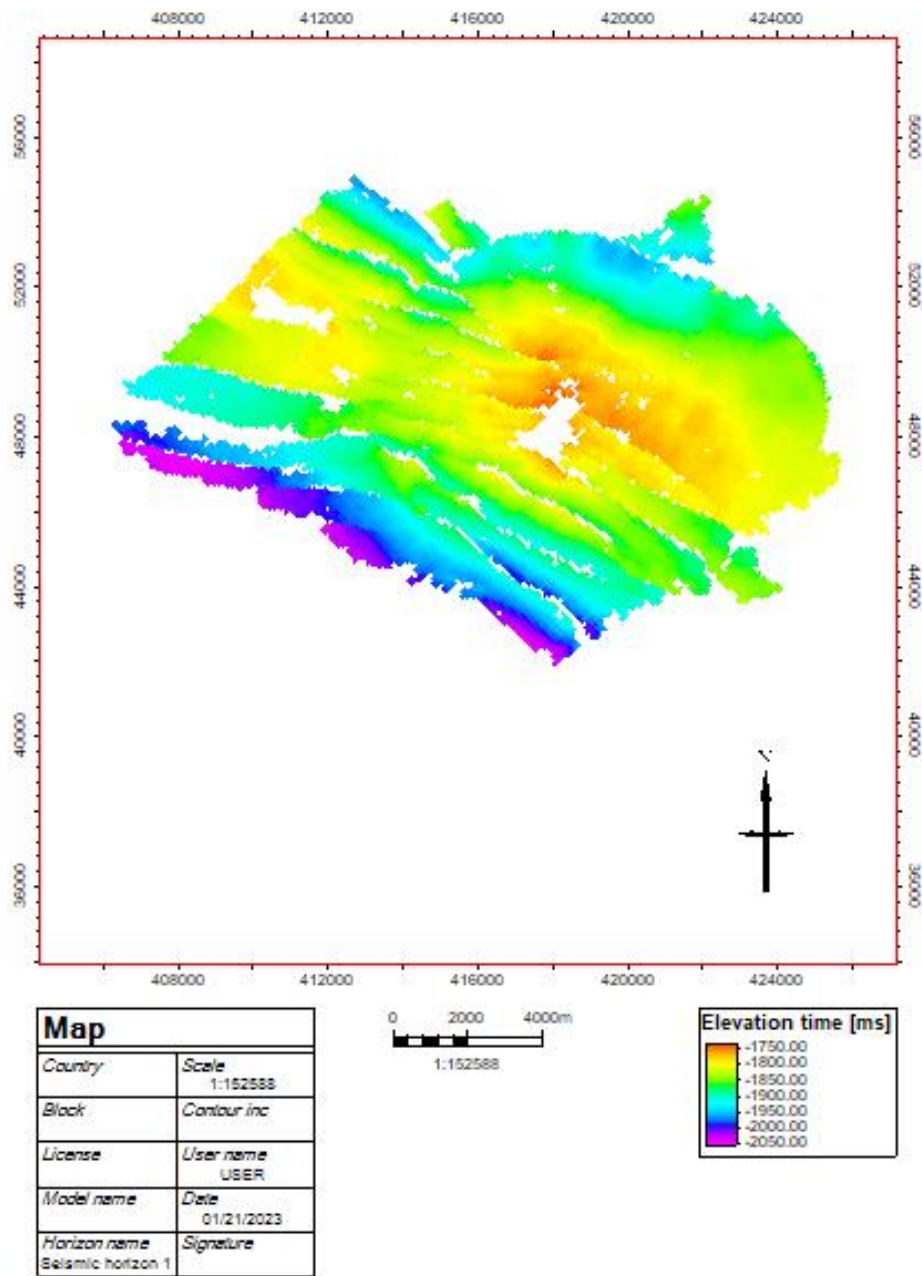


Figure 10: Horizon generation on map window

4.1.3 SURFACE GENERATION

After the interpretation of horizon and structural map generation, a surface was generated in the schlumberger petrel software with the use of the “polygon editing” (to generated a polygon for the surface) and “make surface” option under the “utilities” section in the “seismic interpretation” tool page. The horizon (structural map) generated was the main input in the generation of surface. After surface generating the “polygon editing” tool was then used to generate polygon for the major faults to create a fault geometry on the surface map. A contour map was generated on the surface showing a decrease in elevation towards the south. (figure 10).

4.1.4 TRAP IDENTIFICATION

As a result of fault interpretation and horizon mapping, trap identification comes about. Marked zone A, B and C consist of anticlinal traps. Zone A is close on fault one (F1) which implies fault assisted simple anticlinal traps (also hanging wall traps). On the other hand, zones B and C are simple anticlinal traps.

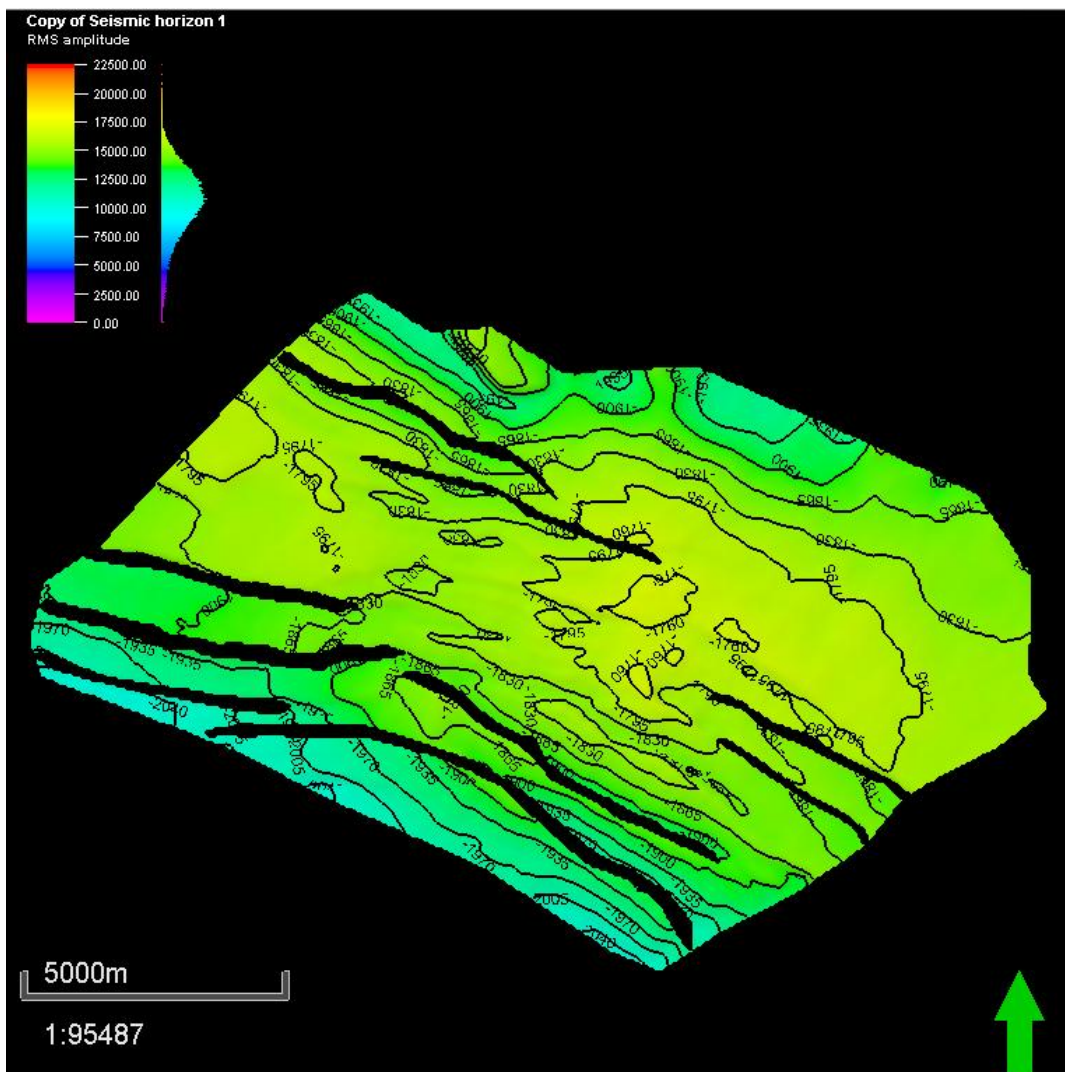


Figure 11: Surface map showing faults and contours

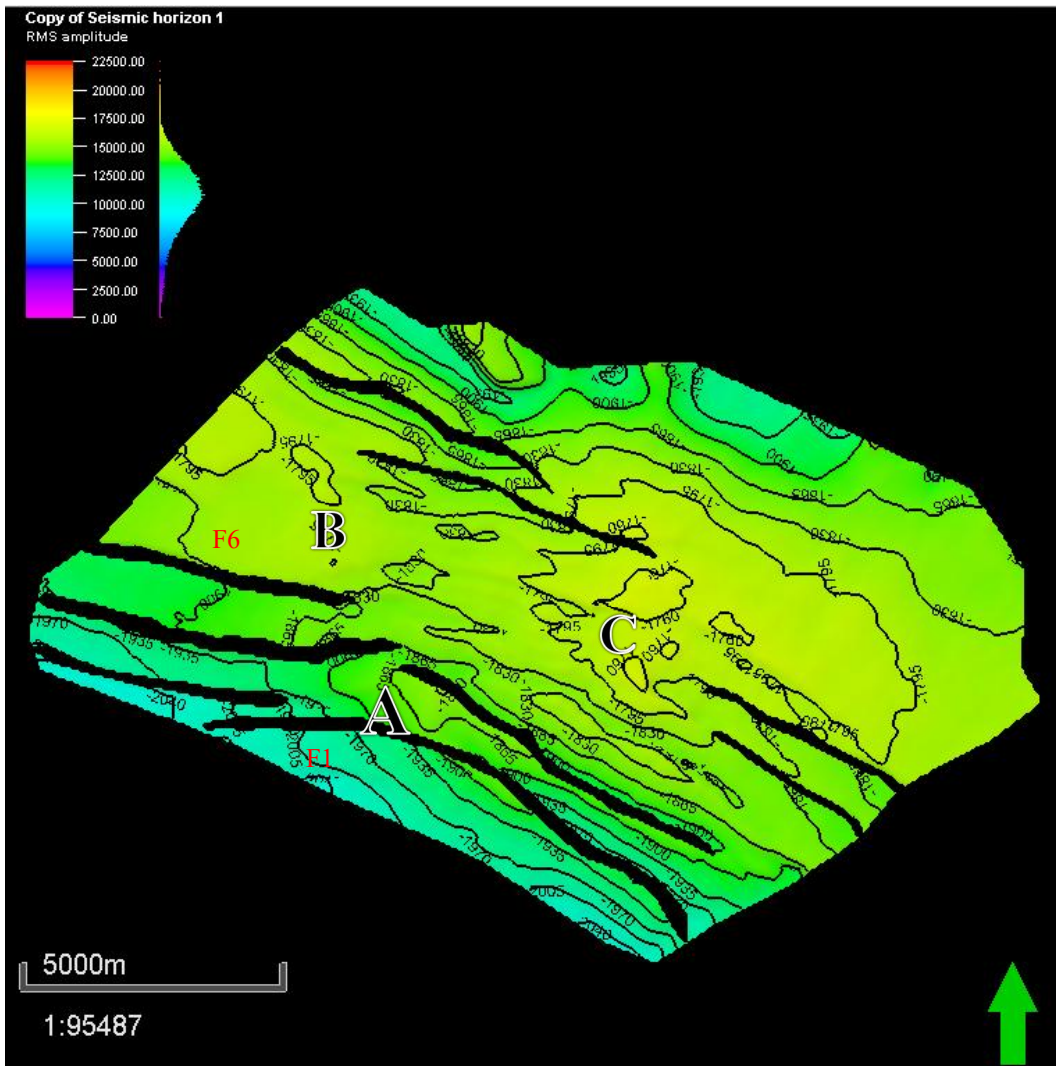


Figure 12: Potential Traps identified on the surface map

4.1.5 AMPLITUDE EXTRACTION

After the generation of the surface map, the Amplitude extraction {Root Mean Square (RMS) Amplitude} is obtained. On the amplitude map on figure13, a concentration of yellow to red patches occur particularly towards the North where lies zone A. These patches indicate potential concentrations of Hydrocarbon in that zone.

4.1.6 PROSPECT RANKING

An interplay of identified traps/ trapping mechanism, Surface generated, contour maps and amplitude extracted, prospects of high confidence and be laid out. Zone A has the highest potential prospect due to consideration of the aforementioned factors.

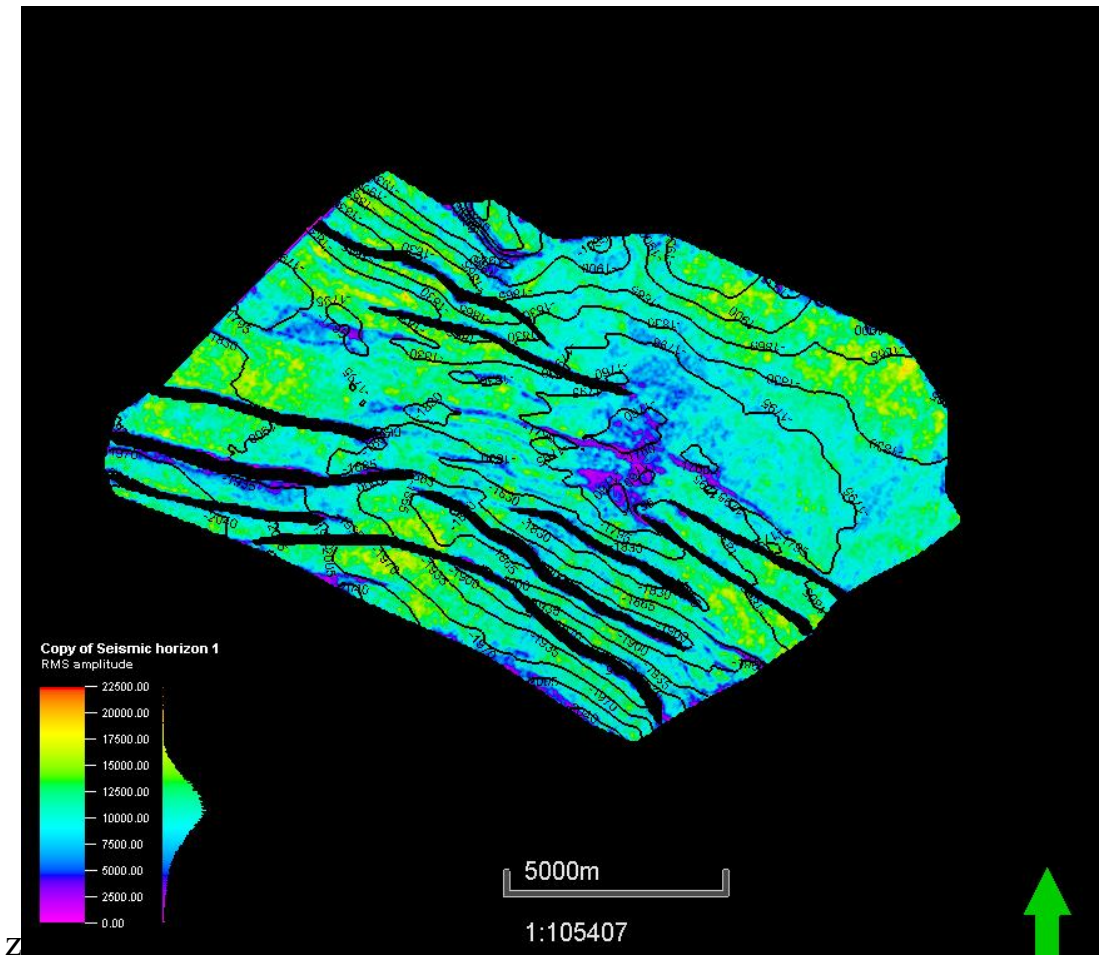


Figure 13: Amplitude extraction on surface map

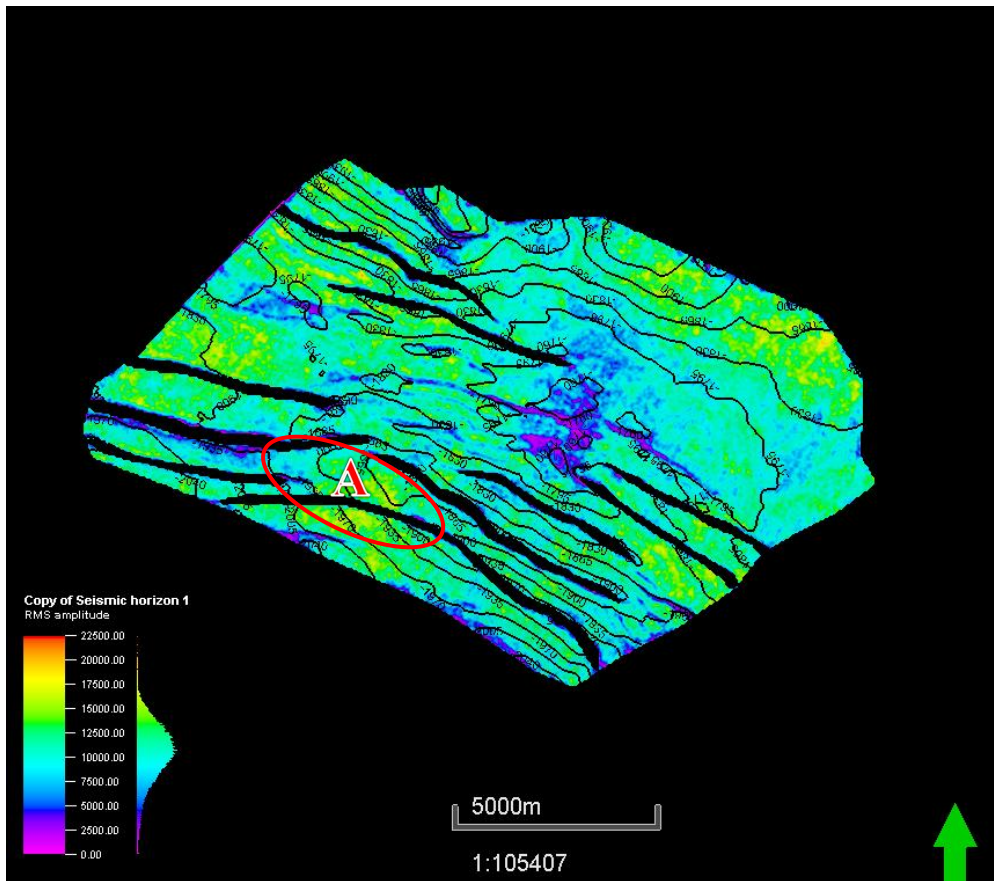


Figure 14: Amplitude supported surface map showing potential prospect

CHAPTER FIVE

SUMMARY, CONCLUSION AND SUGGESTION

5.1 SUMMARY

Based on the subsurface map generated from sulu reservoir, the prospect happens to be a less complex well with a very little potential for exploration of hydrocarbon. More research should be carried out in this well before exploration.

5.2 CONCLUSION

According to the 3D data obtained from SULU Field the interpretation and structural configurations shown areas which could serve as traps. Two structural styles and trapping mechanisms were observed which include simple anticlinal traps and roll over anticlines. Based on these interpreted structures, well data should be acquired to delineate a reservoir rock within the time window of these structures to complete the prospecting.

Fault analysis are also carried out for faults sealing capacity determination and possible leakages.

5.3 SUGGESTION FOR FURTHER WORK

I still think an Amplitude maps should be generated for fluid disparity to know exact location to drill an exploratory well. Knowing that wells to be drilled must be carried out from the crest of the structure.

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