A PROJECT REPORT ON

SUBSURFACE MAPS AND THEIR APPLICATIONS IN THE OIL AND GAS INDUSTRY

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BY

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CERTIFICATION

This is to certify that **EZONG, FAVOUR IWAEDAYI** with matriculation number ENG1503979 carried out a research work titled **THE SUBSURFACE MAPS AND THEIR APPLICATIONS IN THE OIL INDUSTRY** under the supervision of Engr K.O. Bello and that this research work has not been previously submitted for the award of any degree in this or any other university.

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DEDICATION

This project is dedicated to God Almighty my creator, my source of inspiration for his wisdom, knowledge and understanding most especially for making it possible to attain this level of academic pursuit despite all the numerous challenges I have encountered. Also, to my wonderful parents (Mr and Mrs Francis Ezong) for their enormous sacrifices (morally, spiritually and financially) and all others who have contributed positively to my life during the entire period of my education at the University of Benin.

ACKNOWLEDGEMENTS

I thank my Supervisor, Prof. Kelani.O.Bello, for his enthusiasm, support, determination and the guidance he has provided me both as a Supervisor and as a Lecturer, I am extremely grateful.

I also thank my family and friends for their love and support, as well as fellow classmates and other lecturers who have in their respective ways contributed positively to the success of this project as well as other areas of my life as a student throughout the period of my study in the University of Benin.

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ABSTRACT

Seismic interpretation data and applications are the key element of a rapid technological evolution in the remote sensing of the subsurface maps that has resulted in geoscientists movement from data poor to data rich Stewart, S. A. 1999. The proliferation of subsurface data has profoundly affected the productivity of oil exploration of industry within last two decade. This is radically improved of the ability to predict what lies beneath the earth surface, exploration and production.

The objectives of subsurface petroleum geology are to find and develop oil and gas reserves. These objectives are best achieved by the use and integration of all available data and the correct application of these data.

The purpose of subsurface mapping in the geology of petroleum Is to find traps that contain oil and gas pools and the information obtained from wells forms the heart of the data upon which subsurface geology depends, other information are obtained from :

(i) Geophysical surveys. (ii) Pressure and temperature surveys. (iii) The production history of producing oil and gas pools.

The research therefore seeks to characterize the reservoir in the field and determine key reservoir geometric properties across the field. It is also to delineate the extent and limit of the oil reservoir facies which is integrated with paleobathymetry data in inferring the environment of deposition (EOD), and to provide opportunities to new field development.

In this project, the method which can be used for subsurface mapping is majorly the geophysical methods which are used when the depth of exploration is very large, and also when the speed of investigation is of primary importance. These geophysical methods include:

gravitational method, magnetic method, seismic refraction method and electrical resistivity method.

To select the right geophysical method, drilling provides direct information on the subsurface, and ground water sampling allows direct measurement of fluid chemistry. The information acquired is relatively straightforward to interpret and very tangible

CHAPTER ONE

INTRODUCTION

Subsurface mapping involves discussing downhole data, correlations between wells, and how to depict surfaces and three-dimensional units on contour maps. It presents surface maps and geophysical or remote sensing surveys as aids in delimiting important structural and stratigraphic relationships. It also stresses proper correlation and use of borehole information.

Subsurface geological maps are perhaps the most important vehicle used to explore for undiscovered hydrocarbons and to develop proven hydrocarbon reserves. However, the subject of subsurface mapping is probably the least discussed, yet most important aspect of petroleum exploration and development. As a field is developed from its initial discovery, a large volume of well, seismic, and production data are obtained. With these data, the accuracy of the subsurface interpretation is improved through time. The most accurate interpretation for any specific oil or gas field can be prepared only after the field has been extensively drilled and most of the hydrocarbons have been depleted. However, accurate and reliable subsurface interpretations and maps are required throughout all exploration and development activities.

A profitable development of an oil or gas field starts with a good understanding of the subsurface. As part of a subsurface evaluation team the geophysicists and geologists interpret subsurface data and provide geological models that form the basis for development planning. Construction of maps and sections of the subsurface, including integration of seismic and well data, forms an important part of the evaluation. The result should also provide illustration material on which management should be able to make decisions. Computers are frequently used to construct subsurface models and calculate reserve.

At the end of the project one will be able to apply geological concepts, construct maps and sections and validate computer-generated interpretations. One will be able to calculate subsurface volumes and assess their uncertainties. One will develop knowledge on faults dimensions and properties and learn how to perform fault seal analysis. One will acquire practical experience by working on actual field studies in teams.

Subsurface mapping and reservoir characterization has been a major concern in oil and gas industries to adequately estimate reserve; reason is that better reservoir characterization means higher success rates and fewer wells for reservoir exploitation. Thus there is a need to approach this area of interest with more robust interpretation techniques that helps production geologists and reservoir engineers understand reservoir heterogeneities and reduce uncertainties.

BASIC DEFINITIONS

1. Surface mapping: Is a way to visualize various geologic and hydrologic features in any dimension for a 1-D cross section to a 4-D production map.

2. Seismic data: is a method of exploration, geophysics that used the principles of seismology to estimate the properties of the earth subsurface from reflected seismic waves.

3. Seismic interpretation: Is the determination of the geological significance of seismic data.

4. Seismic stratigraphy: Is a technique for interpreting stratigraphic information from seismic data.

1.1. BACKGROUND STUDY

A Geologist is a scientist who studies the solid and liquid matter that constitutes the Earth as well as the processes and history that have shaped it. Geologists usually engage in studying geology. Geologists, studying more of an applied science than a theoretical one, must approach Geology using physics, chemistry and biology as well as other sciences.

Petroleum geology is the utilization of geology in the exploration and exploitation of deposits of petroleum and natural gas. The formation of a commercial deposit of petroleum arises from an influx of petroleum into a reservoir bed which occurs in a trapping situation and is large enough to be exploited at a profit.

Petroleum geology is also the study of origin, occurrence, movement, accumulation, and exploration of hydrocarbon fuels. It refers to the specific set of geological disciplines that are applied to the search for hydrocarbons (oil exploration).

Petroleum geology is principally concerned with the evaluation of seven key elements in Sedimentary Basins: A structural trap, where a fault has contrasted a porous and permeable reservoir against an impermeable seal. Oil accumulates against the seal, to the depth of the base of the seal. Any further oil migrating in from the source will escape to the surface and seep.

The seven (7) key elements that boosts the exploration of oil and gas include:

(i) Source

(ii) Reservoir

(iii) Seal

(iv) Trap

(v) Timing

(vi) Maturation

(vii) Migration

Geology also assists petroleum exploration and exploitation in the analysis of soil rock, basin analysis, production stage etc.

This project report focuses on subsurface structural and mapping methods and techniques and their application to the petroleum industry. These techniques are also important and applicable to other fields of study, and geologists, geophysicists, engineers, and students in related fields, such as mining, groundwater, environmental, or waste disposal, should benefit from this text as well.

Subsurface geoscientists have the formidable task of mapping unseen structures that may exist thousands of meters beneath the earth's surface. In order to accurately interpret and map these structures, the geoscientist must have a good understanding of the basic principles of structural geology, stratigraphy, sedimentation, and other related geological disciplines. The geoscientist must also be thoroughly familiar with the structural style of the region being worked. Since all subsurface interpretations and the accompanying maps are based on limited data, the geologist, geophysicist, or engineer must use:

(1) His or her educational background,

(2) Field and work experience,

(3) Imagination,

(4) An understanding of local structures,

(5) An ability to visualize in three dimensions in order to evaluate the various possible alternate interpretations and decide on the most reasonable, and

(6) Correct subsurface structural and mapping methods and techniques.

1.2. STATEMENT OF PROBLEMS

From regional exploration to a field discovery and through the life of a producing field, many management decisions are based on the interpretations geoscientists present on subsurface maps. These decisions involve investment capital to purchase leases, permit and drill wells, and work over or recomplete wells, just to name a few. An exploration or development prospect generator must employ the best and most accurate methods available to find and develop hydrocarbon reserves at the lowest cost per net equivalent barrel. Therefore, when preparing subsurface interpretations, it is essential to use all the available data, evaluate all possible alternate solutions, use valid structural interpretation methods, and use the most accurate mapping techniques to arrive at a finished product that is consistent with correct geologic models.

All energy companies expect positive economic results through their exploration and development efforts. Some companies are more successful than others. Many factors lead to success, including advanced technology, aggressive management, experience, and serendipity. A significant underlying cause of success that is often overlooked or taken for granted, however, is the quality of subsurface structural and mapping methods.

Improving the quality of subsurface structural and mapping methods which should positively affect any company’s economic picture can be accomplished by:

1. Developing the most reasonable subsurface interpretation for the area being studied, even in areas where the data are sparse or absent.

2. Generating more accurate and reliable exploration and exploitation prospects (thereby reducing associated risk).

3. Correctly integrating geological, geophysical, and engineering data to establish the best development plan for a new field discovery.

4. Optimizing hydrocarbon recoveries through accurate volumetric reserve estimates.

5. Planning a more successful exploration or development drilling program, or preparing a recompletion and workover depletion plan for a mature field.

6. Accurately evaluating and developing any required secondary recovery programs.

1.3. AIMS AND OBJECTIVES

1.3.1. AIM

The aim of this study is to provide fundamental principles of common methods of subsurface exploration, with special emphasis on the application of geophysical prospecting methods to interpretation of subsurface structure in depth.

1.3.2. OBJECTIVES

The objectives of subsurface petroleum geology are to find and develop oil and gas reserves. These objectives are best achieved by the use and integration of all available data and the correct application of these data. This project covers various aspects of geoscience interpretation and the construction of subsurface maps and cross sections based upon data obtained from well logs, seismic sections, and outcrops. It is concerned with correct structural interpretation and mapping techniques and how to use them to generate the most reasonable subsurface interpretation that is consistent with all the data.

1.4. SCOPE

The scope of this project is limited to subsurface maps used in the exploration of oil and gas in the oil and gas industry.

1.5. LIMITATIONS

The limitations include the fact that in subsurface mapping, specialized equipment is required (compared to more conventional subsurface exploration tools). Also, in geophysical testing, results are generally interpreted qualitatively and therefore useful results can only be obtained by an experienced engineer or geologist familiar with the particular testing method.

1.6. SIGNIFICANCE OF THE STUDY

Reservoir properties are mapped to promote optimal field development. Subsurface maps dictate well placement and enable engineers to calculate reserves and monitor trends in reservoir performance. Geologists play a key role in subsurface mapping by using interpretations of depositional environment and diagenetic events to project reservoir data away from relatively few wells control points. In this sense, subsurface mapping is in great contrast to geological mapping of the earth's surface. Whether using traditional concepts or "high technology" computer contouring hardware/software systems, mapping interwell areas places a premium on interpretation rather than straightforward plotting of precise data.

CHAPTER TWO

LITERATURE REVIEW

In the Niger Delta province, we have identified one petroleum system-the Tertiary Niger Delta (Akata-Agbada) petroleum system. The delta proper began developing in the Eocene, accumulating sediments that now are over 10 kilometers thick. The primary source rock is the upper Akata Formation, the marine-shale facies of the delta, with possibly contribution from interbedded marine shale of the lowermost Agbada Formation. Oil is produced from sandstone facies within the Agbada Formation, however, turbidite sand in the upper Akata Formation is a potential target in deep water offshore and possibly beneath currently producing intervals onshore. Known oil and gas resources of the Niger Delta rank the province as the twelfth largest in the world. To date, 34.5 billion barrels of recoverable oil and 93.8 trillion cubic feet of recoverable gas have been discovered. In 1997, Nigeria was the fifth largest crude oil supplier to the United States, supplying 689,000 barrels/day of crude.

The history of the formation of the Tertiary Niger Delta (Akata-Agbada) petroleum system is summarized in the events chart (fig. 2.1).

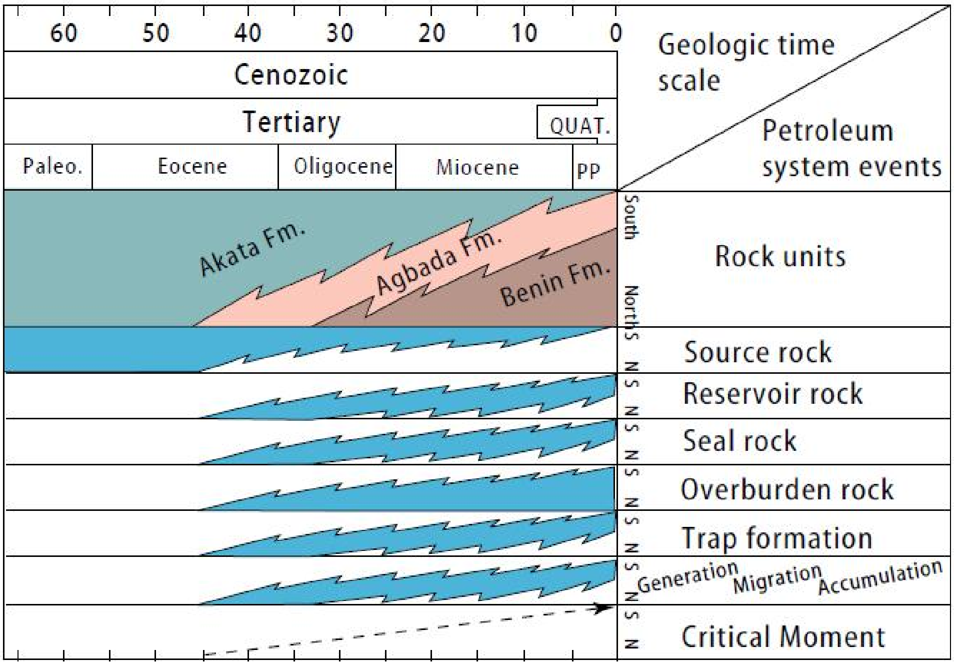


Figure 2.1: Events chart for the Niger Delta (Akata/ Agbada) Petroleum System

Rocks within the petroleum system are from Paleocene to Recent in age. Most of the petroleum is sourced from the Akata Formation, with smaller amounts generated from the mature shale beds in the lower Agbada Formation. Deposition of overburden rock began in the Middle Eocene and continues to the present. Units include the Agbada and Benin Formations to the north with a transition to the Akata Formation in the deep-water portion of the basin where the Agbada and Benin Formations thin and disappear seaward. Petroleum generation within the delta began in the Eocene and continues today. Generation occurred from north to south as progressively younger depobelts entered the oil window. Reservoirs for the discovered petroleum are sandstones throughout the Agbada Formation. Reservoirs for undiscovered petroleum below currently producing intervals and in the distal portions of the delta system may include turbidite sands within the Akata. Trap and seal formation is related to gravity tectonics within the delta. Structural traps have been the most favorable exploration target; however, stratigraphic traps are likely to become more important targets in distal and deeper portions of the delta.

In year 2011 Mohd Fauzi Hamid and Wan Rosli Wan Suleiman of the Department of Petroleum Engineering Faculty of Petroleum & Renewable Engineering University Technology Malaysia talked about fundamentals of Petroleum Engineering in relation with Geology and Exploration and they talked about parameters controlling petroleum appearance in which they talked about the source rock, reservoir rock, traps, migration of petroleum, entrapment of petroleum.

Also in year 1999 Ione L. Taylor a U.S geological surveyor talked about the petroleum product life cycle in relation to geology in which a gave series of explanation in which from the explanation in his notes he was able to give the diagram below

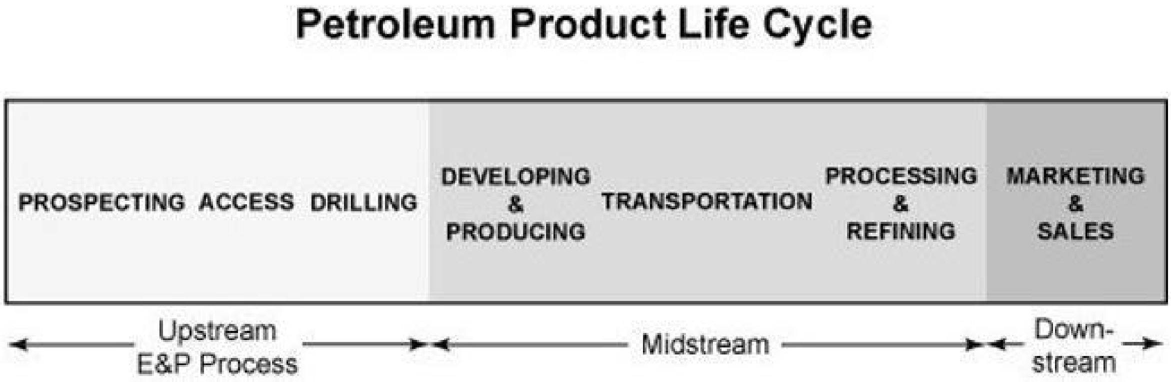


Figure 2.2: petroleum product life cycle

He also said that the majority of the geoscientists employed in the search for oil and gas falls under three categories:

- Geologist (understanding the rocks).
- Geophysicist (interpreting the sub-surface structure or configuration through gravity, seismic etc.).
- Geochemist (understanding the sub-surface fluids like petroleum).

In which in this report we would be focusing on the geochemist, the geochemists are employed by oil exploring and producing companies because of their expertise in applying earth science to predict sub-surface conditions and processes at work in sedimentary basins that form the “hydrocarbon habitat” for oil and gas deposits.

2.1. TYPES OF SUBSURFACE MAPS

There are many types of subsurface maps, such as:

2.1.1 Structural Maps and Sections

Subsurface structures may be mapped on any formation boundary, unconformity, or producing formation that can be identified and correlated by well data. Structure may be shown by contour elevation maps or by cross-sections.

2.1.2. Facies Maps

There are several kinds of facies maps, but the most common type used in petroleum geology is "Lithofacies Maps" which distinguish the various lithologic types rather than formation.

2.1.3. Geophysical Maps

These maps depend on geophysical anomaly (such as local variations or irregularity in the normal pattern) which after correction may be attributed to some geologic phenomena.

2.1.4. Geochemical Maps

These maps are used for mapping various kinds of chemical analysis of rocks and their fluid contents. It may show the surface distribution of hydrocarbons where those hydrocarbons are found at the surface in large amounts than normal indicating that there is a seepage of oil or gas.

2.1.5. Isochore Maps

The Maps which are lines joining points of equal vertical thickness. So isochore maps record the vertical thickness of geological units .These maps illustrate such features as the depth of overburden above some deposits ,or the real variations in the vertical thickness of some concerted unit .

2.1.6. Isopach Maps

Isopach maps are contour maps that indicate the thickness of rock layers and layering of subsurface materials. They display the stratigraphic thickness between an upper and lower horizon. It is measured as the shortest distance between the two surfaces. Isopach maps provide a more accurate picture of stratigraphic thickness, because it reflects the thickness of the deposited bed.

2.2. STRUCTURE CONTOUR MAPS

A structure contour is an imaginary line connecting points of equal elevation(a contour) on a single surface, such as the top of a formation. Structure-contour maps are analogous to topographic maps.

2.3. CROSS SECTIONS

They represent the geologic data as maps but in the vertical view. There are several types of cross-sections but the most common in Petroleum Geology are as follows:

- **Correlation Cross-Sections:**

They are the first figures to be drawn in the first phase of exploratory drilling and they enable the geologist to decide stratigraphic equivalences between the wells.

- **Structural Cross-Sections:**

They show the present structural altitudes of rocks in relation to sea level as a horizontal datum.

- **Stratigraphic Cross Sections:**

They show the correlation of strata with respect to one of them selected as a horizontal datum.

2.4. THE GEOLOGY OF NIGER DELTA

The Niger Delta Basin, also referred to as the Niger Delta province, is an extensional rift basin located in the Niger Delta and the Gulf of Guinea on the passive continental margin near the western coast of Nigeria with suspected or proven access to Cameroon, Equatorial Guinea and São Tomé and Príncipe. This basin is very complex, and it carries high economic value as it contains a very productive petroleum system. The Niger delta basin is one of the largest sub-aerial basins in

Africa. It has a sub aerial area of about 75,000 $\boldsymbol{km^2}$, a total area of 300,000 $\boldsymbol{km^2}$, and a sediment fill of 500,000 $\boldsymbol{km^3}$. The sediment fill has a depth between 9– 12 km. It is composed of several different geologic formations that indicate how this basin could have formed, as well as the regional and large scale tectonics of the area. The Niger Delta Basin is an extensional basin surrounded by many other basins in the area that all formed from similar processes. The Niger Delta Basin lies in the south westernmost part of a larger tectonic structure, the Benue Trough. The other side of the basin is bounded by the Cameroon Volcanic Line and the transform passive continental margin.

2.4.1. Basic formation

The Niger Delta Basin was formed by a failed rift junction during the separation of the South American plate and the African plate, as the South Atlantic began to open.

Rifting in this basin started in the late Jurassic and ended in the mid Cretaceous. As rifting continued, several faults formed many of them thrust faults. Also at this time syn-rift sands and then shales were deposited in the late Cretaceous. This indicates that the shoreline regressed during this time. Concurrently, the basin had been undergoing extension resulting in high angle normal faults and fault block rotation. At the beginning of the Paleocene there was a significant shoreline transgression. During the Paleocene, the Akata Formation was deposited, followed by the Agbada Formation during the Eocene. This loading caused the underlying shale Akata Formation to be squeezed into shale diapirs. Then in the Oligocene the Benin formation was deposited, which is still being deposited today. 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, caused by the thickened crust. Moving basinward is a transition zone, and a contraction zone, which lies in the deep sea part of the basin.

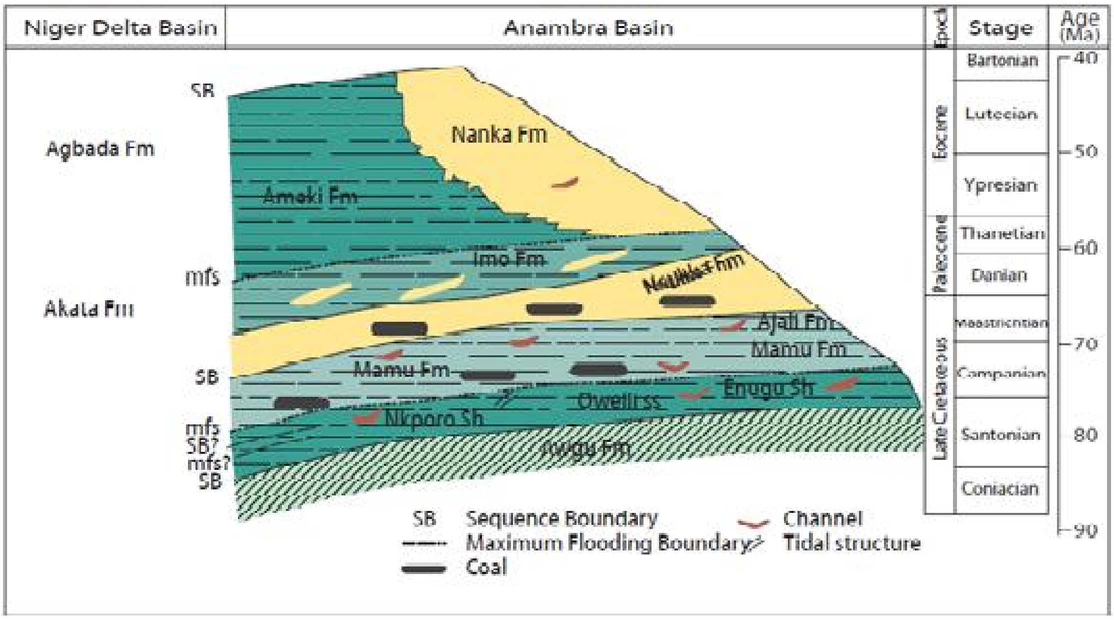


Figure 2.3: Stratigraphic section of the Anambra basin from the late cretaceous through the Eocene and time equivalent formations in the Niger Delta. Modified from Reijers and others, 1997.

2.4.1.1. Lithology

The sediment fill in the Niger Delta basin is characterized by three major depobelts. These three cycles show that the basin experienced an overall regression throughout time as the sediments go from deep sea mud sized grains to fluvial denser sand sized grains. The lithologies of the area experience changes due to several factors. The sediment provenance from the onshore highlands which feed into the delta control the mineralogy of the grains. Additionally, the impact of sea level on sediment deposition is well known; relative sea level will control the basinward extent of lithologies. Volcanic activity in the area may also result in thin deposits of ash (bentonite). The early Cretaceous sediments are thought to be from a tide-dominated system that were deposited on a concave shoreline, and throughout time the shoreline became convex and it is currently a wave-dominated system.

2.4.1.2. Basement

The oceanic basement rock is the oldest rock in the basin and is basaltic in composition. Also, closer to the coast Precambrian continental basement crops out onshore.

2.4.1.3. Akata formation

The Akata formation is at the base of the Niger Delta basin.The Akata Formation is Paleocene in age. It is composed of thick shales, turbidite sands, and small amounts of silt and clay. The clay content resulted in it being a ductile shale formation which was squeezed into shale diapirs in the basin. The Akata Formation formed during lowstands in relative sea level and anoxic conditions. This formation is estimated to be up to 7,000 meters thick.

2.4.1.4. Agbada formation

The Agbada Formation dates back to Eocene in age. It is a marine facies defined by both freshwater and deep sea characteristics. This is the major oil and natural gas-bearing facies in the basin. The hydrocarbons in this layer formed when this layer of rock became sub-aerial and was covered in a marsh-type environment rich in organic content. It is estimated to be 3,700 meters thick.

2.4.1.5. Benin formation

Benin formation is composed mainly of massive and highly porous fresh water bearing sandstones with some thin interbeds of shale. The formation is mineralogically made up of feldspar and quartz. The Benin Formation is Oligocene and younger in age. It is composed of continental flood plain sands and alluvial deposits. It is estimated to be up to 2,000 meters thick.

2.4.2. Tectonic Structure

The tectonic structures in the Niger Delta Basin are typical of an extensional rift system, but the added shale diapirism due to loading makes this basin unique. The main method of deformation is gravitational collapse of the basin, although the older faulting and deformation in the basin are related to the continental breakup and rifting of the African plate and South American plates.

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.

2.4.3. Basin inversion

Basin inversion is caused by uplift and/or compression in this basin. The compression is caused by the toe detachment of the shale diapirs. Basin inversion forms anticline structures, which serve as a great oil trap. Clay smears in the sediments seal the formations so oil does not escape out.

2.4.4. Shale diapirs

The shale diapirs are from the Akata Formation. This structure is formed due to the improper dehydration of the formation and the over pressuring by the overlying and denser Agbada Formation.

2.4.5. Petroleum

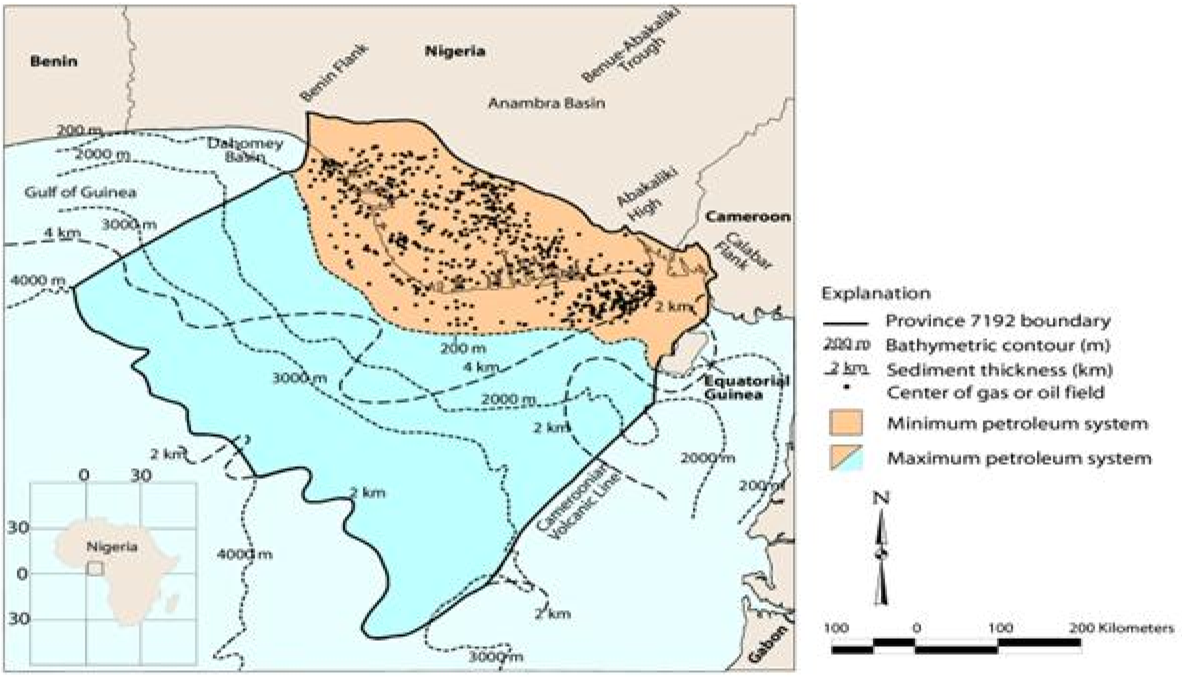


Figure 2.4: Index map of Nigeria and Cameroon; map of the Niger Delta showing province outline (maximum petroleum system); bounding structural features; minimum petroleum systems as defined by oil and gas field center points (data from petroconsultants, 1996a); 200,2000,3000,4000m bathymetric contours; and 2 and 4km sediment thickness.

The Niger Delta Basin produces around 2 million barrels of oil per day. The entire system is predicted to contain 34.5 billion barrels of oil and 94 trillion feet3 of natural gas. This area is still very heavily explored by oil companies today. It is one of the largest oil producers in the world.

CHAPTER THREE

RESEARCH METHODOLOGY

The contents of this report were found through internet search, news reports, research works, text books, and other similar research areas cross referencing geology with petroleum exploration and exploitation and also with the continents of focus in this topic which are Africa, Europe and the United States Of America, most of the results were personal research works and some institutions and also some governmental organisations e.g. EAGE (European associates of geoscientists & engineers), AAPG (American Association of Petroleum Geologists) etc. and also all the document placed in this report are gotten without illegal act.

3.1. PETROPHYSICS/ SEISMIC INTERPRETATION DATA

Petrophysics is the study of physical and chemical rock properties and their interaction with fluids. A major application of petrophysics is in studying reservoirs for the hydrocarbon industry. Petrophysicists are employed to help reservoir engineers and geoscientists understand the rock properties of the reservoir, particularly how pores in the subsurface are interconnected, controlling the accumulation and migration of hydrocarbons. Some of the key properties studied in petrophysics are lithology, porosity, water saturation, permeability and density. A key aspect of petrophysics is measuring and evaluating these rock properties by acquiring well log measurements – in which a string of measurement tools are inserted in the borehole, core measurements – in which rock samples are retrieved from subsurface, and seismic measurements. These studies are then combined with geological and geophysical studies and reservoir engineering to give a complete picture of the reservoir**.** Interpreting seismic data requires an understanding of the subsurface formations and how they may affect wave reception.

3.1.1. Method of analysis

Coring and special core analysis is a direct measurement of petrophysical properties. In the petroleum industry rock samples are retrieved from subsurface and measured by core labs of oil company or some commercial core measurement service companies. This process is time consuming and expensive, thus can not be applied to all the wells drilled in a field.

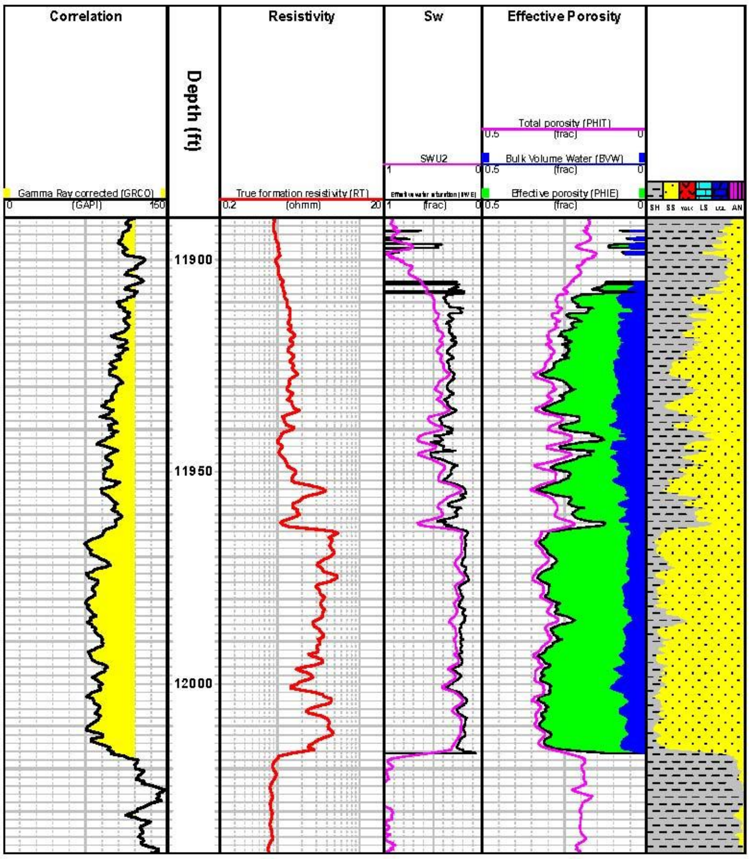


Figure 3.1: Wireline logs with different tracks

Well Logging is used as a relatively inexpensive method to obtain petrophysical properties downhole. Measurement tools are conveyed downhole using either wireline or LWD method.

An example of wireline logs is shown in Figure 3.1. The first “track”, shows the natural gamma radiation level of the rock. The gamma radiation level “log” shows increasing radiation to the right and decreasing radiation to the left. The rocks emitting less radiation have more yellow shading. The detector is very sensitive and the amount of radiation is very low. In clastic rock formations, rocks that have smaller amounts of radiation are more likely to be coarser grained and have more pore space, rocks with higher amounts of radiation are more likely to have finer grains and less pore space.

The second track over in the plot records the depth below the reference point which is usually the Kelly bush or rotary table in feet, so these rocks are 11,900 feet below the surface of earth.

In the third track, the electrical resistivity of the rock is presented. The water in this rock is salty and the salt in the water causes the water to be electrically conductive such that lower resistivity is caused by increasing water saturation and decreasing hydrocarbon saturation.

The fourth track, shows the computed water saturation, both as “total” water (including the water bound to the rock) in magenta and the “effective water” or water that is free to flow in black. Both quantities are given as a fraction of the total pore space.

The fifth track shows the fraction of the total rock that is pore space, filled with fluids. The display of the pore space is divided into green for oil and blue for movable water. The black line shows the fraction of the pore space which contains either water or oil that can move, or be “produced.” In addition to what is included in blackline, the magenta line includes the water that is permanently bound to the rock.

The last track is a representation of the solid portion of the rock. The yellow pattern represents the fraction of the rock (excluding fluids) that is composed of coarser grained sandstone. The gray pattern represents the fraction of rock that is composed of finer grained "shale." The sandstone is the part of the rock that contains the producible hydrocarbons and water.

3.2. USE OF SEISMIC IN CONSTRUCTING STRUCTURE ISOPACH MAPS

Isopach maps show by means of contours the varying thickness of the rock intervening between two reference planes commonly bedding planes or surfaces of unconformity. Isopach maps offer a simple method of showing the distribution of a geological unit in three-dimensions (3D) thickness of individual formations of reservoir rocks of groups of formations of intervals between unconformities.

Isopach Maps are used to:

- Determine the time of faulting and folding.
- The time of traps formation in regional studies.
- Development of a pool, especially in showing the thickness of the pay formation.

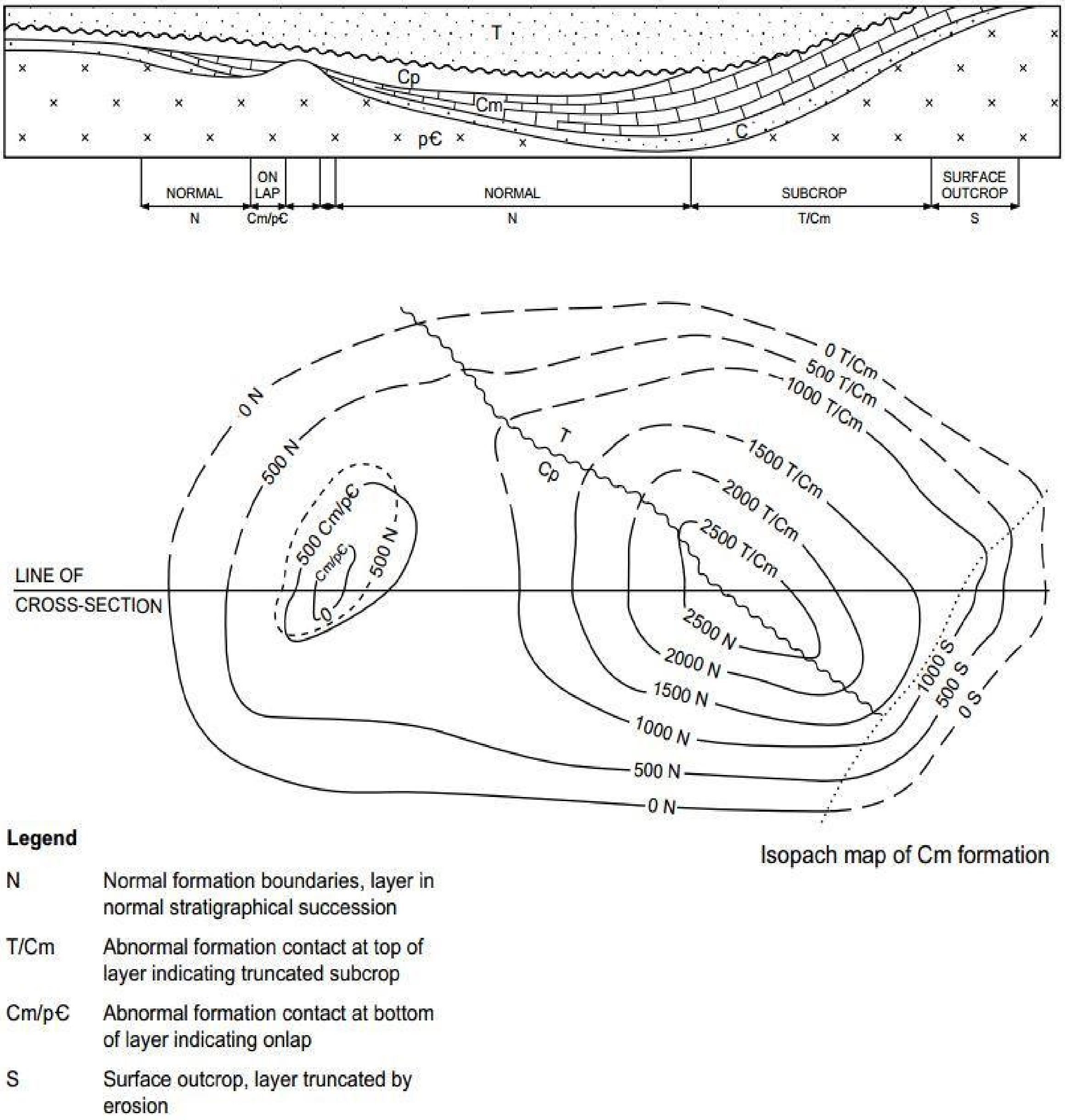


Figure 3.2: A typical isopach map

Thus, An isochore and isopach map are the same only when both the top and bottom surfaces of the layer shown are horizontal. When the layer shown is inclined, as is usually the case, the thicknesses displayed in an isochore map of the layer will be greater than the thicknesses displayed in an isopach map of the same layer. Unfortunately the terms isopach and isochore are widely confused, and many times maps of True Vertical Thickness (TVT), which by definition are isochore maps, are incorrectly labeled isopach maps.

3.2.1. Use of Log in constructing Isopach/Isochore maps

To construct an isopach map from borehole logs, one locates the top and bottom of the stratigraphic unit on a given log, subtracts the lesser depth from the greater, and plots the resulting thickness on a map. Repetition for each of the available logs generates the data that are then contoured on the map.

3.3. METHODS

Geophysical methods are used when the depth of exploration is very large, and also when the speed of investigation is of primary importance. These geophysical methods include: gravitational method, magnetic method, seismic refraction method and electrical resistivity method. Typically, the main geophysical methods used by engineering geologists are electrical resistivity

GEOPHYSICAL methods of exploring the subsurface have proved their worth for preliminary surveys in connection with many of the problems encountered in civil engineering. These rapid and relatively inexpensive methods have been used to explore foundation conditions at proposed sites for buildings, bridges, and large dams, to classify excavation materials in highway grading operations, to determine the depth of swampy materials, to investigate proposed tunnel sites, to study potential and existing slide conditions, and to locate and outline supplies of construction materials such as sand, gravel, solid rock, and other special geologic formations of engineering importance.

In conclusion, it can be stated that both seismic and resistivity tests are capable of providing dependable information when used in subsurface exploration studies for many of the problems associated with high way and other civil engineering construction.

The earth-resistivity test is probably the better of the two methods in that it is faster and has wide application to air of the problems involving the shallow tests; while the seismic refraction test is of greatest use for the deeper tests to locate a rigid, dense medium, such as solid rock.

In the light of the foregoing discussion, it **is** evident that both methods may be used jointly to explore a given subsurface condition, one to corroborate the results obtained with the other. This procedure is followed in the work done-by BPR, the seismic test being used to obtain a rapid check on the accuracy of the indications from the more-rapidly made resistivity survey. The resistivity test is particularly adapted to prospecting for construction materials while the seismic test has only a limited value for such work. Use of these geophysical tests in conjunction with presently employed methods of direct exploration should result in a considerable saving of time and expense in future explorations of the subsurface and make possible a better, more-economical design of engineering structures.

3.4. SEISMIC ATTRIBUTES

3.4.1. Application of seismic attributes

All instantaneous seismic attributes (amplitude, phase, frequency) can be used in interpretation. In practice, most interpreters use instantaneous amplitude, or some variation of an amplitude attribute, as their primary diagnostic tool. Amplitude is related to reflectivity, which in turn is related to subsurface impedance contrasts. Thus, amplitude attributes provide information about all the rock, fluid, and formation-pressure conditions listed in Geological influences on acoustic impedance which include:

- **Geologic Condition**

Impedance Effect

- **Lithological interfaces**

A common cause of impedance contrasts. Generally p and V change whenever there is a change in lithology.

- **Porosity variations**

p and V are porosity dependent. Gradual changes in porosity generate modest impedance contrasts. Abrupt changes in porosity can create large reflection coefficients.

- **Changes in pore fluid**

Pore-fluid density affects bulk density p and velocity V. A change of pore fluid from water to oil creates a small impedance contrast that can be detected seismically only in ideal signal-to-noise conditions. A change from liquid (either water or oil) to gas can produce large impedance contrasts and robust seismic reflections.

- **Overpressure**

p and V decrease in overpressure zones. If the onset of overpressure is gradual, the impedance contrasts may be too small to create detectable seismic reflections. Abrupt onsets of overpressure can produce strong reflections.

- **Cementation**

Cementation affects the mechanical strength of rocks. V generally increases as mechanical strength increases (assuming a constant rock type). In some instances, variations in cementation can create impedance contrasts sufficient to result in seismic reflections.

Instantaneous phase is useful for tracking reflection continuity and stratal surfaces across low-amplitude areas where it is difficult to see details of reflection waveform character. In general, instantaneous phase is the least used of the seismic attributes.

Instantaneous frequency sometimes aids in recognizing changes in bed thickness and bed spacing. Anomalous values of Instantaneous frequency (negative values or unbelievably high positive values) are particularly useful for recognizing:

Edges of reservoir compartments

Subtle faults

Stratigraphic pinchouts

Hardage demonstrated these applications of Instantaneous frequency.

CHAPTER FOUR

ANALYSIS OF RESULT AND DISCUSSION

CASE STUDY: ENENA FIELD, OFFSHORE NIGER DELTA

An integrated approach using, seismic and geological information was employed for the mapping and evaluation of the S30, T40, U50 and V60 reservoirs of the Enena field for estimation of the reservoir properties, fluid distribution, and 3D modeling. This research focuses on the integration of petrophysical and structural data to develop an algorithm through Guassian random function simulation for static modeling. The resultant static model was then used for volumetric distribution of the field. The resultant 3D static model shows that S30, T40 and V60 reservoir have a STOOIP of 51.3, 15.1 and 17.1MBO respectively with recoverable reserves of 18, 5.3 and 6 MBO assuming a primary recovery factor of 0.35 and 33.5, 9.8 and 11.1 MBO using a 2P recoverable reserve of 0.65. The GIIP was estimated to be 28, 8 and 9 BCF of gas and the recoverable reserves shows a P1 of 18.2, 5.2 and 5.85 MBO at a recoverable reserve of 0.65 and a 2P of 22.4, 6.4 and 7.2 MBO at a recoverable reserve of 0.8 was estimated. STOOIP and GIIP was not calculated for the U50 reservoir because despite the thick/ good sand package as seen on the GR log, the reservoir was found to be completely water wet. The S30 reservoir is found to be the most prolific both in the oil and gas case. The individual sands and their sub-units are separated by thick to thin shales. It was also estimated that the natural drive mechanism of the Enena field is the water drive and recommended for marginal field operators.

4.1. FAULT INTERPRETATION

Fault Interpretation Majorly, the structures identified (Fig. 4.1) are rollovers and normal faults which are majorly synthetic, listric and downthrowing towards the same direction and also consistent but the few antithetic faults identified were not consistent. Fault interpretation was picked on every 10th inline and crosslines, a total of ten (10) faults were picked and coloured differently but only four (4) were consistent with two (2) major consistent fault (F1 and F3) and two (2) minor consistent faults (F6 and F9).

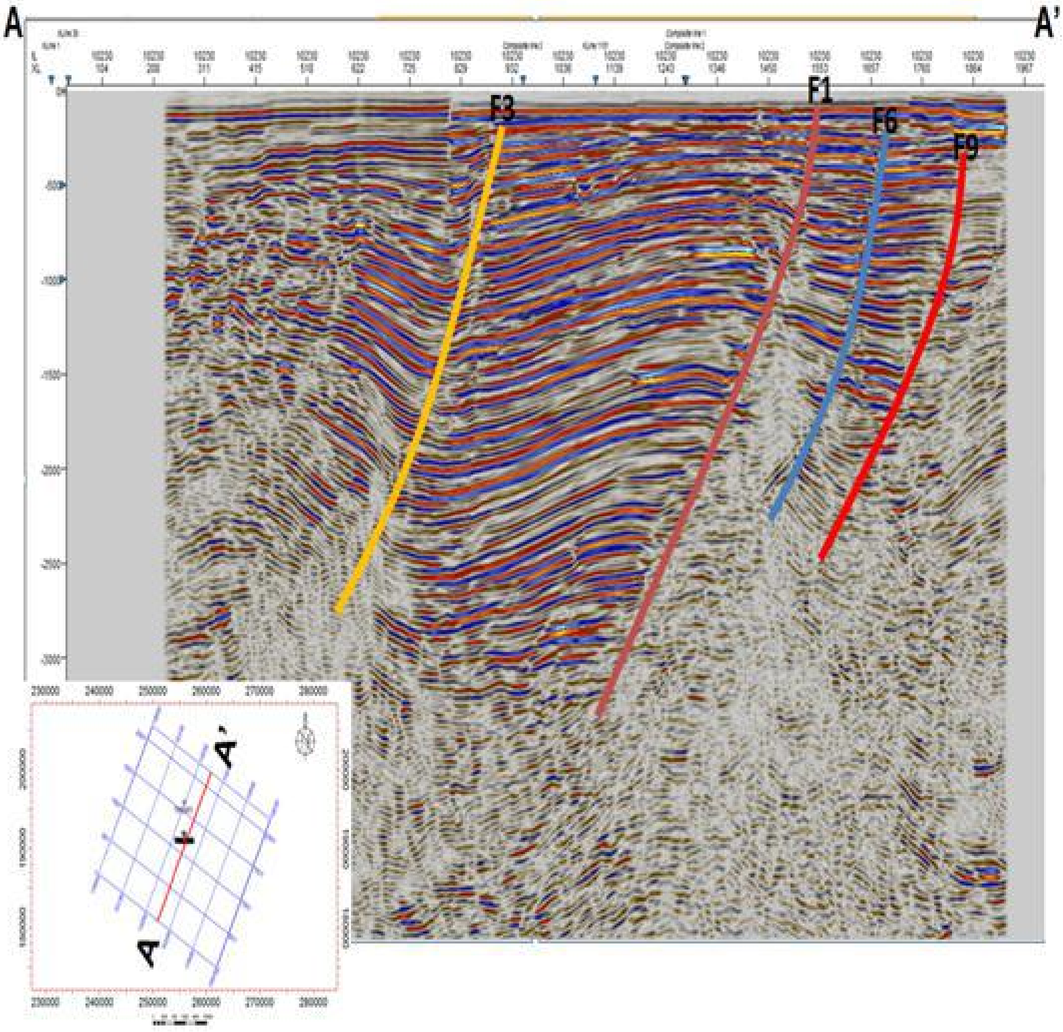


Fig 4.1: Fault framework of Enena field showing the rollover structures, normal, listric and synthetic faults (structure with multiple growth faults)

4.2. STRUCTURE MAPS TIME STRUCTURE MAPS

Time structure map and RMS (Root Mean Square) amplitudes (Fig. 4.2) was generated to show high amplitude zones also, the RMS amplitude map complements the structural map by highlighting prospective zones. After the time structural map was generated, a lookup function (Fig. 4.3) was generated and used to make the depth structure map.

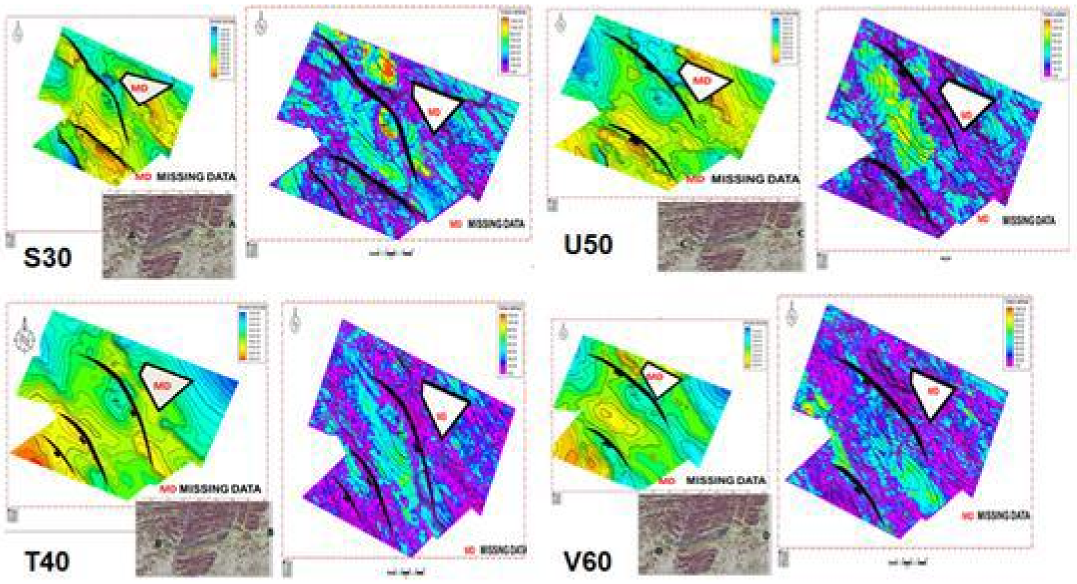
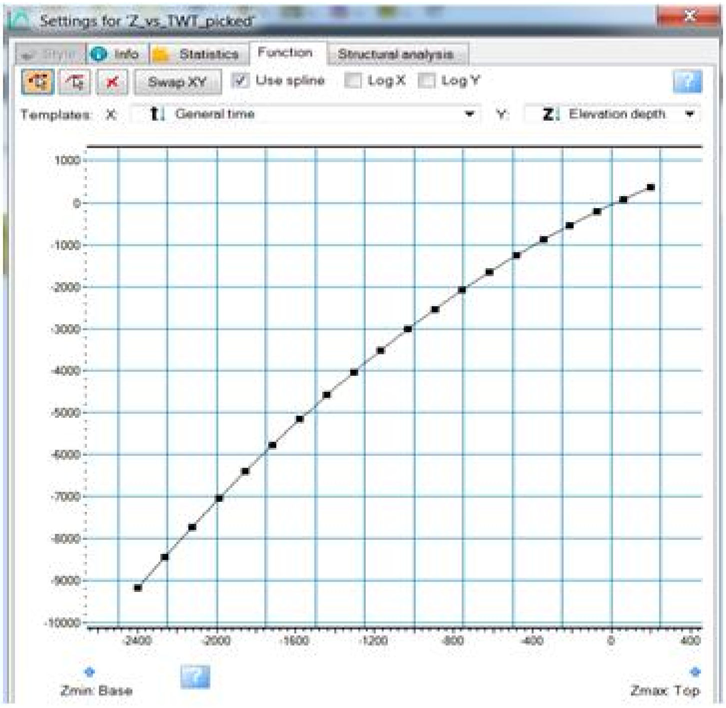


Figure 4.2: Time and RMS structure maps



Settings for 'Z_vs_TWT_picked'

☑ Use spline ☐ Log X ☐ Log Y

Templates: X: General time Y: Elevation depth

Figure 4.3: Look up function developed and used for time structural map conversion to depth structural map

4.3. DEPTH STRUCTURE MAPS

The depth structural map was derived from the structural framework (fault and Horizon) of Enena field after which the look up function (Fig. 4.3) was applied to convert the time structure map to depth structure map. The depth structure map (Fig. 4.4) shows the various highs, lows (structures) and faults. From the map, it shows that the field is a rollover structure with multiple growth faults, fault dependent with no four way dip closure and as such, the growth faults serves a trap that that prevents seepage of hydrocarbon. The structures are proven to contain hydrocarbon. The depth structural map for was used to calculate hydrocarbon by creating a polygon around the prospective zone highlighted by the RMS amplitude attribute, the zone was then divided into discovery, prospects and leads (Fig. 4.4).

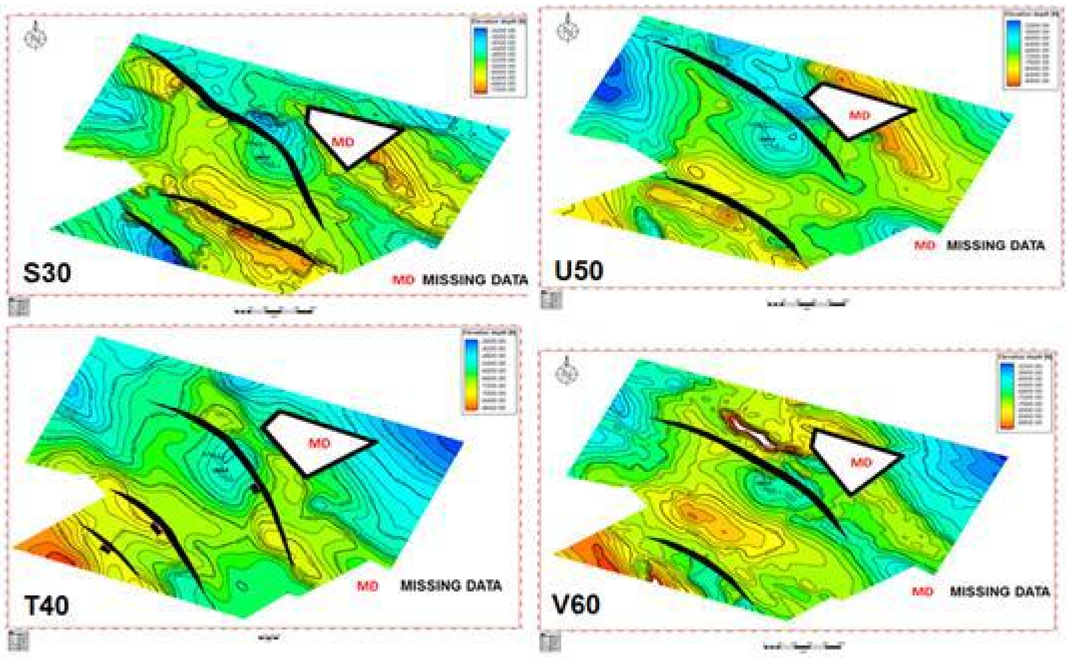


Figure 4.4: Depth Structure Map

4.4. PROPERTY MODELING

The S30 reservoir is proven to be hydrocarbon bearing with a good sand thickness and a relatively good NTG. Since the effective porosity and water saturation of each well per depth within the reservoir was given, it was interpreted using the property model to determine that the porosity within the reservoir ranges from 0.09 to 0.38 (Fig. 4.5), water saturation ranges from 0.4 to 1, pore volume ranges from 200 t0 10,000 *106 rm3 and STOIIP ranging from 200 to 9200 *106sm3 (Fig. 4.6). The T40 reservoir is proven to be hydrocarbon bearing with a good sand thickness and a relatively good NTG. The reservoir was interpreted using the property model to determine that the porosity within the reservoir ranges from 0.5 to 30 (Fig .4.5), water saturation ranges from 0.4 to 1, pore volume ranges from 0 to 10,000 * 106rm3 and STOIIP ranging from 0 (water wet) to 9200 *106sm3 (Fig. 4.7). The V60 reservoir is proven to be hydrocarbon bearing with a good sand thickness and a relatively good NTG. The reservoir was interpreted using the property model to determine that the porosity within the reservoir ranges from 0.05 to 0.29 (Fig. 4.5), water saturation ranges from 0.45 to 1, pore volume ranges from completely water wet to 10,000 * 106rm3 and STOIIP ranging from 0 (water wet) to 9200 *106sm3 (Fig. 4.8). Estimation from the model shows that reservoir V60 does not as much hydrocarbon in commercial quantity as reservoir S30 and T40.

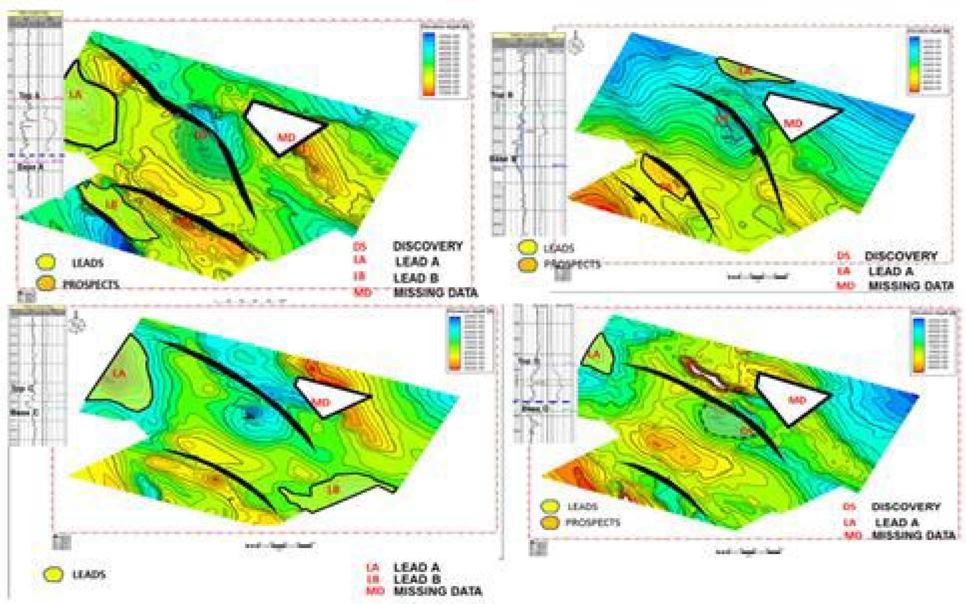


Figure 4.5: Identified Discovery, Prospects and Leads

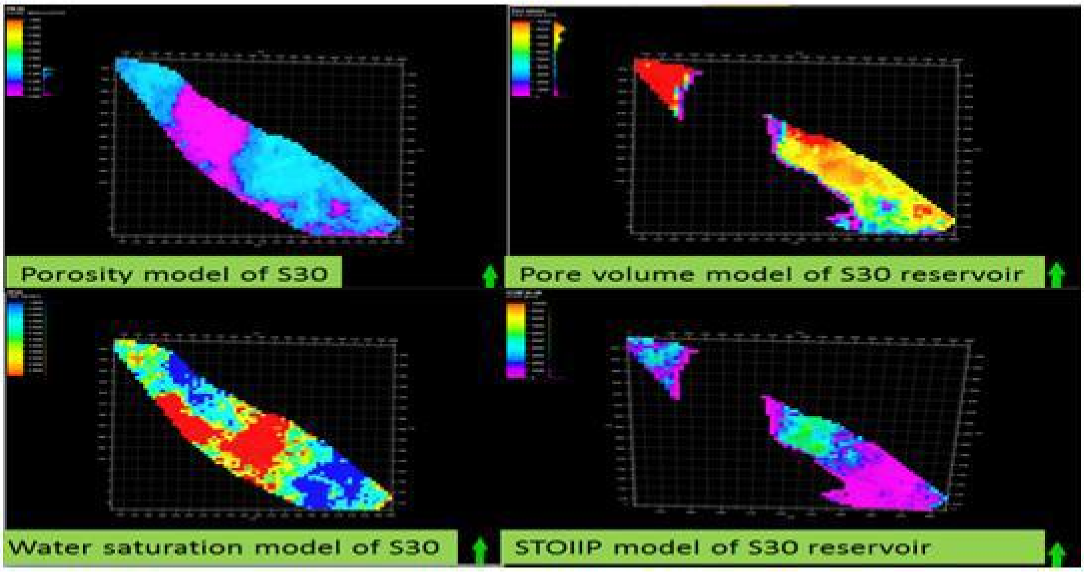


Figure 4.6: Property distribution of S30 reservoir

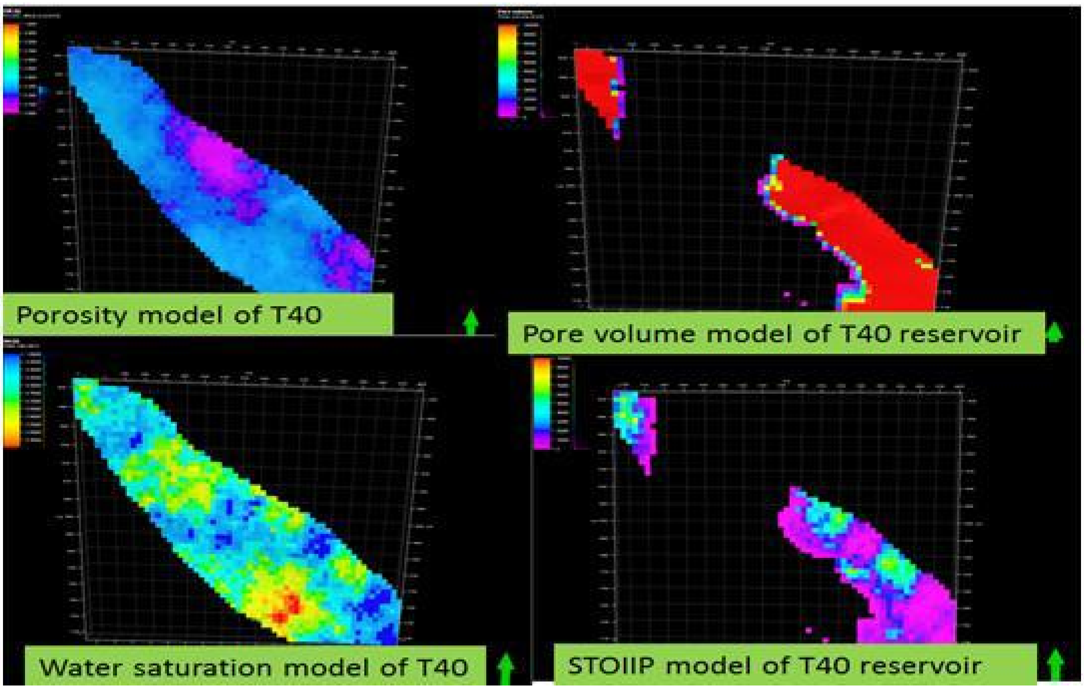


Figure 4.7: Property distribution of T40 reservoir

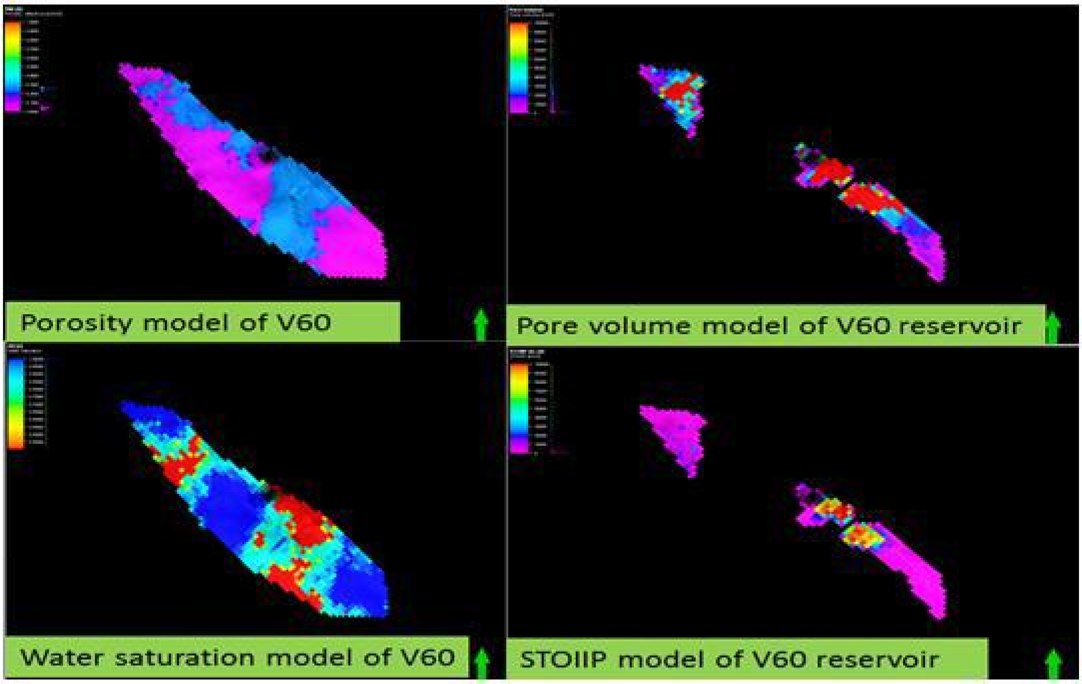


Figure 4.8: Property distribution of V60 reservoir

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0. Conclusion and recommendations

Based on the research concerning the different types of subsurface maps used in the exploration of oil and gas, the most commonly used are the isochore and isopach maps and are preferable to others.

5.1. Conclusions

The isopach maps display the stratigraphic thickness between an upper and lower horizon. It is measured as the shortest distance between the two surfaces.

Isopach maps provide a more accurate picture of stratigraphic thickness, because it reflects the thickness of the deposited bed.

The importance of the isopach maps in the evaluation of the reservoir is that isopach maps offer a simple method of showing the distribution of a geological unit in three- dimensions (3D) thickness of individual formations of reservoir rocks of groups of formations. The isopach maps give information pertaining to formation thickness and they follow all normal rules for maps in general.

An isochore map is a map which is used to predetermine the drilling depths of wells and locate the structures buried in regions where formation becomes thinner over certain structural crests.

The importance of the isochore maps is that they measure the thickness from a point on the upper surface straight down to the corresponding point on the lower surface. It means subtracting the difference in vertical distance between upper and lower surfaces.

Isochore maps are similar to isopach maps due to their thickness; however, isochore maps describe distinct methods for displaying the variations in thickness within the layer. The difference between the two types of thickness maps is that isochore maps exhibit equal thickness in the layers while isopach maps do not.

Both isochore and isopach maps show the thickness between two mapped surfaces but differ in how the thickness is measured. The thickness in isopach maps is measured perpendicular to the boundaries of the layer whereas in isochore maps, it is measured vertically.

5.2. Recommendations

Because of the numerous importance of the isopach and isochore maps, it is recommended to introduce trainings for more understanding of creating or constructing isopach maps, and how to apply in terms of locating the presence of oil in any subsurface. For instance, **To construct an** isopach map **from borehole logs, one locates the top and bottom of the stratigraphic unit on a given log, subtracts the lesser depth from the greater, and plots the resulting thickness on a** map**. Repetition for each of the available logs generates the data that are then contoured on the** map**. More platforms should be created for the use of isopach maps in oil industries thereby making it acceptable globally.**

From the research, interpreting these maps manually(by hand) is simple and easy to understand but it cannot be used for complex situations which may give rise to difficulty in handling the situation at a certain point and accurate information or data may not be completely available concerning a particular subsurface region. So with this kind of circumstance, it is necessary to introduce software which can interpret maps of large and complex regions with different information and characteristics.

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