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Evaluation of Hydrocarbon Volume in ‘TRH’ Field, Onshore Niger Delta, Nigeria

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Abstract
TRH field is an oil field located in Niger Delta, Nigeria and the study was aimed at reservoir evaluation of the field. The research methodology involved integration of seismic and geophysical well log data for the identification of hydrocarbon bearing reservoirs, computing reservoir petro physical parameters and estimation of initial hydrocarbon in place. Four wells were correlated across the field to delineate the lithology and established the continuity of reservoir sands as well as the general stratigraphy of the area. The well analysis carried out on the sand bodies indicates two sand units that are hydrocarbon bearing reservoirs (A1000, and A2000). The estimated thicknesses of the two reservoirs are 45m and 23m for A1000 and A2000 respectively. The average porosity for reservoir A1000 and A2000 are 0.26 and 0.25. The quality of the porosity is very good. The computed average water saturation is 0.33. This shows that the hydrocarbon saturation is 0.63. These sands units were further evaluated using seismic interpretation. Horizons and faults interpretation were carried out to produce subsurface structure maps from seismic data to study the field’s subsurface structures serving as traps to hydrocarbon and estimate the prospect area of the reservoirs. The fault interpretations revealed three listric faults labeled F1, F2, and F3, and two antithetic faults F4 and F5. The estimated hydrocarbon in place for the two reservoirs (A1000, and A2000) are13646986.97 bbl and 6914317.50 bbl respectively. The antithetic and synthetic faults act as good traps for the hydrocarbon accumulation in the study area.

1. Introduction

Geophysical methods, principally seismic surveys and well logs are commonly used by the petroleum industries to assess the quantity of hydrocarbon available for production from a field or to assess the potential of an undeveloped resources. A quantitative and detailed description of reservoir architecture and its properties using geophysical and geological information can strongly improve the economics of reservoir development and enhance its production. In the majority of reservoir development projects, the description of the reservoir is achieved through integrating well information and seismic data [1, 2]. The knowledge of reservoir dimension is an important factor in quantifying producible hydrocarbon reservoir [3, 4]. Precise determination of reservoir thickness is best obtained from well logs, especially using the gamma ray and resistivity logs [5]. The integration of seismic and well logs data have been used to determine whether the hydrocarbon accumulation in a reservoir is of commercial quantity and to formulate an initial field development plan.

The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province [6]. From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development [7]. These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km^2 [8], and a sediment thickness of over 10 km in the basin depocenter. The aim of this study is to integrate geophysical log and seismic data for evaluation of hydrocarbon volume in order to assess the production potential of TRH field in Niger Delta.

2. Summary of the Geology of the Study Area

The study was carried out on an oil field located in the Niger Delta sedimentary basin. The map of the Niger Delta showing the study area and the Base map of study area are shown in Figures 1 and2 respectively.

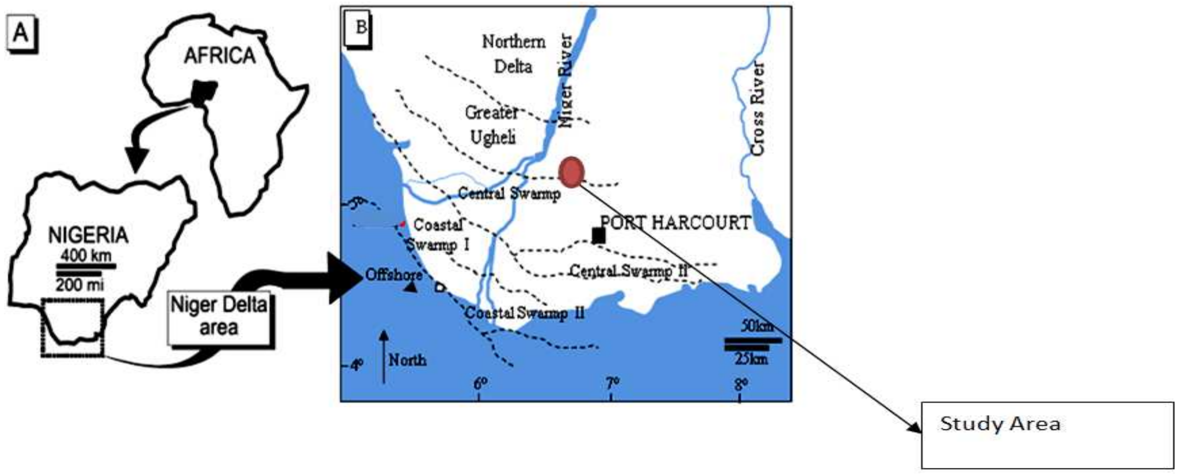
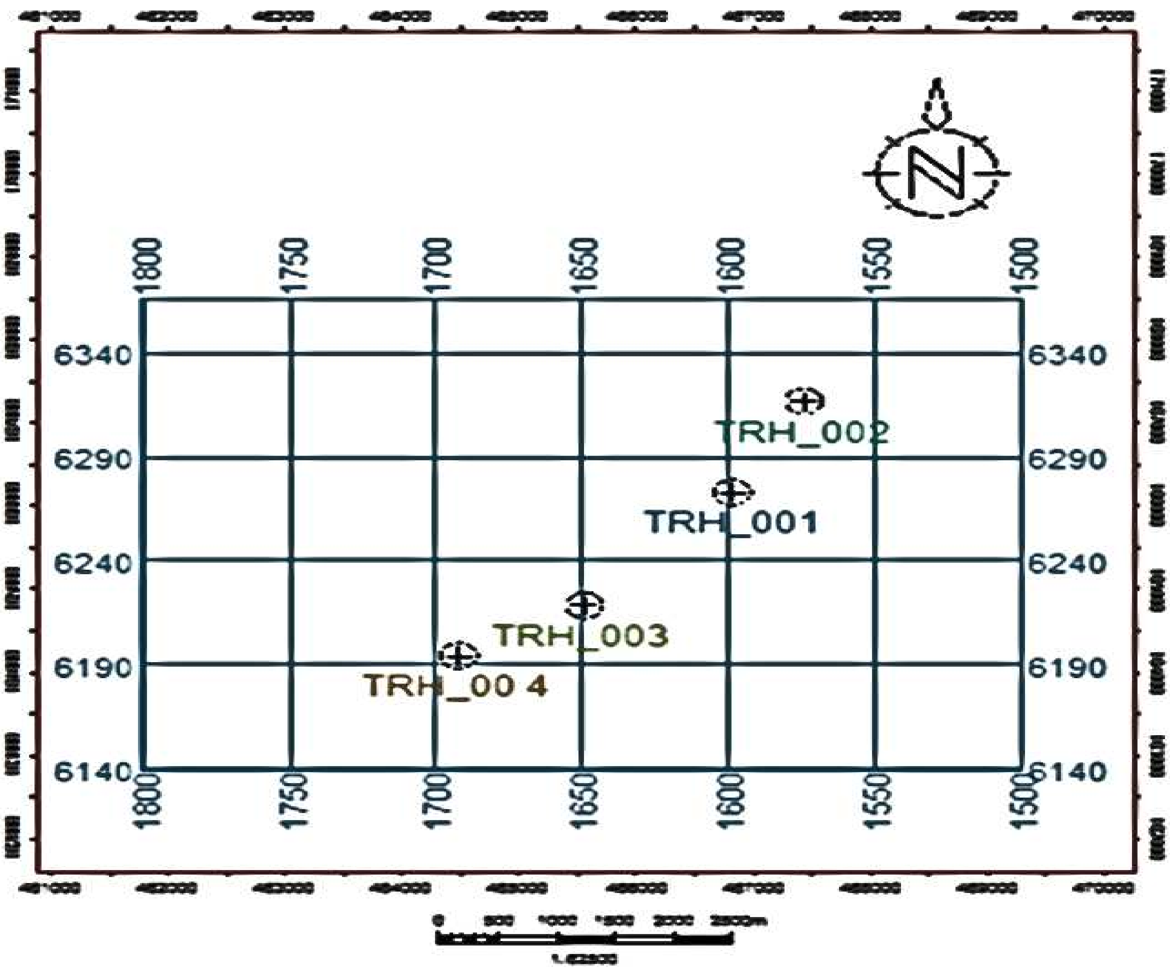


Figure 1. Map of Niger Delta showing the Study Area.



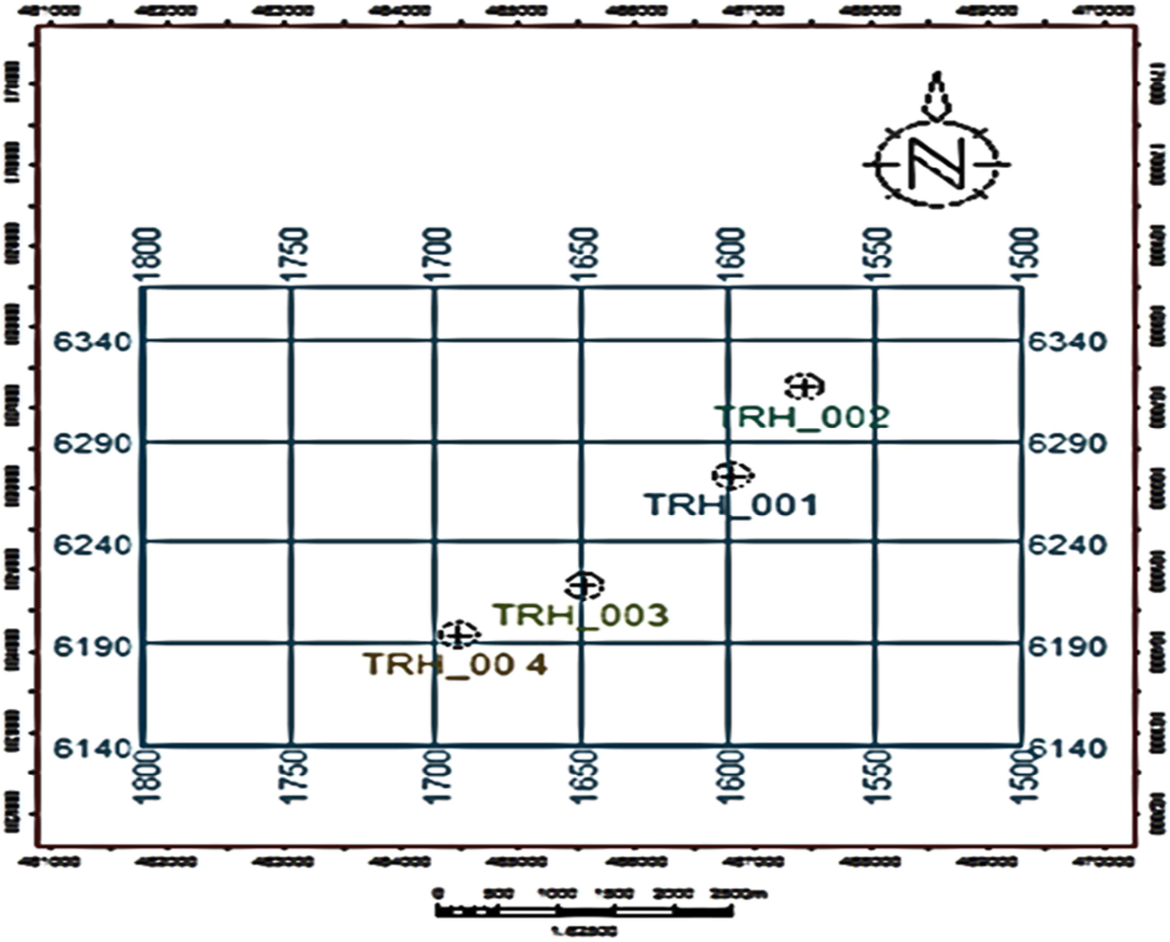


Figure 2. *Base Map of TRH-Field.*

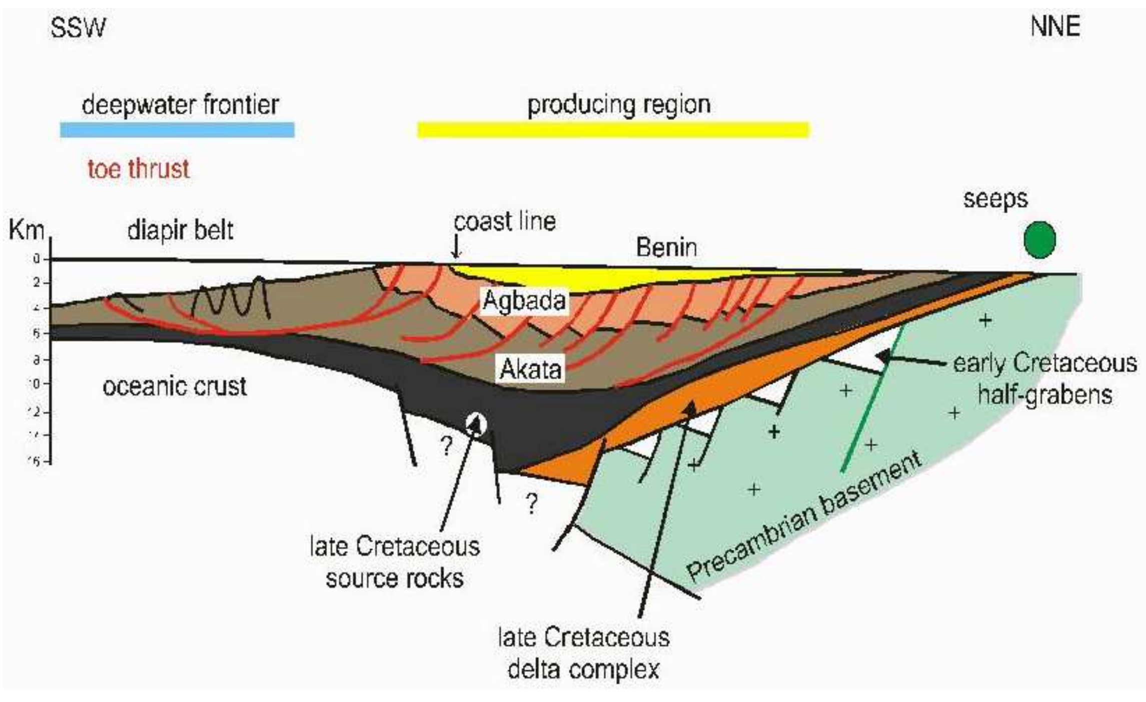


Figure 3. *The Niger Delta lithostratigraphic cross section showing the Benin, Agbada and Akata Formations [10].*

The geology of the Tertiary Niger Delta is divided into three formations, representing prograding depositional facies distinguished mostly on the basis of sand-shale ratio. They are Benin Formation, the ParalicAgbada Formation and Prodelta

Marine Akata Formation [7].

The Benin Formation consists mainly of sands with thickness ranging from 0 to 2,100 meters. The Agbada Formation which consists of paralic Siliciclastics, underlies the Benin Formationand it is the principal reservoir of the Niger Delta. The Akata Formation is the major basal time transgressive lithologic unit in the Niger Delta Complex with approximate range of thickness ranging from 0 – 6 km. The Formation is mainly shale but sandy or silty in the upper part where it grades into the Agbada Formation [8, 9]. The Akata Formation is the major source rock in the Niger Delta. The Niger Delta lithostratigraphic cross section showing the Benin, Agbada and Akata Formations is shown in Figure 3.

3. Materials and Methods

The two principal data used for this study are 3D seismic data and suite of geophysical well logs from four oil wells. The data were obtained from Agip Oil Development Company, Nigeria. The 3D seismic data is a high resolution Pre-Stack Time Migration in SEG-Y format. The base map covers approximate area of 170sqkm with inline- range of 1500m-1800m and cross-lines range of 6140m to 6366m. The line spacing is 25 m by 25m.

The wells were drilled to depth of 3872.15 m, 3429.91 m, 3919.73 m and 3236.98 m respectively. Each of the well logs suite consists of Gamma ray and deep induction log(ILD) except TRH 001 that also contain porosity and Density logs which were used in evaluating petrophysical properties such as hydrocarbon saturation, porosity (Φ) and water Saturation (Sw).The main software package used for the study is Schlumberger Petrel 2009.1. The procedure applied in this study involves;

3.1. Lithology and Reservoir Identification

Lithologies of the TRH wells were determined using the gamma ray log. The gross lithology was corroborated and compare across the well. Hydrocarbon bearing reservoirs were identified using the electrical resistivity log. To enhance the ability to determine similar reservoirs across the wells, the wells were viewed in 2D window in order to observe their locations in the base map and after that a well fence was built to bring the wells from distal to proximal.

3.2. Determination of Porosity

The porosity was calculated from density log by using the relationship

$$\Phi = \frac{(\rho_{max} - \rho_b)}{(\rho_{max} - \rho_{fl})} \tag{1}$$

Where

Φ=porosity derived from density log

ρmax = matrix density(2.65 g/cm^3)

ρb = bulk density (as measured by the tool and hence includes porosity and grain density)

ρfl = fluid density(1 g/cm)

3.3. Determination of Water Saturation

According to Udegbunam and Ndukwe [11], water saturation can be estimated by

$$S_w = \frac{0.082}{\Phi} \tag{2}$$

Where,

S_w = water saturation

Φ = Effective porosity

3.4. Well to Seismic Tie

Well-to-seismic tie of the hydrocarbon reservoirs was carried out using check-shot data. This helps in studying how seismic characters vary as the stratigraphy changes across the basin. It also aid in identifying reflection and determine seismic events that are related to particular boundary surfaces or sequences. The logs from well TRH001 was tied to the seismic data

3.5. Seismic Interpretation

The seismic interpretation involved faults and horizons identification and mapping. The faults were identified in the seismic section and after that they were picked. The faults identified in the 3D seismic sections were used to produce time structural map. The fault mapping was done for the 3D seismic data by defining fault sticks in the seismic section to indicate the dip of the faults. Series of key pillars were joined laterally to indicate the shape and the extent of the faults.

Horizon mapping was achieved by tracking the series of time corresponding to the top of the reservoirs identified in the wells on the seismic section. The key horizons were identified and mapped on both inline and cross line seismic sections using their continuity and seismic to well tie.

3.6. Calculation of the Volume of Oil

The calculation of hydrocarbon volume in a reservoir requires the volume of the formations containing the hydrocarbons, the porosity, and the hydrocarbon saturation of the formation. The volume of the reservoir depends on the area and the thickness. The initial oil in place is given as

$$\mathrm{OIIP} = 7758\ \mathrm{AH}\phi(1 - \mathrm{S_w}) \tag{3}$$

Where

OIIP = original oil in place

A = area

ϕ = formation porosity

H = thickness of the reservoir

(1 – Sw) = hydrocarbon saturation

The amount of oil originally in place in the reservoir when measured at the pressure and temperature conditions prevailing in the stock tank is calculated from the equation

$$\mathrm{STOOIP} = \frac{7758\ \mathrm{x\ AH}\ \phi(\ 1 - \mathrm{S_w})\mathrm{x\ NTG}}{\mathrm{B_o}} \tag{4}$$

Where

STOOIP = stock tank original oil in place

B_o is the formation volume factor given as 1.89

4. Results and Discussion

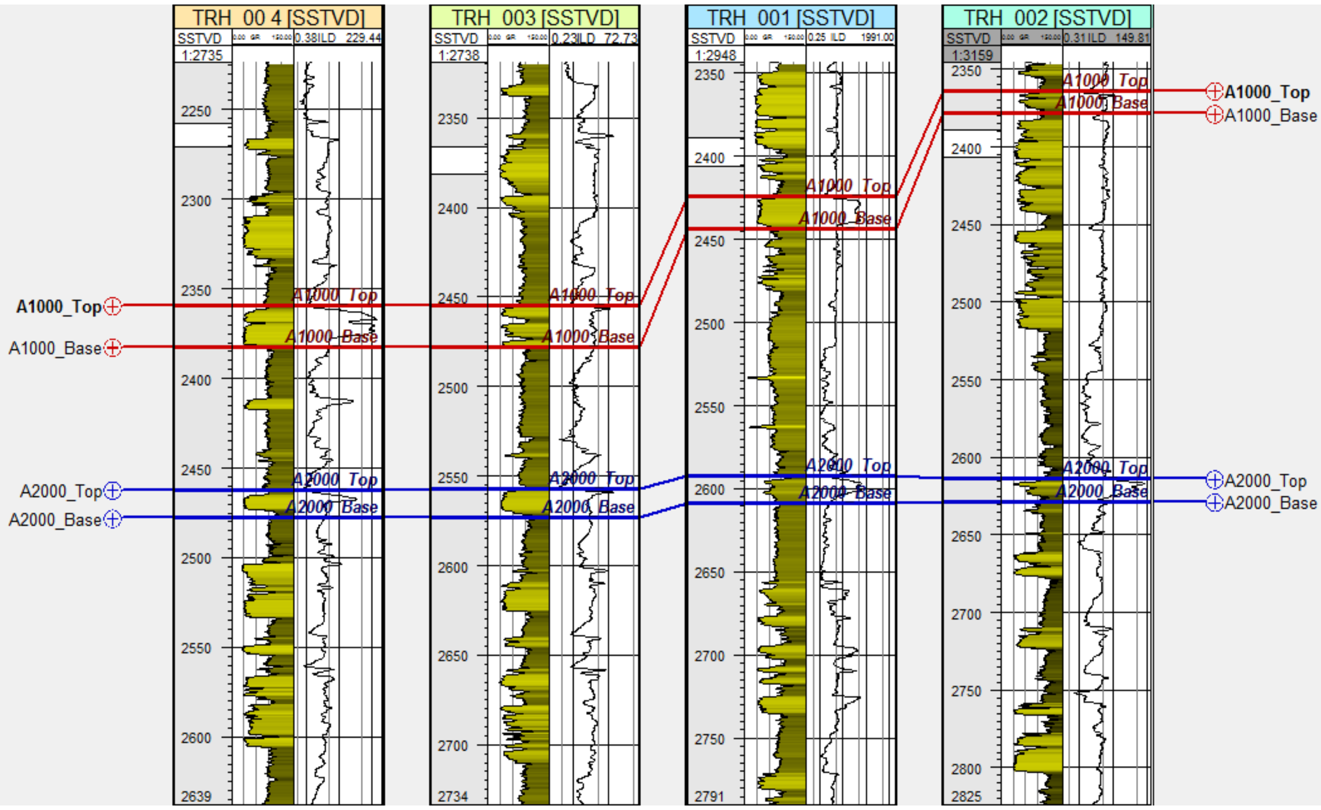


Figure 4. *Reservoirs A1000 and A2000 delineated on well logs.*

The major lithologies delineated from the gamma ray log were sand, shale and sandy shale beds. The sand lithology is associated with low gamma ray reading while the shale lithology has the maximum gamma ray values. The sand shale lithology is occurs in between the sand and shale values. A total of two hydrocarbon bearing zones A1000 and A2000 were identified from the gamma ray and resistivity logs. The well log correlation panel of the reservoirs in four wells in the field is shown in Figure 4.

The estimated thicknesses of the two reservoirs are 45m and 23m for A1000 and A2000 respectively. The average porosity for reservoir A1000 and A2000 are 0.26 and 0.25. The quality of the porosity is very good. The computed average water saturation is 0.33. This shows that the hydrocarbon saturation is 0.63.

The seismic section presented here extends to 3.5 seconds two way travel time. The character of the seismic record changes with depth. The seismic reflector patterns within sequences can be divided into lower and upper parts. The lower part is characterised with very low amplitude chaotic patterns or a set of inclined reflectors while the upper part where reflectors are generally parallel and more closely spaced.

Five faults F1, F2, F3 F4 and F5 were identified and mapped over the entire field in the seismic sections. The fault interpretations revealed three listric faults labeled F1, F2, and F3, that extend across the entire field and two antithetic faults F4, F5 as shown in Figures 5 and 6 respectively. The growth faults are sub-parallel to one another. The throw of the faults causes some missing section of the sand formation within some wells hence the reservoirs were not delineated at the same depth.

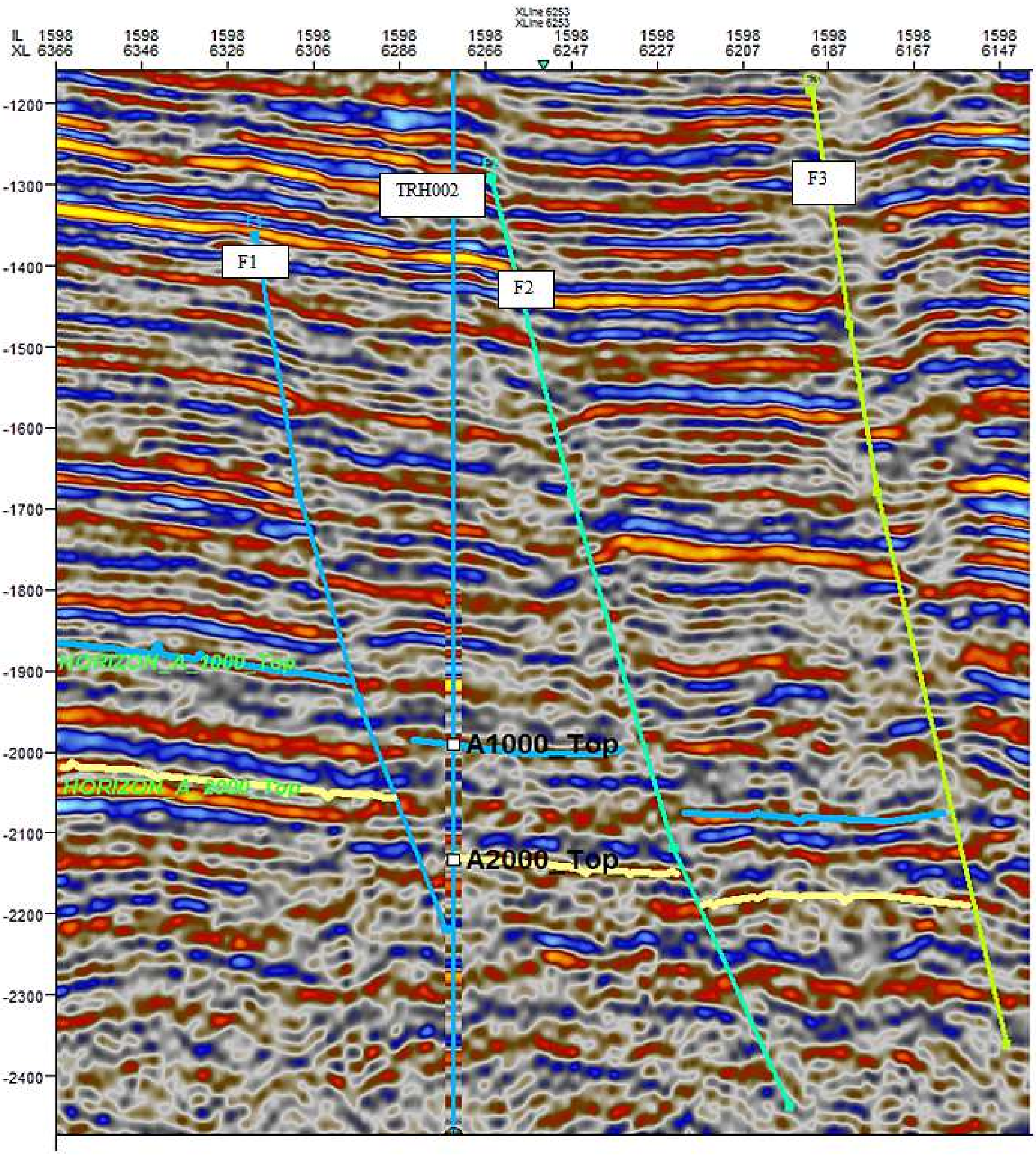


Figure 5. *Seismic profile of line 1598, showing the faults F1, F2, F3 and horizons A1000 and A2000.*

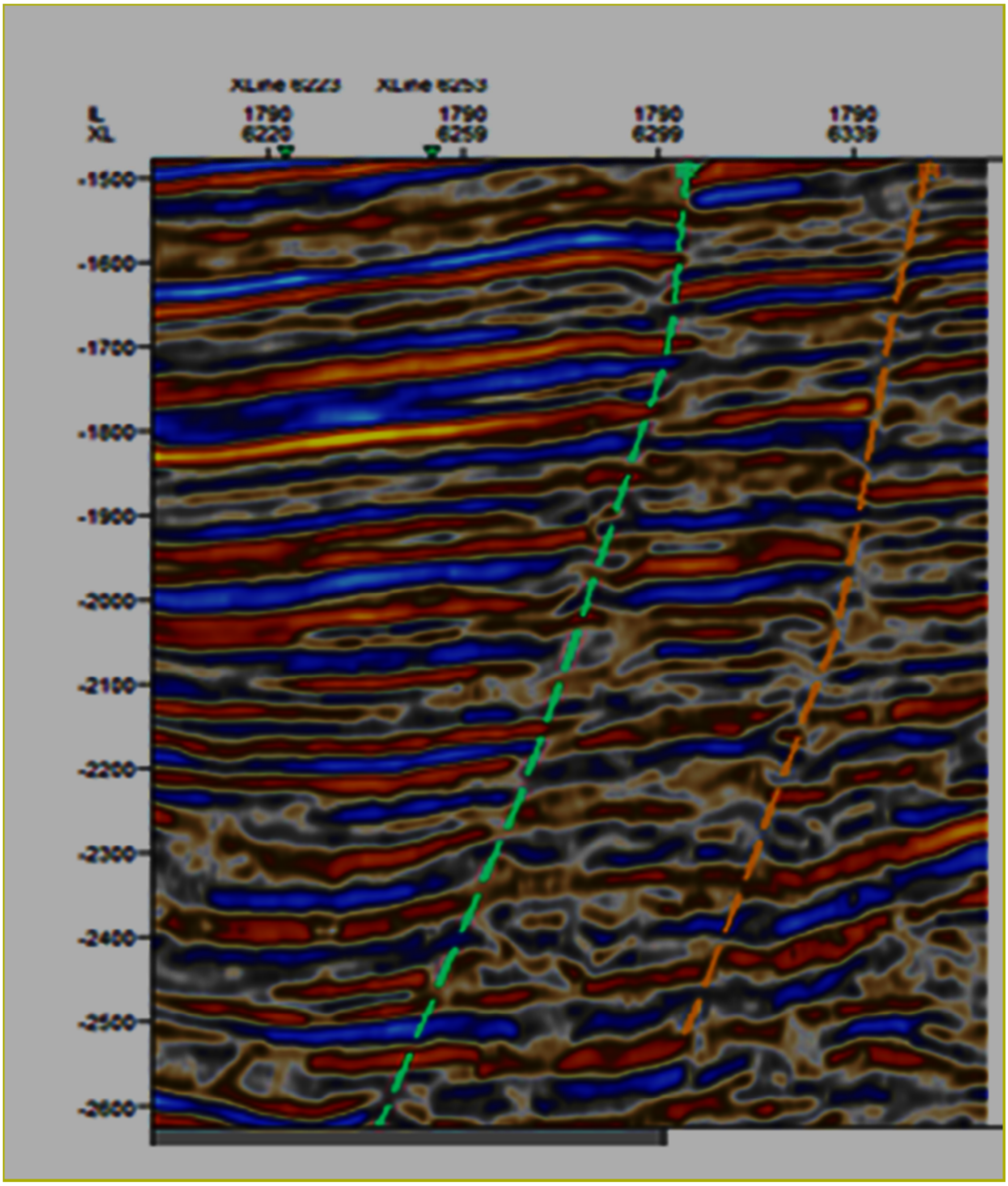


Figure 6. *Seismic profile of inline 1790, showing the faults F4 and F5.*

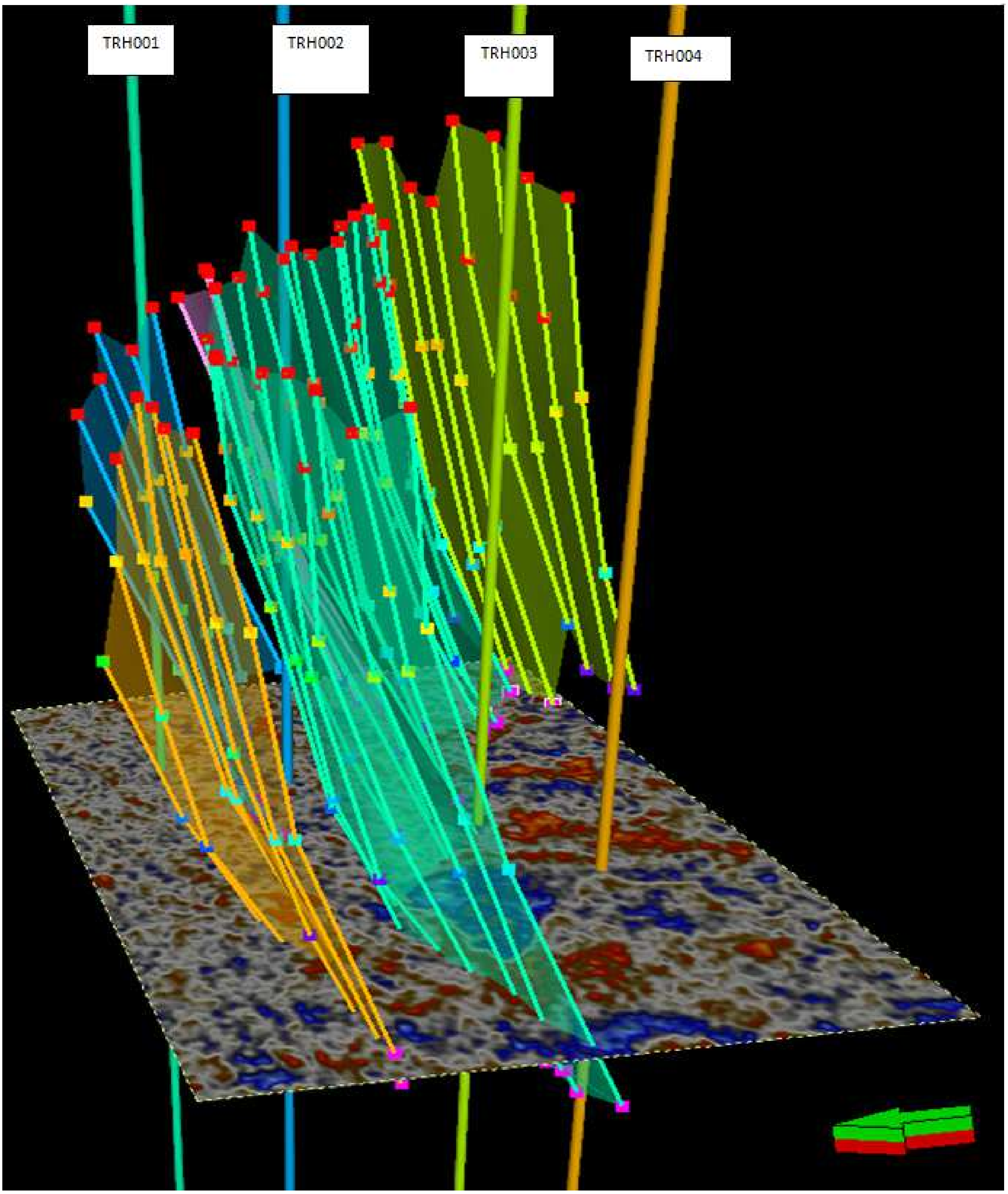


Figure 7. *Interpreted fault sticks and TRH wells.*

All interpreted synthetic faults F1, F2, and F3 trend northeast and all faults dip in the south. The faults started from area of sharp amplitude reflection and deep toward the chaotic region of the seismic section. The interpreted fault sticks and the TRH wells were place on the seismic to determine the trend of the fault on the seismic and the well location, as shown in Figure 7.

The result of well to seismic tie is shown in Figure 5. The seismic traces show that above the delineated well tops (A1000 Top) at 2115.63m in well TRH001, there is characteristic low density and variable velocity. Below the delineated well top (A1000 Top), density, velocity and gamma ray reading increases significantly.

Two key horizons (A1000 Top and A2000 Top) were identified and mapped using their seismic continuity and seismic to well tie. The two horizons were interpreted in both the cross line and inline seismic sections. It was observed that Horizon A1000 Top was characterized by low-to-high or variable amplitude reflections, with poor-to-low continuity. In some places, it is disturbed by some truncations which are more of fault related than lithologic heterogeneity. Horizon A2000 Top was characterized by high amplitude and moderate-to-good continuity reflections, mostly appearing parallel-to- sub parallel.

4.1. Depth Map Generation

The depth structural maps of the tops of reservoir A1000 and A2000 are shown in Figures 8 and 9 respectively. These depths were obtained from the two way travel time of the seismic data with the aid of the checkshot data. The top of reservoir A1000 as deduced from the depth map is dominated by structurally low areas except in the eastern, central and western part of the field with structurally high areas. Similarly, the top of reservoir A2000 is dominated by structurally low areas in western and southwestern part, except in the eastern and central part of the field with structurally high areas.

The depth structural maps show a system of rollover anticlines associated with growth faults. The faults appeared crescent-shaped with the concave side being towards the down-thrown block. Faults brought about the heterogeneous of reservoirs A1000 and A2000.The well TRH 001 is at the up - throw side of F2 and it shows F2 closing up perfectly with F3 which is one of the major growth faults as shown in Figure 8.0. The faults are sealing on the up-thrown side of the fault zone where most of the hydrocarbons could be trapped. The faults may have act as migratory paths for hydrocarbon into the structural closures and the reservoir units.

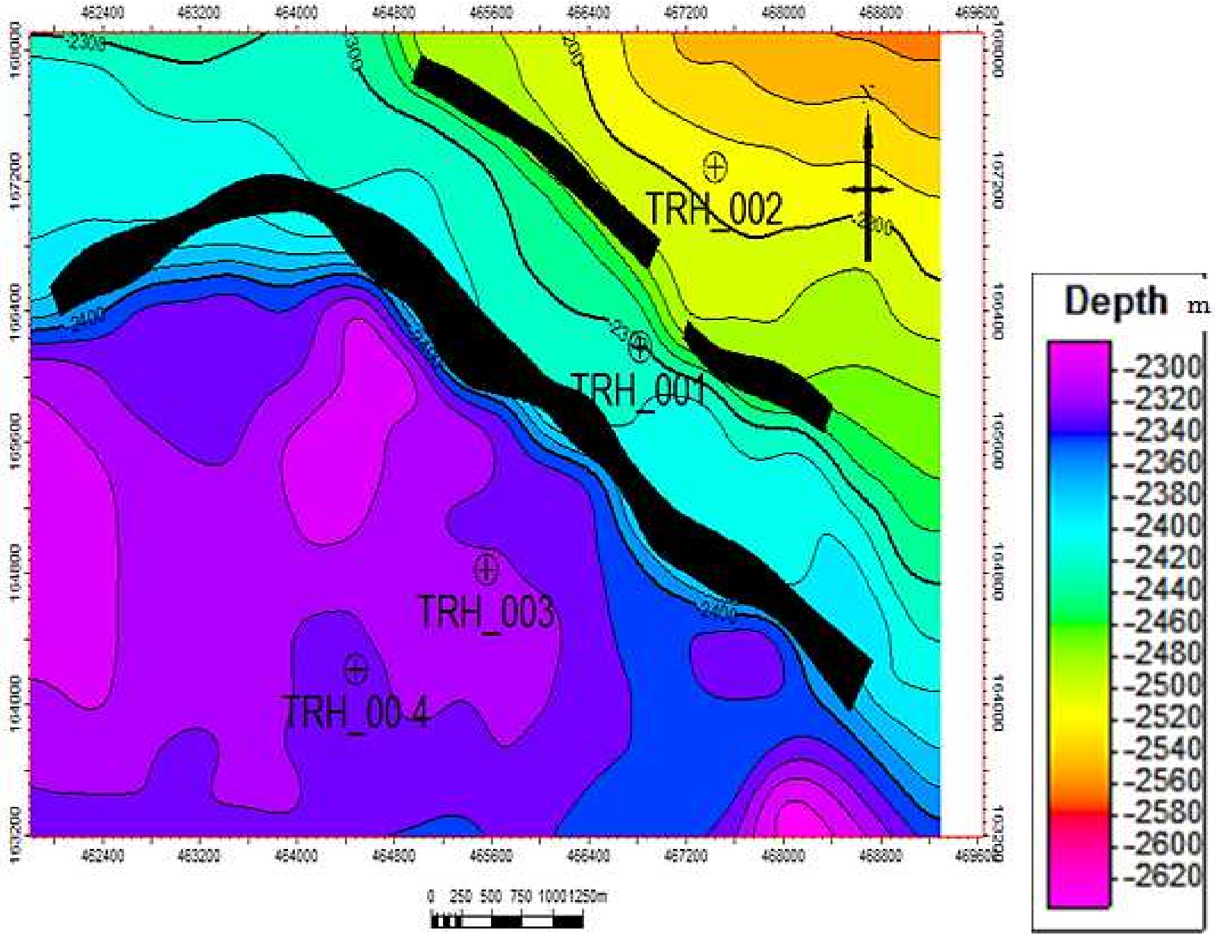


Figure 8. *Depth Map of A1000_Top.*

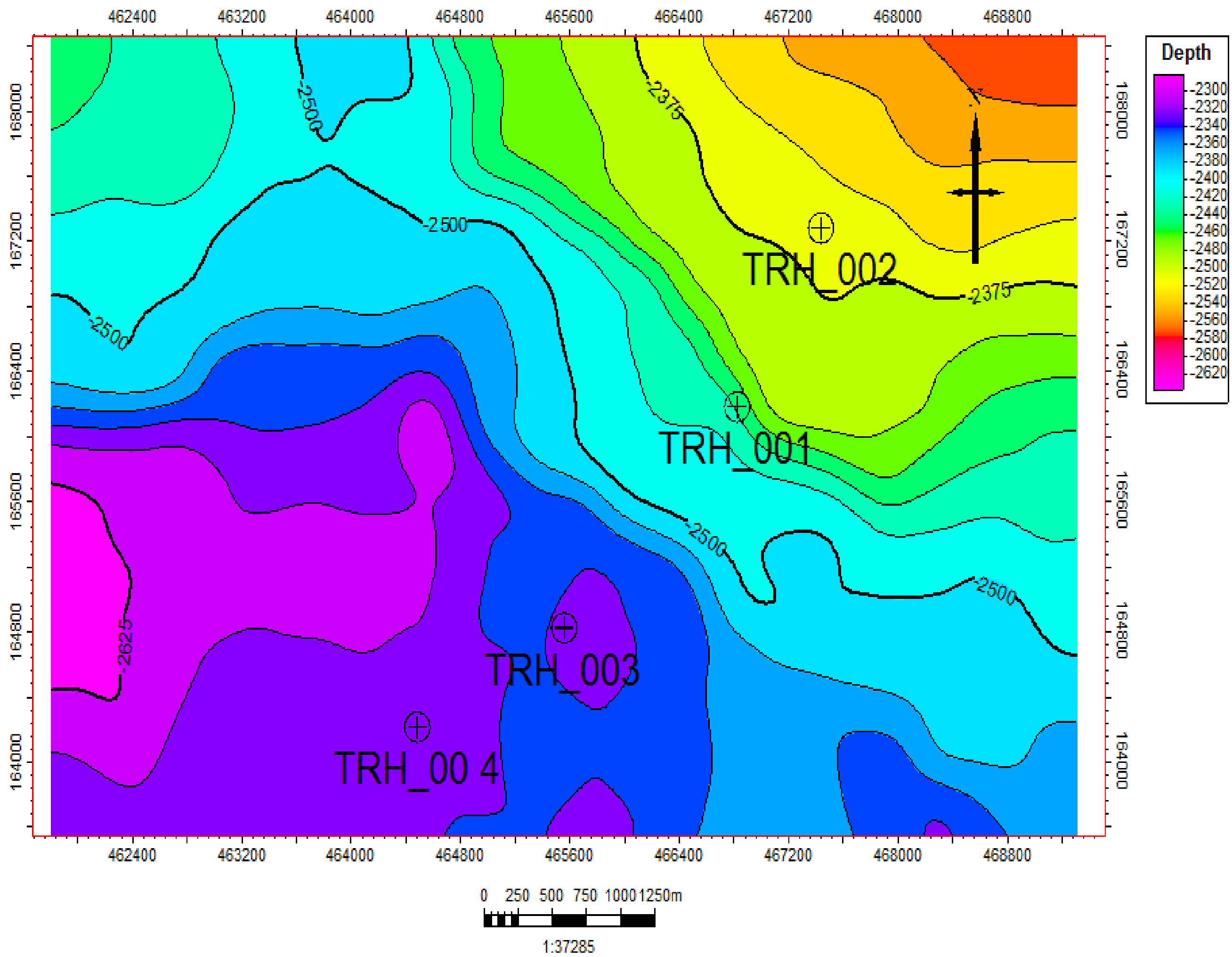


Figure 9. *Depth Map of A2000_Top.*

4.2. Petrophysical Property

Having mapped out the A1000 and A2000 reservoir, it is necessary to characterize the lithology in terms of the quality of the reservoir sand and the fluid types, in terms of hydrocarbon/water. This was done on TRH 001, comprising of gamma ray log, resistivity log, density log and sonic log. The average calculated petrophysical parameters (Shale volume content, Net –to- gross, Water saturation.) are shown in Table 1.The estimation of hydrocarbon reserves was done using the computed petrophysical parameters. The computed STOOIP (stock tank original oil in place) for A1000 and A2000 are13646986.97 bbl and 6914317.50 bbl respectively.

Table 1. *Computed average petrophysical properties for reservoir A1000 and A2000.*

RESERVOIR	AREA (ARCE)	PAY THICKNESS (ft)	POROSITY (FRACTION)	WATER SATURATION (FRACTION)	NET-TO-GROSS (FRACTION)	STOIIP (barrel)
A1000	1200	45	0.26	0.32	0.74	13646986.97
A2000	1350	23	0.25	0.35	0.62	6914317.50

5. Conclusion

Information extracted from 3-D seismic data volume and well logs resulted in more understandingof the structuresand hydrocarbon potentials of the TRH field. This research has shown that it is possible to use relevant geophysical logs and seismic data forthe determination of petrophysicalparameters needed to characterized reservoir in a field. The horizons picked for the two reservoirs units were used to generate depth contourmaps where the closures were delineated and estimated in acres. The result of the seismicinterpretation and petrophysical analysis shows that the field under consideration hasgood hydrocarbon prospect.

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