2D SEISMIC REFLECTION DATA INTERPRETATION

AND

PETROPHYSICAL ANALYSIS

OF MIANO AREA, LOWER INDUS BASIN, PAKISTAN

BY

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BS GEOPHYSICS

2016-2020

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To start with the greatest name of Almighty Allah. Most gracious and merciful, with Him is the knowledge of the Hour, He sends down the rain, and knows that which is in the wombs. No person knows what he will earn tomorrow, and no person knows in what land he will die. The knower of the unseen is Allah these are the keys of the unseen, whose knowledge Allah alone has kept for himself and no one else knows them unless Allah tells him about them

ACKNOWLEDGEMENT

First praise is to Allah, the most Beneficent, Merciful and Almighty, on whom ultimately, we depend for sustenance and guidance. With the grace of ALLAH, I have been able to overcome yet another task which was impossible without ALLAH's Blessings.

Heartfelt appreciation goes to **Dr Mumtaz Shah**, for his supervision, support and advice to shape this dissertation into its final form. I would like to express cordial gratitude to my whole family, especially my parents. Their support, prayers, encouragement and confidence has always given me strength to be able to achieve my goals.

I sincerely wish to express my appreciation to the whole faculty of Department of Earth Sciences. Their support and guidance have been priceless throughout my course and dissertation work.

Finally, I would like to thank all my friends and colleagues for their endless support, care and affection.

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DEDICATION

I dedicate my work to my beloved Parents (my support system) and my siblings whose efforts means a lot to achieve my goals at every step of life.

ABSTRACT

Miano gas field is one of the prominent gas-producing fields of the Middle Indus Basin, SW Pakistan. In this dissertation, focus is placed on the structural interpretation of the Miano Field Block-20 in order to demarcate the probable zone for the accumulation of hydrocarbons. This study attempts in preparation of synthetic seismogram of Miano-10 well. Analysis of geophysical borehole logs provides one of the best approaches to characterize rocks within boreholes.

For the interpretation of the seismic lines, two 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 maps.

Petrophysics is the one of the most reliable tools for the confirmation of the types of the hydrocarbon and for marking the proper zone of the interest for the presence of the hydro carbon by combination of the different logs results. In this dissertation the petrophysics is performed on the Miano-10 well and different zone of interest are marked where there is chance of the presence of the hydro carbon. Rock properties of zone of interest are VSH is 22.5%, PHID is 10% and HC 56.3%.

Contents:

Introduction

Energy sector plays an important role in the development of any country. As the demand of energy increases in the world, the exploration increases in the energy sector of the countries. No doubt with exploration we mean the exploration of hydrocarbons over the unexplored areas to full fill the demand of energy. Developing countries like Pakistan is in the list of countries which have increased its explorations of hydrocarbons to increase its economy. Miano gas field is one of the prominent gas producing fields of the Middle Indus Basin, SW Pakistan. Daily average production of this field is 98 MMscf gas, and 52-barrel condensate. Present dissertation comprises of exploration results in this field.

One of the exploration concerns of Miano Field is its identification of the prospective structural design within the heterogeneous structural and stratigraphic reservoir system. These reservoir systems are composed of varied architectural elements such as the Horst and Graben geometries. The productive sand in the up thrown block i.e Horst is favorable for exploration of hydrocarbons and for the implication of reservoir characterization (Zareef et al., 2016).This dissertation comprises the attempt of the identification of structural features and the characterization of clastic sediments of Lower Goru reservoir using the preliminary seismic interpretation to the 2D seismic profiles of the Miano Gas Field, Middle Indus Basin, SW Pakistan. B- Sand is found to be the lead in seismic interpretation.

Geophysicists have been trying for hydrocarbon exploration since a long time ago and developed many techniques in this regard. Seismic method is direct result evaluating and accurate geophysical method used for litho-structural analysis especially; Seismic Reflection Method has greater precision than refraction method for deep hydrocarbon exploration in petroleum geology. Petroleum geology refers to the specific set of geological disciplines that are applied to the search for hydrocarbons. Oil and gas fields are geological features that result from the; source rocks, Migration, reservoir rocks, seals, and traps (Sroor, 2010). Hence geology and petroleum system of the area are important factor regarding exploration.

Petrophysics is one of the most important and reliable technique in the field of the earth sciences. Petrophysics provide the link between the rock physics properties i.e. lithology, water saturation, porosity, clay content, acoustic impedance, Primary and secondary wave velocity, and the elastic moduli. Similarly, the rock physics is used for forecasting the seismic response with assumed reservoir and overburden properties (Avseth et al., 2010).

Objectives

The main objective of dissertation is to present a subsurface model of study area and to characterize the reservoir potential in the zone. In following all objectives, mentioned in points, to interpret surface structure exposed by satellite image and previous studies. Picking horizon at different intervals using synthetic from well data.

- Detailed seismic interpretation for identification of the structures favorable for hydrocarbon accumulation.
- Petrophysical analysis for the identification of the hydrocarbon bearing zones.

Data used

To achieve all the objectives, seismic and borehole data given in Table-1.1 and 1.2 is used provided by DGPC to complete the Thesis project

Table 1.1 Seismic Data used in interpretation

Line name	Orientation of line	Nature of the line
P2094-213	E-W	Dip line
P2094-214	N-S	Strike line
P2094-221	E-W	Dip line

Table 1.2 well data used in the interpretation Well Data obtained from DGPC for completion of Thesis work Miano-10

Well name	Total depth(m)	Well type
Miano-10	**3610**	**Gas development**

BASE MAP

Base map generally 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. Topographic maps are used as base maps for assembly of surface geologic information. The base map of the study area is shown in the Figure.1.2 which contains 2 dip lines and a strike line along with the Miano-10 of miano area.

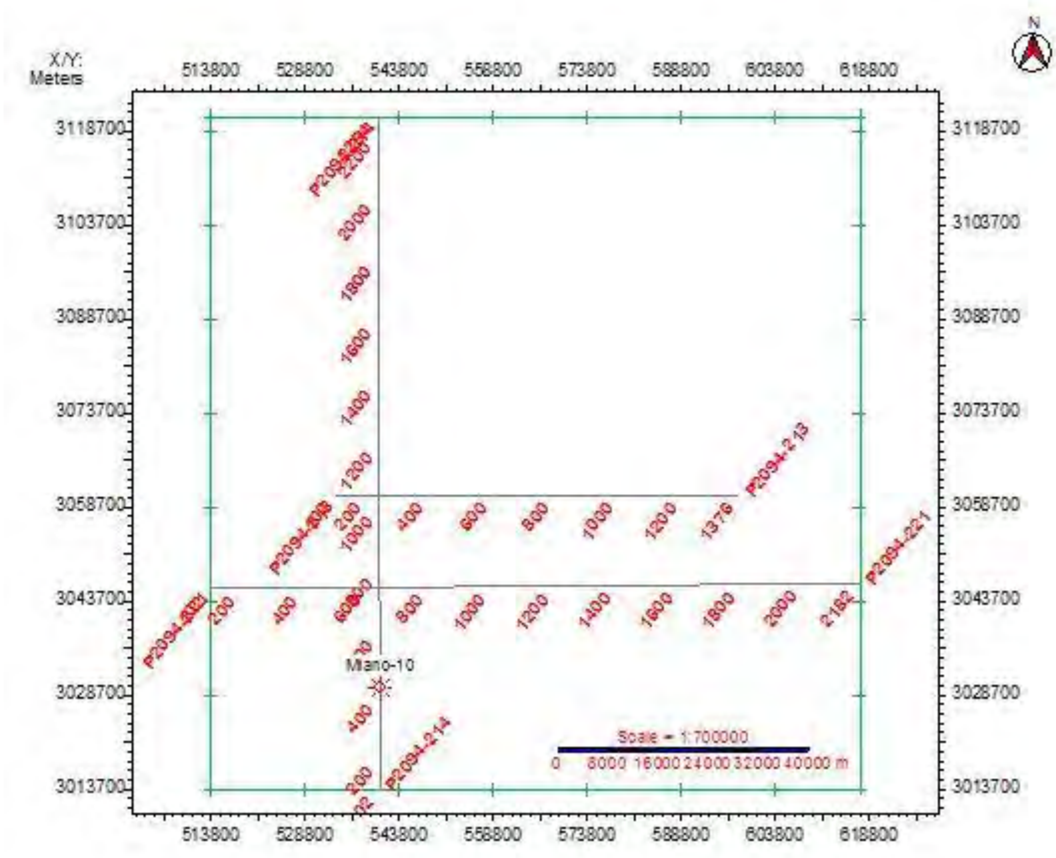

Fig:1.1 Base map

Software Tools used

To complete project and completion of this dissertation course work I used following software tools

- SMT KINGDOM 8.8

Geographical Location

My study area the (Miano, Field Block-20) is located 62 km away in the southeast direction of the Sukkur city Sindh province. This field is about 42km long along the strike.

Miano gas field is one of the prominent gas-producing fields of the Middle Indus Basin, SW Pakistan. Two of the largest gas field of the Pakistan Mari gas field and the Sawan gas fields are located in the north of this area at 75km and 150km away from this are, Basically the Miano gas field is located in the Thar desert. Geologically it is located at the boundary of the Lower and Middle Indus basin, between Indian basement and Kirthar fold and thrust belt. The geographic coordinates of the area are below.

- **Latitude of the area:**
- Latitude of the area 27.15º to 27.45º N
- **Longitude of the area:**
  Longitude of the area is 69.00º to 69.45º E

The Location and Tectonic Map of the study area are shown below in Figures below:

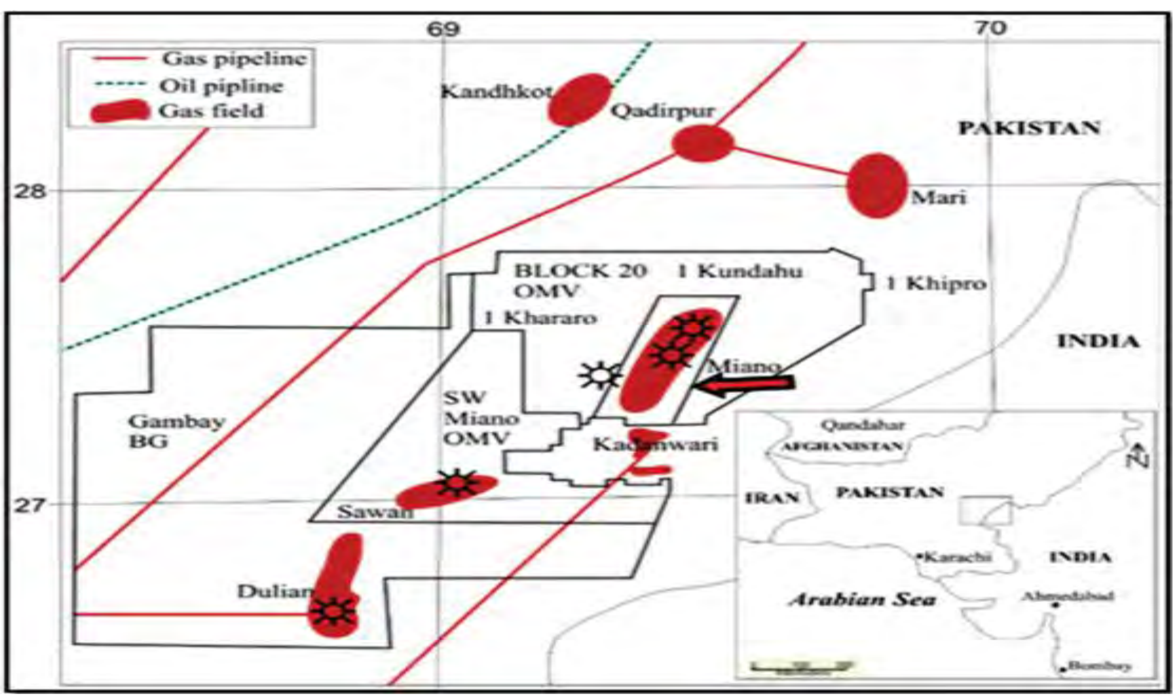

Fig: 1.2Location map of study Area (Zareef et al., 2016)

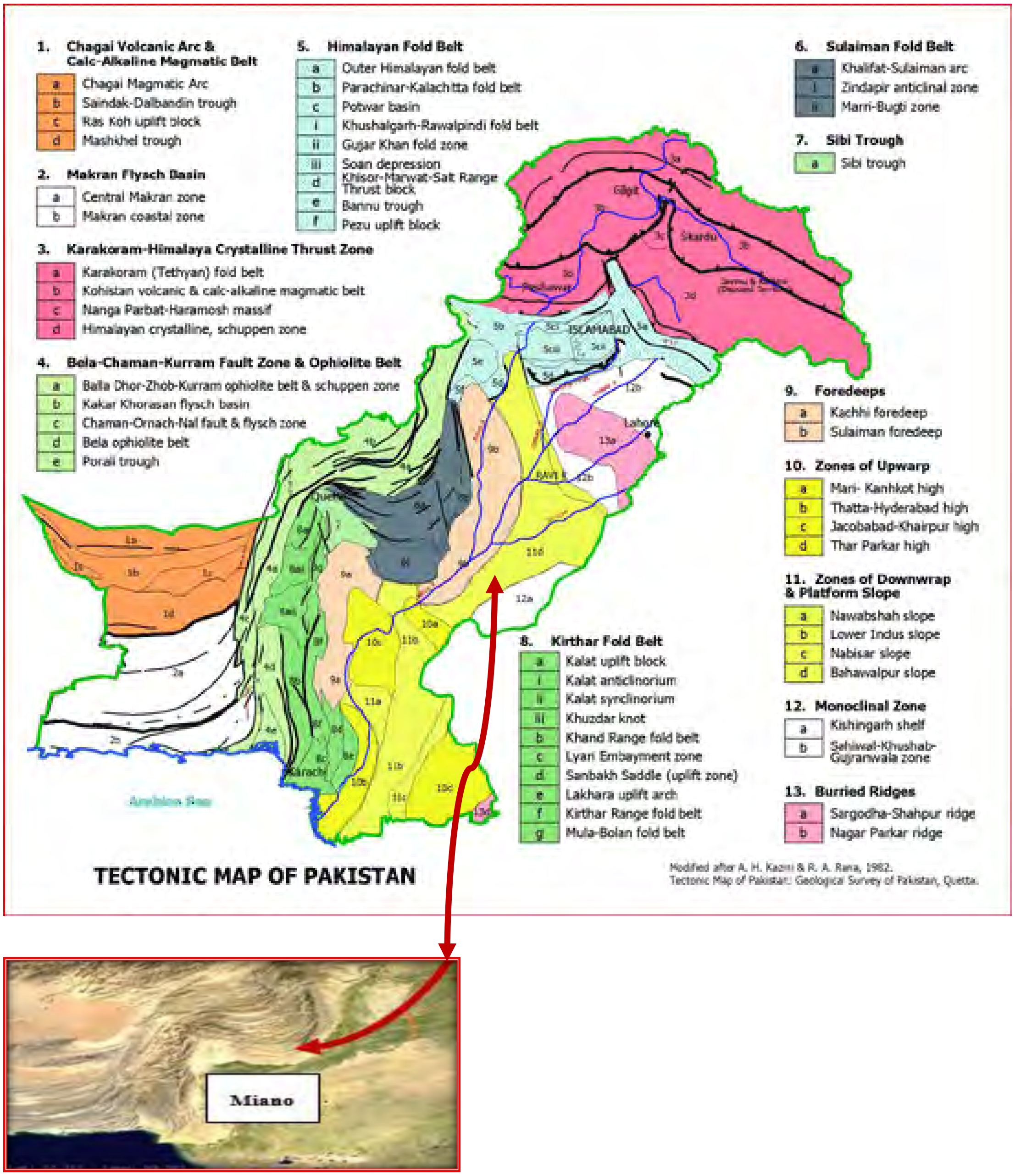

Figure 1.3 Geographical location of the Miano Area (Nadeem et al., 2004)

Thesis Organization

This Thesis is divided into four chapters with first chapter forming an introduction. The 2nd chapter covers the Geological setting and History of study area. In Chapter 2 central Indus Basin is discussed more thoroughly and Stratigraphic Chart with Source, Seal and reservoirs of study area are mentioned with various colors on the other hand, are mentioned as a whole too. Chapter

3 deals with the Basic goal of this dissertation i.e. Seismic interpretations of study area using Seismic reflection methods. In Chapter 4, various Petro-physical properties of concerned reservoir in study are found by using well-logs.

CHAPTER:2

GEOLOGY OF THE AREA

Importance of the Geology

In field of the oil and gas exploration study about the geological history of the area is most important. Basically, the geological history of the area is related to the tectonic behavior of the area and deposited sedimentary sequences of that area (Kingston et al., 1993).

Sedimentary basin

Sedimentary rocks are deposited in the depressed area called the "Sedimentary basin". The sedimentary basins are depressed sites having the thick sediments in interior and thin sediments at sides (Shah et al., 2009). According to the depositional history and the tectonic behavior the Pakistan is comprises on the two main sedimentary basins which are below.

- Indus Basin
- Baluchistan Basin

Both these basins are evolved through different geological episodes and were finally combined together during the cretaceous age along Ornach Nal and the Chamman transform fault (Kazmi and Jan., 1997).The Indus basin is then further divided into three main parts ,and our study area lies in the central part of the Indus basin. The basin division of the Pakistan and then further subdivisions of the Indus basin are shown in the below Figure 2.1 (Kadri, 1995).

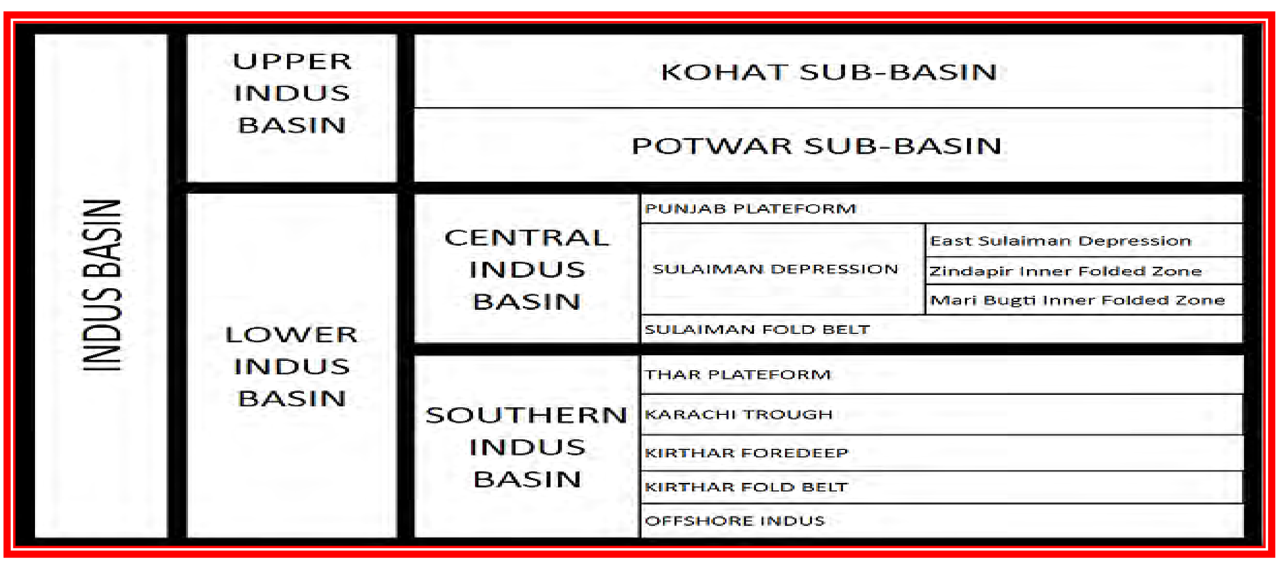

Figure 2.1 Division of the Indus Basin (Kadri, 1995)

Structure and Tectonic Settings of the study Area

The tectonic study of the Pakistan shows that Pakistan lies in the two main domain of large land masses i.e. Gondwanaland domain and the Tethyan domain. The northern most part and the western part of the Pakistan lies in the Tethyan domain and is having most complex geology and structure, while the southern part lies in the Gondwanaland domain. The Indus basin is the largest basin in the Pakistan. The orientation of the Indus basin along SE-SW Direction is 2500 sq. km. The tectonic history of the Pakistan shows that it is most stable area as compared to the other tectonic zone of the Pakistan (Kazmi and Jan, 1997).

The study area for this project is (Miano, Field Block-20). This block is located in the eastern part of the Jacobabad-Khairpur High, which is the most prominent feature identified in the seismic survey of the Indus basin. This study area lies at the boundary of the Middle and Central Indus basin. The Miano field has the series of the fault which are mostly Normal and Strike Slip in the nature and having extension in the direction of N-NW to S-SE. According to the seismic study of this area mostly features of this area are extensional and middle Indus basin is mostly characterized by the passive roof complex types structures (Kadri I.B., 1994). The tectonic setting of this area after is shown in the below Figure 2.2.

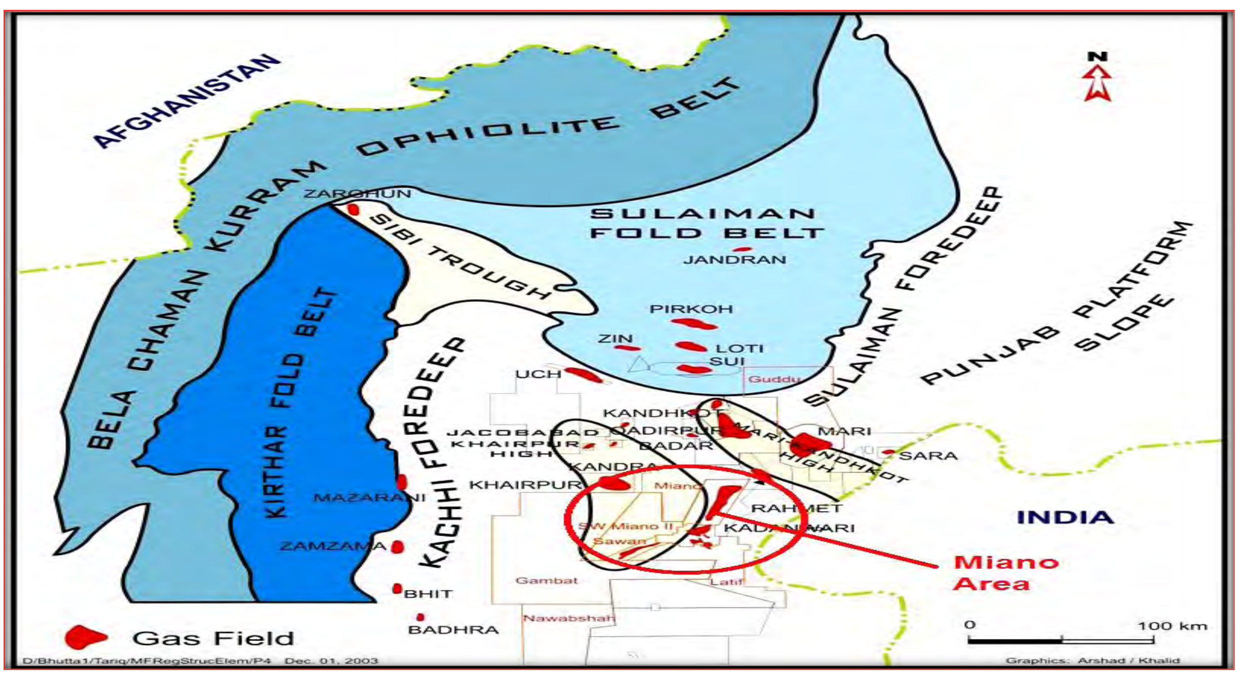

Figure 2.2 Regional tectonic map of Miano, Field Block-20 in the Middle Indus Basin.

Stratigraphy of the Area

To study the depositional history of that area the stratigraphic study of that area is most important.The study area Miano lies in the Central Indus Basin, which is located very close to the rift margin of the Indian plate and the African plate.

According to the stratigraphic history of this area this basin comprises mostly Permian to Mesozoic sediments which are overlying on the very clear angular unconformity of the late Paleozoic age whole of the study area is thickly covered by the alluvium and we cannot see any out crop on the surface, which is a direct indication of the stratigraphic succession. According to the stratigraphic study of this area lower Goru is acting as a reservoir in this area. The lower Goru is further divided into different four intervals, the lower Goru B-Interval is main productive reservoir in Miano area .According to the well log study the progradational sequences are founded in this area and Mesozoic progradational sequence is deposited on east ward inclined gentle slope. The sequence stratigraphic study shows that every prograding unit represent the lateral variation in the facies from shallow marine to continental side in the east and west.

In the Thar platform these Mesozoic sediments are regionally plunging towards west direction and are unconfirmabaly truncated by the (Khadro formation's basalts) volcanic rocks, also they show the truncation towards sedimentary section of the Paleocene age (Nadeem et al., 2012).

The interbedded siltstone, sand stone and shales of the shallow marine and the continental origin are also present of Permian, Triassic and Jurassic age. Mostly sedimentary rocks of this area belong from the Permian and Mesozoic age and overlaid by the stronger angular unconformity of possibly Paleozoic age (Kadri I.B, 1994). The Chilton Lime stone having the strongest and prominent seismic reflector in the middle Indus Basin. This Chilton Lime stone is down lapped and overlain by the cretaceous and late Jurassic regressive strata consists on the bottom sets, clinoform and the topsets which prograde towards the western part of the Indian Craton.

The source rock of the area is Sembar formation while the seal and Reservoir rocks are present within the lower Goru formation. The Sembar formation mostly consists on the argillaceous Foreset while initial topsets are called the Chichali formation. The younger topsets are "A-Sand" of the Lower Goru formation. Still no name has been associated with the submarine fan system associated with prograding system according to (Sturrock and Tait. 2004).

The Sembar formation is deposited in the marine environmental condition which consist on mostly black shales and subordinate siltstone and it is the main source of the hydrocarbon in the middle and the lower Indus basin. The TOC in Sembar formation ranges from the 0.5 TO 3.5 percent (William, 1995). The stratigraphic column of the area after Nadeem et al., 2012 is shown in the below Figure 2.3.

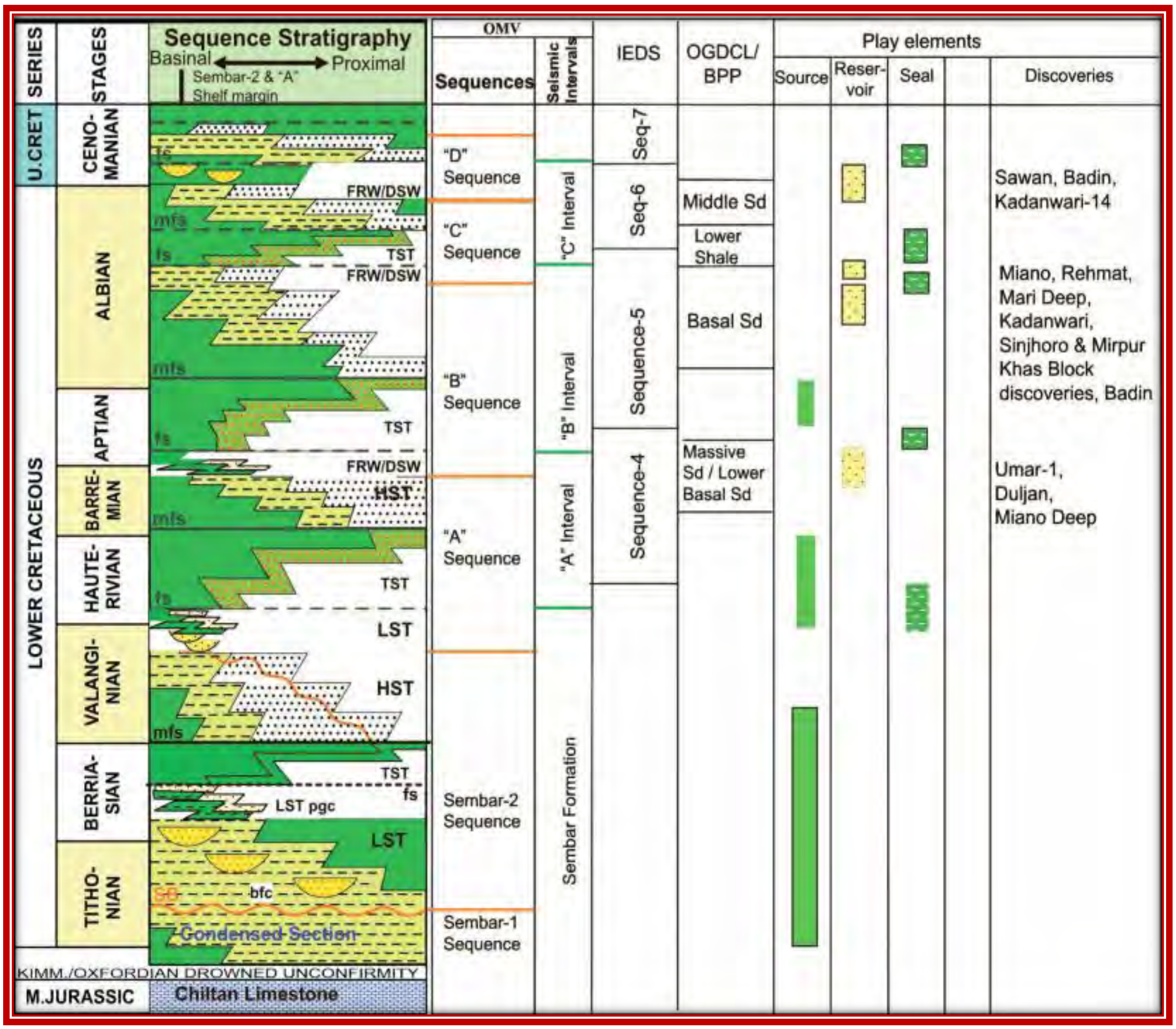

Figure 2.3 Stratigraphic chart for the Sembar and lower Goru formation (Nadeem et al., 2012).

The Sembar formation consist on the type-III kerogen which having ability to generate the gas, also type-II kerogen is present in Sembar formation (Wandrey et al., 2004).

The Lower Goru Formation which is reservoir in the study area is deposited during the Jurassic and the Early Cretaceous regressive system. The lower Goru “A”, “B”, “C” and “D” interval is deposited during the long term third order gradual sea level rise, but the deposition is mostly punctuated by the high frequency 4^{th} and 5^{th} order relative sea level fluctuation. Hence, they led the deposition of the prograding clastic sand packages on the vast and wide spread ramp. The balance between the sediment supply and the accommodation space from “E” to “SE” maintained slightly aggradation to overall progradational profile on the “A”,” B” and “C” interval of the lower Goru formation (Krois et al., 1998). The Progradation is occurred in the result of the relative sea level fall due to which the sediment supply becomes enhanced than the accommodation space (Nadeem et al., 2012).

Petroleum System

The petroleum System of the area tells us about the Source, Reservoir and Trap Mechanism. Different gas fields like Kadanwari, Sawan Miano and Tajjal are present in the area. The Stratigraphic column of the area shows different rocks act as Source, reservoir and Cap rock in the area. The general description is given below.

Source Rocks

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.

- **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 within the sand stone of formation.

Reservoir Rocks

The main reservoir rocks in the study area are lower Goru formation. 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 ancemented,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.

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 an "effective zero reservoir" line.Transgressive shales of the Lower Goru "C" Interval directly overlying the ‘B’ interval of reservoir sands, and thick shales and marls of the Lower Goru Formation form the regional top seal for the reservoir in the area. Shales and tight sands within the C-Interval of Lower Goru Formation act as lateral and bottom seals (Krois et al. 1998).

CHAPTER 3
SEISMIC INTERPRETATION

Introduction

This chapter deals with the structural Interpretation of 2D seismic data of Block-20 Miano area. Seismic interpretation is the transformation of the 2Dseismic reflection data in to a Geological image by the application of corrections, migration and time to depth conversion The seismic reflection data interpretation usually involves calculating the position and identifying geologically hidden interfaces or sharp transition zone formed seismic pulses return to ground surface by reflection. The impact of varying geological condition is brightened along the profiles to transform the irregular recorded travel time in to acceptable sub surface models.

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

- Structural analysis
- Stratigraphical analysis

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 techniques. By making some alterations in recorded data results in better prospect evaluation or mainly reservoir characterizations (Sheriff, 1999).

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 picture depicting how the dissertation has been carried out

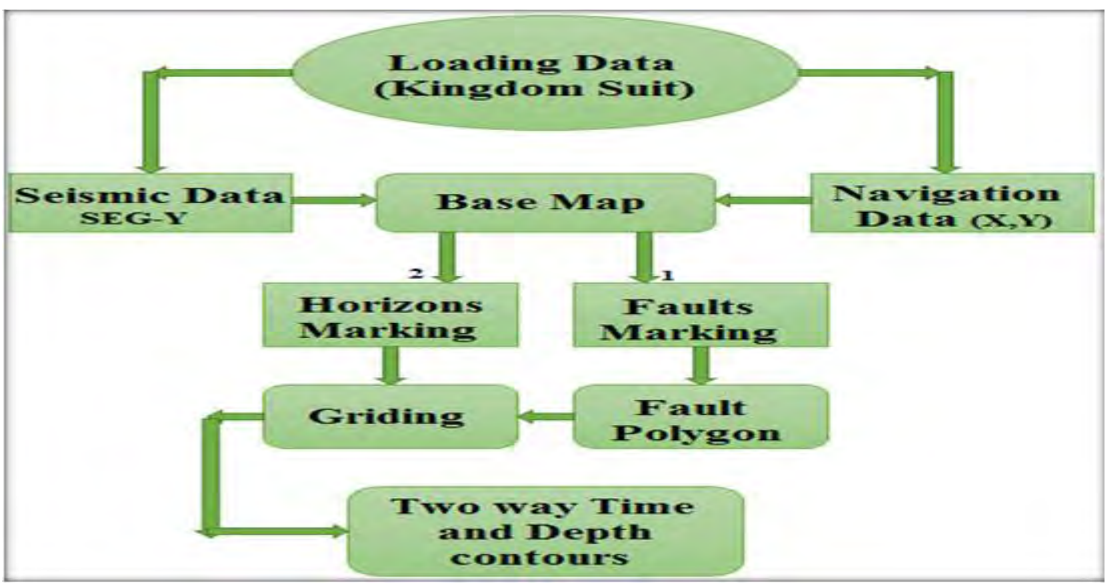

Figure 3.1 Work flow adopted for the seismic data interpretation

By loading navigation data of seismic lines and SEG-Y in IHS 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.

Interpretation of the seismic lines

The Primary task of interpretation is the identification of various horizons as an interface among geological formation. For this purpose, good structural as well as 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-10. We marked the two horizons. The horizons are named on basis of well tops of the well Miano-10. 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:

- GP2094-214…………………. (Strike Line)
- GP2094-221………………… (Dip Line)
- GP2094-213………………… (Dip Line)

Synthetic Seismogram

Synthetic seismograms are artificial seismic traces use to establish correlations between local stratigraphy and seismic reflections. To produce a synthetic seismogram a sonic log is needed. Ideally, a density log should also be used, but these are not always available hence we can also use the constant density for that area. With the help of Miano-10 the synthetic seismogram was constructed shown in the (Figure 3.2) in order to mark the horizons.

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 lithology's 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 lithology. 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).

Now the generated seismogram is used to confirm the horizon The display of the synthetic seismogram is showen in the Figure (3.2)

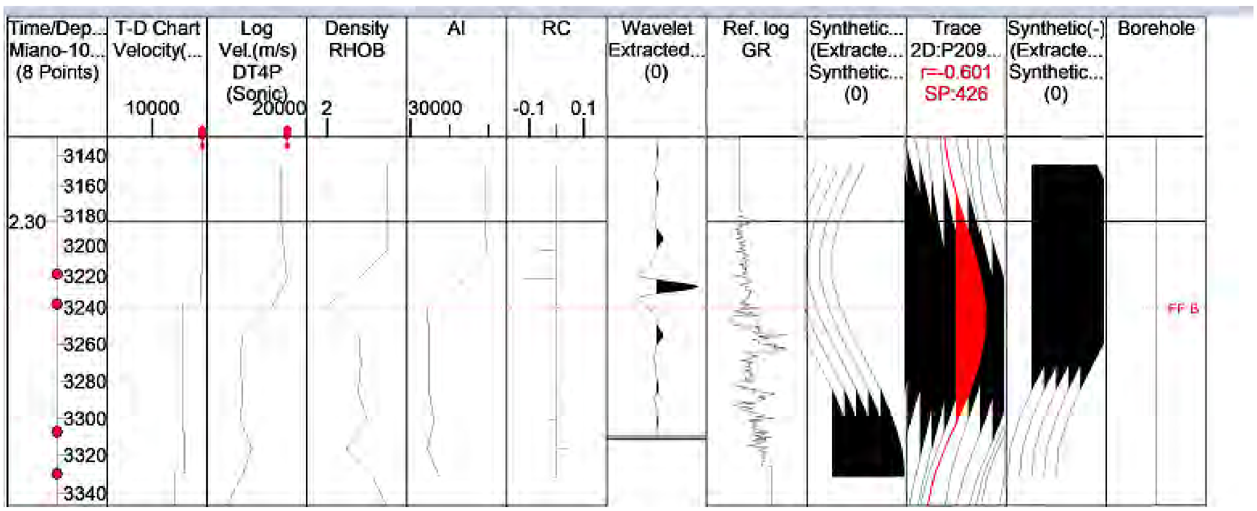

Figure 3.2 Synthetic Seismogram of the well Miano-10

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 Field Block-20 is lying in extensional regime hence we have conjugate normal faulting due to which the clear-cut horst and Graben are formed.

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 (Kemal et al., 1991). However basic aim in seismic section interpretation is picking a horizon, and mostly, reflections on the section represent a certain geological formation where change in acoustic impedance occurred and this is the seismic way to interpret subsurface stratigraphic features. Following are interpreted seismic sections of all lines assigned to me for completion of this dissertation.

Interpretation of the seismic Strike line GP2094-214

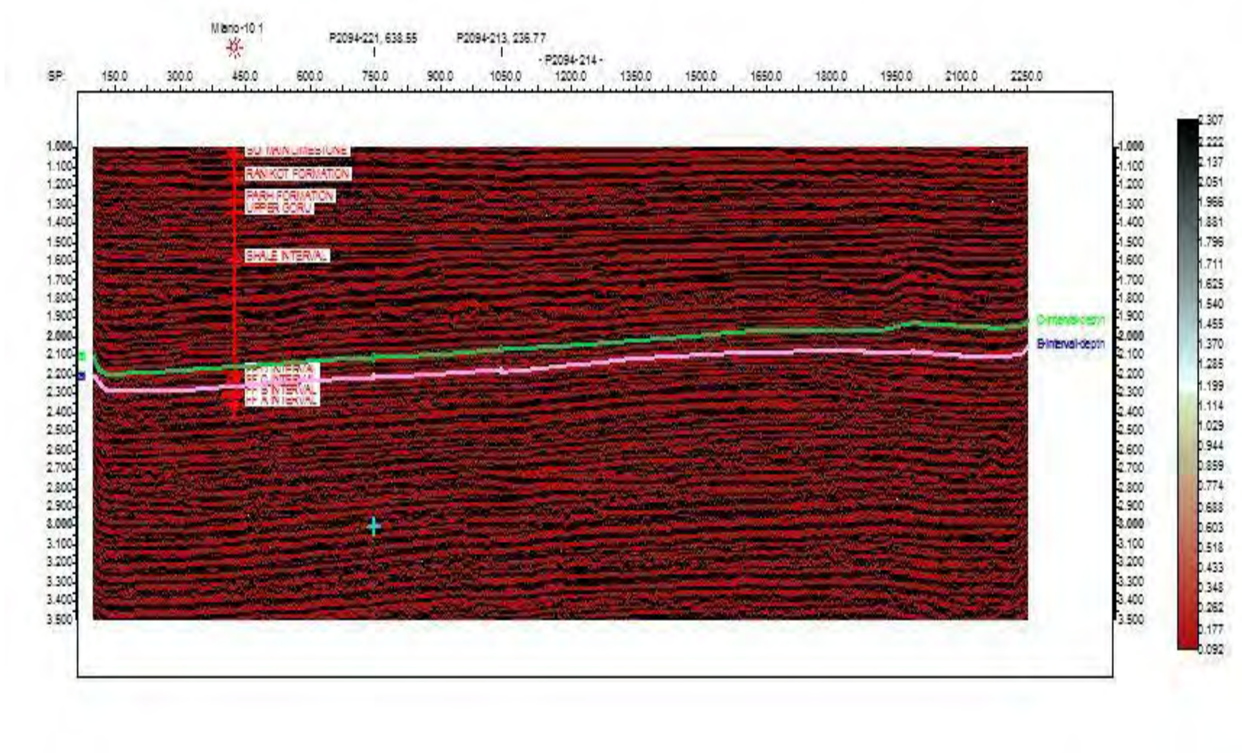

Figure 3.3 interpretation of strike line GP2094-214

The given seismic section does not show any faults. The reason behind is that the given line is a strike line and the orientation of the line against the basin configuration.

Interpretation of the seismic Dip line GP2094-221

After marking the seismic strike line GP2094-214 we correlated this strike line with dip line GP2094-221 because this strike line was crossing all the dip lines which are showen 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 showen in the below figure 3.4. The main purpose to interpret this line was to show the favourable 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.

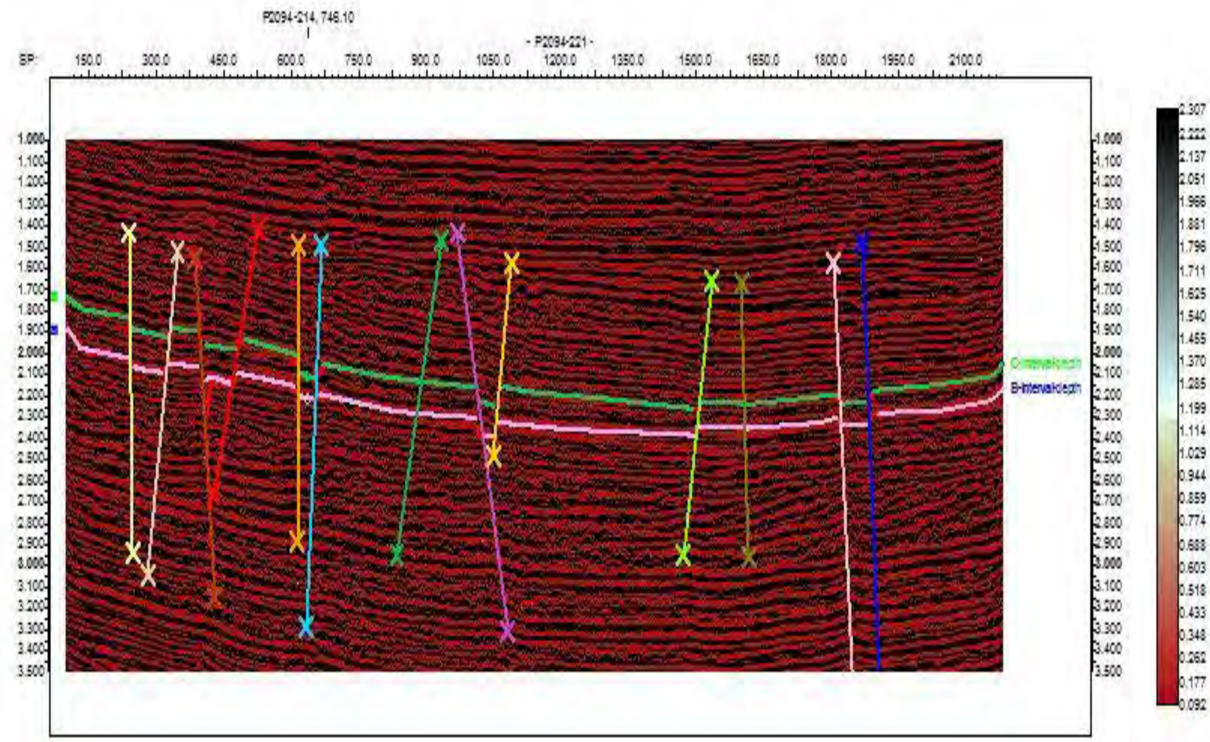

Figure 3.4 interpretation seismic Dip line GP2094-221

Interpretation of seismic Dip line GP2094-213

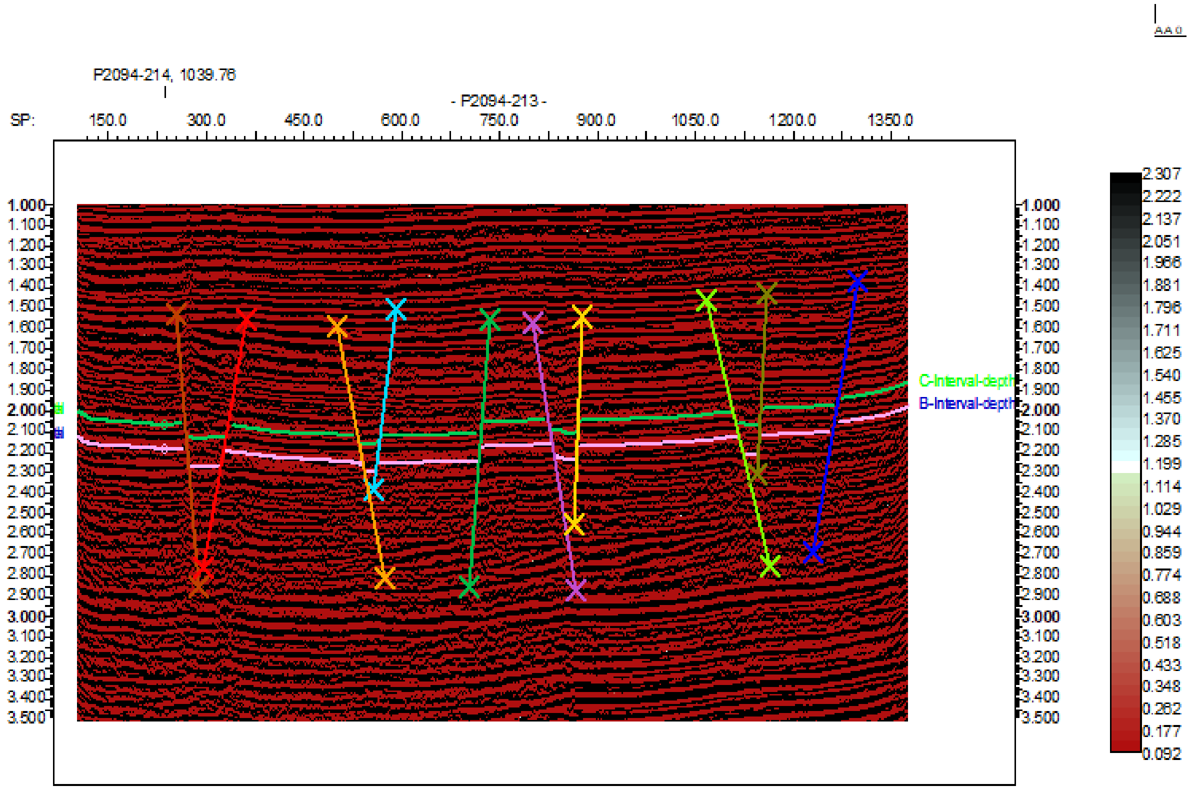

Figure 3.5 interpretation of Dip line GP2094-213

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 total fault should be converted into fault polygon before the contouring. The reason is that if we will not convert them into fault polygon then the software will not recognize it as a barrier due to which a wrong picture of the earth will be generated. 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 levels are shown in the below figures.

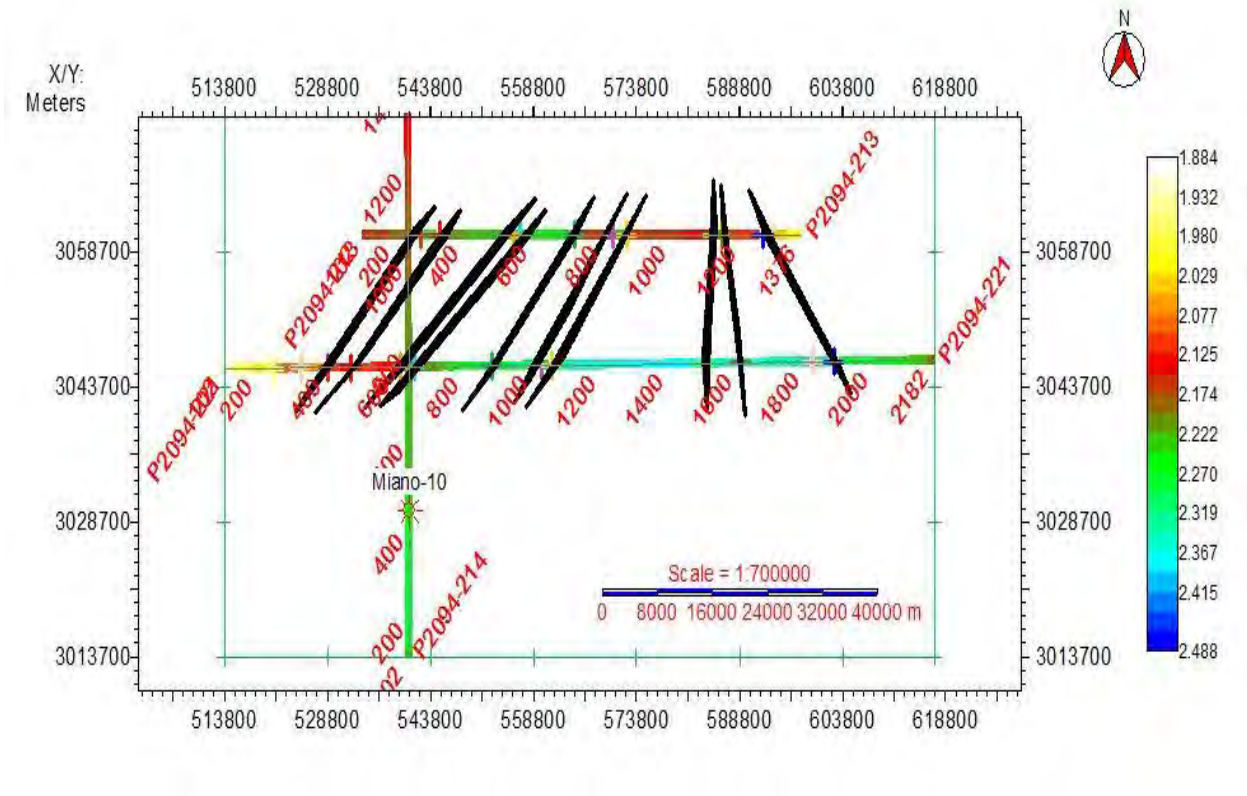

Figure 3.6 Fault polygon

Contour Maps

The final products of all the seismic exploration are the contour maps, time or depth. The mapping is one of the most important part of the data interpretation on which entire operations depends upon. The contours are generally the lines which join the point of the equal depth and time (Coffeen, 1986). Contours represent the three-dimensional earth surface into the two-dimensional earth surface. These contour maps represent the structural relief of the formation, any faulting and folding including dip of the strata. The following contours maps are generated in order to represent the two-dimensional picture of the various layers with in the area which is intersected by the various shoot lines. These contours maps are generated with the help of the advanced micro seismic technology (IHS kingdom 8.8).

Time based contour maps of B-interval of the Lower Goru formation

From the time contour map, it is clear that the red color represents the low time and the blue color represent the high time. The low time represent the horst and high time represent the Graben. In the time contour map the closing of the contours represent the leads. The leads having three types

1. One-way dip closure (Not bounded by the faults)
2. Two-way dip closure (one side bounded by the faults)
3. Three-way dip closure (Two sides bounded by the faults)

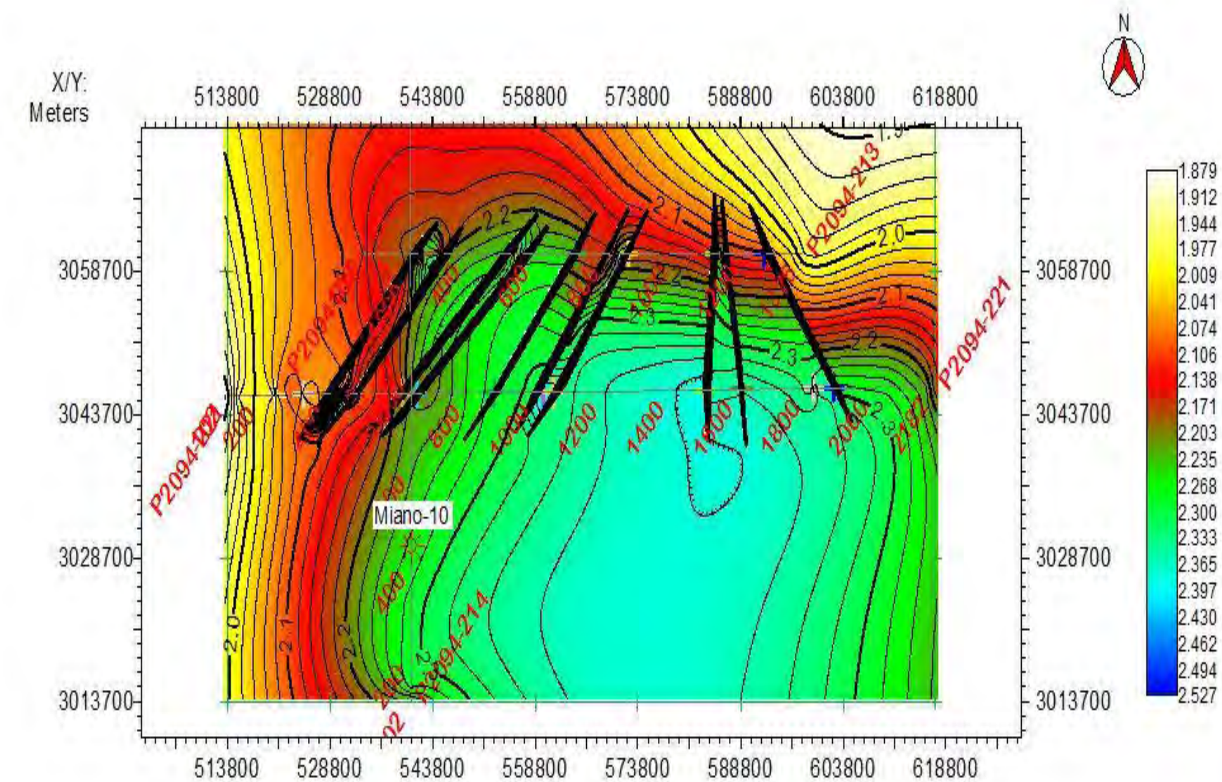

Figure:3.7-Time contour of B interval

Depth contour Map of the B-interval of the lower Goru formation

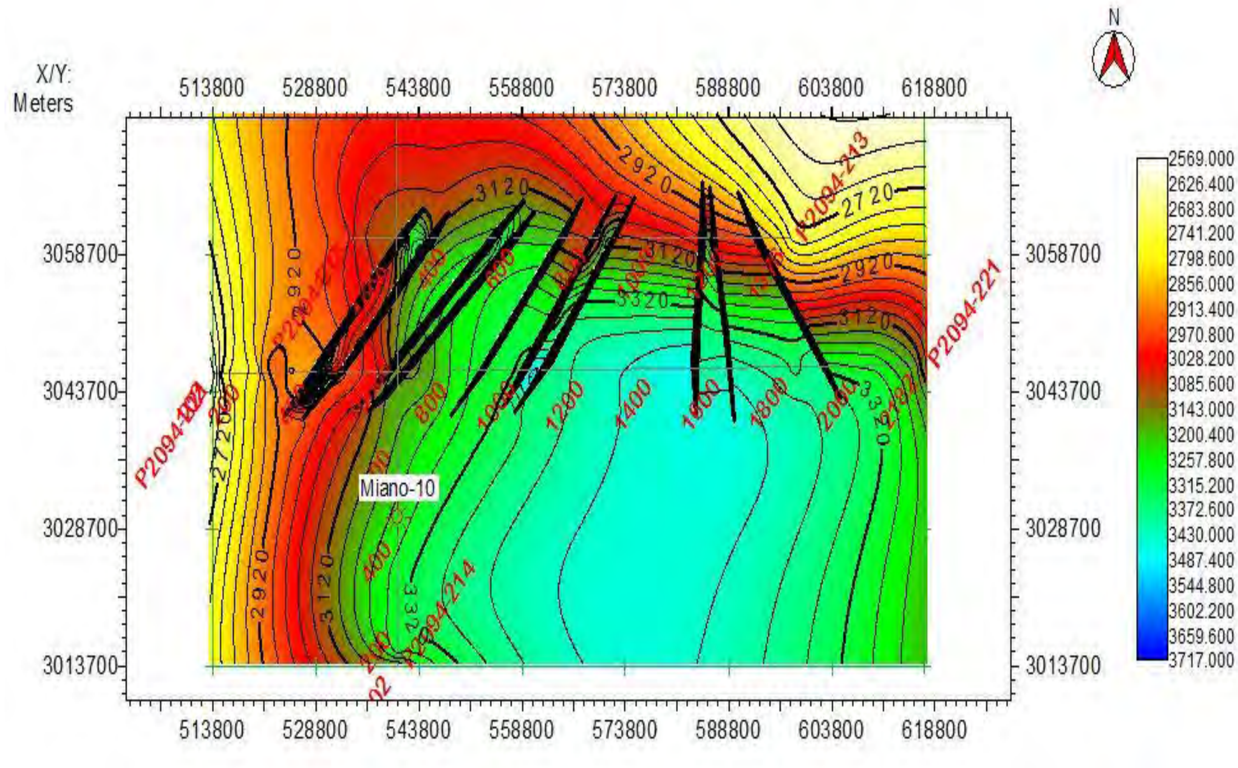

Figure: 3.8 Depth contour of B interval

Time contour of C interval

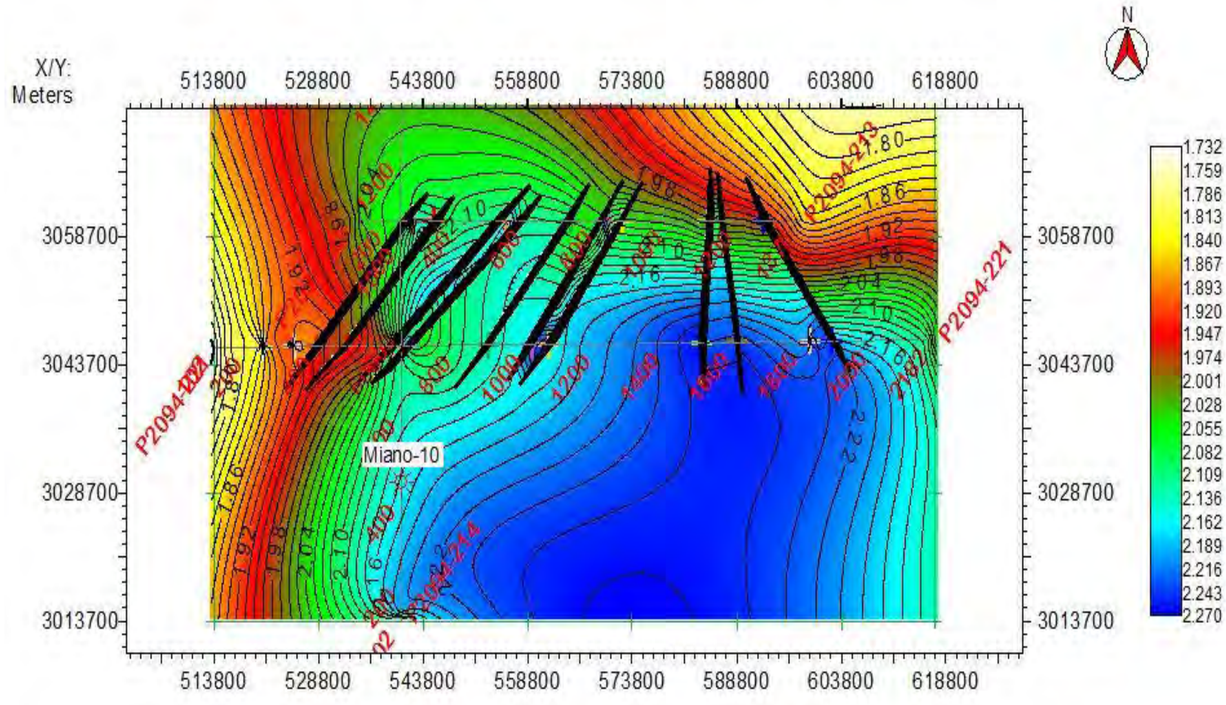

Fig 3.9 Time Contour of C interval

Depth contour of C interval

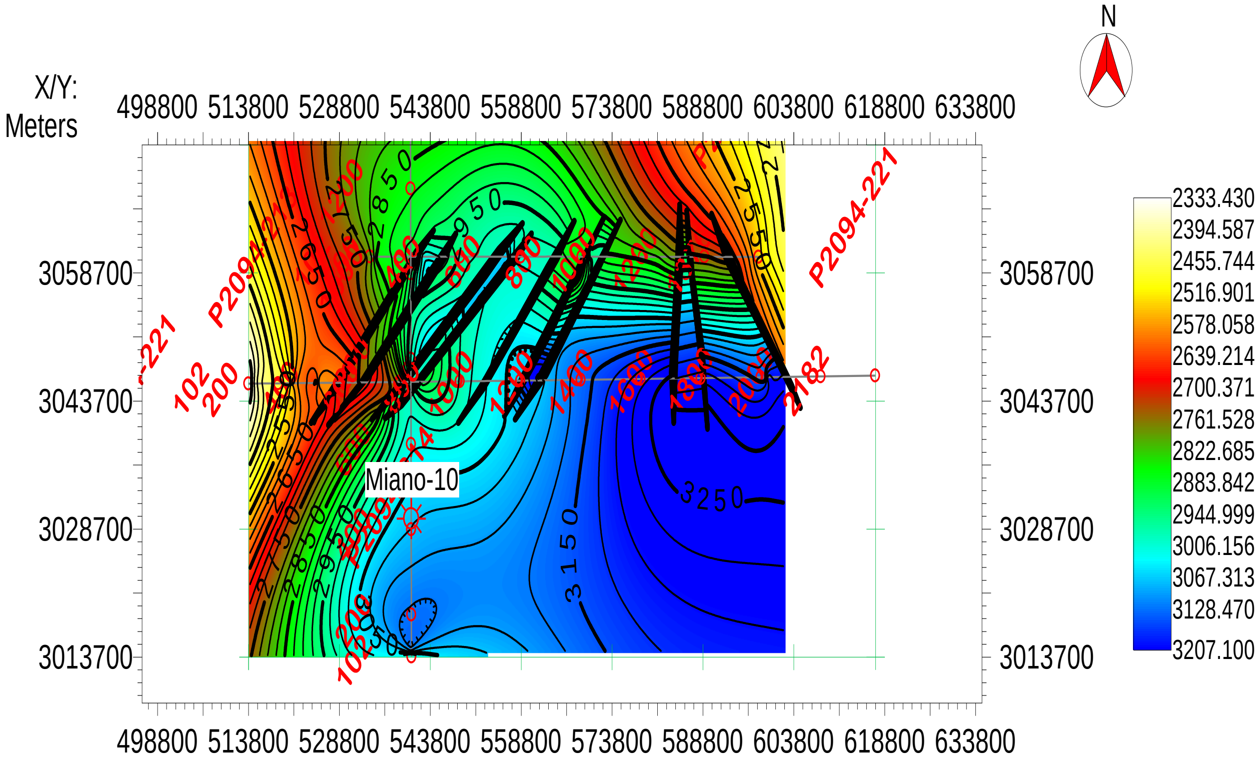

Fig 3.10 Depth Contour of C-interval

Conclusion

After all interpretation it is concluded that in my study area there are horst and graben structures. The horst and Graben structures are formed in the results of the normal faulting which are also confirmed in the above interpretation. Hence we have favourable structures formed in the result of the normal faulting for accumulation of the hydrocarbon in the Miano area. This normal faulting is generated in the results of the Permo Triassic rifting, during the initial Gondwanaland breakup. Subsequent Triassic and Jurassic rifting initiated a marine incursion from the Southeast.

All models shown above either 2D showing clear horst and Graben structures which can act a very good structural trap in the petroleum play point of view. From stratigraphic column discussed in previous chapter and Petroleum Plays in study area B-interval of the lower Goru formations has potential for hydrocarbons and faults in the area are major migration pathways for hydrocarbon and in most places are acting as traps.

CHAPTER 4

PETROPHYSICAL ANALYSIS

Introduction

Petrophysics is study of the physical properties relating the incidences, behavior of the rocks and fluids inside the rocks Reservoir characterization is the key step in oil and gas industry as it helps in defining the well and field potential so identify the zones within the reservoir which bears the hydrocarbons and can be recovered. Petrophysics is one technique used for the reservoir characterization. This study facilitates in identification and quantification of fluid in a reservoir (Aamir et al., 2014). Knowledge of reservoir physical properties like volume of shale, porosity, and water and hydrocarbon saturation is needed to define accurately probable zones of hydrocarbons. The integration of petrophysics along with the rock physics enables the geologists and geophysicists to understand the risks and opportunities in the area.

Petrophysics uses different geophysical tools (GR, Caliper Log, SP, LLD, and LLS etc.), core data and production data and integrates the results extracted. These geophysical tools are designed to quantify some specific reservoir property such as porosity, shale volume, net pay, effective porosity, saturation of hydrocarbon etc. Pertophysical analysis is often less related to seismic data but more concerned to well log data for reservoir description.

Data set

The petrophysics analysis has been carried out in order to measure the reservoir characterization of the miano area using the borehole data of Miano-10.We used the log curves including spontaneous potential log (SP), Gamma ray (GR), Sonic log (DT), Latero Log Deep (LLD), Latero Log Shallow (LLS), Neutron log, Density log, Photo electric effect log (PEF).For petrophysics analysis the following parameters are acquired on the basis of the log curves.

- . Volume of shale
- Water saturation
- Hydrocarbon Saturation

Before going to calculate these properties we must have to know about the different types of the logs and there characteristics which area explained below.

CLASSIFICATION OF GEOPHYSICAL WELL LOGS

Different classifications and some short explanation of geophysical well logs is as follow. The logs are explained according to the tracks in which they are run and this is clear from the flow chart given below.

LITHOLOGY TRACK

In lithology track the following three logs are displayed which are explained as follow.

- Gamma ray (GR)
- Spontaneous Potential log (SP)

Gamma ray (GR)

With the help of this log we measure the natural radio activity of the formation. Basically the gamma ray log is the passive logging because we measure only the formation property without using any source. The gamma ray emits from the formation in the form of the formation in the form of the electromagnetic energy which are called the photon. When photon collide with the formation electron hence, they transfer the energy to the formation electron so the phenomenon of the Compton scattering occurs. Now these emitted gramma ray reached to the detector of the gamma ray and counted and displayed as count per second which is termed as the Gamma ray. Basic purpose of this log is to differentiate between the shale and non-shale (Asquith and Gibson, 2004).

Spontaneous Potential log (SP)

The SP log is also passive log which record the naturally occurring potential in the well bore. In this log we used the single moving electrode in the bore hole and reference electrode at the surface, located in the mud pit. Hence the SP log therefore record the potential difference between the reference electrode and the moving electrode in the borehole.

This log is used for the following purposes:

- Identification of the permeable and non-permeable zone.
- Detection of the bed boundaries.
- Determination of the shale volume.

- Determination of the resistivity of the formation.
- Up to some extent the qualitative measure of the permeability.

Caliper Log (CALI)

Caliper log use to measure the borehole size. This log give us help to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. Because if any where there is say wash out then in front of the wash out the porosity and resistivity log will not give the correct reading. Hence caliper log is very important in pertophysical logs.

Porosity Logs Track

Porosity logs measure the porosity in the volume of the rock. These logs are also helpful in order to distinguish between the oil, gas and water in combination with the resistivity log.

Porosity log include

- Sonic logging (DT)
- Density logging (ROHB).
- Neutron logging (NPHI).

Sonic Log

Sonic log device consists of a transmitter that emit sound waves and a receiver that picks and record the compressional waves as it reach the receiver. This log is a recording verses depth of time (t) which is required by a compressional wave to go across 1 feet of formation, called interval transient time Δt, while it is the reciprocal of the velocity of sound wave. This time (Δt) is depended upon lithology and porosity of the formation (Asquith and Gibson, 2004). Sonic log can also be used for the following purposes in combination of other logs as given by (Daniel, 2004).

1-Porosity (using interval transit Time)

2-Lithology identification (with Neutron or Density).

3-Synthetic seismograms (with Density).

4-Mechanical properties of formation with (Density).

5-Abnormal formation pressures detection.

Density Log

In the density logging gamma ray collide with the electron in the formation and scattered gamma ray (Compton scattering) received on the detector which indicate the density of the formation. Increase in the bulk density of the formation causing the decrease in the count rate and vice versa.

Bulk density which is obtained from the density log is considered the sum of the density of the fluid density and the matrix density of the formation.

Neutron log (NPHI)

This is the type of porosity log which measure concentration of Hydrogen ions in the formation. Neutron is continuously emitted from chemical source in the tool of the neutron logging. When these neutron collide with nuclei in the formation and results in loss of some energy. Hydrogen atom has same mass as that of neutron, maximum loss of energy occurs when electron collides with hydrogen atoms.

Hydrogen is an indication of the presence of the fluid in the formation pores; hence loss of energy is related to the porosity of the formation.

The neutron porosity is very low when the pores in the formation are filled with the gas instead of the water and oil, the reason is that gas having les concentration of the hydrogen as compared to water and oil. This less porosity by the neutron PHI due to the presence of the gas called the Gas effect (Asquith and Gibson, 2004).

Electrical Resistivity Logs Track

Basically there are different types of electrical Resistivity Logs. But in my work I have only two logs available in my data which are simply explained as follow.

This log measures the resistivity of the subsurface, but actually they measure the resistivity of the formation fluids. They are very helpful in order to differentiate between water filled formation and the hydrocarbon filled formations. Resistivity logs includes the following.

- Latero log Deep (LLD).

- Latero log shallow (LLS).
- Micro spherical focused log (MSFL), but MSFL was not present in my Data of Miano-09 and Miano-10.

Laterolog Deep (LLD)

Latero log deep is used for the deep investigation of the quietly undisturbed (Uninvaded zone) and it is called Laterolog deep (LLD). This log is also used for saline muds also in case of fresh mud. This log is generally used for measuring the formation resistivity. IT having deep penetration as compared to the (LLS).

Laterolog Shallow (LLS)

Laterolog shallow (LLS), used for shallow investigation of the transition zone / invaded zone. Because the depth of the investigation is smaller than the LLD .

SCALE USED FR THE DIFFERENT LOGS TRACK

The scales used for different logs track area explained in the below table 4.2

Table 4.1 Scale used for the different logs track in SMT kingdom for petrophysical logs

N0	Logs name	Abbreviation	Scale	Unit
1	Gamma ray Log	GR	0------------300	API
2	SP Log	SP	-120--------40	Mvolt
3	Caliper Log	CALI	3-------------16	INCHES
4	Sonic Log	DT	120----------40	µsec/ft
5	Density Log	ROHB	1.95---------2.95	Gm/cm3
6	Neutron Log	NPHI	0.45---------(-0.15)	PU

7	Laterolog Deep	LLD	1-------------1000	Ωm
8	Laterolog Shallow	LLS	1-------------1000	Ωm

Workflow for Pertophysical Analysis

Petrophysical interpretation is carried out using the kingdom software. First of all the raw log curves are loaded step by step and different log properties are calculated. Different mathematical equations and the schlumberger charts are used in order for the calculation of the different log properties. Work flow is given in Figure 4.1.

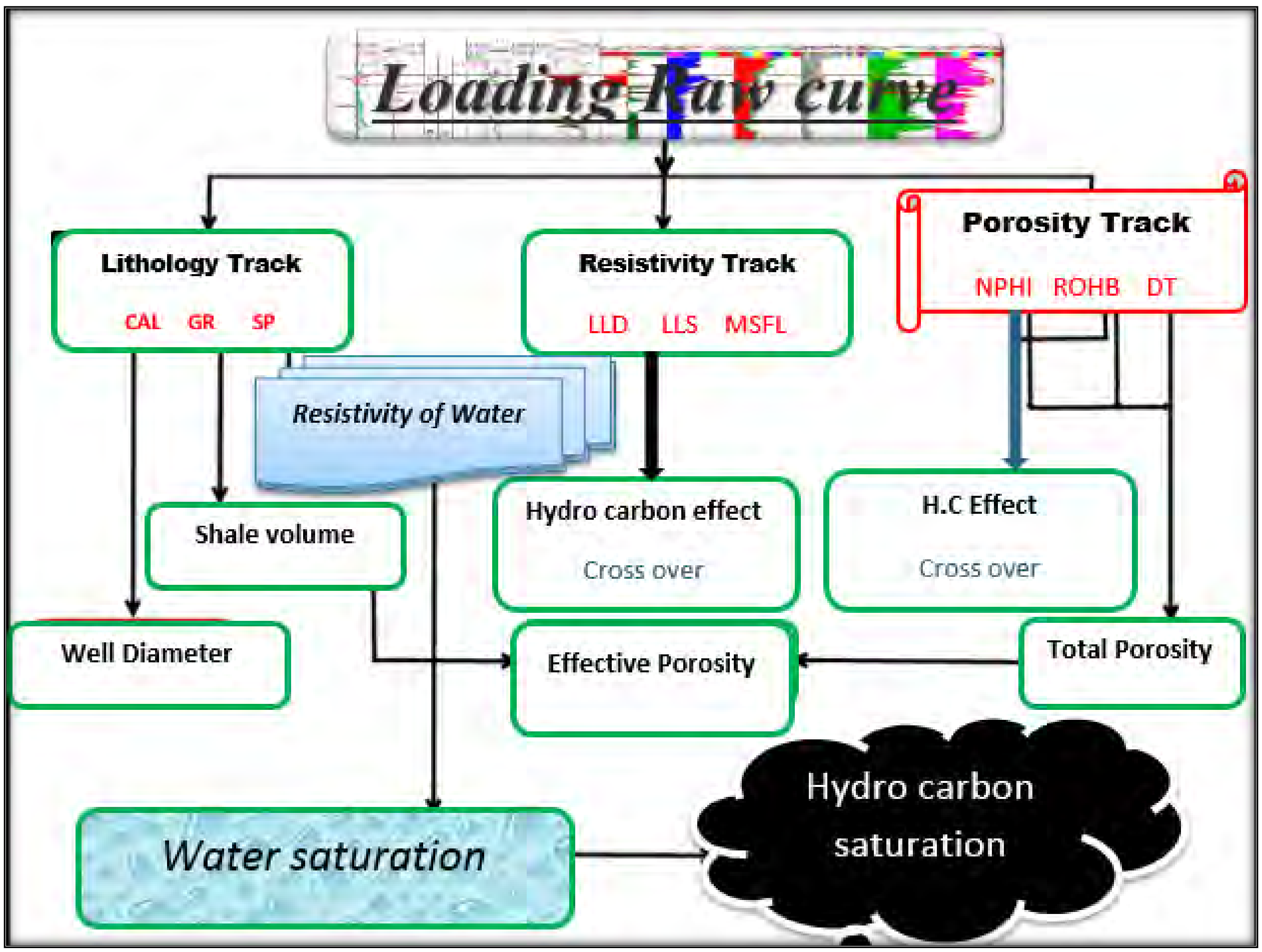

Figure 4.1 Petrophysical interpretation workflow

Raw log curves from the well Miano-10 are used for the petrophysical interpretation .The main reservoir in the area is Lower Goru formation of the cretaceous age. The lower Goru is divided into the 4 intervals (A, B, C, and D interval).In Miano area the B-Interval is acting as a reservoir .The top and the bottom of the well is defined by the petrophysical analysics.The zones of interest are also identified on the basis of the petrophysical interpretation where there is chance of the presence of the hydrocarbon. The raw logs curves which are used are showen in the above interpretation workflow.

CALCULATION OF ROCK PROPERTIES

Many of the rock properties can be derived using geophysical well logs. We have calculated the following properties using the different equations which are given in below Table 4.3.

Table4.2 Different equations for calculating rock properties (Asquith et al., 2004)

	PROPERTIES	***MATHMATICAL FORMULAS***
1.	VOLEUME OF SHALE (Vsh)	VSH=(GR-GRCLN)/(GRSHL-GRCLN)
2.	DENSITY POROSITY (PHID)	PHID=(RHOMA-RHOB)/(RHOMA-RHOF)
3.	SONIC POROSITY(PORS)	PORS=(DLT-DLTM)/(DLTF-DLTM)
4.	TOTAL POROSITY (PHIT)	PHIT=(DPHI+NPHI)/2.0
5.	EFFECTIVE POROSITY (PHIE)	PHIE=((DPHI+NPHI)/2.0)*(1-VSH)
6.	STATIC SPOTANIOUS POTENTIAL (SSP)	SSP=SP(CLEAN)-SP(SHALE)
7.	RESISTIVITY OF MUD FILTRATE(Rmf2)	$R_{mf2} = \frac{(ST + 6.77) \times R_{mf1}}{(FT + 6.77)},$

8.	FORMATION TEMPRATURE (FT)	$FT = \frac{(BHT - ST)}{TD} \times FD$
9.	SATURATION OF WATER (Sw)	$S_w = \sqrt[n]{\frac{F \times R_w}{R_t}},$
10.	HYDRO CARBON SATURATION (HS)	HS= 1-S_W

Volume of Shale

The volume of shale is calculated using the Gamma ray (GR) log. This log is used to measure the natural radio activity of the formation. Hence it provides the concentration of the radioactive material present in the formation, hence it is very useful in order to identify the lithology. The value of the gamma ray is low in the carbonate and in sandstone while it having higher value in the shale. The reason is that the concentration of the radioactive material is larger in the shale as compared to sand and the carbonates.

This will lead us to distinguish between reservoir and the non-reservoir rocks (Acquith and Gibson, 2004).The volume of the shale is estimated by using the following equations given in table 4.3 by (Rider, 1996).

Calculation of Porosity

Porosity is one of the most important property in order to understand the petroleum system. The porosity is estimated by using the Neutron, Density, and the Sonic log. Sonic log is acoustic measurement and the Neutron and Density log are nuclear measurement. The combination of these three logs gives the accurate estimation of the porosity. We have different types of the porosities which are given below.

Average Porosity

Average porosity is the sum of the all porosities logs divided by the number of the logs. The mathematical equation (Schlumberger, 1998) is given in the table 4.3.

Effective Porosity

The effective porosity is the ratio between the pores volume of the rock and the total volume of the rock calculated after removing the effect of the shale. The effective porosity is used to estimate the water saturation. The effective porosity is calculated using the mathematical equation of the (Schlumberger, 1989) given in the table 4

Now to calculate the Water saturation we have required the Resistivity of the water of formation. This is a Lengthy procedure which is explained as follow.

Resistivity of formation water (Rw)

When the volume of the shale, effective total and sonic porosity has been calculated the next step is the calculation formation of the water. Computing the resistivity of the water is the initial step in finding the saturation of the water. The following steps has been carried out in order to calculate the resistivity of the water.

Step 1: The values of the surface temperature (ST), maximum recorded temperature (BHT), and the resistivity of the mud filtrate (RMF1) from the well headers, the very first step is to find the (SSP) static spontaneous potential from the relation given in the table 4.3 from (Rider, 1996).

Step 2: Formation temperature is calculated using the using the relation which is given in the table 4.3 by (Rider,1996).

Step 3: In this step the resistivity of the mud filtrate is calculated using the relation given in the table4.3.

Step 4: In step 4 the resistivity of the mud equivalent (Rmf_{eq}) is calculated by the equation given in the table 4.3.

Step 5: Rweq (Water equivalent resistivity) is determined from the Essp (Static spontaneous potential)

After calculating the all the above explained properties and the resistivity of the water equivalent the next step is to find the value of the resistivity of the water (Rw) against (Rmfeq) at SSP value BHT from the graph (Figure 4.3).

Step 6: This is the last step in this step the value of the resistivity of the water (Rw) is obtained against the value of the Rweq (Resistivity of the water equivalent) and formation temperature. Now when the resistivity of the water is determined the next step is to compute the saturation of the water by using the famous Archie equation as showen in the (Table 4.3)

Petrophysical Interpretation:

Petrophysical analysis is carried out on the basics of the different logs' curves. The first indicator is Gamma ray which is very useful to differentiate between shaly and sandy portion in Miano area. So on the basics of the gamma ray the clean and shaly zones are marked to make the further interpretation easily. Where there is low value of the shale, we can say that this is the zone in the reservoir where the hydrocarbon can be present, but not confirm. Basically, to confirm the types and amount of hydrocarbon we go towards the integrative results of other logs that give a comprehensive report about the hydrocarbon and water present in that zone Resistivity log is used for the detection of hydrocarbon. The principle of resistivity log is detection of hydrocarbon. Volume of oil and gas in the particular zone of reservoir is found with the help of resistivity log. When Sw is not 100%, then hydrocarbons are present there. Higher values of resistivity usually indicate the presence of hydrocarbons or fresh water. The separation between LLD and LLS is indication of a hydrocarbon zone as value of LLD is much higher in case of oil or gas. Density in the study field mainly vary from 2 to 2.8 g/cm3. Higher density is observed as corresponding to very low resistivity. It may be due to the Presence of some heavy minerals like gluconate, Chlorite, Chamosite Siderite etc. (Fareed et al 2003) The other best indication of the presence of hydrocarbon is the crossover that formed by the combination of neutron and density log (Rider, 1996). B-interval is interpreted as reservoir zone after considering all the above explained results and logs. Some important petrophysical properties are quantified which are given in the below table 4.2.

Interpretation of Entire B interval (3331-3385m): Depth range of B interval varies from (3331-3386m) in well Miano-10. It consists of alternate layers of shale and sand. Values of GR ranges are given below:

- GR Minimum ………… 12.05 API
- GR Maximum…………284.93 API

Prominent zone for hydrocarbon is marked through the well in Figure 4.3 where high net pay is expected. The zone of interest is marked on the basis of following criteria • Separation between LLS and LLD • Low value of GR • High resistivity • High porosity These parameters are confirmed by log curves shown in fig 4.2.

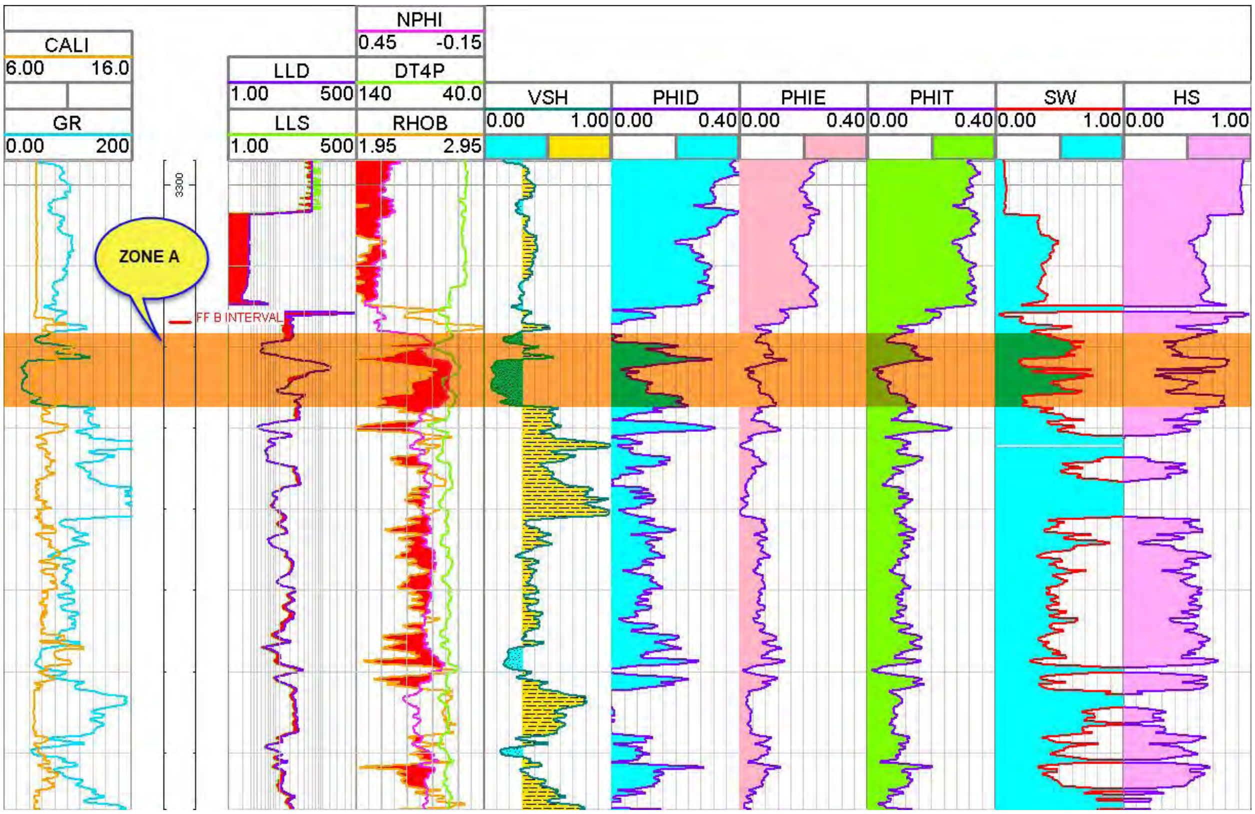

Figure 4.2 Petrophysical analysis of Miano-10

Interpretation of Zone of Interest:

Only one main zone of interest is marked. Depth range Zone of interest or reservoir varies from 3338- 3346.2 m in well Miano-10 Shale volume for whole depth range is 22.4 %. Effective porosity is about 7.3% and hydrocarbon saturation of 56.3%. Petrophysical properties of these zones are given in the Table 4.2

Zone Marking Criteria:

On the basis of the single log we cannot give the information about the productive zone we correlate the different logs and get the results. We marked the zone of interest from 3338-3345.2

m. Because there was low value of GR which is clear cut condition that it is reservoir zone. Now in 2nd track we run the LLD, LLS, these are resistivity log now there cross over is also the clear cut indication of the formation contain some high resistivity fluid i.e. hydrocarbon. Similarly in the track three the crossover of density and neutron logs is also showing that this is hydro carbon bearing zone. Also calculated effective and average porosity are greater than other zone and hydrocarbon saturation is greater than water saturation. Hence combination of all these calculated properties makes us assure that this zone is productive zone and hence we marked this zone which is shown in Figure 4.3.

Table 4.3 Rock Properties of the Zone-A Miano-10

Zone/ Rock properties	**Zone of interest**
Average Volume of Shale	22.5%
Average Sonic Porosity	10.8%
Average Porosity	10%
Average, Effective Porosity	7.3%
Average Saturation of Water	43.7%
Average Saturation of HC	56.3%

Conclusion:

- Two horizons are marked on the basis of available well log data.
- Structural interpretation indicates the Horst and Graben structures associated with Normal Faulting which indicates that there is Extensional Regime in this area.
- Time contour maps are generated that confirms the Horst and Graben structures by indicating high values in Graben and low values in Horst.
- Depth contour maps shows the same result as time contour maps because we use average velocity value for the computation of depth.
- Petrophysical analysis is carried out on Miano-10 well which shows the highest porosity and hydrocarbon prospect zone in the zone A.

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