Science and Technology 2013, 3(4): 127-135
DOI: 10.5923/j.scit.20130304.06

Construction and Interpretation of Structural Map Using Seismic Reflection Times in Location of Prospective Hydrocarbon Trap

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Abstract Geophysical investigation of the subsurface structure at Mapi, Niger Delta area was carried out by the construction and interpretation of structural maps using Seismic reflection times. Surfer 8.0 software was used for the structural interpretation to prepare the contour map from seismic reflection times, with a view to identify surface location of prospective geologic traps containing hydrocarbon. The acquired seismic reflection time data from Mapi field was computed into the surfer 8 software and the structural map was generated, showing all the contours. The map showed that the geological formation mapped is upfolded, downfolded, dipped gently and tipped steeply in different areas. This indicates that the topography of the sedimentary bed is not of a particular type. Two anticlines were seen in two areas of the map (high contour closed) labeled A and B in red. These anticline structures are prospective traps to be test drilled. The study showed that anticline B is more prospective than anticline A because B is larger in size and deeper than A. The surface location of tops of the anticline A and B are indicated by red dots, the position coordinates are respectively A (424272, 205337) and B (427257, 203995). Also the study revealed a steeply dipping potion of the sedimentary bed shown by closely spaced group of contours decreasing toward the northern part of the map, this is also a target. This steeply dipping feature suggests an indication of position of tilted and faulted part of the formation. To minimize drilling risk, exploratory well could be located on anticline B first, to test the predicted stratigraphy of oil and gas accumulation.

Keywords Structural Maps, Surfer 8.0 Software, Anticlines, Sedimentary Bed, Mapi Field

1. Introduction

Seismic interpretation is the scientific analysis of seismic data, which lead to appropriate inference of the geology structures at depths within the earth structures. The interpretation process in this work is divided into three interrelated categories: Structural, Stratigraphic and lithologic analysis[1].

The structural seismic interpretation is directed towards the development of structural maps of the subsurface from the observed 3-dimensional arrival times of the seismic waves. On the other hand, the seismic sequence stratigraphic interpretation relates the processed reflection patterns to a model of cyclic episode of depositions which are applied to accurately provide lithologic interpretation in relation to fluid pores, porosity, density, and flow directions.

In order to effectively interpret the 3D seismic data, some essential procedures need to be followed such as base map studies, study of the initial processed data, fault mapping, heave calculation, depth contour from which the reservoir and fluid contact can be identified from a reliable geologic session[1].[2], carried out an integrated structural, seismic facies and stratigraphic study conducted in the Fabi field, onshore western Niger Delta, and targeted at improving the present understanding of the structural development, sequence stratigraphic history, paleo-depositional environm ents and hydrocarbon reservoir potential of the field. 3-D seismic section, check shot data, five wireline logs and core data were analyzed and utilized in the study to ensure the construction and interpretation of structural map where the use of seismic reflection times was engaged in the location of prospective hydrocarbon trap.

1.1. Location of Study Area

The study area is situated within the Niger Delta Basin, which is located in continental margin of Gulf of Guinea in equatorial West Africa , between latitude 3° N and 6° N and longitude 5° E and 8° E .Geographically, Niger Delta is located at some part of Western Nigeria and Eastern Nigeria. It is a fan-shaped piece of land, which covers part of Port-Harcourt province of River State in the Eastern Nigeria and Southern of the Delta province in the Western Nigeria. These are interconnecting channels, which open the area to

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Published online at http://journal.sapub.org/scit

the Atlantic by several mouths. These discharge large tones of water and sediments into the sea.

1.2. Geology of Study Area

The Niger Delta, where oil and gas are predominantly trapped in sandstones and unconsolidated sands in the Agbada formation, ranked among the world's major hydrocarbon provinces[3]. The study area falls within the Niger Delta of Nigeria. Niger delta is made up of quaternary rocks. The oldest sediments in the delta areas of Nigeria are of Albion age. The main rocks are shale, sandstone and limestone. These rocks are overlain conformably by cenomanian and younger upper cretaceous sediments. These deposits are believed to have been laid down during a predominantly marine depositional cycle in three stages. The first stage consists of a phase of folding, faulting and uplift occurring in santonian time as observed mainly in the areas of Abakaliki Anticlinorium.

The second stage of deposition took place during the companion to Maestrichtian, when the formation of the proto Niger Delta took place. The second depositional cycle ended with major Paleocene marine transgression which terminated the advance of proto delta, thus separating it stratigraphically from the modern Delta. The modern Niger Delta was formed during the third cycle of deposition. It began in the Eocene and continues into present time.

The Niger front is generally composed of shale and clays. In the Niger Delta there is high pressure shale that has led to the diapiric structure. Shale generally does not compact when loading neither do they compact following the loading of the Delta. This high pressure shale have been contracted to make diapiric flowage to compensate for the pressure. The enormous mass of the Akata formation underlying the fluviatile deposit is under compacted and over pressured. Loading of this clay or shale substratum by the overburden has created an instability which is accommodated by diapiric flowage,[4]. Subsurface Analysis of Fluvial Sandstone Bodies using well logs and 3D seismic dataset has been done[5]. The fluvial sandstone reservoirs of interest within the study area of these formations were examined by using 3D seismic and well log data.

Interpreted 3-D seismic reflection data (seismic section) and well logs to study the structural configuration of "Sam's Field" onshore Niger Delta has been carried out[6]. Favorable trapping systems that could be diagnostic of possible hydrocarbon accumulation were located in the field.

The proliferation of 3-D Seismic technology is one of the most exciting developments in the earth sciences over the past century. According to[7], 3-D reflection data provide interpreters with the ability to map structures and stratigraphic features in 3-D detail to a resolution of a few tens of meters over thousands of square kilometers. It is a geological "Hubble", whose resolving power has already yielded some fascinating (and surprising) insights and will continue to provide a major stimulus for research into geological processes and products for many decades to come.

[8], outlined that the use of 3-D seismic interpretation and visualization in today's industry, has become pervasive in exploration and development. All modern 3-D interpretation systems and many well path planning systems use 3-D visualization as the base display for the interaction required to conduct the work at hand.

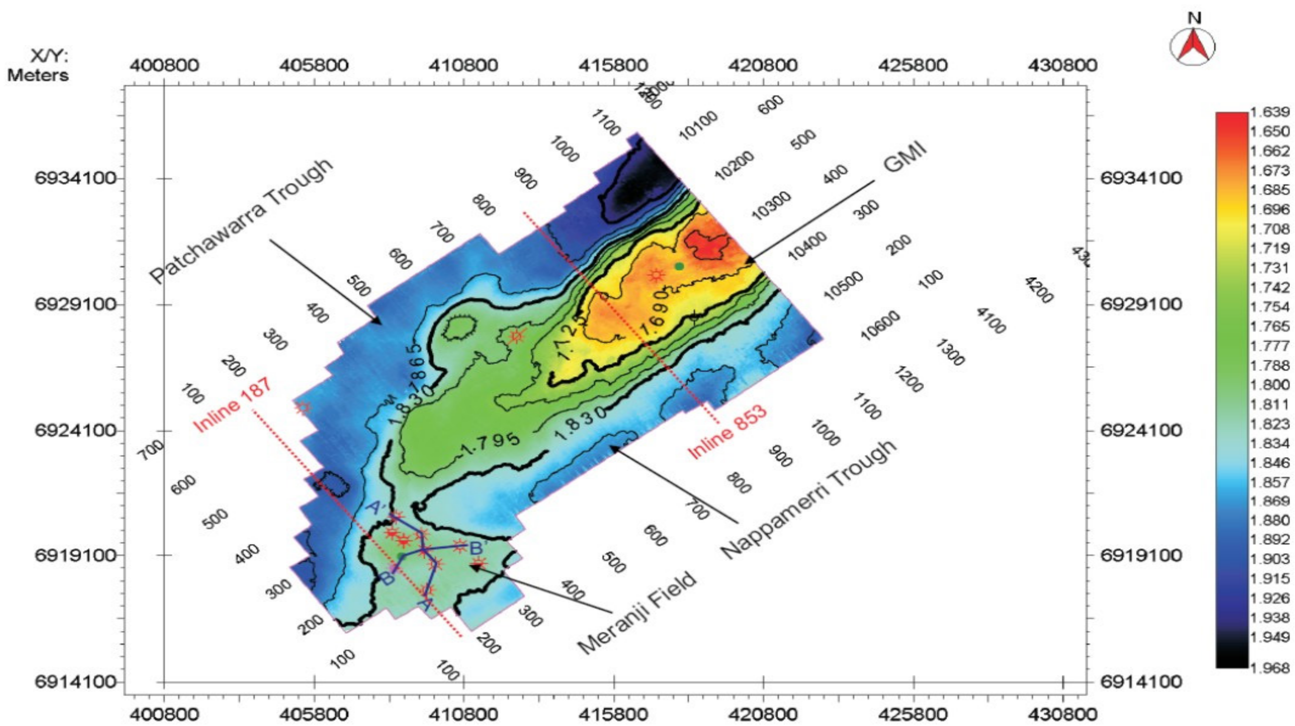

Figure 1. Time-structure map showing the major structural elements of the study area

The Epsilon and Toolachee formations consist of fluvial, deltaic, and shoreface deposits. The fluvial sandstone reservoirs of interest within the study area of these formations were examined by using 3-D seismic and well log data. In engineering geology, the greatest application of seismic method is in search for geological structure favorable to oil accumulation[9; 10]. Although, some use has been made of gravity and magnetic observations, which respond to changes in rock density and magnetization respectively, it is the seismic method that is by far the most widely used geophysical technique for subsurface mapping[10]. Seismic method is by far the most important geophysical technique in terms of expenditures and number of geophysicists involved. Its predominance is due to high accuracy, high resolution, and great penetration[11].

Detailed interpretation of seismic sections and seismic time, strata and proportional slices through flattened and un-flattened 3D volumes, along with seismic facies analysis, horizon mapping, and attribute extractions, allow detailed analysis of the Pliocene-Quaternary fluvial systems.

The model encompasses a 3D detailed structural framework, including essential stratigraphic units and related faults, and improves on the initial regional subsurface model 'NCP-1'. Rock and fluid parameters and 3D burial history analysis are being used to perform a petroleum systems analysis. The offshore area is subdivided into seven regions along the outlines of major Mesozoic structural elements. The regions are being modeled separately and will then be combined into one composite model for the entire offshore area.

Interpretation of 3D and 2D seismic surveys provides input for mapping the major stratigraphic units and 3D fault systems. Stratigraphic interpretations of available wells aid in the identification of horizons in the seismic data. Faults are only interpreted when they can be traced over a substantial distance and have resulted in a significant offset of the horizons they affect. The compilation of all faults and horizons into a single 3D model is an important and elaborate part of the modeling process.

2. Methodology

With the Data acquired, showing the Seismic reflection times was converted from a Time Data to a Depth Data using Time to Depth conversion chat. The corresponding depths computed on the Surfer 8.0 software and the contiur map produced. Seismic map present the shape and form of geological formation top or bottom. It makes visible the area where geologic traps might be located and the high area of the traps, where and gas might be accumulated. Structural interpretation is done by constructing contour map of the horizons of interest.

Arrival times or depths at the shot points are the data used for constructing contour map. The techniques for obtaining data for seismic contouring is by marking horizon of interest on selected seismic sections with color pencil at each shot point or convenient point on the horizon (the point should be directly below the shot number). Time the reflection by reading the timing lines. Conversion of the reflection time to depth was carried out. The reflections time or depths by the x-y coordinate of the shot points on the base map (location map) was tabulated. Engaging surfer 8.0 in the computer contouring, the x, y, z data are entered into the program for automatic contouring.

2.1. Contour Map Interpretation

2.1.1. Interpretation by Inspection

The techniques used to determine the shape of the subsurface – configuration by inspection of a constructed contour map is:

1. High contour closed, going completely round some area on a map indicate up-folded subsurface. The top of the feature is seen by a ring contour with no other contour inside it. Oil and gas may be collected in the high area, and a well may be located in the high area enclosed.
2. Two or more separated sets closed contours on map shows alternate high and low area (up-fold and down-fold subsurface).Oil and gas may be collected in the high area.
3. Group of contours decreasing or increasing toward certain direction shows dipping bed: closed spacing of the contours indicate steep slope which show prospective part of the formation. Oil and gas may be collected in the up-dip.

2.1.2. Interpretation by Section Drawing

Section shows a visual form of the subsurface topography along a horizontal profile drawn on map. The following steps are used in drawing section from contour map manually:

1. Draw a section line (that is a straight line joining points between which the section is to be drawn.
2. Choose a vertical scale. The scale examines the contours along the section line for the lowest and highest contours and draw up the numbered scale on plain paper or square paper equal to the length of the line drawn.
3. Lay the straight edge of piece of paper on the section line and mark all points at which it is crossed by contour lines, writing down the depth or time of each. Where the same contour crossed two or more times, it shows rise and fall respectively.
4. Transfer the paper to the bottom of the scale of depths or times and at each point draw a vertical line to the corresponding depth or time scale.
5. Join up the point with smooth line.

The high part of the subsurface as indicated by the section drawn may be prospective for oil and gas.

3. Data Presentation

3.1. Location Map Description

The location map show in plan area where seismic data was acquired. A total of 25 shot points, shown in dots were located on the base map.

3.2. Seismic Time Post Map

The seismic time data were posted in the base map using Surfer 8.0 program running on a PC.

Table 1. Seismic Time Data

EASTHING (m)	NORTHING(m)	TIME (ms)
425570	202513	1480
426425	204153	1400
427280	205425	1340
427708	207068	1290
428135	207979	1250
428990	209801	1150
427964	202149	1450
425143	203424	1380
425314	205064	1310
429674	206521	1300
430016	207797	1290
420440	206613	1250
421894	206157	1240
423176	205702	1220
424288	205246	1210
424544	204791	1230
427109	203971	1300
428306	203424	1320
431042	202058	1340
423433	203060	1300
424373	204335	1290
424801	206066	1250
425314	207524	1190
425741	208708	1130
426341	210165	1120

X= Easthing Coordinate,
Y= Northing Coordinate

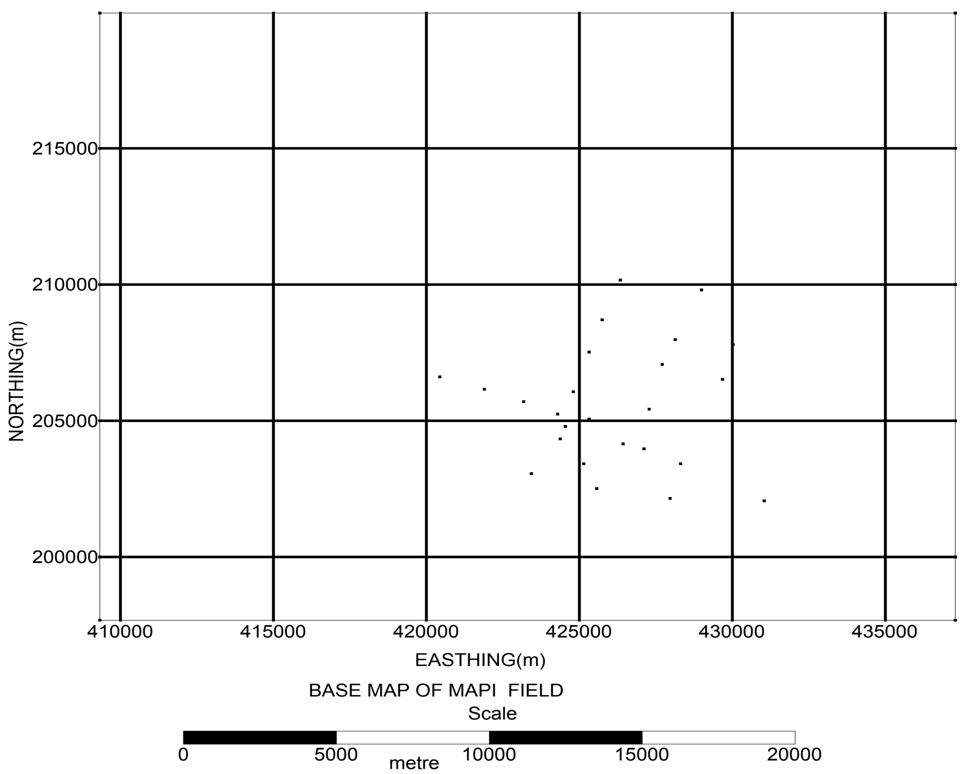

Figure 2. Base Map of Mapi Field

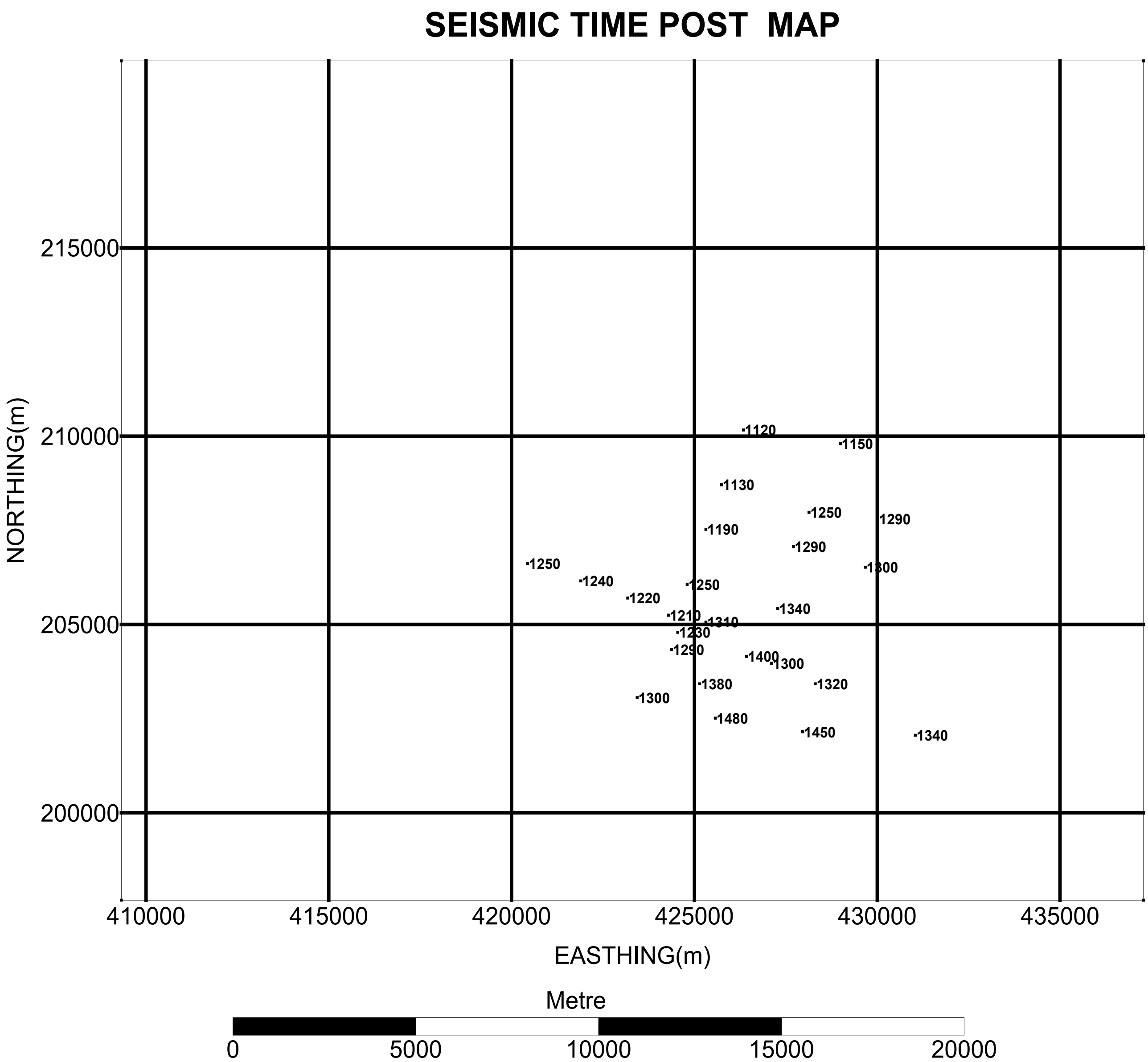

Figure 3. Seismic Time Post Map

3.3. Seismic Time to Depth Conversion

Table 2. Time-depths Chart of Mapi Field

Time(ms)	Depth(m)	Time(ms)	Depth(m)	Time(ms)	Depth(m)	Time(ms)	Depth(m)
0	7	600	1847	1160	4133	1700	6717
20	57	620	1920	1180	4222	1720	6818
40	107	640	1994	1200	4313	1740	6919
60	158	660	2069	1220	4404	1760	7021
80	210	680	2141	1240	4495	1780	7123
100	263	640	1994	1260	4587	1800	7226
120	317	660	2069	1280	4679	1820	7329
140	371	680	2141	1300	4772	1840	7332
160	427	700	2219	1320	4865	1860	7535
180	483	720	2296	1340	4959	1880	7638
200	540	740	2373	1360	5053		
220	598	760	2451	1380	5148		

240	657	780	2529	1400	5243
260	716	800	2608	1420	5338
280	777	820	2688	1440	5434
300	838	840	2768	1460	5531
320	900	860	2849	1480	5627
340	963	880	2931	1500	5725
360	1026	900	3013	1520	5822
380	1091	920	3096	1540	5920
400	1156	960	3263	1560	6018
420	1221	980	3347	1580	6117
440	1283	1000	3432	1600	6216
460	1355	1020	3518	1620	6316
480	1425	1040	3604	1640	6415
500	1492	1060	3691	1600	6216
520	1562	1080	3778	1620	6316
540	1632	1100	3866	1640	6415
560	1703	1120	3954	1660	6515
580	1775	1140	4043	1680	6616

4. Results

Table 3. Seismic Dept Data

EASTHING (m)	NORTHING(m)	Depth (m)
425570	202513	5627
426425	204153	5243
427280	205425	4959
427708	207068	4726
428135	207979	4543
428990	209801	4088
427964	202149	5483
425143	203424	5483
425314	205064	4819
429674	206521	4772
430016	207797	4726
420440	206613	4541
421894	206157	4495
423176	205702	4404
424288	205246	4359
424544	204791	4450
427109	203971	4772
428306	203424	4866
431042	202058	4959
423433	203060	4772
424373	204335	4722
424801	206066	4541
425314	207524	4268
425741	208708	3999
426341	210165	3954

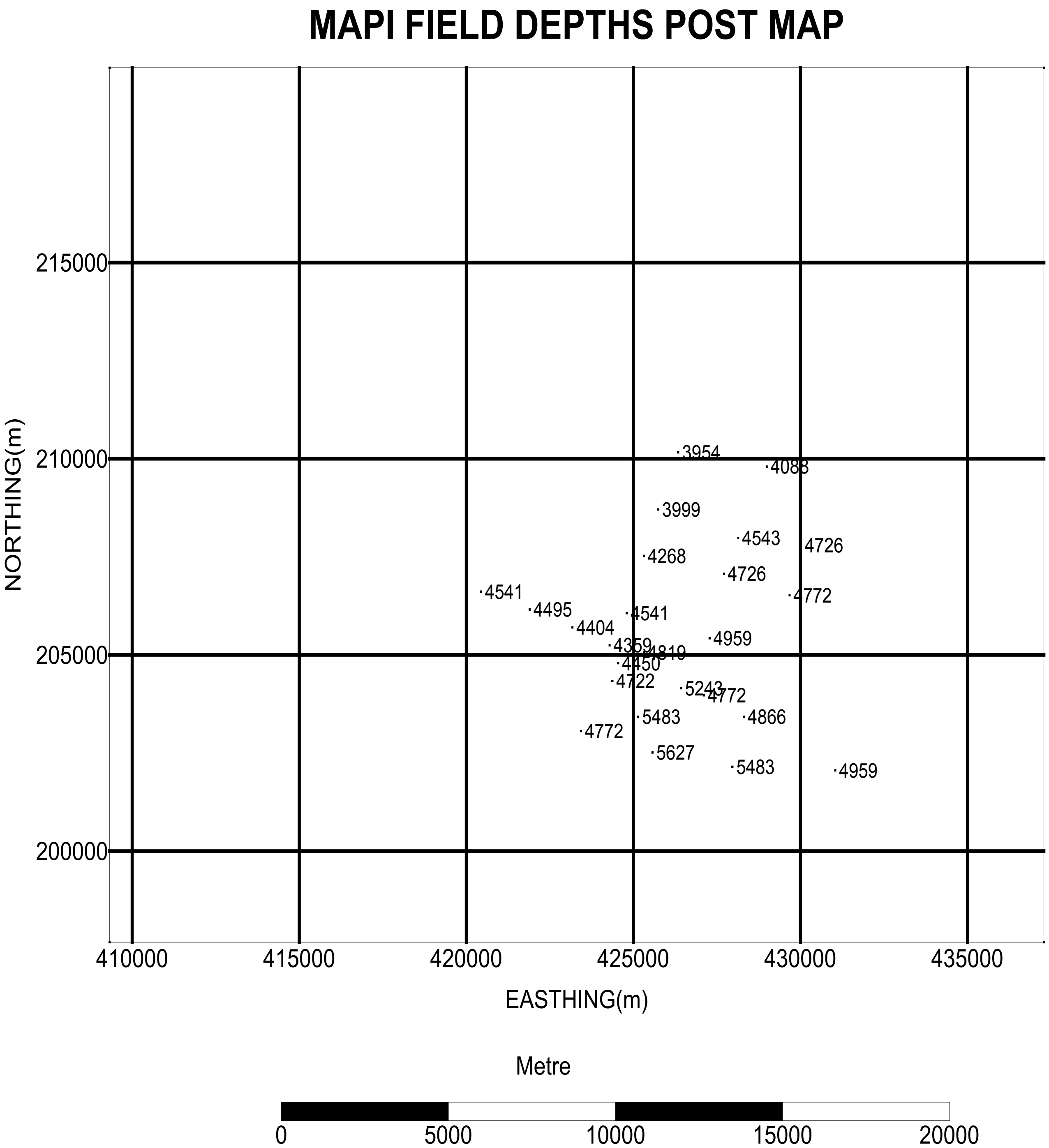

Figure 4. Depth Post Map of Mapi Feild

4.1. Structural Map Construction and Interpretation

Depth data in fig 4 were input into surfer 8.0 program running on a PC to produce contour map shown in fig 5.

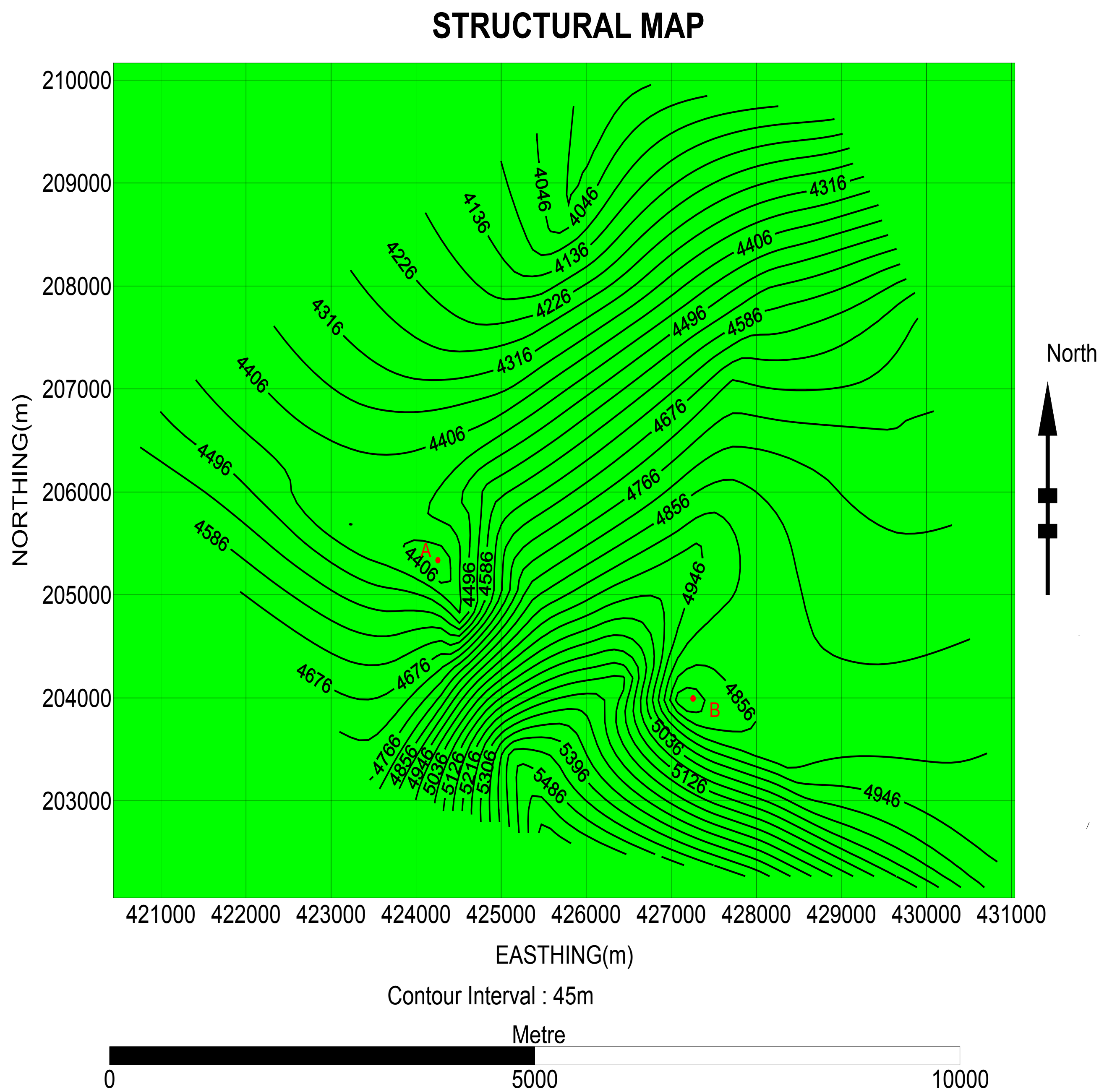

Figure 5. Structural Contour Map

From the map, it is clearly seen that the geological formation mapped is upfolded, down-folded, dipped gently and dipped steeply in different areas. This indicates that the topography of the sedimentary bed is not of a particular type. Two Anticlines are seen in two areas of the map (high contour closed) labeled A and B in red. These anticlines structures are prospective traps to be test drilled in view of the fact that it can be hundreds of kilometers long and thousands of meters in height. And as such a number of oil pools (field) can be found in an anticline. The anticline A, is smaller in size than B, therefore, anticline B is more prospective. Also, anticline B is deeper than A. The Surface location of tops of the anticlines and are indicated by red dots, and the position coordinates are respectively A (424272, 205337) and B (427257, 203995).

The steeply dipping portion of the sedimentary bed shown by closely spaced group of contours decreasing toward the northern part of the map is also a target. This steeply dipping feature may indicate position of tilted and faulted part of the formation, tilted lithofacies or unconformity surface. To minimize drilling risk, exploratory well could be located on anticline B first to test the predicted stratigraphy for oil and gas accumulation.

5. Conclusions

The result of the structural map construction and interpretation of seismic times recorded at Mapi Field of

Niger Delta area of Nigeria reveals; the presence of anticlines and dipping parts of the sedimentary bed mapped. Two prospective anticlines designated as anticline A and B could be test drilled for hydrocarbon accumulation. The position coordinates of the proposed exploratory drilling locations were respectively A (424272, 205337) and B (427257, 203995).

Dipping parts of the bed probably indicate positions of tilted and faulted part of the formation, tilted lithofacies or unconformity surface. These portions are not seen to be dipping enough for oil and gas accumulation. However, further study in the area is encouraged.

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