# 2D SEISMIC REFLECTION AND DATA INTERPRETATION INTEGRATED WITH RESERVOIR CHARACTERIZATION OF MIANO AREA


**BY**

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***"PAY THANKS TO ALLAH EVERY MOMENT AND GO TO EXPLORE THE HIDDEN TREASURES, ITS ALL FOR YOUR BENEFIT (AL-QURAN).***

## CERTIFICATE OF APPROVAL

This dissertation submitted by **Hameed Ullah** is accepted in its present form by the Department of Earth Sciences, Quaid-i-Azam University Islamabad as satisfying the requirement for the award of degree of **Bs. Geophysics.**

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# DEDICATION

I dedicate my whole thesis work to my beloved and respected parents, my supervisor, teachers and whole family who motivated, supported and encouraged me to continue my academic career and gave me a good solution to my problems at the moment whenever required and whatever today I am is just because of them.

## Acknowledgement

In the name of Allah, the most Beneficent, the most Merciful. All praises to Almighty Allah, the creator of universe. I bear witness that there is no God but Allah, and Holy Prophet Hazrat Muhammad (P.B.U.H) is the last messenger of Allah, whose life is a perfect model for the whole mankind till the Day of Judgment. Allah blessed me with knowledge related to Earth. Without the blessing of Allah, I could not be able to complete my work as well as to be at such a place. I am especially indebted to my dissertation supervisor **Mr.Matloob Hussain** and the Chairperson of the Department of Earth Sciences **Dr. Mona Lisa** and all the respected faculty members of the department for giving me an initiative to this study. Their inspiring guidance, dynamic supervision and constructive criticism, helped me to complete this work in time. I pay my thanks to whole faculty of department of Earth Sciences especially the teachers and senior students of Department of Earth Sciences, their valuable knowledge, assistance, cooperation and guidance enabled me to take initiative, develop and furnishing my academic carrier. I am thankful to all my friends, my class fellows and senior students of Department of Earth Sciences, for giving their kind support during my dissertation work.

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**Bs. Geophysics**

# ABSTRACT:

In this dissertation, focus is placed on the structural interpretation of the Miano block - 20 in order to demarcate the probable zone for the accumulation of hydrocarbons. This thesis work includes preparation of synthetic seismogram of Miano - 09 well. Analysis of geophysical borehole logs provides one of the best approaches to characterizing rocks within boreholes. So Facies analysis is also done in order to identify lithologies. Another important tool called AVO analysis is done in order to recognize the cl ass of the sand in the study area. Also a portion of the sequence stratigraphy is discussed to interpret the Depositional sequence system of the reservoir in the study area.

For the interpretation of the seismic lines, fours reflectors are marked by correlating synthetic seismogram on seismic section. As the area of study lies in the Lower Indus Basin, horst and graben geometry in this region is common which is confirmed by fault polygon and time and depth contours made from time and depth grid respectively. Facies modeling is one of the reliable tool for the confirmation of lithologies. In this dissertation, with the help of facies analysis of Miano- 09 well, we came to the result revealing sand as the reservoir lithology.

Petrophysics is the one of the most reliable tools for the confirmation of the types of the hydrocarbon and for marking of the proper zone of the interest of the presence of the hydrocarbon by combination of the different logs results. In this dissertation the petrophysics is performed on the Miano- 09 and zone of interest are marked where there is chance of the presence of the hydro carbon.

At last the AVO is performed in order to identify the class of the sand present in the study area.

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# Seismic Interpretation

# CHAPTER # 1

# INTRODUCTION

## 1.1 Introduction

Seismic interpretation provides an assessment of a prospect‘s hydrocarbon potential and, if favorable, identifies best location for drilling wells. Interpretation should make us of all the following that are available. The final interpretation of the seismic data is only as good as the validity of the processed data. It is imperative that the interpreter be aware of all problems encountered in the field data acquisition and processing stage (M.Gadallah and Ray Fisher 2009).

Vertical seismic section

Horizontal seismic section

Velocity models Well logs VSP data

Amplitude verses offset (AVO) analysis

It is the last step in the seismic method. It means the transformation of seismic data present on the seismic section in meaningful geological information. Seismic interpretation is an art that need clear knowledge of highly developed technology and proper understanding of what actually can happen with in the earth. In the past interpretation was mainly directed to the geologic subsurface structures. In the present time, interpretation has been extended to include the detection and mapping sand bodies and stratigraphic traps. Mahmoud M. Badwy (2015), Seismic method is more than a tool for reconnaissance exploration, for finding structures; it has become a tool for studying discovered reservoir its extent, its barriers, its variation of thickness, and its trends of porosity (Anstey, N.A; 1986).

Petrophysics is the well log estimation of rock properties. Interpretation of well logs will reveal both mineralogy and solid constituent of the rock (i.e. grain matrix and cement), and the nature and proportion (porosity, saturation), of interstitial fluids.log analyst distinguish only two categories of solid component in rock matrix and shale. This classification is based on the sharply contrasting effect they have not only on the logs themselves, but on petrophysical properties of the reservoir rock.(Permeability, saturation etc.).Shale in a certain cases treated in term of two constituent “clay” and silt. Petrophysical interpretation of well log also gives us a relation between porosity and resistivity which help in thickness and internal structure of strata (Oserrra and elsvier 1984).

Petrophysical well-logs are incremental-depth records of rock, mineral, fluid, and other properties of the subsurface. Well logs and the practice of well-log interpretation by geologists and represent a critical component of the exploration and assessment of potential hydrocarbon producing formations and reservoirs (Dr. George B. Asquith; 2012).

## 1.2 Objective of the research project

The main of the project is the identification of hydrocarbon traps using seismic and petrophysical interpretation techniques. The data used for research purpose consist of 2D dip lines and strike lines. After interpretation mapping was done by incorporating given well data.The following steps have been incorporated in order to achieve the goal.Identification of key seismic reflection using stratigraphic column and well data and marking of fault on the seismic section.Preparation of time section and depth section for getting true picture of subsurface.Preparation of synthetic seismogram for correlation with seismic data for (Well Miano 09).Seismic attribute analysis to confirm interpretation.Performing well correlation to confirm the lateral extension of lithology.Petrophysical interpretation in combination with log to estimate rock matrix and pore fluid properties like hydrocarbon water saturation to distinguish between the fluids Well log to seismic tie for identifying the regionally extensive mappable horizon and sequence Stratigraphic surfaces such as flooding/maximum flooding surfaces and sequence boundaries.Gridding and mapping of the picked seismic horizon followed by isochore (or isopach).Seismic attributes map (RMS and Min negative amplitudes) over different windows to visualize different shaper and linear to sub-linear trends indicative of the depositional trends and potential presence of sands. Compare the seismic attributes map with isopach map of the above and with the well log stratigraphic correlation. Finally, use petrophysical evaluation and core analysis results from the offset wells and from the analogue producing sands to characterize the interpreted and mapped sand body for it reservoir attributes (net sand, N:G, porosity/permeability relationship etc.).

## 1.3 Data Used In Research Project:

The 2D data of Miano field of (WELL MIANO-09) consist of strike line and dip lines are given in the table below.Which is provided by the department of earth sciences Quaid-i-Azam University Islamabad

### 1.3.1 Seismic data

| **No** | **Line Name** | **Orientation** | **Nature** | **SP Range** |
|---|---|---|---|---|
| 1 | GP2094-217 | E-W | Dip | 102-919 |
| 2 | GP2094-221 | E-W | Dip | 102-1142 |
| 3 | GP2094216 | N-S | Dip | 102-1035 |

Table 1.1Total number of Dip and strike line used in the data.

### 1.3.2 Well data:

| Well Name | Total Depth | Status |
|---|---|---|
| Miano-09 | 3385 | Development GAS |

Table1.2 shows well data used in study area.

## 1.4 Introduction to study area

Miano field is located in the Sindh provinceIt is a joint venture between OMV (Pakistan) exploration G.m.b.H (Austria), Eni exploration and limited (Italy), Pakistan petroleum limited Pakistan oil And development company limited. A total eleven wells have been drilled in the prospect area. As per joint utilization agreement between Miano and Kadanwani joint venture and government Miano raw gas Miano field is located in the Sindh province. It is a joint venture between OMV (Pakistan) exploration G.m.b.H (Austria), Eni exploration and production limited (Italy), Pakistan petroleum limited Pakistan oil and gas development company limited. A total eleven wells have been drilled in the prospect area. as per joint utilization agreement between Miano and Kadanwani joint venture and government Miano raw gas processed at kadanwani plant A prospect was identified in the southcentral part of the block.

## 1.5 Base Map of Study Area

map shows the well locations, concession boundaries, orientations of seismic survey lines and seismic surveys shot point The base map also contains cultural data such as buildings and roads with a geographic reference like latitude and longitude or Universal Transverse Mercator (UTM) grid information are used as base maps for assembly of surface geologic information. Base map of my project as shown in the Figure1.3 having dip and strike lines, well location and geographic coordinates.

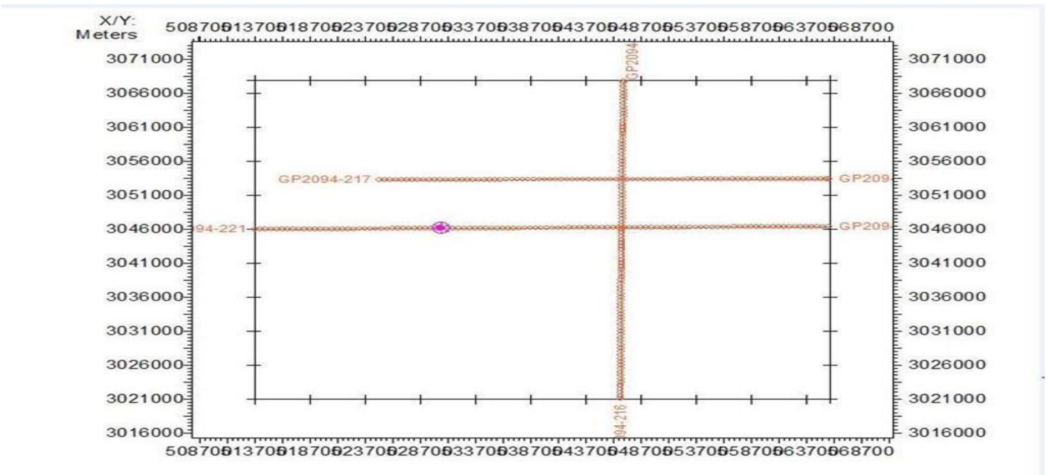



Figure 1.3 Base map of the study area

# CHAPTER 2

# GEOLOGY OF THE STUDY AREA

## 2.1 General Geology of the field Area:

Pakistan is comprised of three broad geological subdivision that, from north to south, may be referred to as the laurasian, tethyn and gondwana land domains kazim and jan(1997).their origin may be traced back tolate Paleozoic. In late Paleozoic all the continents had drifted to form a continuous landmass, the super continent of pangea. By the Triassic, Pangaea had split into two continents, laurasia to north and gondwana to south separated by Tethys seaway. Pakistan is located at the junction of gondwana and Tethyan domains. Active plate boundaries of various types are exceptionally well exposed in Pakistan.In the north there is an active continent-island arc-continent collision boundary, the west end of Himalayan.In the southwest, there is an active boundary of oceanic lithosphere subducting beneath arc-trench gap sediments and continental sediments, the oceanic part of the Arabian plate passing under the makran arc-trench gap and afghan micro plateThe Miano Block discovered in 1993 is located in the Central Indus Basin which is a part of an extensional regime exhibiting normal faulting, formed as a result of split of the Indian Plate firstly from Africa and then from Madagascar and Seychelles The field area lies in the central part of southern indus basin of Pakistan. And in the lower middle Indus platform area.Normal faulting with a dominant NW-SE trend has taken place. Clastic sediments of Ranikot on lap the Base Tertiary unconformity. From Lower Eocene onwards to Middle Eocene, the area of present day Khairpur High occupied again a basinal position. oriented Khairpur High which is interpreted as a large basement induced structure The Central and Southern Indus Basins are divided by Jacobabad and Mari-saif-ur-rahman k.jadoon etal (2016) Kandhkot highs, which are collectively known as the Sukker Rift. The High has been active since Jurassic and Paleocene strata are absent alongside the crust and its adjoining region.khaista Munawwar Hassan etal (2013).eneral geology and geological history of an area is very important for exploration of oil and gas. A geological history basin can be compiled by considering basin forming tectonics and depositional sequence (Kingston et al., 1993). Variations in reservoir quality principally reflect differences in the development of early diagenetic grain coating chlorite and subsequent levels of quartz cementation. Mineralogy is also important especially the presence of even small amounts of the "hot" heavy mineral monazite, commonly mistaken for zircon, which can lead to high GR signatures in sandstones and potentially be the cause of overlooking sand-prone reservoir horizons The productive reservoirs in the upper part of the "B" interval occur at different stratigraphic levels in the Kadanwari field some 15 km to the south as compared to those of the Miano field. The Miano "B" sand is interpreted to represent an incised valley complex comprising at least two members. Extension of these deposits to the west is predicted, associated with an increase in accommodation space basinwards; provided that sufficient sand supply was available. The incised valley complex is overlain by transgressive shoreface bar sands representing deposits of transgressive systems.

## 2.2 **Tectonics of the prospect are**T

ectonically Pakistan comprises of two domains of large landmasses, i.e.Tethyan and Gondwanian Domains and is continued by the Indo- Pakistan crustal plate. western regions of Pakistan fall in Tethyan Domain which have complicated geology and complex crustal structure, While the Indus basin consists of the Gondwanian domain. The Indus basin is the largest basin in Pakistan, oriented in NE- SW direction including the 25,000 square kilometers of SE part of Pakistan. Tectonically Indus basin is much stable area as compared to other Tectonic zones of Pakistan.(Kazmi & Jan, 1997) It is further divided into three parts which has been explained above.The Block- 20 (Miano Field) is located on the eastern part of a regional high, named as Jacobabad- Khairpur High, which is the major feature identified on the regional seismic lines in the Basin. The study area lies at the boundary of Middle Indus Gas Basin and southern Indus basin.The second majn phase of inversion in the eastern platform part of the Middle and Lower Indus basin took place in late Eocene time. Miano field shows a series of faults that trend in a nearly N- NW to S- SE .These faults are normal and strike slip in nature similar to the faulting found in the other fields in the area. These faults have some throw so these faults could isolate some of the sand reservoirs in the field . The Tertiary faults may have resulted from bending of the crustal plate due to collision and rebound relief or tensional release (Nadeem et al., 2012).Seismic studies and fault plane solution indicates that these are extensional features. Middle Indus basin is generally characterized by passive roof complex type structures. (Kadri I.B, 1994).Tectonically the Miano Block lies on the Panno-Aqil graben between two extensive regional highs *i.e.* Jacobabad-Khairpur High and Mari Kandhkot High. Four migrated seismic lines were used for structural enhancement Time and depth contours were generated for four horizons, Habib Rahi Formation, Sui Main Limestone, Ranikot Formation and Lower Goru Formation which showed the presence of horst and graben structures in the subsurface. The interpretation of horst and graben structures is based on a parallel set of NS-oriented high-angle planar normal faults with dips either towards SE or SW with majority of the faults dipping towards the

## Stratigraphy of Area

The study area is situated in the central part of the Indus Basin, which is located close to the rift margin between the African and Indian plates and trends perpendicular to that rift. The sedimentary section of the study area in central Indus basin comprises mainly of Permian to Mesozoic sediments overlying, a strong angular unconformity of late Paleozoic age. The whole of area of study is thickly overlain by alluvium deposits as such no out crops are present at the surface, which can yield a direct evidence of the stratigraphic succession. The Mesozoic progradational sequence is deposited on eastward incline gentle slope.Every prograding time unit represents lateral facies variation from continental to shallow marine in the west to the east. In the Thar slope areas all of Mesozoic sediments are regionally plunging to the west and are truncated unconfirmabaly by volcanic rocks (basalts of Khadro formation) and the sedimentary rocks of Paleocene age (Nadeem et al., 2012).Permian, Triassic and early Jurassic sedimentary rocks in the study area consists of inter bedded sandstone, siltstone and shale of continental to shallow marine origin. The sedimentary cover in the study area consists mainly of Permian to Mesozoic sedimentary rocks overlying a strong angular unconformity of possibly late Paleozoic age. (Kadri I.B, 1994) .The early to middle Jurassic aged Chiltan Limestone in the Middle Indus Basin forms a prominent seismic reflector, which has a smooth planar character. Flattening seismic sections on this horizon helps to remove the complexity of Tertiary structural tilting and faulting, a process that better resolves depositional architecture. The Chiltan Limestone is overlain and down lapped by a Late Jurassic to Early Cretaceous regressive strata comprising bottom sets, forests and topsets that prograde towards west from the Indian craton. In lithostratigraphic terms the argillaceous forests to these prograde are called the Sembar Formation which is an important source rock in the basin. The initial topsets to the progrades have been called the Chichali Formation, while the younger topsets are called the “A” Sand Member of the Lower Goru. No name has yet been given to the sandy submarine fan systems associated with this prograding complex. (Sturrock and Tait, 2004) The sember Formation was deposited over large area of the Indus Basin in marine environment; it consist mainly of black shale with subordinate amounts of siltstone, sandstone and source of hydrocarbons for most of the Lower and Middle Indus Basins and for the Sulaiman- Kirthar fold and trust belt with TOC’s ranging from 0.5 to 3.5 percent in the area (William, 1959) .The stratigraphic column of the area is shown in the Figure 2.4

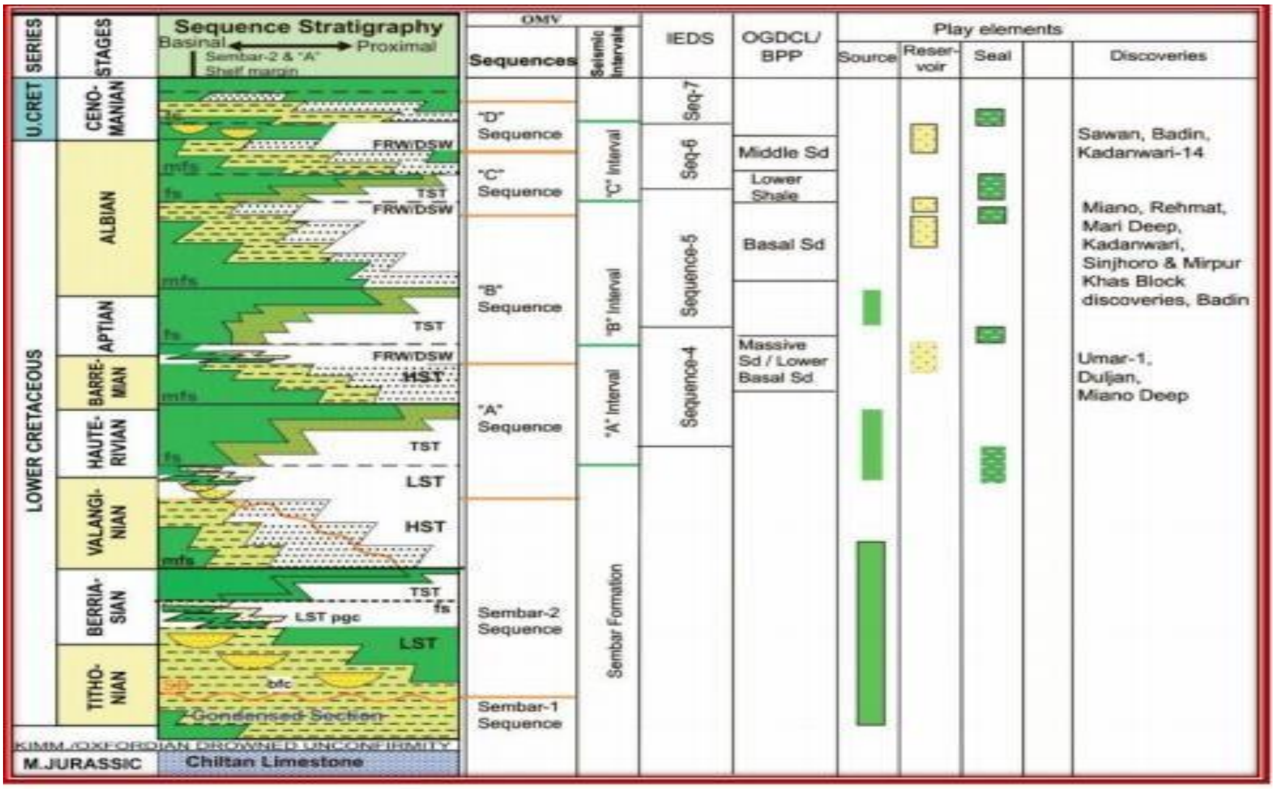


Figure 2.4 Stratigraphic chart for the Sembar and lower Goru formation (Nadeem et al., 2012).

## 2.3 Petroleum Play

### 2.3.1Source Rock

Source rock is the productive rocks for hydrocarbons; these rocks also initiate the conversion of organic compound into oil and gas. The Formations which act as source rocks in the study area are as follow.

### 2.3.2 Sember Formation

Sember Formation is believed to be the major source of hydrocarbons in central and southern Indus basins, also huge gas accumulation in Sulaiman province. Potential of a reservoir also occurs with in the sand stone of formation.

### 2.3.4 Ranikot Formation:

Ranikot shales were used to be considering as the main source for all the gas present in the region, these are the source for overlying Lakhi Formation.

## 2.4 Reservoir Rocks

The main reservoir rocks in the study area are lower Goru and Parh formations.The depositional Environment of the Lower Goru "B" sands in the Miano field is interpreted to be a tide dominated lithology of sandstone with interbedded shales.B- sands is the major producing reservoir in the study area. Sandstone is dirty white, and yellowish brown color, medium hard, friable medium grained, sub angular to sub- rounded, fairly sorted and cemented ,argillaceous, visual inter-angular porosity ranged between 10- 15%, fair oil shows with scattered and patchy yellowish to bluish white fluorescence and very weak, pale yellowish white residual cut. The low acoustic impedance of seismic waves together with strong seismic amplitudes indicates the presence of reservoir quality sands. This type of reservoir quality sands are only present in the depositionally up dip, i.e. the shallowest marine part of the lowstand wedge, as are found in the Sawan, Miano and Kadanwari Fields

### 2.4.1 Trapping Mechanism

The trapping Mechanism for the target reservoir in the study area is combination of structural and stratigraphic.An E-NE to S- SW trending isopach thick in the Lower Goru "C" Interval forms the structural trap, Supported by the horsts due to normal faulting.Towards the NE and SW trapping is caused by shaling out of the reservoir.The northwestern limit is defined by a facies controlled deterioration in reservoir quality, which creates and effective zero reservoir" line. Transgressive shales of t interval of reservoir sands, and thick shales and marls of the Lower Goru Formation form there regional top seal for the reservoir in the area.

# Chapter 3

# SEISMIC INTERPRETATION

## 3.1 Introduction:

Seismic interpretation is transformation of the 2D-seismic reflection data to a geological image by the application of corrections, migration and time to depth conversion (Badley, 1985). Seismic interpretation is the Interpretation is a technique or tool by which we try to transform the whole seismic information into structural or Stratigraphical model of the earth. Since the seismic section is the representative of the geological model of the earth, by interpretation, we try to locate the zone of final anomaly. Not only a good interpretation be consistent with all the seismic data, it also important to know all about the area, including gravity and magnetic data, well information, surface geology as well as geologic and physical concept (Sheriff, 1999).Seismic interpretation & subsurface mapping are key skills that are used commonly in the oil industry for exploration (Sroor, 2010). Seismic interpretation determines information about the subsurface of the earth from seismic data. It may determine general information about an area, locate prospects for drilling exploratory wells, or guide development of an already discovered field (Coffeen, 1986). Conventionally seismic reflection data which is result of seismic image of acoustic impedance interfaces having lateral continuity is used for picking and tracking laterally consistent seismic reflectors for the purpose of mapping geologic structures, stratigraphy and reservoir architecture. Keary et al., (1986) have described two main approaches for analysis of seismic data. Time contour maps of the Lower Goru and the B-Sands are prepared to analyze the trend of the regional structure and to observe the thinning and the thickening of the reservoir sands.

## 3.2 Types of the Interpretation :

There are two main approaches for the interpretation of the seismic reflection data (Dobrin and Savit, 1988).

Qualitative Interpretation

Quantitative Interpretation

Qualitative interpretation is conventional or traditional seismic technique which is used primarily for mapping the sub- surface geology (Sheriff, 1999). In this dissertation main emphasis is on the structural traps in which tectonic plays an important role.Whereas quantitative interpretations are more valuable than conventional 32 techniques. By making some alterations in recorded data results in better prospect evaluation or mainly reservoir characterizations (Sheriff, 1999). The most important of these techniques include post - stack amplitude analysis (bright- spot and dim - spot analysis), off set- dependent amplitude analysis (AVO analysis), acoustic and elastic impedance inversion, and forward seismic modeling etc. These interpretations yield reservoir characterizations and quality. In this dissertation we have done 1- D forward seismic modeling , AVO analysis and facies modeling for determining characteristics and the sand class of the reservoir encountered in the study area. It is just due to lack of time and unavailability of well log data. We could not characterize each of formation in my study area, but in the same way each one can be characterized and results can be explained.

## 3.3 Interpretation Workflow

The Interpretation was carried out using different techniques and steps with each step involve different processes which were performed using the software tools as mentioned above. Simplified workflow used in the dissertation is given in Figure 3.1, which provides the complete Interpretation work chart picture depicting how the dissertation has been carried out.

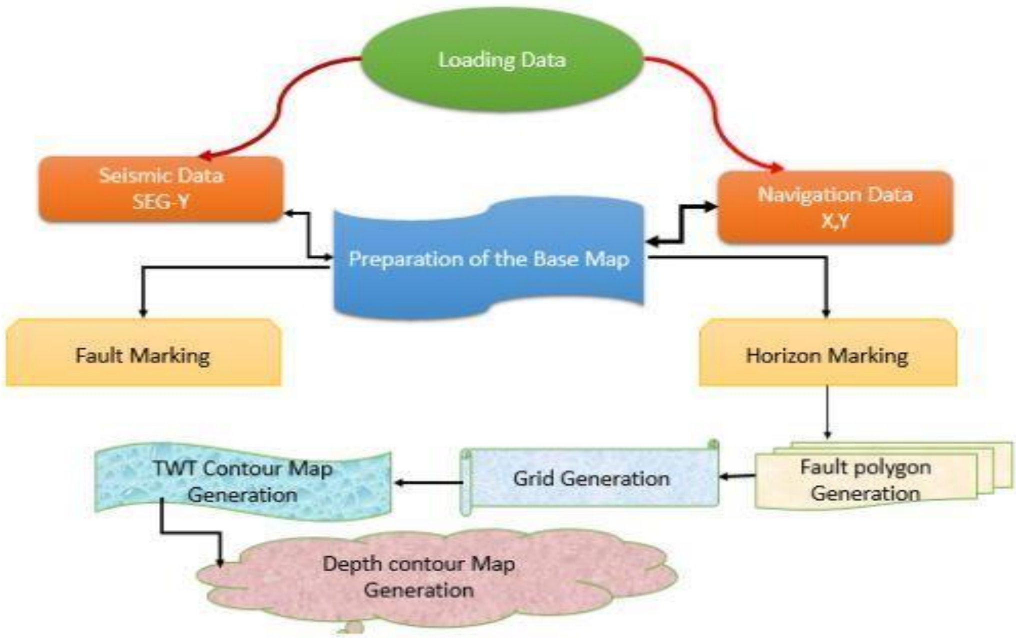



Figure 3.1 Work flow adopted for the seismic data interpretation

By loading navigation data of seismic lines and SEG- Y in HIS kingdom .Software, base map was generated. Faults and Horizons of interest were then marked manually. Identification of marked horizons was done with help of synthetic seismogram, generated with help of well data and faults were marked by keen observation on seismic section and knowing geologic history of study area.

## 3.4 Interpretation of seismic lines:

The Primary task of interpretation is the identification of various horizons as an interface between geological formations. For this purpose, good structural as well a s stratigraphic knowledge of the area is required (McQuillin et al., 1984). Thus during interpretation process, we marked both, the horizons and faults on the seismic section by the information obtained from the synthetic seismogram generated from Miano- 09. We marked the four horizons. The horizons are named on basis of well tops of the well MIANO- 09. Hence the first step before the Marking of the horizons is the generation of the synthetic seismogram. The steps used in the generation of the synthetic seismogram are explained below. For completion of this dissertation I have been assigned the following lines.

- GP2094- 217………………… (Dip Line)
- GP2094- 221………………… (Dip Line) • GP2094- 216…………………. (Strike Lin)

## 3.5 Synthetic seismogram:

The more control the geoscientist has in mapping the subsurface, the greater the accuracy of the maps. Control can be increased by the correlation of seismic data with borehole data. The synthetic seismogram (often called simply the "synthetic") is the primary means of obtaining this correlation. Velocity data from the sonic log (and the density log, if available) are used to create a synthetic seismic trace. This trace closely approximates a trace from a seismic line that passes close to the well in which the logs were acquired. The synthetic then correlates with both the seismic data and the well log from which it was generated. Synthetic seismograms provide a crucial link between lithological variations within a drill hole and reflectors on seismic profiles crossing the site. In essence, they provide a ground truth for the interpretation of seismic data. Synthetic seismograms are useful tools for linking drill hole geology to seismic sections, because they can provide a direct link between observed lithologies and seismic reflection patterns (Handwerger et al., 2004). Reflection profiles are sensitive to

changes in sediment impedance, the product of compression wave velocity and density. Changes in these two physical parameters do not always correspond to observed changes in lithologies. By creating a synthetic seismogram based on sediment petro - physics, it is possible to identify the origin of seismic reflectors and trace them laterally along the seismic line (Handwerger et al., 2004).

### 3.5.1 Calculation of Synthetic Seismogram:

The calculation of a synthetic seismogram generally follows these steps The sonic and density curves are digitized at a sample interval of 0.5 to 1 ft. (If the density curve is not available, the sonic alone may be used.A computer program computes the acoustic impedance log from the sonic velocities and the density data. The data are often averaged or "blocked" to larger sample intervals to reduce computation time and to smooth them without aliasing the log values. .The resulting acoustic impedance curve is then used by the program to compute reflection coefficients at each interface between contrasting velocitiesA wavelet is chosen that has a frequency response and band width similar to that of the nearby seismic data. The synthetic wavelet is convolved with the reflection series for the entire well survey and generates a synthetic seismic trace Inc.. generation is using a wavelet of fixed frequency over the entire survey. Care should be taken to choose a wavelet whose frequency is similar to a key interval of the seismic data to which it will be compared. The resulting trace is displayed at the same vertical scale as the seismic section for direct comparison. To improve the match with the seismic data, the synthetic seismic trace can be recomputed using different wavelets and filters. Figure 1 shows an example of a synthetic seismogram and associated well log data used in its generation. Different wavelets have been convolved to produce two additional synthetic seismogram displays. The synthetic trace can now be compared to a trace from the seismic line. This is commonly done by laying the synthetic directly on top of the appropriate seismic trace and adjusting the synthetic vertically until the two coincide. Through a trial-and-error process, the interpreter determines at what point the synthetic trace "best fits" the seismic data. In an ideal world, there is an obvious agreement between the seismic line trace and the synthetic seismogram. A formation top or other correlation marker on the well log can then be tied to the corresponding seismic horizon with relative ease. In the real world, however, the interpreter may be, and often is, confronted with a synthetic trace and seismic data trace that bear little resemblance to each other ( Fateh et al., 1984).

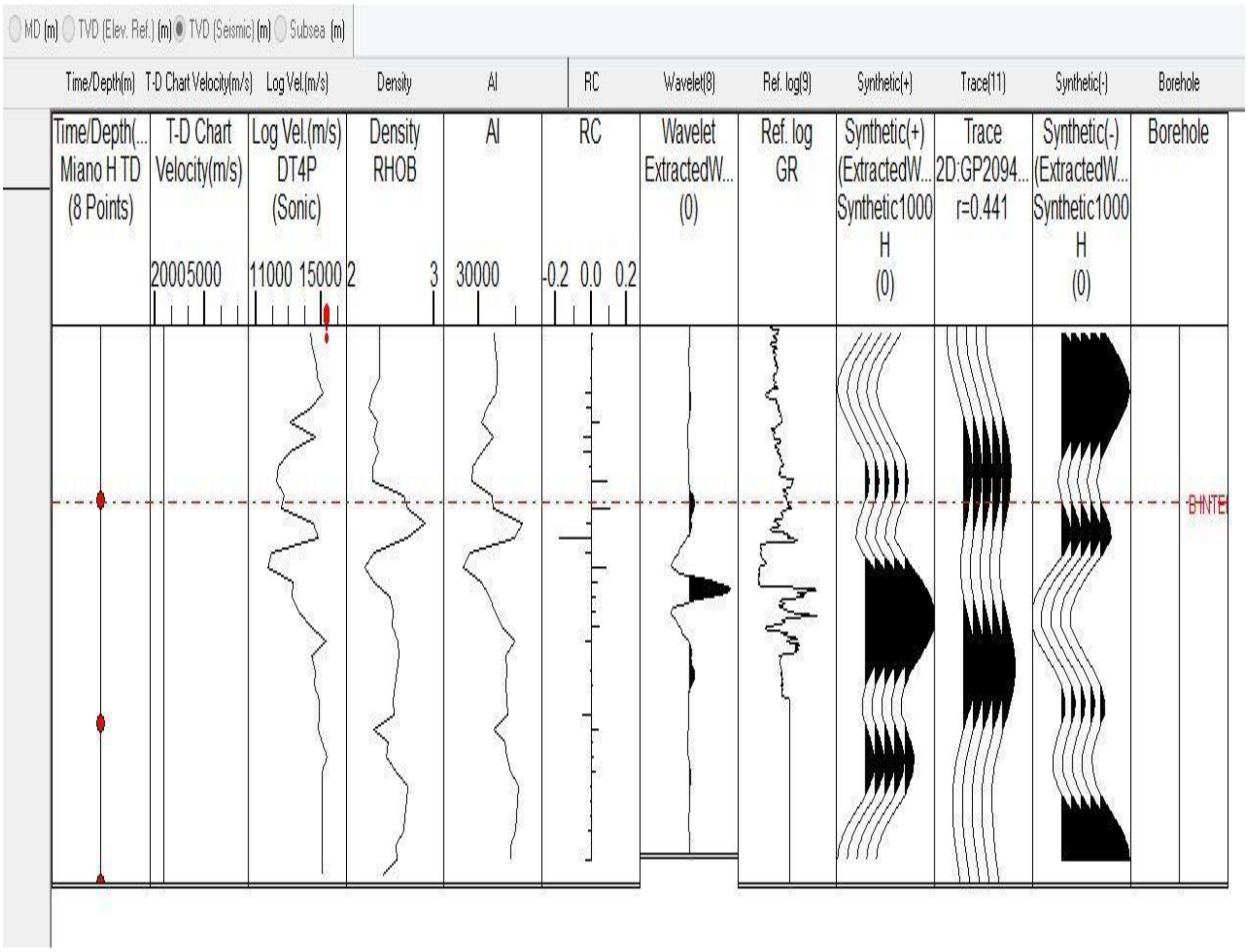



Figure Synthetic Seismogram of the well Miano- 09 on line GP2094- 221

### 3.6 Fault marking

Conventional seismic interpretations are the arts that require skills and thorough experience in Geology and Geophysics to be precise (Mc. Quillin et al., 1984). Fault marking on real time domain seismic section is quite a hard work to do without knowing tectonic history of area (Sroor, 2010).

Faults are marked on the basis of breaks in the continuity of reflection. This Discontinuity of the reflector shows that the data is disturbed here due to the passing of the faults. The Miano block 20 is lying in extensional regime hence we have conjugate normal faulting due to which the clear cut horst and Graben are formed .

## 3.7 Horizon Marking:

Interpreting seismic sections, marking horizons, producing time and depth maps is a task Which depends on interpreter's ability to pick and follow reflecting horizons (reflectors)

across the area of study (Mc. Quillin et al., 1984). Reflectors usually correspond to horizon marking the boundary between rocks of markedly different lithology but it does not always occur exactly at geological boundary of horizon which is sometimes important problem in seismic interpretations

## 3.8 Interpretation of the of Dip line GP2094-221:

Figure shows well tie with real time domain section . We marked horizons of B- interval, C- interval. Top of the lower Goru and the Ranikot formation on the basis of the change in the acoustic impedance also confirmed by the synthetic seismogram .The following color scheme is used to mark the horizon.

- B- sand ………………Dark Green
- C- sand ………………Cyan
- Top of Lower Goru ………………Dark Magenta
- Ranikot ……………… Hot Pink

The interpretation shows the alternatively horst and Graben are formed between conjugate normal faulting. The fault having almost trend of the N - S. The main purpose was to show the favorable structure for petroleum accumulation. The horst sand graben structures a considered good structural traps for the petroleum accumulation. considered good structural traps for the petroleum accumulation.

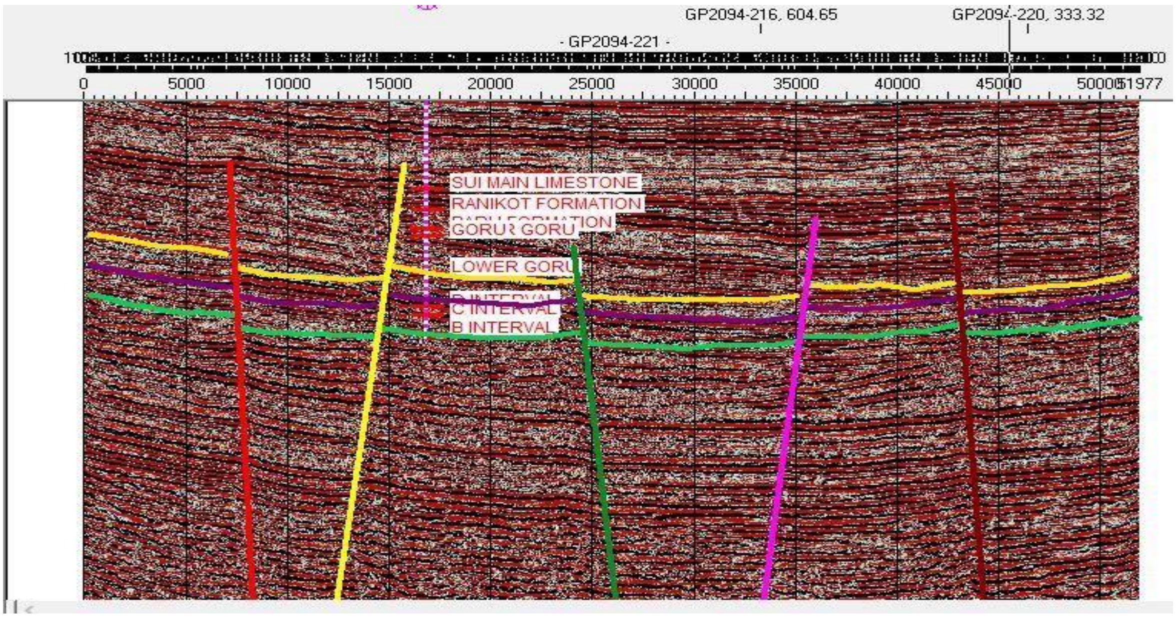



Figure Well tie and interpretation of Dip line GP2094- 223

In the interpretation of the line GP2094- 216 the conjugate normal faulting can be seen. Due to this conjugate normal faulting the horst and graben structures are formed. These structures are considered favorable for the hydrocarbon accumulation in the extensional regime as in the Miano area. The marked horizon are named as given in below legend.

**Legend:**

Top of lower goru

C-interval

B-interval

## 3.9 Interpretation of the seismic Strike line GP2094 -216:

Using IHS kingdom we digitize the seismic line GP2094- 223 with the strike li ne GP2094-214 .Then we removed the misstie however, in the given seismic section doesn't show any faults. The reason behind is that the given line is a strike line and the orientation of the line is against the basin configuration.

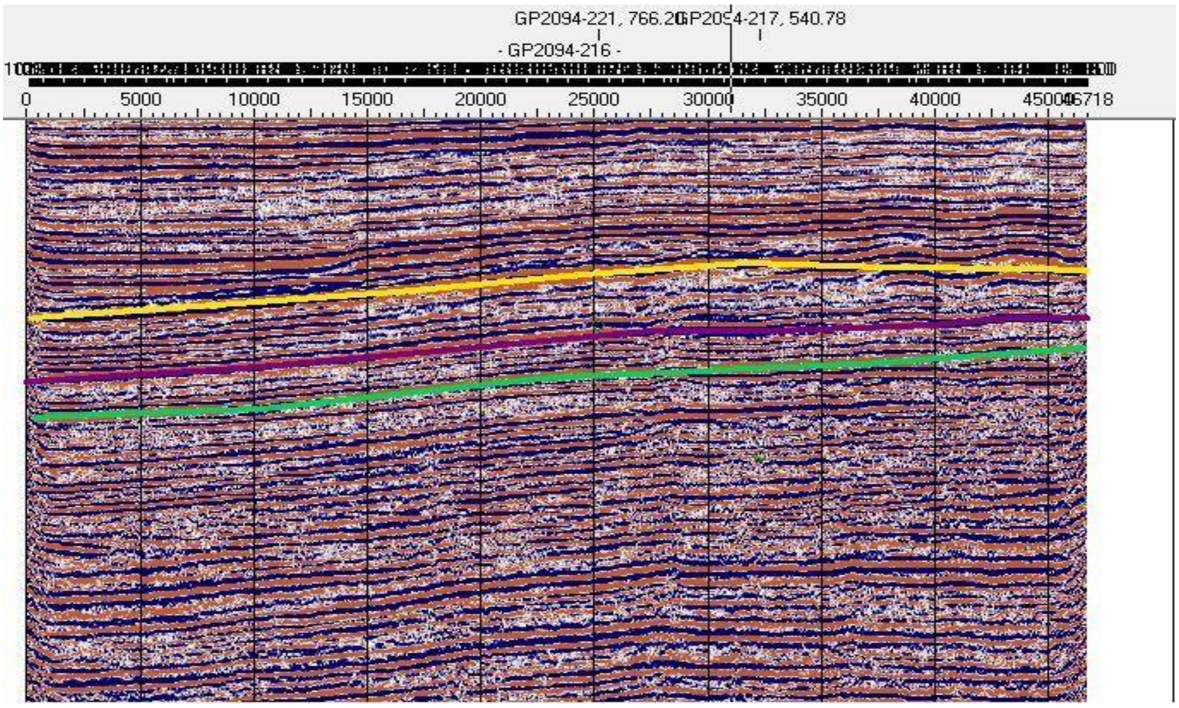



Figure Interpretation of the seismic Strike line GP2094 – 216

## 3.10 Interpretation of the seismic Dip line GP2094 -217:

After marking the seismic strike line GP2094- 216 we digitized this strike line with dip line GP2094-221 because this strike line was crossing all the dip lines which are shown in the base map in chapter- 01. After digitizing the strike line with this dip line we marked the horizon and removed the miss tie. The faults were already marked on this seismic section. When faults and horizon were marked then the horst and Graben geometry is formed as shown in the below figure 3.6. The main purpose to interpret this line was to show the favorable structures for accumulation of the hydro carbon. The horst and graben structures are considered the good structures for petroleum system to accumulate the hydrocarbon after migration.

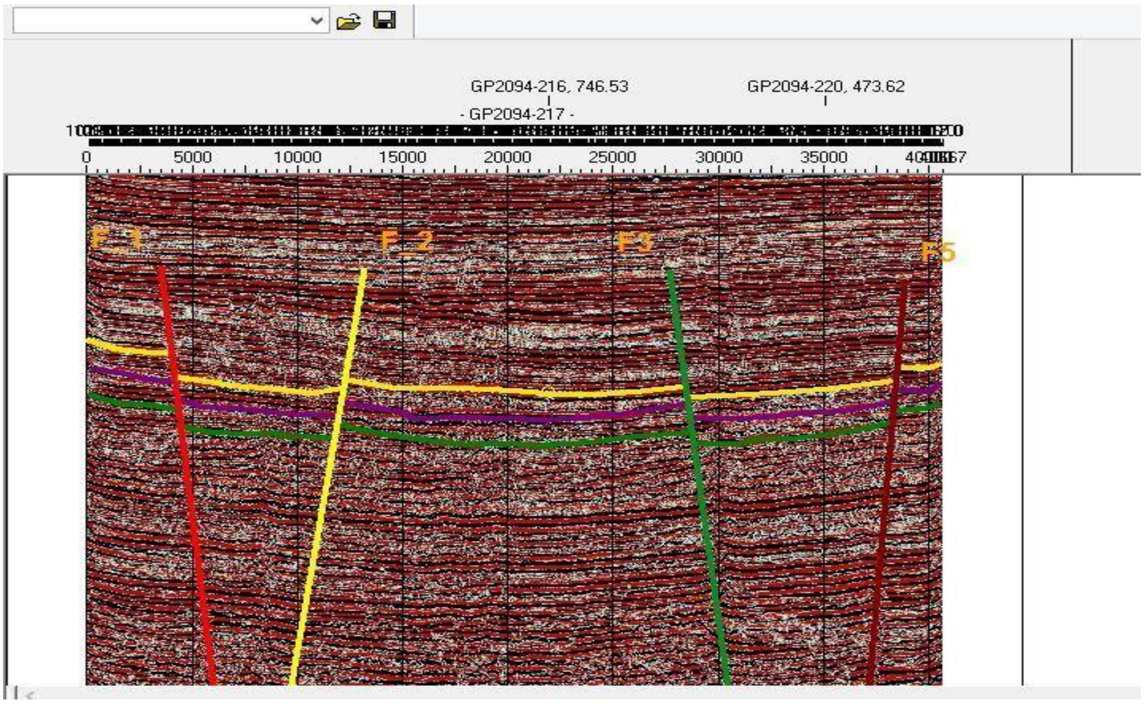


Figure interpretation seismic Dip line GP2094- 217

### 3.11 Fault polygon construction:

We pick the fault on seismic section & find it at the other seismic lines. The fault in seismic section is called Fault Segment and the fault on map view is called Fault Polygon (Sroor,2010). In any software for mapping an area all faults should be converted in to polygons prior to contouring. The reason is that if a fault is not converted into a polygon, the software doesn't recognize it as a barrier or discontinuities, thus making any possible closures against faults represent a false picture of the subsurface. I construct the

fault polygon at B- interval level and at C- interval level. Because the B- interval is acting as reservoir in my study area and C - interval is acting as seal. The fault polygon on both these level are shown in the below.

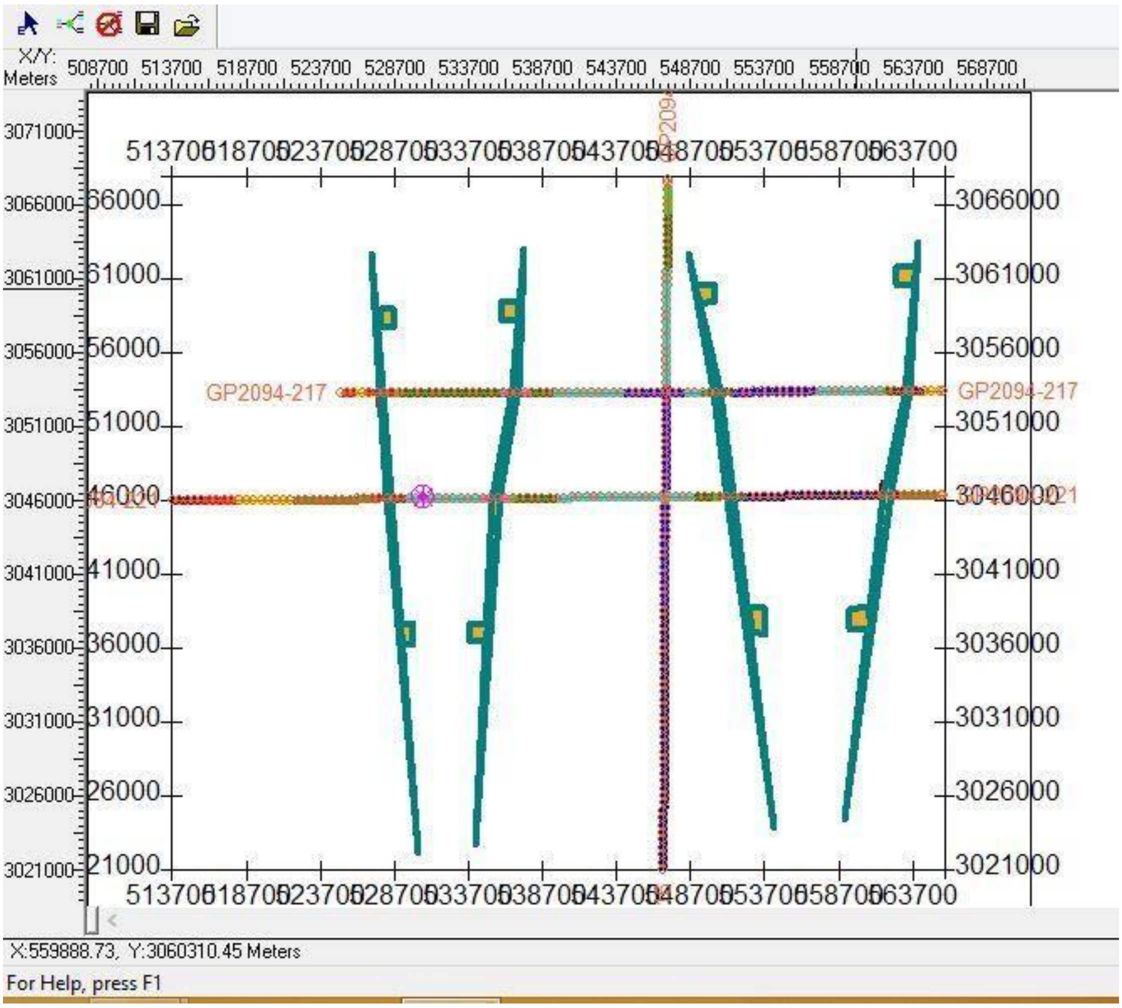



Figure 3.8 polygon constructed at b interval.

In the above fault polygon the small red rectangle shows the dip direction of the faults. It is clear that two conjugate normal faults are dipping towards each other hence Grabens are formed also when two conjugate normal faults are dipping away from each other horst is formed. The horst and graben geometry is clear from the faults polygon.

## 3.12 Time Contour Maps

Time contour map gives the information about the subsurface structure. It cannot show the structure directly but gives the idea about the structure and also give the information

about the horizons. The contour maps are generated by the HIS Kingdom software. The time contour map for the B-interval and C-interval is generated.

### 3.12.1 Time contour map of b interval:

TWT contour map of the B-interval has been prepared with contour interval of 75 milliseconds (0.075 seconds) as shown in Figure 3.7. Five major faults F1, F2, F3, F4 and are considered in mapping. F1, F3 have dip direction NW-SE while F2 and F4 have dip direction of NE-SW. These faults are normal faults making the geometry of horst and graben. F3 and F4 are the left and right lateral faults making the horst and graben for the B . Those kinds of geometries represent the favorable sites for potential zones. The Figure 3.8 represent that there is very minor throw of the faults. The contours which are observed in the time contour map for the B-interval start from 2.188s and last contour has time 2.638s.Time contour map shows that B interval are shallower in the West and deeper in the East. As the contour time increases the response of the reflection is from the lager depth rather than the contour having the smallest time. The main objective of the time contouring is to get information about undulation in the time horizon due to folding and faulting.

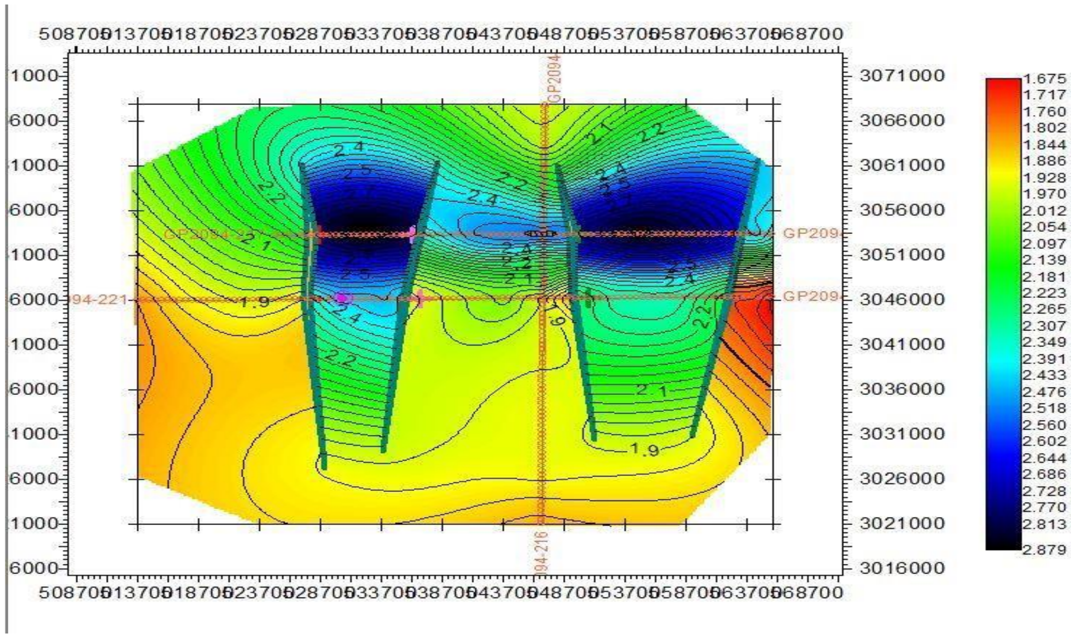



Fig Time  contour map of B-interval.

### 3.12.2 Depth contour Maps

As the data is in the two way travel time, gives information about the subsurface structure. The depth contour map is prepared that truly related to the subsurface structure. Starting depth for B interval is 1930.530m and it ends up to 2743.805m depth. We have five faults having same directions as in the time contour maps. Formations are shallower in the West having depth of 1767.605m and deeper in the East with the depth of 2607.503m. Depth of the horizons is plotted against the Northings and Easting of the survey. Depth contour maps of the horizons are shown in the Figure

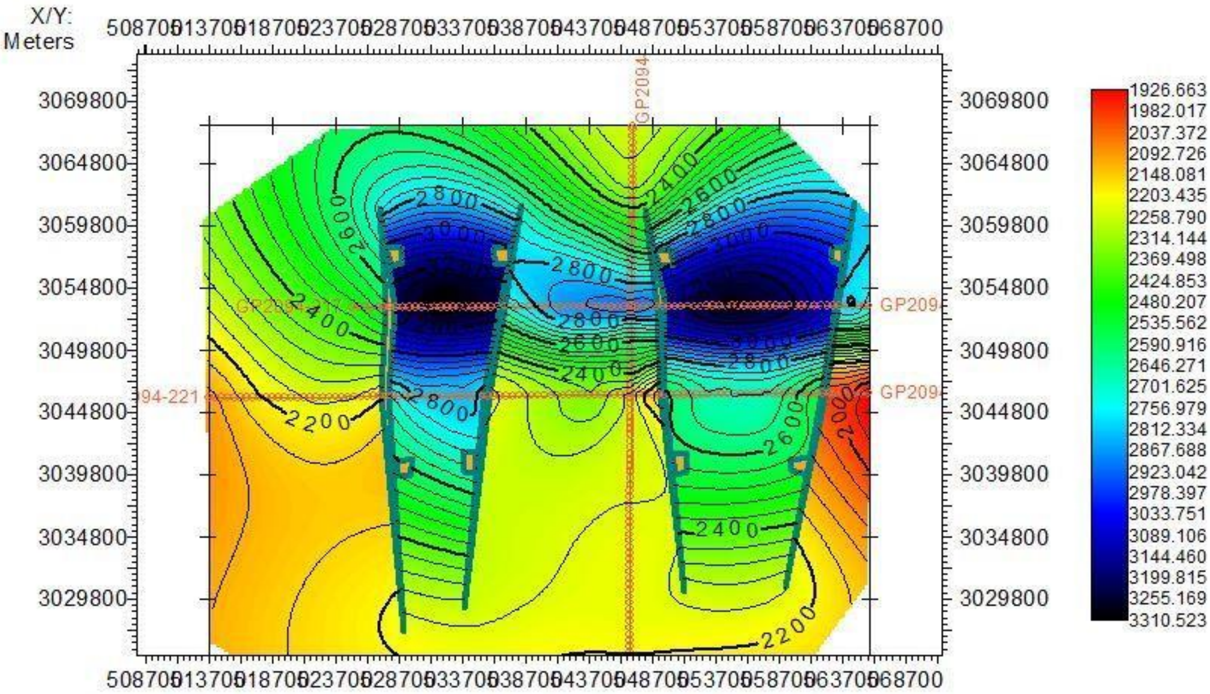



Fig depth contour map of b interval.

## 3.14 Seismic Attributes:

### 3.14.1 Introduction:

Seismic attribute is defined by as a measurement derived from seismic data. Such a broad definition allows for many uses and abuses of the term. Countless attributes have been introduced in the practice of seismic exploration (Brown, 1996 and Chen et al, 1997) which led Eastwood 2002 to talk about attribute explosion. Many of these attributes play an exceptionally important role in interpreting and analyzing seismic data (Chopra et

Energy, etc. A seismic attribute is any quantity derived from seismic data using measured time, amplitude, frequency, attenuation or any combination of these. It intends to output a subset of the data that quantifies rock and fluid properties and/or allows the recognition of geologic patterns and features. Almost all seismic attributes are post- stack but there are few pre- stack ones. They can be measured along a single seismic trace or throughout various seismic trace. The first attributes developed were related to the 1D complex seismic trace and included: envelope amplitude, instantaneous phase, instantaneous frequency, and apparent polarity. Acoustic impedance obtained from seismic inversion can also be considered an attribute and was among the first developed. In this research attribute analysis is performed for the B - interval of the lower Goru formation. The Seismic Attributes are classified basically into two categories.

- Physical Attributes
- Geometric attributes

## 3.15 Physical Attributes:

Physical attributes are defined as those attributes which are directly related to the wave propagation, lithology and other parameters. These physical attributes can be further classified as pre- stack and post- stack attributes. Each of these has sub- classes as instantaneous and wavelet attributes. Instantaneous attributes are computed sample by sample and indicate continuous change of attributes along the time and space axis. The Wavelet attributes, on the other hand represent characteristics of wavelet and their amplitude spectrum. Post stack attributes are derived from the stacked data. The Attribute is a result of the properties derived from the complex seismic signal..

## 3.15 Geometrical Attributes:

The Geometrical attributes are dip, azimuth and discontinuity. The Dip attribute or amplitude of the data corresponds to the dip of the seismic events. Dip is useful in that it makes faults more discernible. The amplitude of the data on the Azimuth attribute corresponds to the azimuth of the maximum dip direction of the seismic feature.

## 3.16 Envelope of Trace (Reflection Strength / Instantaneous Amplitude):

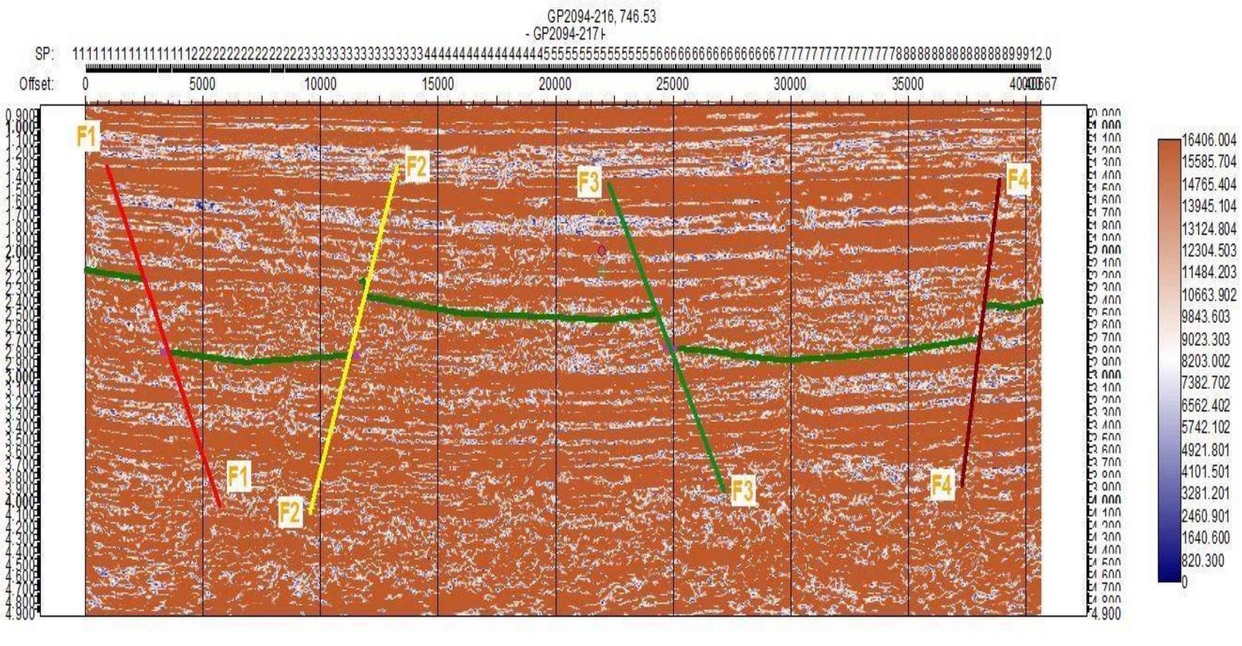



Figure 3.20 shows the envolope of the seismic trace

Trace envelope attribute represent t mainly the acoustic impedance contrast, hence reflectivity strength. It always remains positive whether the reflection coefficient is positive or negative. Figure (3.16) clearly shows reflection strengths of marked reservoir horizons. This attribute is mainly useful in identifying; (Chopra et al.2005) Bright spots gas accumulation. Sequence boundaries, major changes or depositional environments. Major changes of lithology Local horizontal changes indicating faultin

### 3.17 **Instantaneous phase:**

Instantaneous phase is measured in degrees it is independent of amplitude and shows continuity and discontinuity of events. It shows bedding very well. Phase along horizon should not change in principle, change can arise there is a a picking problem, or if the layer changes laterally due to "sink- holes" or other phenomena.this attribute is useful as (Chopra et al., 2005)Best indicator of lateral continuity.Relates to the phase component of the wave propagation.Detailed visualization of bedding configuration. Has no amplitude information, hence event Used in computation instantaneous frequency and acceleration.

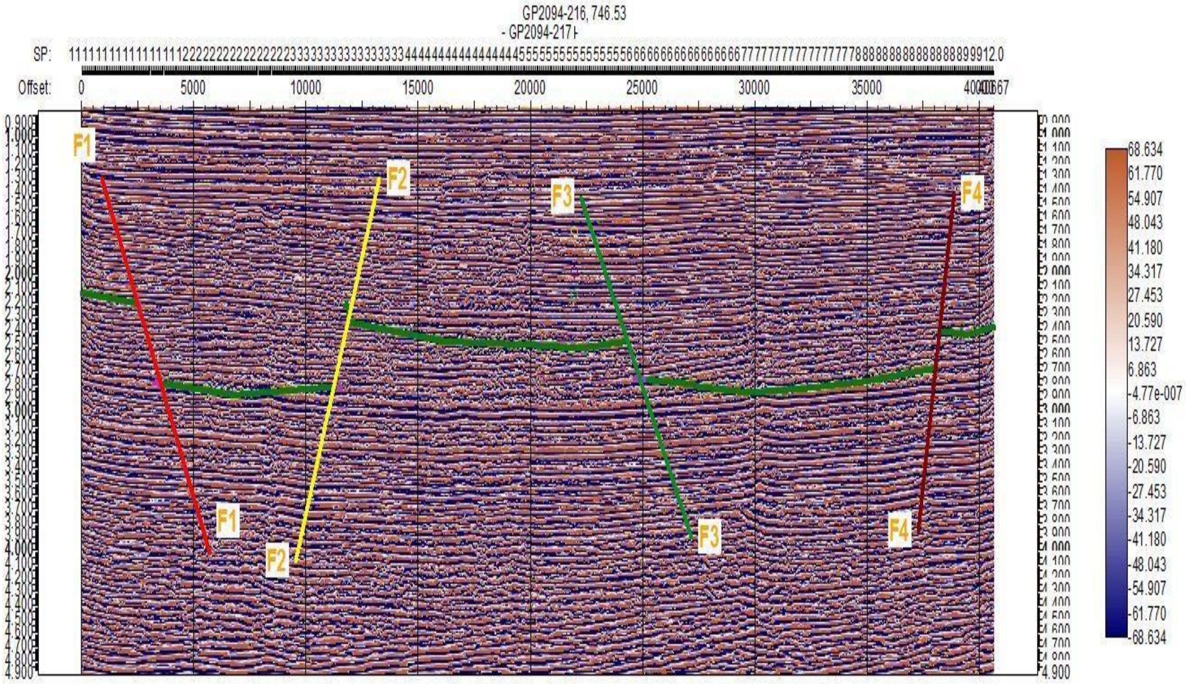



Figure 3.21 shows the instantaneous phase of the seismic section.

### 3.18 **Instantaneous frequency:**

These attributes are mainly direct Hydrocarbon indicator by low frequency anomaly inhigh resolution 3D data because this effect is sometimes accentuated by unconsolidated sands due to the oil content of the pores. Fracture zone indicator, since fractures may appear as lower frequency zones. Bed thickness indicator. Higher frequencies indicate sharp interfaces such as exhibited by thinly laminated shales, lower frequencies are indicative of more massive bedding geometries, e.g. sand- prone lithologies (Taner, 2001). From figure 3.18 at marked horizons are low frequencies indicating presence of hydrocarbon in the zone whilst as move downward, and time increases instantaneous frequency increases i.e. at greater depths.

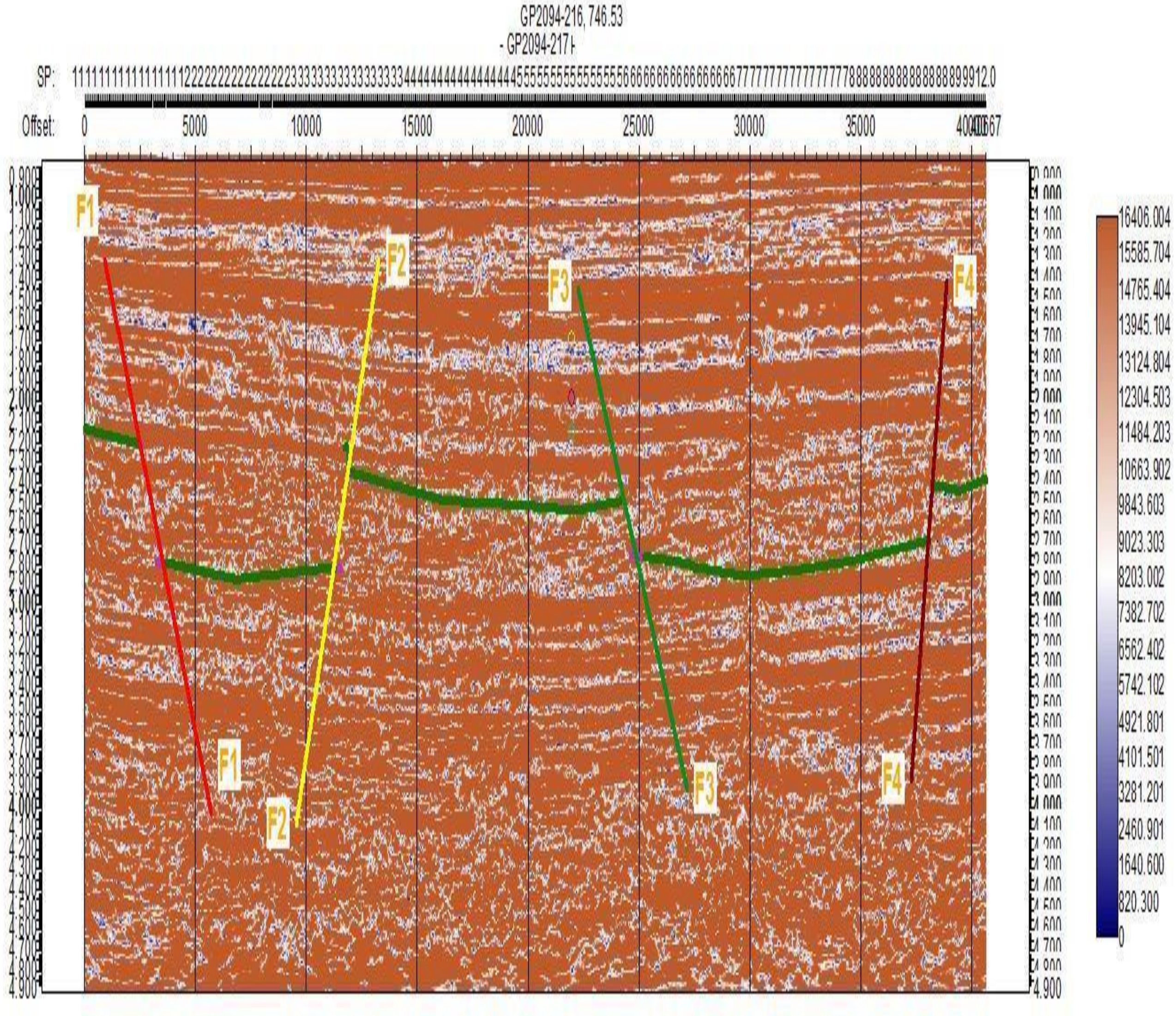



Figure 3.22 shows the instantaneous frequency of  the seismic section.

# Chapter 4

# PETROPHYSICS

## 4.1 . Introduction:

## Petrophysics:

Petro physics, as understood in the oil and gas industry, is the characterization and interaction of the rock and fluid properties of reservoirs and non-reservoir. Determining the nature of interconnected network of pore spaces – ***porosity***; the distribution of oil, water and gas in the pore spaces –**water saturation;** and. the potential for the fluids to flow through the network – **permeability.**.Petrophysical interpretation is fundamental to the much of the work on the subsurface carried out by geologists, geophysicists and reservoir engineers and drillers. To characterize the subsurface successfully requires physical samples, electrical,chemical, nuclear and magnetic measurements made through surface logging, coring and drilling and wireline tools (sondes).Terms such as 'formation evaluation' and 'log analysis' are often used to capture specific parts of the petrophysical workflow, but should not be seen as synonyms.'Rock physics, which sounds as though it might be similar, is usually reserved for the study of the seismic properties of a reservoir; similar concepts apply but at larger scale (Steve cannon; 2016).

## 4.2 Classification of geophysical well logs

Geophysical well logs can be classified into three categories

- Lithology logs
- Resistivity logs
- Porosity logs

### 4.2.1 Lithology Logs

Lithology log are designed to identify the boundaries between the permeable and non- permeable formation, information about the permeable formations provide lithology data for the correlation with other well logs.

Lithology logs are

- Caliper (CLAI)
- Spontaneous potential (SP)
- Gamma Ray (GR)

### 4.2.2 Caliper (CLAI):

Caliper logs measure the diameter of the borehole. It records the cavities where the well is caved in, and also the hardness of the rock cut during drilling. Where there is the porous material, mud cake will be formed that cause the hole diameter to become smaller. Variation in the diameter of the borehole influence the record of the different logs .Therefore it is important to consult with the caliper logs any artifacts (Knut BjØrlykke. 2010).

### 4.2.3 Gamma Ray Log

Gamma ray logs are lithology logs that measured the natural radioactivity of a formation. The concentration of radioactive material are present in shale, shale has high gamma ray reading. Therefore shale free sand and the carbonates have low gamma ray reading. Volume of shall can be calculated by the following formula

$$IGR = \frac{GRLOG - GRmin}{GRmax - GRmin},$$

Where GRmin is minimum value and GRmax is the maximum value of the gamma ray, Igr is the gamma ray index and GRLOG represent the gamma ray log. Gamma ray logs are used to identify lithology, the volume of the shale and the correlation between the formations.(Asquith and Krygowski, 2004).

### 4.2.4 Resistivity well logs

Resistivity well logs give the thickness of the formation, accurate value for the true formation resistivity and information for the correlation purposes. All these logs are plotted on the logarithmic scale due to more variation in resistivity (0.2 to 2000 ohm) with depth.

Resistivity well logs are

- Deep laterolog (LLD)
- Shallow laterolog (LLS)

### 4.2.5 Deep laterolog (LLD)

Deep laterolog is the electrode logs and are designed to measure formation resistivity in the borehole filled with saltwater muds (Rmf).The effective depth of the laterolog investigation is controlled by the extent to which the surveying current is focused.(Asquith and Krygowski, 2004).

### 4.2.6 Shallow laterolog (LLS)

Shallow laterolog measure the resistivity of in the invade zone (Ri).In waterbearing zone, the shallow laterolog records a low resistivity because mud filtrate resistivity (Rmf) is approximately equal to mud resistivity (Rm), (Asquith and Krygowski, 2004).

### 4.2.7 Porosity well log

Porosity well logs are provide the data through which the water saturation can be determine, provide the accurate lithologic and porosity determination and provide data to distinguish between oil and gas.

Porosity well logs are

- Sonic/Acoustic (DT)
- Neutron Porosity (NPHI)
- Density (RHOB)

### 4.2.8 Sonic/Acoustic (DT)

Sonic logs measure the interval transit time (delta t) of the compressional sound wave through the formation. The interval transit time is related to the porosity of the formation. The unit of measure is the microseconds per foot or microseconds per meter. (Asquith and Krygowski. 2004).

Relation for the calculation of the porosity from the sonic log

Porosity of the formation can be calculated by using the following formula

$$\emptyset \mathbf{s} = \frac{\Delta \mathbf{tlog} - \Delta \mathbf{tm}}{\Delta \mathbf{t}_{\mathbf{f}} - \Delta \mathbf{t}_{\mathbf{m}}} \qquad (2)$$

Where ∅s represent the calculation that derived from the sonic log, Δtm is the interval transient time of the matrix, Δtlog interval transient time of formation, represents the transient time of the fluid (salt mud=185 and fresh mud=189).the interval transient time of the formation depends upon the matrix material, its shape and cementation (Wyllie et al., 1956).If fluid (hydrocarbon or water) is present in the formation, transient interval time is increases and this behavior shows increase in porosity which can be calculated by using sonic log (Rider., 2002; Asquith and Gibson., 2004).

### 4.2.9 Neutron Porosity (Φn)

Neutron log is the porosity log that measure hydrogen ion (HI) concentration in a formation. (Asquith and Gibson.2004).In the shale free formations where the porosity is filled with the water, the neutron log is related to the water filled porosity (NPHI).In gas reservoir, porosity measured by the neutron log is low then the formation n true porosity as the hydrogen ions concentration are less in gas reservoir then that of oil and water (Asquith and Krygowski., 2004).It is the one limitation of neutron log that is known as the Gas effect.

### 4.2.10 Density (RHOB)

Density log is the porosity log that measure electron density of the formation, (Asquith and Krygowski.,2004) Formation electron density is actually related to bulks density of formation. It is actually the sum of fluid density multiplies its relative volume plus matrix density time relative volume. The density log are used with other logs and separately for different purposes.(Tittman and Wahal., 1965).

Relation for the calculation of the porosity from the Density log (Ød)

Density log can be used to find out the accurate porosity of the formation, if the matrix densities in the formation or rock type are known (Asquith and Gibson. 2004).The rock type in my research work is sandstone and shale

Where, Ød represent porosity derived from the density log, ρbrepresent bulk density of formation, ρmrepresent matrix density and for sandstone it is 2.65 and ρf represent density of fluid. The main purpose of present petrophysics is to obtain calculation about porosity, saturation of water and hydrocarbon.

## 4.10 Work flow:

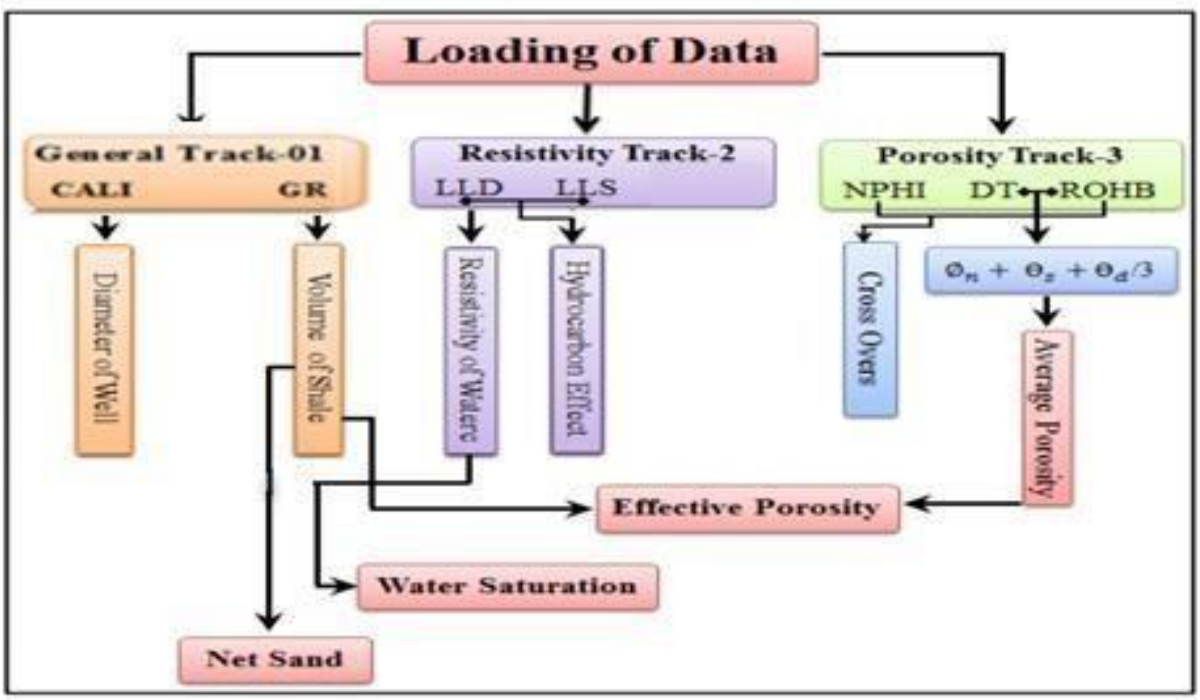



Figure 4.1: Methodology adopted for petrophysical interpretation.

## 4.13 Interpretation of well log

IHS Kingdom software is used for the analysis of Miano-09 well; within the depth Range of the B-sand 3331 m to 3390 m. Due to collapsing of wellbore Ruguosity effect will be occur. Therefore in the depth ranges, if there is Ruguosity, the value of the other log is not consistent. GR log, Caliper log are displayed in track-1.LLD and LLS log are displayed intrack2.

DT, NPHI and RHOB are displayed in track-3.The crossover of NPHI and RHOB is importaDepth of NPHI is remain same but value of the RHOB is changed within that depth, it indicate fluid contact (Figure 4.2). Depth scale is shown in track-4. Volume of shale

Vsh is displayed in track-5. Shale and sand can be separated by applying 40% cut-off value. Below this cut-off value, there is a sand and above this cut-off, there is a shale. Density porosity is displayed in track-6, calculated from DT4P.Average porosity (PHIT) is displayed in track-7 and actually is the sum of NPHI and DT4P divided by 2. Effective porosity is displayed in track-8 after removal of the shale effect. Water saturation (SW) is displayed in track-9 and Hydrocarbon saturation is calculated from the water saturation.B-sand petrophysics is done to depth from (3331 m) to (3390 m ).In this way, interest zone that called the reservoir is from 3338 m to 3346 m defined where sandstone is encountered.

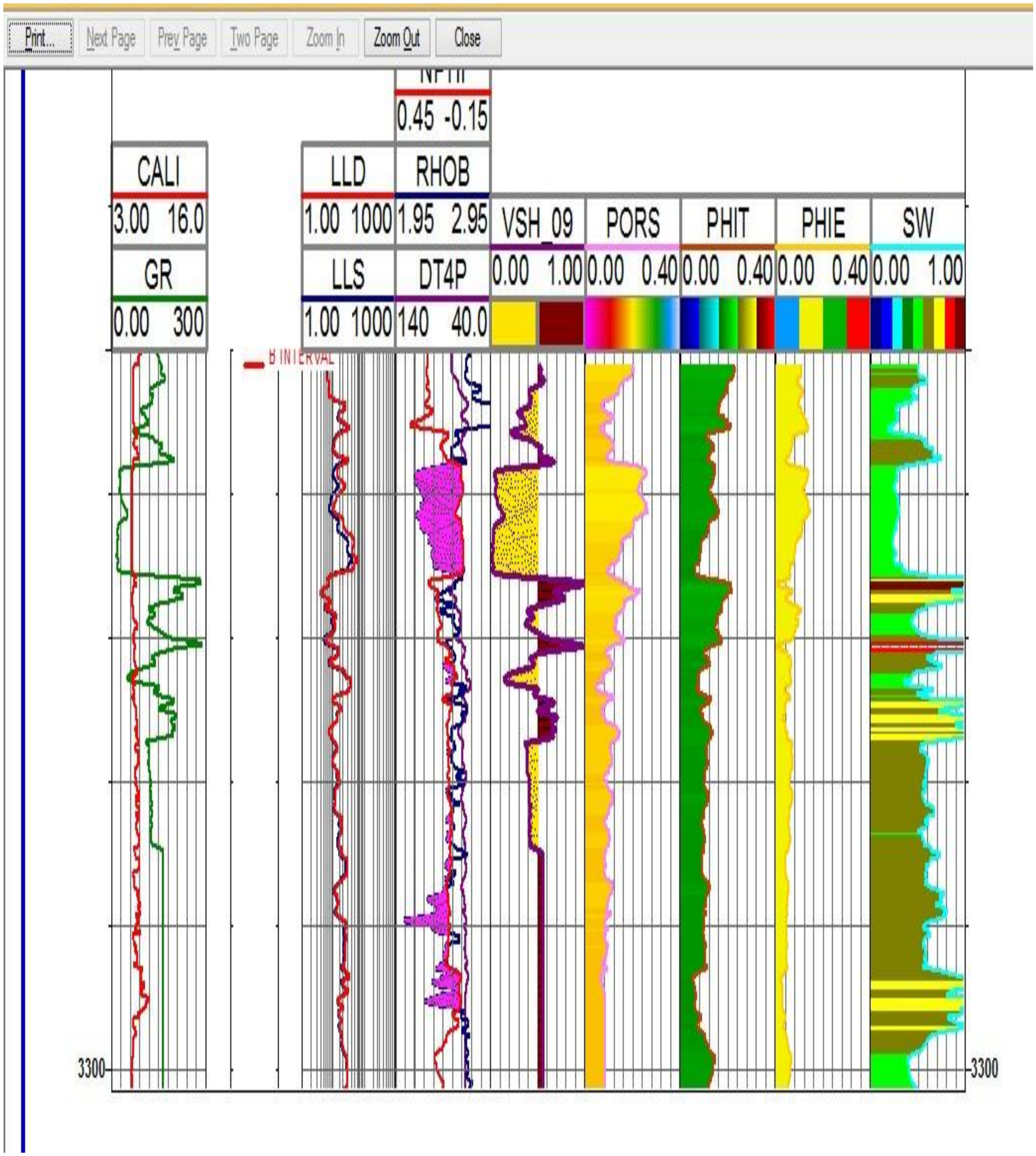



Figure 4.2: Petrophysical analysis of B-sand Miano well-09.

# CHAPTER 5

# FACIES MODELING

## 5.1 Introduction:

In geology, a facies is a body of rock with specified characteristics (Ravia et al., 2010). Ideally, a facies is a distinctive rock unit that forms under certain conditions of sedimentation, reflecting a particular process or environment. Sand-shale investigation has constantly been challenged for geoscientist. Key challenge is to classify and identify the facies, from logs or cores, degree to which shale content affect the reservoir properties. This feature is chief factor in illustrating the reservoir productive zones (Kurniawan, 2005). This leads us to identify different cross-plots that have relationship between reservoir properties and log response (Naji et al., 2010).All these facies are releated to the certain sedimentary depositional environments. The depositional environment is a specific type of place in which sediments are deposited, suchas a stream channel, a lake, or the bottom of the deep ocean. They are sometimes called sedimentary environment.

## 5.2 Types of Facies:

### 5.2.1 Sedimentary Facies

Sedimentary facies Sedimentary facies are bodies of sediment recognizably different from adjacent sediment deposited in a different depositional environment.

## 5.3 PHIE, GR and Depth Cross-plot:

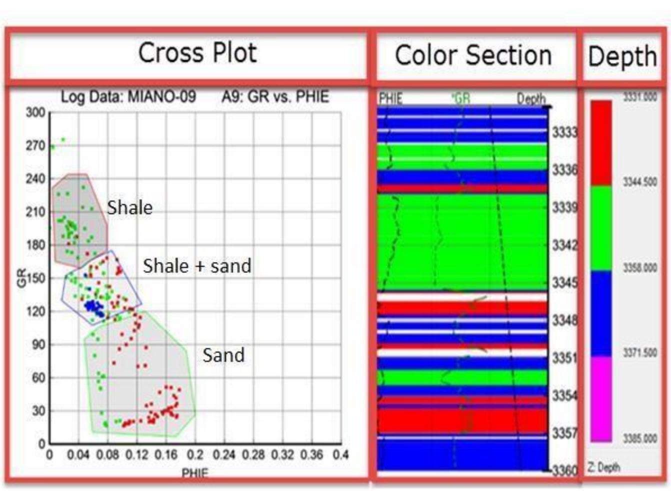
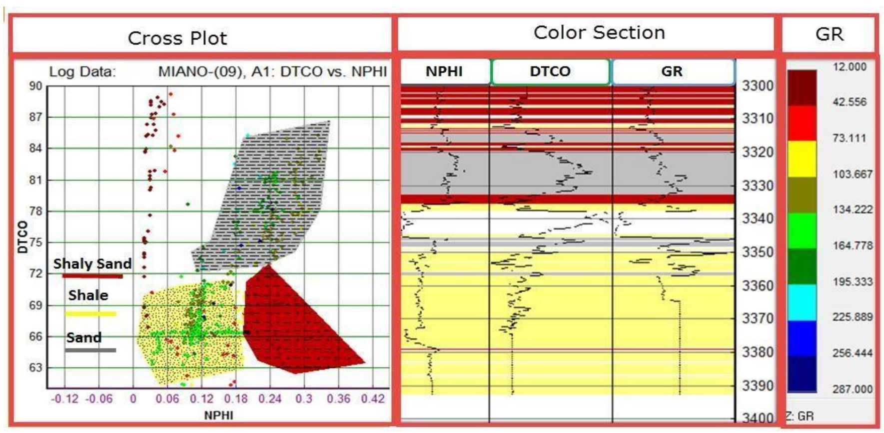



Figure 4.3: GR, PHIE & depth cross-plot.

Figure 4.3 shows a cross-plot between effective porosity (PHIE), Gamma Ray log (GR) and depth of the formation under study. We can see the sand layer with good high effective porosity with low Gamma Ray log value at depth range of 3338 to 3346m. Three parts relative to the corresponding values are marked.

## 5.4 GR, LLD and Depth cross plot:

The cross plot of the N-PHIE and GR is obtained from miano -09 for B-interval shown in figure 5.3. Cross plot in the figure reveals that there is an inverse relationship between DT and NPHI. Sand intervals are marked by high values of DT and low value of the NPHI comparatively to shale and low value of GR. The low value of NPHI in gas bearing reservoir is called the gas effect as in our reservoir area .Shale has direct relation with GR but low values of DT and PHIE.The GR is marked on the Z-axis with color dots. Yellow color is representing the sand while the Cyan color is representing the shale.




## 5.5 NPHI, GR & Depth Cross-plot:

Figure 4.5 shows a cross-plot plotted between gamma ray (GR), Neutron log (NPHI) and depth of the formation under study. A zone with low values of GR and even total porosity at depth range of 3338 to 3346 m marked is sand layer while greenish part reflects high GR and NPHI values satisfies shale presence. Sandy shale is often sandwiched in between sand and shale in the reservoir zone.

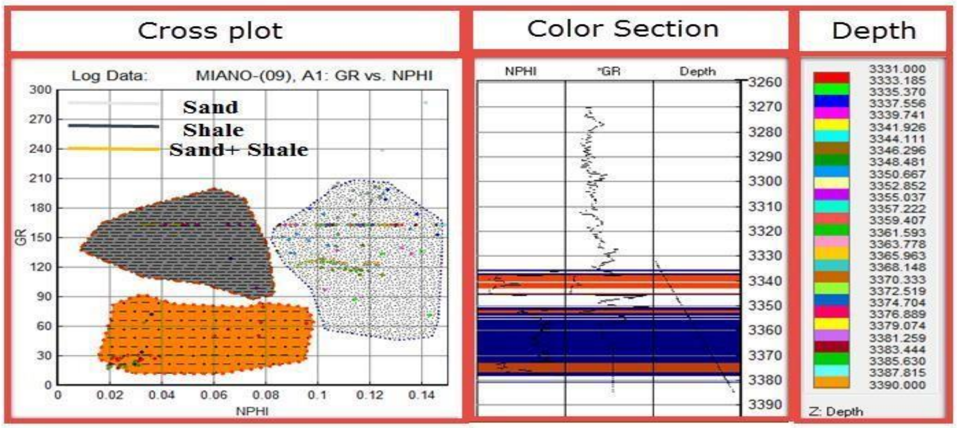



Figure 4.5: NPHI, GR & Depth Cross-plot

## 5.6 NHPI, DTCO & GR Cross-plot:

Figure 4.4 shows a cross-plot plotted between Neutron log (NPHI), density log (DTCO) and gamma ray log (GR). Low values of GR with high resistivity at depth range of 3338 to 3346m are observed. This is quite possibly the properties of sand layer with hydrocarbon.

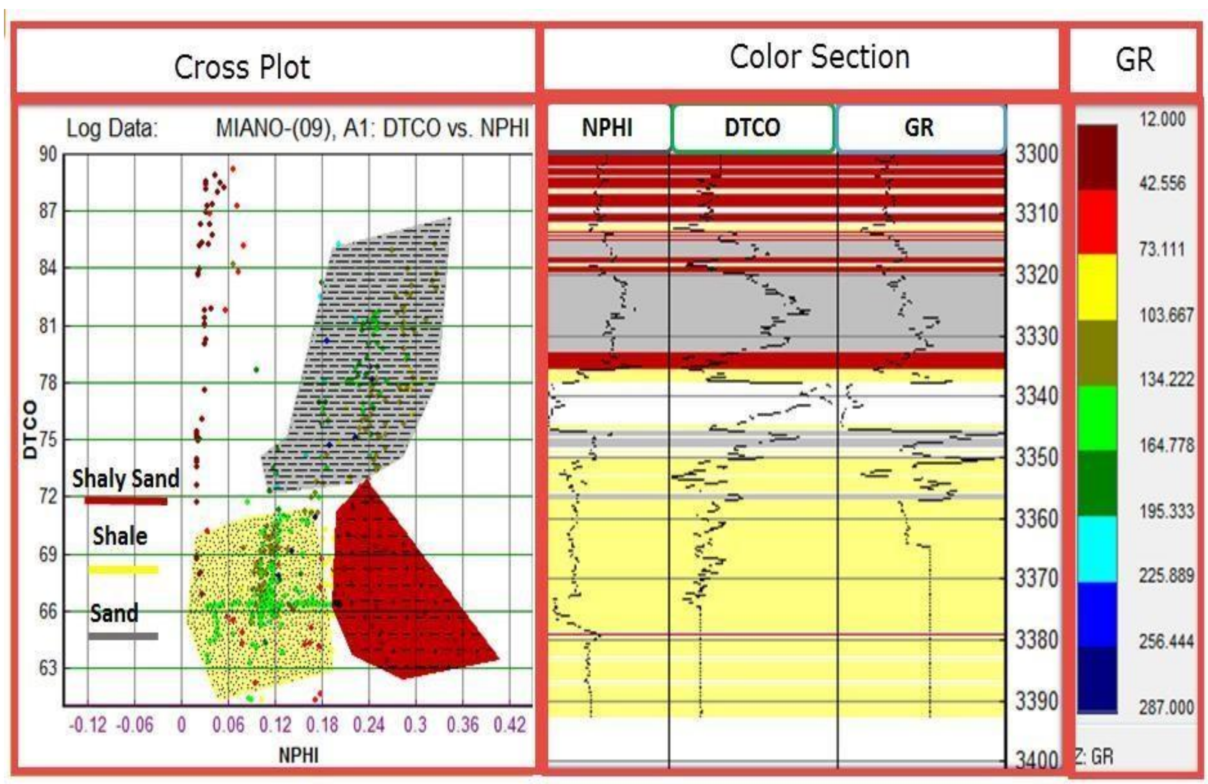


Figure 4.4: NPHI, DTCO & GR cross-plot. **5.7**

### NPHI, GR & Depth Cross-plot:

of the formation under study. A zone with low values of GR and even total porosity at depth range Figure 4.5 shows a cross-plot plotted between gamma ray (GR), Neutron log (NPHI) and depth of 3338 to 3346 m marked is sand layer while greenish part reflects high GR and NPHI values satisfies shale presence. Sandy shale is often sandwiched in between sand and shale in the reservoir zone.

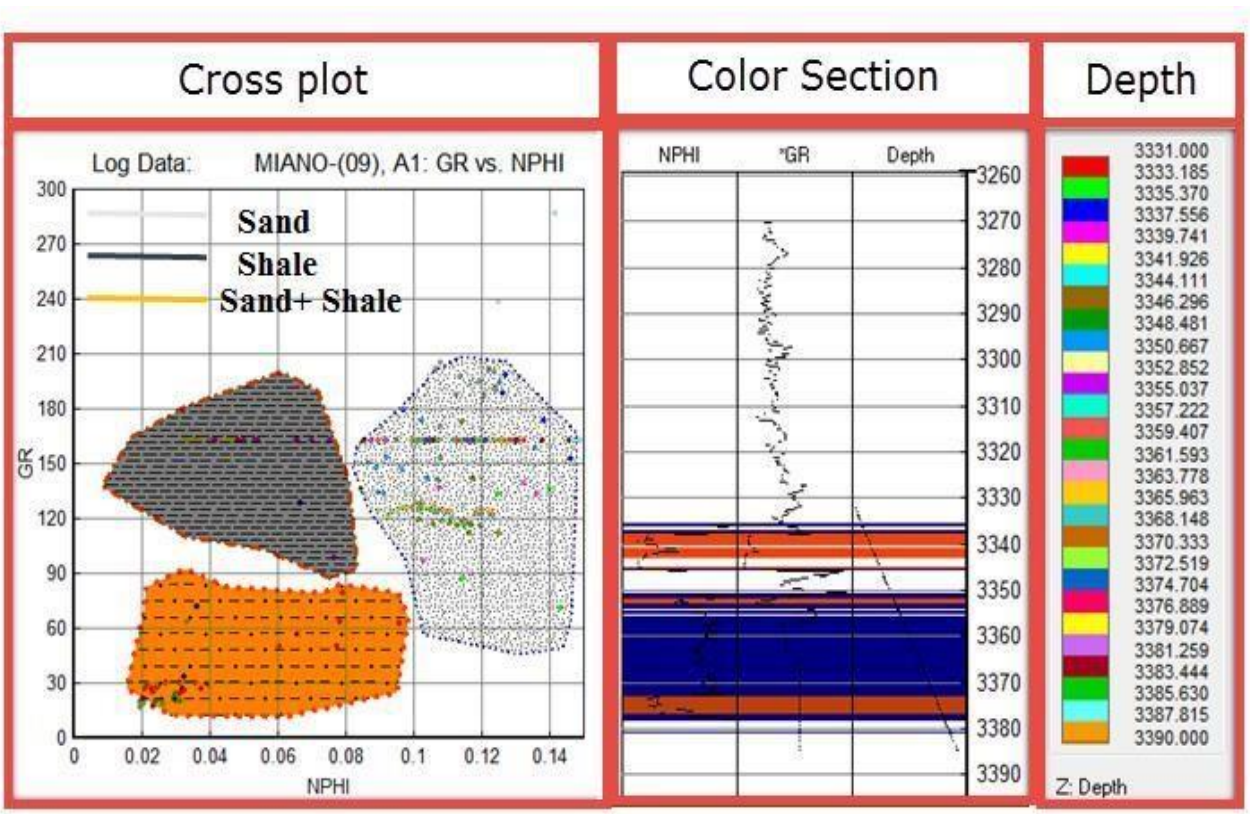



Figure 4.5: NPHI, GR & Depth Cross-plot.

# <u>5.8 Sequence stratigraphic analysis of the lower Goru</u>

### 5.8.1 Introduction to sequence stratigraphy:

The sequence stratigraphy is the branch of the stratigraphy that deals with the relatively rise and fall on sea level causing the deposition and erosion of the sedimentary formation. The analysis of sedimentary response to changes in base level, and the depositional trends that emerge from the interplay of accommodation (space available for sediments to fill) and sedimentation. (Catuneanu, 2006).As the seal level changes than the facies migration occur. This migration is explained by the Walter (1995).

## 5.9 Walther's Law of Facies

Walther's Law of Facies, or simply Walther's Law, states that the vertical succession of facies reflects lateral changes in environment. Conversely, it states that when a depositional

environment "migrates" laterally, sediments of one depositional environment come to lie on top of another. A classic example of this law is the vertical stratigraphic succession that typifies marine transgressions and regressions. However, the law is not applicable where the contact between different lithologies is non-conformable (Lucia 1995).

## Sequence

A group of relatively confirmable strata that represents a cycle of deposition and is bounded by unconformities or correlative conformities, Sequence is a fundamental unit of interpretation in the sequence stratigraphy. Sequence comprise of system tract. Before studying the system tract analysis using the well log data we must have to know about the some basic terminologies of the sequence stratigraphy. There are different terms releated to the sequence deposition which are shortly explained below.

## 5.10 System Tract:

Subdivision of sequences that consist of discrete depositional units that differ in geometry from other system tract and have distinct boundaries on seismic data OR

The system is 3-dimensional unit of deposition. Tract mosaic of different deposition of pattern joined with one another. Different system tract represents different phases of eustatic changes.

## Aggradation:

The process in which various sedimentary facies stacked over each other.This occurs when

**Accommodation space=sedimentary facies**

When aggradation occurred toolsets and Forest have equal thickness, offlap break is straight; sea level is neither decreases nor increases.

## 5.11 Retrogradation:

The process in which sedimentary facies migrates towards proximal side (continental side). This is due to transgression.

**Accommodation space > sedimentary influx**

# ***Conclusion and Discussion***

**1**: Seismic interpretation results have identified Horst and Graben structures in the area of study which are favorable structures for the accumulation of hydrocarbons.

**2.** On the basis of time and depth contour maps different probable leads (lead-1, lead-2, lead-3 and lead-4 and Lead-5) have been identified in the study area. These leads have been marked at B-interval of the Lower Goru formation.

**3.** Due to limitation of data control seismic attribute analysis only confirm the interpretation at some locations but not give any reliable location to identify hydrocarbons.

**4.** The petrophysical interpretation of well Miano-09 leads us to 0ne probable zone for hydrocarbon extraction and Two probable zone are identified in Miano-10 which having potential of the hydro carbon.

**5.** For the confirmation of reservoir lithology Facies analysis is done on Miano-09 well which reveals the result as the reservoir lithology as sand.

**6.** From the AVO modeling it is confirmed that the B-interval of the lower Goru formation is class one sand.

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