INTEGRATED APPROACH TO HYDROCARBON ASSESSMENT OF MIANO AREA OF LOWER INDUS BASIN PAKISTAN USING 2D SEISMIC AND WELL LOGS DATA

BY

Abdul Waseh

BS Geophysics

2016-2020

Department of Earth Sciences

Quaid-i-Azam University Islamabad

TO Allah belongs all that is in the heavens and all that is on the earth, and whether you disclose what is in your own selves or conceal it, Allah will call you to account for it. Then He forgive whom He wills and punishes whom He wills. and Allah is Able to do all things. (surah Al-Baqarah)

CERTIFICATE

This dissertation submitted by **ABDUL WASEH** s/o **MANZOOR AHMED** 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 bachelor's degree in Geophysics.

RECOMMENDED BY

Dr. MUMTAZ SHAH: ______________________________

(Supervisor)

Dr. AAMIR ALI: ______________________________

(Chairperson Department of Earth Sciences)

EXTERNAL EXAMINER: ______________________________

DEDICATED

TO

MY BELOVED PARENTS,

TEACHERS AND FRIENDS.

ACKNOWLEDGEMENT

In the name of Allah the most merciful and most beneficent. All praises to him who is Almighty, The One, The Everlasting, Who begets none, is begotten, by no one, and there is none His equal. O' God I am really thankful to you that you make me capable to complete my work. I am nothing without your help. Please keep me always in prostration before you and let me not leave before anyone except you.

I am especially thankful to my dissertation supervisor **Dr. MUMTAZ SHAH** that he always gave me his loving guidance whenever I asked and spared His precious time for me during my work. I extremely grateful to all my teachers for their endless love, prayers and encouragements and I inspired throughout my degree at QAU.

I am thankful to my respectable seniors, Tahir Nagra, Badar Ali, Saad and besties Mohsin Ali Khan and Ahsan Saleem for his corporation and guidance in every aspect of life not only in thesis work.

ABDUL WASEH

GEOPHYSICS

Q.A.U. ISLAMABAD

Abstract

Quantitative and qualitative interpretation of Miano Area has been carried out for hydrocarbon assessment through integrated geophysical technique. 2D seismic and well data of Miano-05 is incorporated to pursue the research work. Seismic interpretation provide aids for subsurface structural interpretation and borehole logs are employed for reservoir characterization.

For the interpretation of the seismic lines, three reflectors Lower Goru, C-Sand and B-Sand 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 of time and depth contour maps made from time and depth grid respectively.

Petrophysical analysis of Miano-05 has been carried out by incorporating the cumulative response of all the available logs to mark the potential zones. Combined wireline logs response of Miano-05, pronounced 12 meters hydrocarbon potential zone in the study area. Furthermore, from this study we also get the idea about the sea level at the time of deposition.

Table of Contents

CHAPTER # 1
INTRODUCTION

1.1 INTRODUCTION

The area of concern is Miano (Block-20), which is located approximately 62 kilometers in southeast of Sukkur city in Sindh province, Pakistan. The length of the field is approximately 42km along strike of the strata. The southernmost well in the field is about 10 kilometers away from Kadanwari field and 45 kilometers from the Sawan Gas field to the southwest. Two of largest gas fields of Pakistan, the Mari gas and Sui gas fields producing from the Eocene aged Sui main limestone are found 75km and 150km to the north of the area respectively. Many wells have been drilled to appraise the Miano field targeting the Lower Cretaceous-aged B-Sand interval of Lower Goru Formation. The Miano gas field is located in the Thar Desert, Geologicaly it is located at the boundry of Lower and Middle Indus Basin, between the Indian basement and the Kirthar Fold and Thrust belt (Figure 1.1). It is thought to extend from the southern blocks. The Geographic coordinates of the area are

Latitude: 27° 41' N to 27° 32' N
Longitude: 68° 52' E to 69° 28' E

Figure 1. 1 Location Map of the study area (google-earth)

1.2 DATA USED:

In 1994, 600sq km 2D seismic data was acquired in the northern half of the Block-20 Miano Area. 2D seismic reflection data of P2094 venture and LAS file of the well Miano-5 logs is used in the study area.

Line Number Direction Shot points Line Type

P2094-212 N-S 102 - 500	Strike
P2094-215 E-W 103 - 852	Dip
P2094-219 E-W 102 -1140	Dip

1.3 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 one strike line and two dip lines and one well of Miano area.

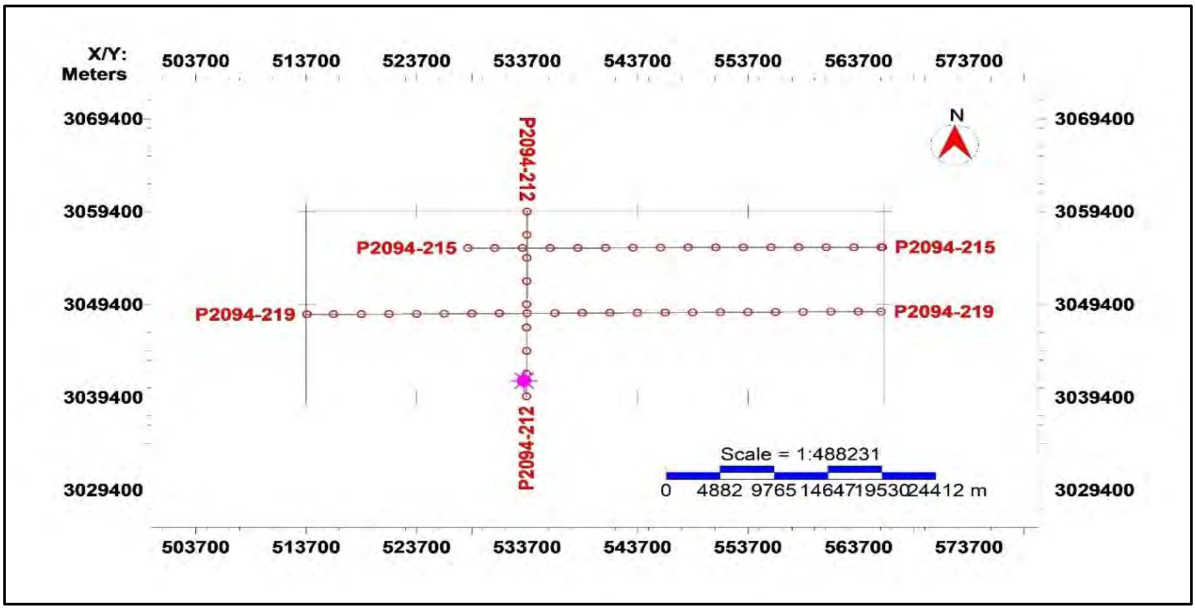

Figure 1. 2 Base Map of the study area showing seismic lines and well location.

1.4 BASIC SEISMIC AQUISTION PARAMETERS:

The following basic parameters were in the acquisition of the seismic data

Area Miano	(Lower Indus Basin)
Company	OMV
Crew	S.S.L
Date Shot	May1994
Nominal Fold	60
Party Number	115
Instruments	SN 348 (NO. 158)
Record Length	5 Seconds
Sampling Rate	2 milliseconds
Recording Filter	LC out;HC125 HZ 72DB/OCT
RecordType	SN368
Format	SEG-D 6250BPI
Traces	120
Source	Vibroseis (Y2700)
No.of Sweeps per vibrater	8
VIB Spacing	15M
Array Length	88.75M
VP Interval	50M
Geophones Group Distance	50M
Geophone Type	SM4 UB 10HZ
Geophones per Group	24
String Spacing	3M
Geophone Spacing	1.39 M

1.5 OBJECTIVE OF RESEARCH WORK:

The main objectives of research work are:

- Horizon marking
- Fault marking
- Generation of synthetic seismogram
- Seismic to well tie
- Generation of time and depth contour maps
- Reservoir characterization through petrophysical analysis

1.6 METHODOLOGIES:

To achieve the desired objectives the dissertation work following methodologies

are used:

a) Seismic data Interpretation: Structural interpretation of the study area has been carried out by using seismic and well data with the help of SMT Kingdom 8.8.

b) Reservoir characterization by using petrophysical analysis.

CHAPTER # 02
GEOLOGY OF THE AREA

2.1 INTRODUCTION:

This chapter deals with a brief description of the tectonics, structural setting and Stratigraphy of the study area and its adjoining areas of Middle Indus basin. The hydrocarbon significance of the area is also incorporated in the chapter. As the seismic data interpretation is based on the Stratigraphy and structure geology of the area, so it is important to have information about the geologic aspects of the area.

2.2 Structure and Tectonic Settings:

Tectonically Pakistan comprises of two domains of large landmasses, i.e. Tethyan and Gondwanian Domains and is continued by the Indo-Pakistan crustalplate. The northern most and 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 are;

· Upper Indus basin

· Middle Indus basin

· Southern Indus basin

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 Basin and southern Indus basin. The uplift episode occurred near cretaceous-tertiary (K-T) boundary established as the base of Tertiary unconformity against which many of the deep basement related and shallower wrench-tectonics related faults terminate. The second major 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. 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, 1995). Regional Tectonic setting of the area is shown in the Figure.2.1

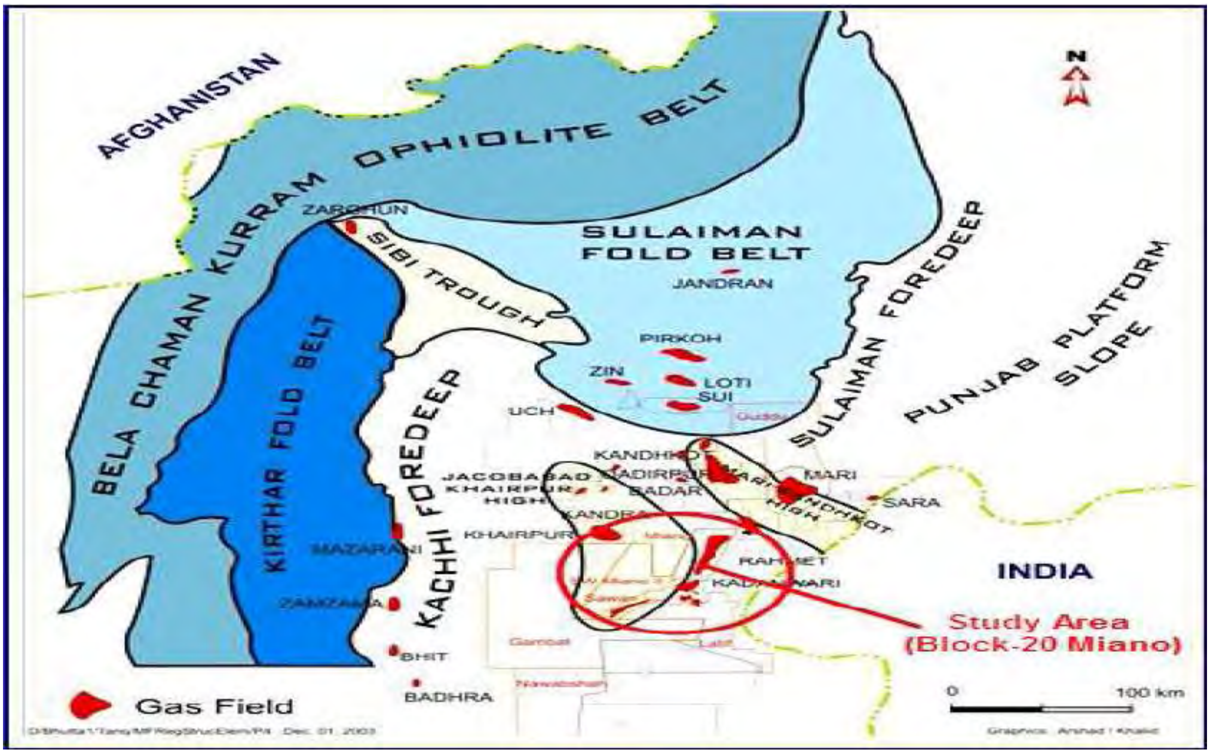

Figure 2.1 Regional tectonic map of Block-20 in the Middle Indus Basin (Mehmood et al., 2004)

2.3 STRATIGRAPHY

The sedimentary section of the 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 shallo 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. Permain, 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 bottomsets, foresets and topsets that prograde towards west from the Indian craton. In lithostratigraphic terms the argillaceous foresets to these prograde are called the Sembar Formation which is an important source rock in the basin. Lower Guru sands act as a reservoir in Middle Indus Basin. (Sturrock and Tait, 2004). The Sembar 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 3.5percent in the area. The organic matter in the Sembar Formation is type-III kerogen which is capable of generating gas, but type-II kerogen is also present(Wandrey et al.,2004). The Lower Goru Formation was deposited during the deposition of the latter part of Late Jurassic to Early Cretaceous regressive system.

The Lower Goru "A", "B", "C" and "D" sequences were deposited during a gradual and long term 3rd order eustatic or tectonic-eustatic sea level rise. The deposition is punctuated by high-frequency 4th and 5th order relative sea level fluctuations. These fluctuations led to the deposition of prograding clastic sand packages on a vast and widespread ramp. Balance between intermittent and slow addition of accommodation space and ample sediment supply from the east and E-SE

maintained an overall aggradational packages to slightly progradational profile on"A", "B", and "C" intervals'. The present-day eastward tilt of strata in the study area works with the westwards facies related shale-out of sands to provide stratigraphic trapping of hydrocarbons. In the study area lateral (N-S) shale-outor corrosion in reservoir quality of the "B-sand" reservoir, towards west shale-out of sand to distal settings and to the east structural tilt provide combined structural-Stratigraphic trapping system. (Krois et al.,1998) the generalized stratigraphic coloum of the indus basin is shown in the Figure 2.2

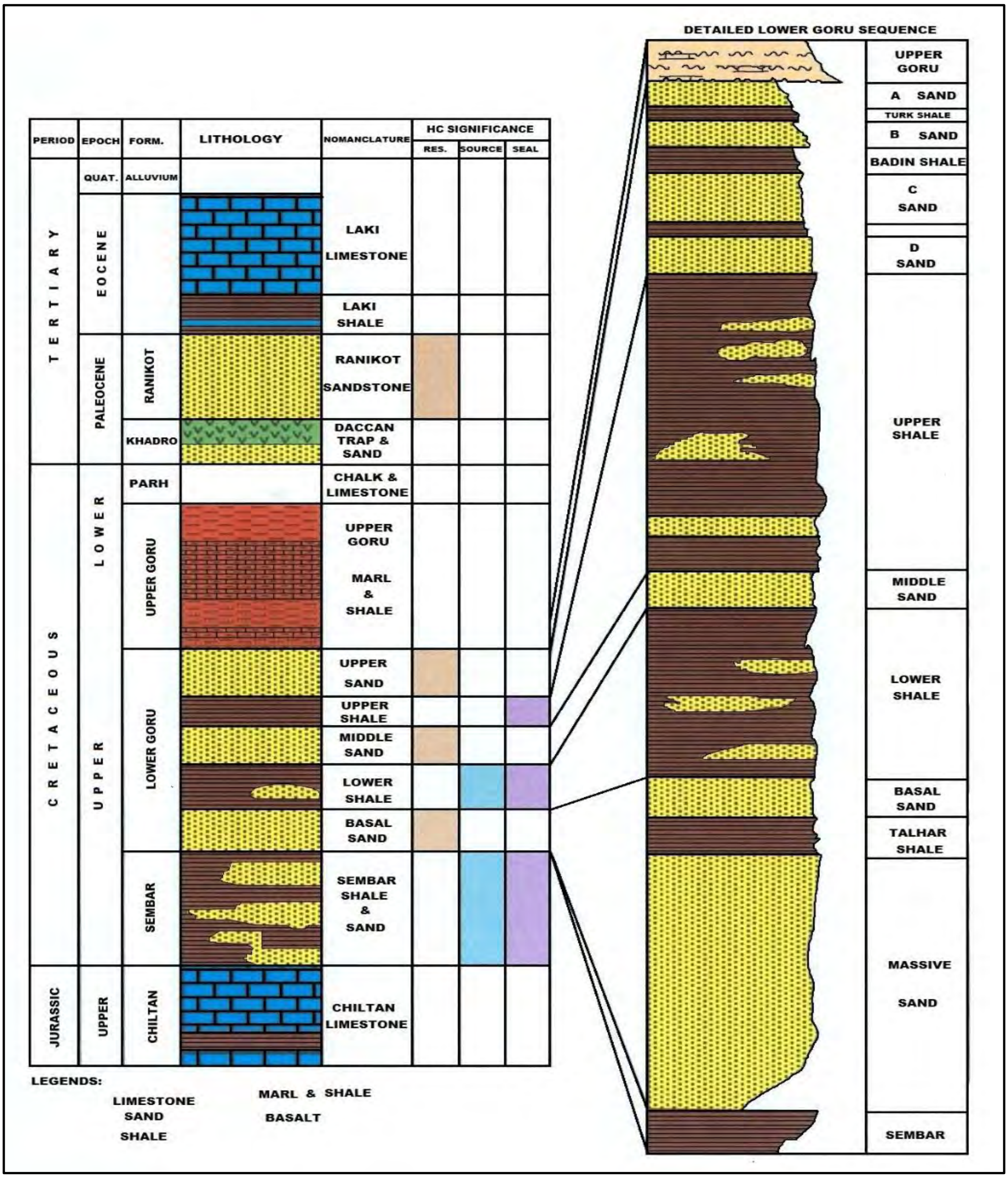

Figure 2.2 Generalized stratigraphic column of Indus basin *(Krois et al.,1998)*

2.4 Petroleum Prospects:

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.

2.4.1 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 follows:

- **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 sandstone of formation (Ahmad et al,2012).

- **Ranikot Formation:**

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

2.4.2 Reservoir Rocks:

The main reservoir rocks in the study area are upper , 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, sugry, 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. Major faults in the subsurface plays the significant role; firstly, they provide the migration path to hydrocarbon to flow from source rock to Lower Guru Sands. Secondly they maintain good seal over the reservoir and provide trap for the potential reserves (Wandrey et al., 2004).

2.4.3 Cap, Seal and 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 (Wandrey et al., 2004).

CHAPTER # 03
SEISMIC INTERPRETATION

3.1 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. This is very important for confident approximation of the depth and geometry of the bed rock or target horizons.

Seismic Interpretation provides the detail and comprehensive image of the subsurface for structural and stratigraphic analysis. Four horizons (SML, Lower Guru, B-Sand, C-Sand) and seven faults are marked to pursue the structural interpretation of the study area.

This is done to get information for the deposits of the hydrocarbon. Structural Interpretation of 2D seismic data of Miano area is described in this chapter.

3.2 MARKING AND IDENTIFICATION OF SEISMIC HORIZONS:

To distinguish different horizons on seismic sections is an important query in the interpretation of seismic data, which may be structural or Stratigraphic. For this purpose, the seismic data is correlated with well formation tops data and already known geology of area (Dobrin and savit ,1988).

The first step of Seismic data interpretation is to mark the prominent reflectors also called horizons on the seismic sections. A reflector (Horizon) is defined as “an interface or boundary between two rock units (formations)”.Those reflectors are selected which are real, show strong character ,continuity and can be followed throughout the seismic line and also can be correlated at tie points of other seismic lines of the area (Badely,1985).Six prominent horizons are marked on the Seismic lines. These horizons were marked through the same steps and all the sections are correlated at their respective tie points. The reflectors are strong enough to be picked because of contrast in acoustic impedance that is ultimately caused by changes in lithology. But in this study due to the unavailability of VSP data the identification of Horizons has been done by using the depths of the formations from the well top data and synthetic seismogram (Figure 3.1) of Miano-5 and also depths can be calculated by using interval and average velocities derived during processing of seismic data. In this study three prominent reflectors are marked. other wells of Miano area.

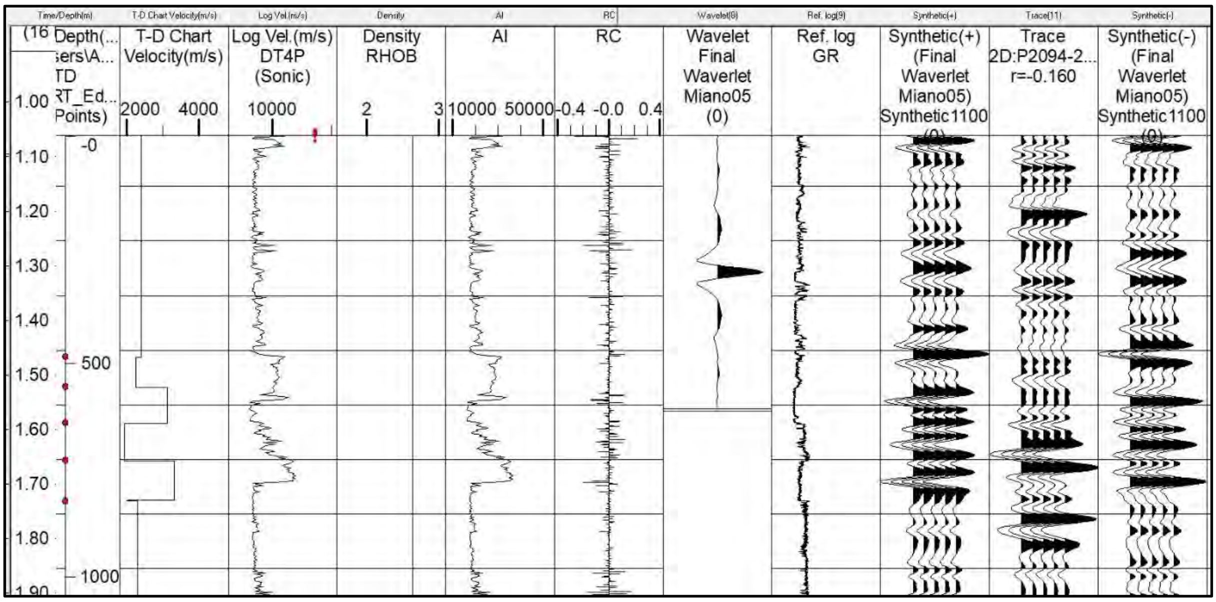

Figure 3. 1 Synthetic Seismogram of well Miano 05

3.3 SEISMIC TIE:

After marking horizons on a seismic section, the next step is to tie the seismic section with the other intersecting seismic lines of the area. In this study horizons on the seismic line P2094-223 are marked first because it is nearer to the well Miano-5. The tie points of the lines are confirmed from the base map, where tie points of the lines have been mentioned. At the tie point of both intersecting seismic lines have same horizons at the same time. If the horizon does not have same time, then there may be mistie that may be removed later on. Taking seismic line P2094-212 as a reference line, all other seismic sections used in the study are marked. At the tie point we not only mark the horizons but also mark the points of faults are also marked in the same manner all the faults were correlated.

3.4 SEISMIC INTERPRETATION:

To develop complete interpretation there is a need for congregation of all the relevant seismic and well data and this would be helpful in providing the accurate results. The basic aim of seismic data interpretation is to construct a geological model. In the first step the prominent reflector are picked and correlated with the well tops of miano-5 and the reflectors are identified. Also the lines are correlated with the synthetic seismogram of these wells. The nearest line to the well miano-05 is P2094-212 so first of all this line is interpreted. Using tie of seismic lines from P2094-212 the other lines used in the study are marked. Six prominent horizons were marked on all the seismic lines used in the study, with the help of well data all these horizons were named and ages were assigned to Horizons. The detail of marked Horizons with specific color assigned is given as under Horizon 1 is Sui Main Limestone of Eocene age (green) Horizon 3 is the Top of lower Goru Formation of Cretaceous age (red) Horizon 4 is the C-interval of sand in lower Goru Formation (orange) Horizon 5 is the B-interval of sand in lower Goru Formation (pink) Horizon 6 is Chiltan Limestone of late Jurassic age (yellow) The horizons (reflectors) were marked with a specific color scheme as color of each reflector is mentioned above. Throughout the study color scheme is kept constant for each horizon. The direction of deposition is east to west in the study area so the EW trending lines are dip lines and the structures (faults) are clearly observed on these lines. The NS trending line is strike line and on strike line the faults cannot be clearly observed so the fault tie points from dip lines were highlighted. The base map of the lines used for the study along with the well location is shown in figure 1.2. Numbers of normal faults are marked on the seismic lines but there are two major horst structures as the area is in extensional regime. All the horizons are marked in manual picking mode in SMT Kingdom software.

3.4.1 Interpreted Seismic Section

The seismic line P2094-215 and P2094-19 are the dip lines and the horizons are marked as shown in figure 3.3 and figure 3.2.11 Normal faults are marked on both the section forming 2 major horst structures. Five are the major faults while the others are steps faults. The time of the horizons on seismic sections is given as; Top of Lower Goru is at 1.30 to 1.60 seconds and other two are C-Sand and B-Sand sub-horizons of Lower Goru. The time of horizons increases from west to east and so is the thickness of horizons, which indicates that the direction of deposition in the area is from west to east.

Three horizons Lower Goru, C-Sand and B-Sand are marked (from top to lower) on the lines are with associated five faults are identified (on dip lines) among these two faults forming a graben while rests are step faults. The interpreted seismic sections of the lines P2094-212, P2094-219 and P2094-215 are shown in figures 3.2 and 3.3 and 3.4 respectively.

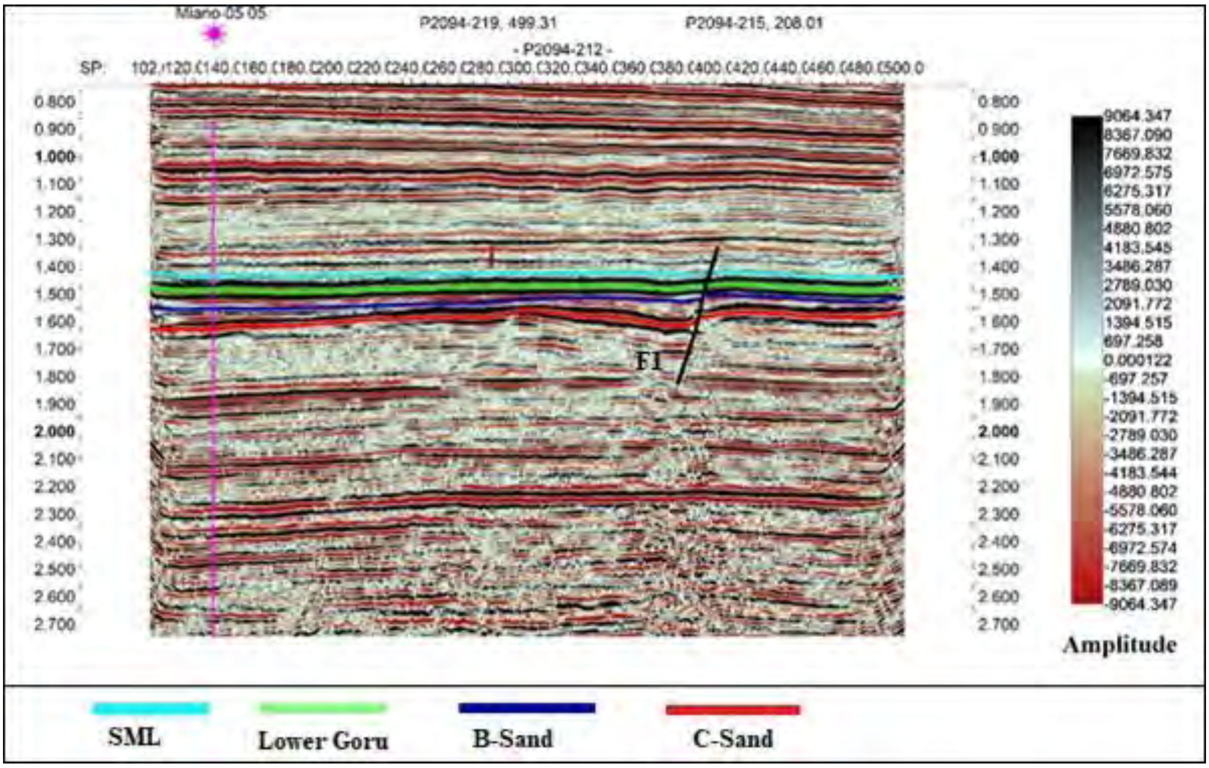

Figure 3. 2 Interpreted seismic section of P-2094-212

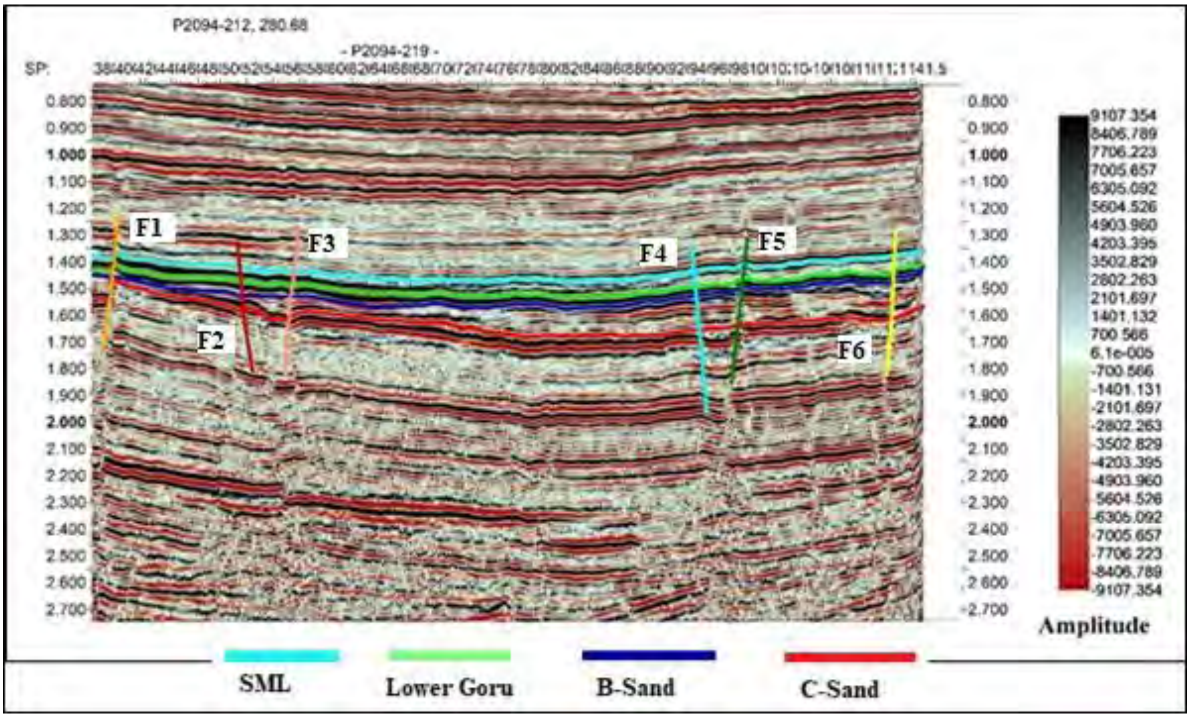

Figure 3. 3 Interpreted seismic section line P2094-219

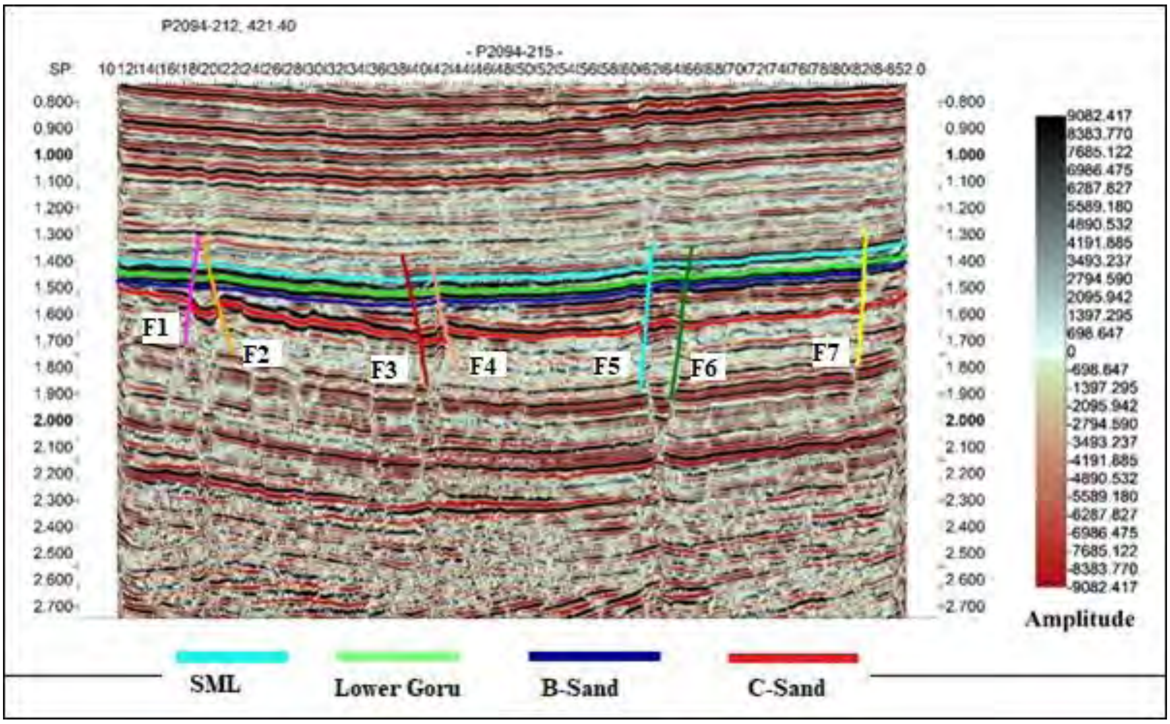

Figure 3. 4 Interpretation of seismic lines P2094-215

3.4.2 DEPTH SECTION:

The average velocity for any velocity function can be calculated by using the formula:

Vav= Vint*Tn-Tn-1 + Vav n-i + Tn-1/ Tn – Tn-1

However, the use of appropriate values of velocity and time, the depth of each interface can be easily calculated.

Depth= V*T/2.

3.5 Time Contour Maps

A map prepared by seismic time of horizons at every seismic line is intended to show the structure in the subsurface. Obviously, it doesn't show structure directly but it gives us the idea of subsurface structure as well as the distribution of horizon in subsurface. The time and depth contour maps are limited to the specific area so basically it is a local study of the area. In this study time contour maps are generated with the help of the SMT Kingdom software. Two-way travel time of the seismic waves is plotted against the Northings and Eastings (X and Y's) and the contours of time are calculated. Time contour maps of Lower Guru, B-Sand, C-Sand were generated with respect to time for true structural interpretation of the subsurface.

3.5.1 Time Contour Map of Lower Goru Formation:

The two-way time contour map of the Lower Goru Formation has been prepared with contour interval of 2 milliseconds as shown in Figure 3.14. Four major faults are considered in mapping while the minor faults are ignored. Figure 3.14 represents that there is very minor throw of the faults. The contours show that the structure is dipping at a steeper angle towards the higher values of the time i.e. from N-S. The contour on Top of Lower Goru Formation with time 1.30 seconds is shallowest and it is at the western side as shown in figure 3.5. Also the contour show the deepest part of the area with time up to 1.730 seconds is at large Graben in the eastern side which is bonded by faults on both sides. Four major faults were shown on the map forming to major horst structure at eastern side where two grabens are also present. As horst and grabens are formed in the area so tectonically the area lays in extensional regime. The contour maps clearly show that the formation is shallow towards west and vice versa which clearly indicates that this formation was deposited on a slope from west to east. Also, 3D time surface map for Top of Lower Goru Formation is generated as shown in figure 3.5.

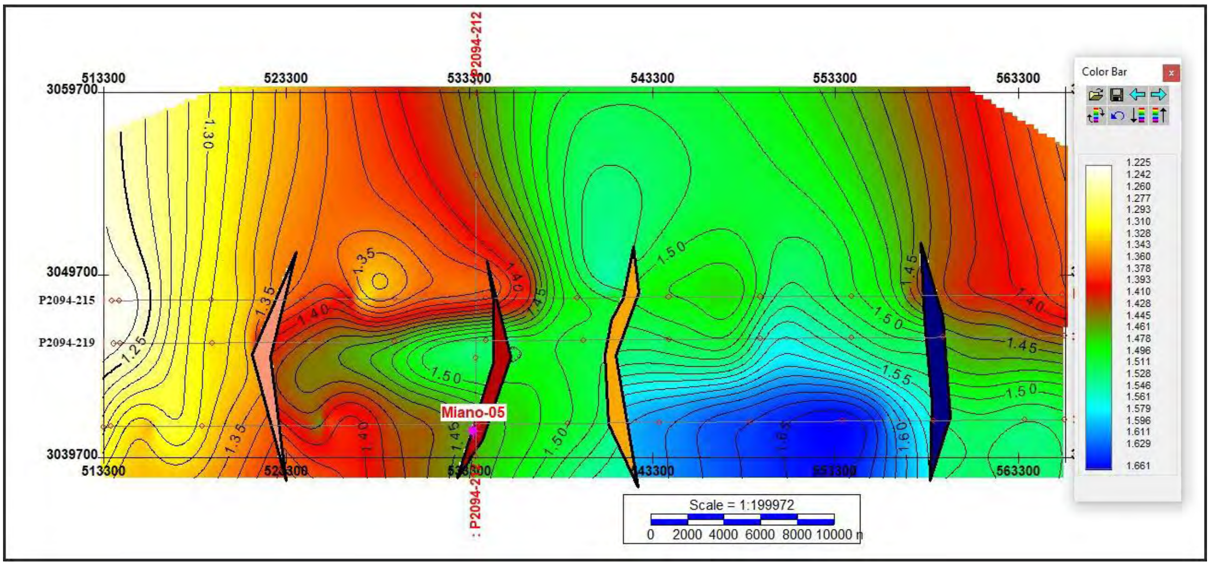

Figure 3.5 Time contour map of lower Goru Formation

3.5.2 Depth contour Maps of Lower Goru Formation:

As structures are related to the depth, and the data is in two-way travel time of seismic waves. To prepare a map that is more truly related to the subsurface shapes and structures, depths must be calculated from these time maps using the velocity of the horizons from the sonic log or velocity functions of seismic data. For this purpose, time and depth contour maps of reservoir formations of the area i.e. Lower Goru Formation. These maps are generated with the help of the Kingdom software. Depth of the horizons is plotted against the Northings and Easting of the survey. Five major faults were plotted on the maps. The depth of Lower Goru Formation Ranges from 1800 to 2500 meters. Depth contours maps show that the depth of horizons increases from East to West direction. Depth contour maps of the horizons are shown in the figure 3.6.

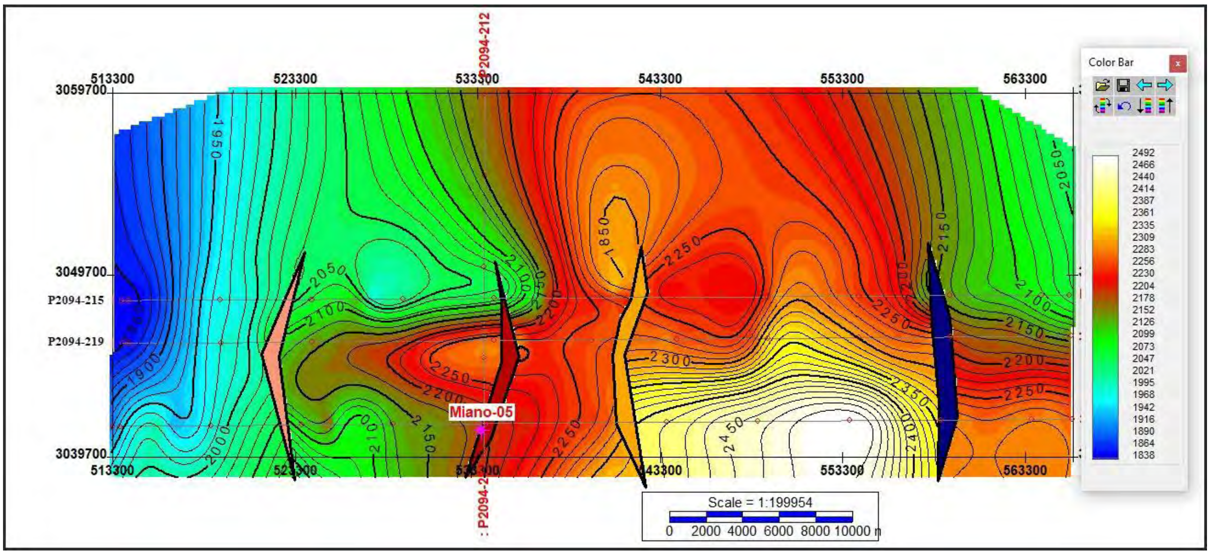

Figure 3.6 Depth contour map of lower Goru formation

3.5.3 Time Contour Map of B-Sand:

The TWT contour map of the C Sand Formation has been prepared with contour interval of 10 milliseconds (0.010 seconds) as shown in Figure 3.7. Four major faults are considered in mapping while the minor faults are ignored. Figure 3.7 represents that there is very minor throw of the faults. The contours show that the structure is dipping at a steeper angle towards the higher values of the time i.e. from N-S. The contour on Top of B Sand

Formation with time 1.30 seconds is shallowest and it is at the western side. Also, the contours show the deepest part of the area with time up to 1.730 seconds is at large Graben in the eastern side which is bonded by faults on both sides. Five major faults were shown on the map forming to major horst structure at eastern side where two grabens are also present. As horst and grabens are formed in the area so tectonically the area lays in extensional regime.

The contour maps clearly show that the formation is shallow towards west and vice versa which clearly indicates that this formation was deposited on a slope from west to east.

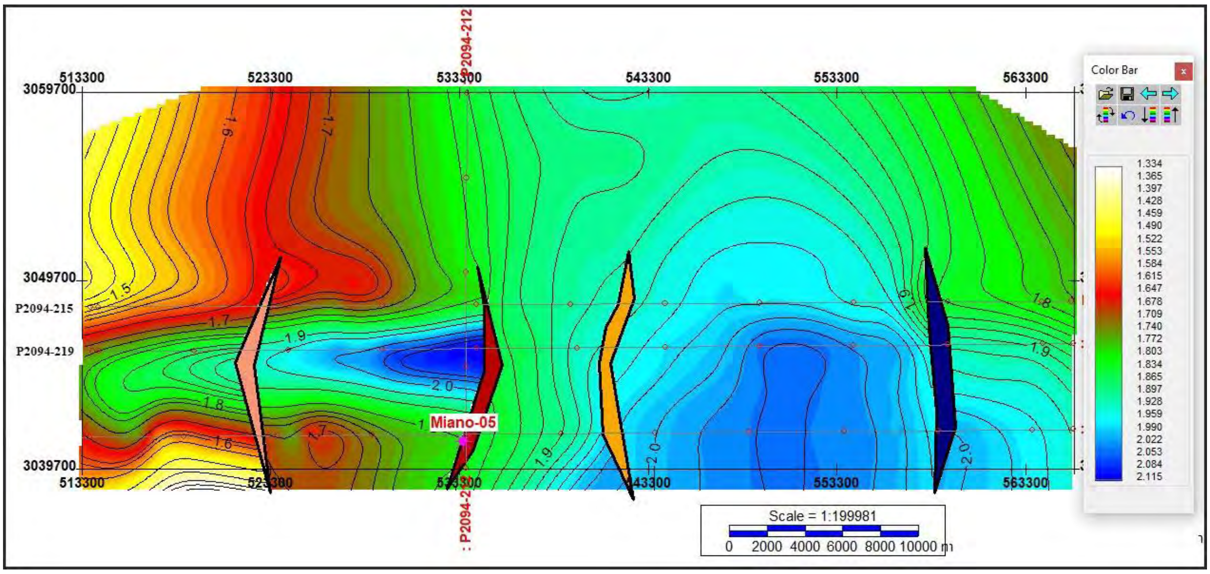

Figure 3.7 Time contour map of B-Sand

3.5.4 Depth contour Maps of B-Sand:

As structures are related to the depth, and the data is in two-way travel time of seismic waves. To prepare a map that is more truly related to the subsurface shapes and structures, depths must be calculated from these time maps using the velocity of the horizons from the sonic log or velocity functions of seismic data. These maps are generated with the help of the Kingdom software. Depth of the horizons is plotted against the Northings and Easting of the survey.Four major faults were plotted on the maps. Depth contour maps clearly indicates the presence of horst and graben structure in the study area. Depth contour maps of the horizon is shown in the Figure 3.8.

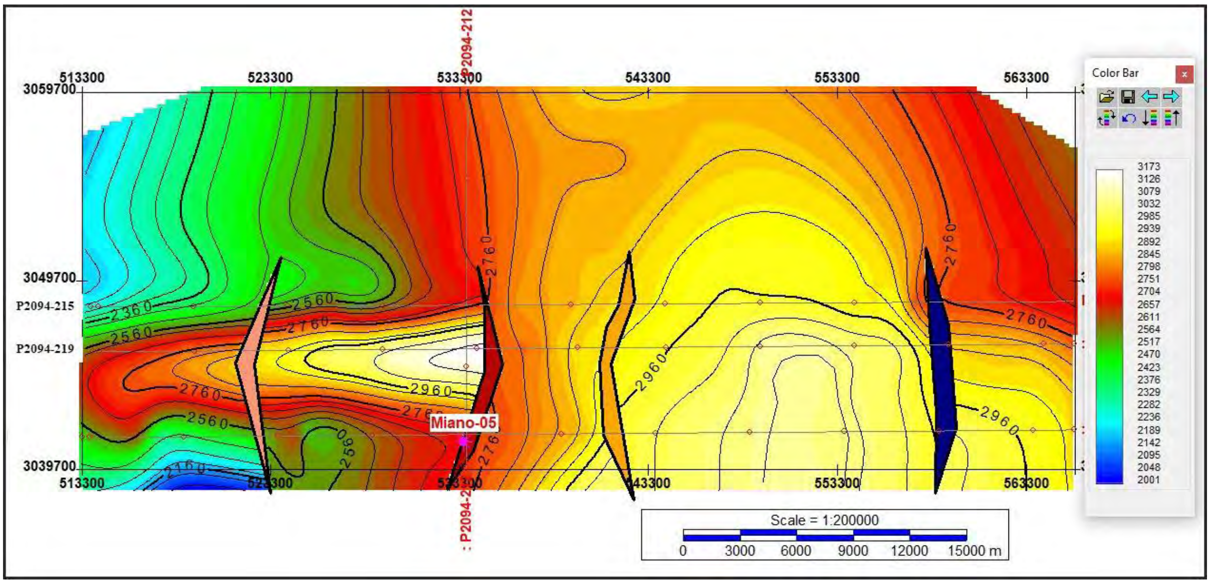

Figure 3.8 Depth contour map of B-Sand

3.5.5 Time Contour Map of C-Sand:

The two-way time contour map of the B-Sand has been prepared with contour interval of 10 milliseconds (0.010 seconds) as shown in Figure 3.9. Four major faults are considered in mapping while the minor faults are ignored. Figure 3.9 represents that there is very minor throw of the faults. The contours show that the structure is dipping at a steeper angle towards the higher values of the time i.e. from N-S. The contour on Top of C-Sand with time 1.30 seconds is shallowest and it is at the western side. Also, the contours show the deepest part of the area with time up to 2 seconds is at large Graben in the eastern side which is bonded by faults on both sides. Five major faults were shown on the map forming to major horst structure at eastern side where two grabens are also present. As horst and grabens are formed in the area so tectonically the area lays in extensional regime. Time contour map of the C-Sand becomes shallow as we move from right to left, which confirms the presence of faults and also validate the presence of Horst and Graben structure.

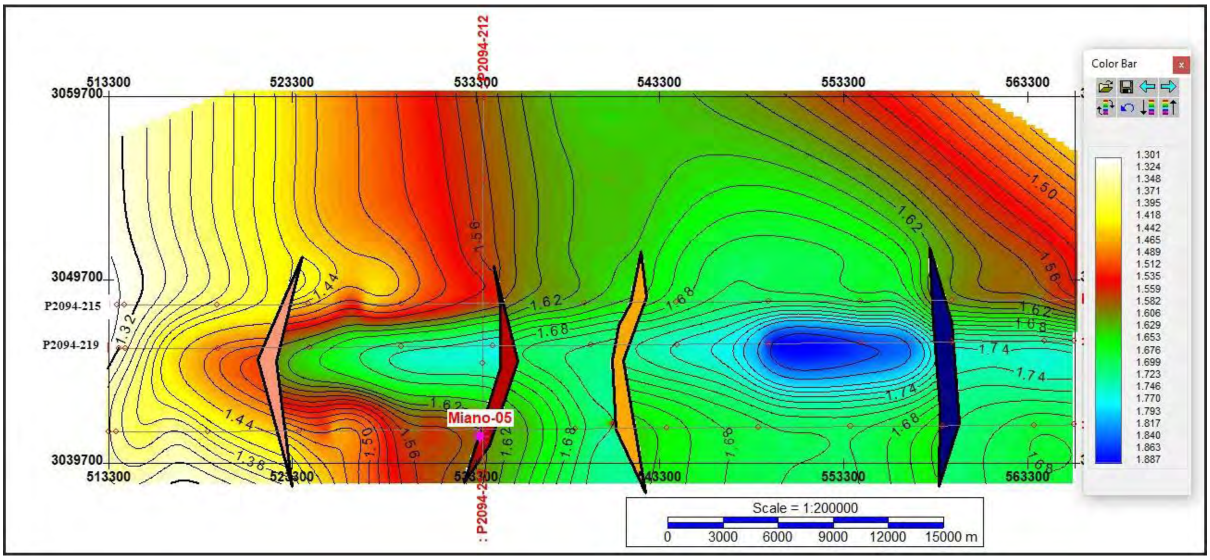

Figure 3.9 Time contour map of C-Sand

3.5.6 Depth contour Maps of C-Sand:

As structures are related to the depth, and the data is in two-way travel time of seismic waves. To prepare a map that is more truly related to the subsurface shapes and structures, depths must be calculated from these time maps using the velocity of the horizons from the sonic log or velocity functions of seismic data. For this purpose, time and depth contour maps of reservoir formations of the area i.e. Lower Goru Formation, C-sands and the most prominent horizon of the area. These maps are generated with the help of the Kingdom software. Depth of the horizons is plotted against the Northings and Easting of the survey. Five major faults were plotted on the maps. The depth of B-Sand Ranges from 2000 to 3200 meters. Depth contours maps show that the depth of horizons increases as we move from left to right direction. Depth contour map of the horizons is shown in the Figure 3.10.

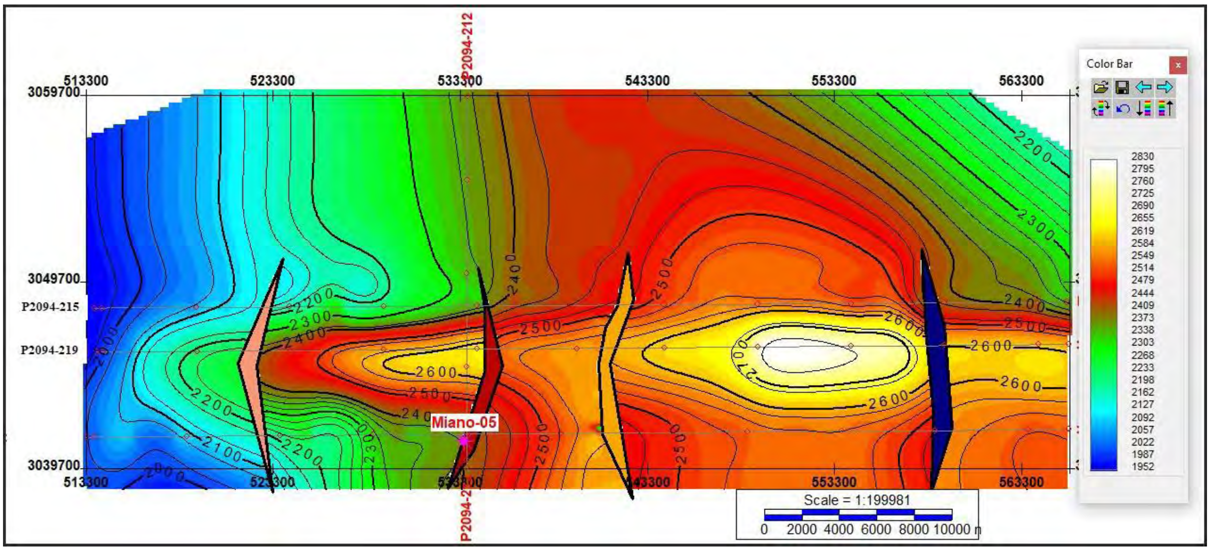

Figure 3.10 Depth contour map of C-Sand

CHAPTER 4.
PETROPHYSICS CHARACTERIZATION

4.1 PETROPHYSICS

Electrical well logging was introduced to the oil and gas industry over half a century ago and since then, many improved and additional logging tools and devices have been developed and have been put in general use. The art of interpretation of the data advanced along with the advancements in well logging science. Today, the detailed analysis of a carefully chosen suite of wireline services provide a method of inferring or deriving accurate values for the hydrocarbons and water saturations, the permeability index, the porosity, and the lithology of the reservoir rock (Schlumberger, 1998).

Petrophysics is the study of the physical and chemical properties that describe the occurrence and behavior of rocks, soils and fluids. To accurately characterize oil or gas reservoir, measurements such as resistivity, neutron and density are made, from which effective porosity, saturations, and permeability can be quantified (Asquith et al.,2004). A major application of petrophysics is in studying reservoirs for the hydrocarbon industry. It includes the rock properties of the reservoir, particularly how pores in the subsurface are interconnected, controlling the accumulation and migration of hydrocarbons. Some of the key properties studied in petrophysics are lithology, porosity, water saturation, permeability and density. These studies are then combined with geological and geophysical studies and reservoir engineering to give a complete picture of the reservoir.

4.2 Petrophysical Analysis

The petrophysics analysis has been carried out through Kingdom 8.8 in order to measure the reservoir characterization of the Miano area using the borehole data of Miano-05. 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 and Photo electric effect log (PEF) simple methodology is shown in the Figure 1.1.

For petrophysics analysis the following parameters are calculated for reservoir rock.

- Volume of shale (Gamma ray log)

- Porosity of reservoir (Sonic, Density and Neutron logs)
- Water saturation (LLD, LLS and SP logs)
- Hydrocarbon Saturation $(1 - S_w)$
- Permeability of reservoir rock

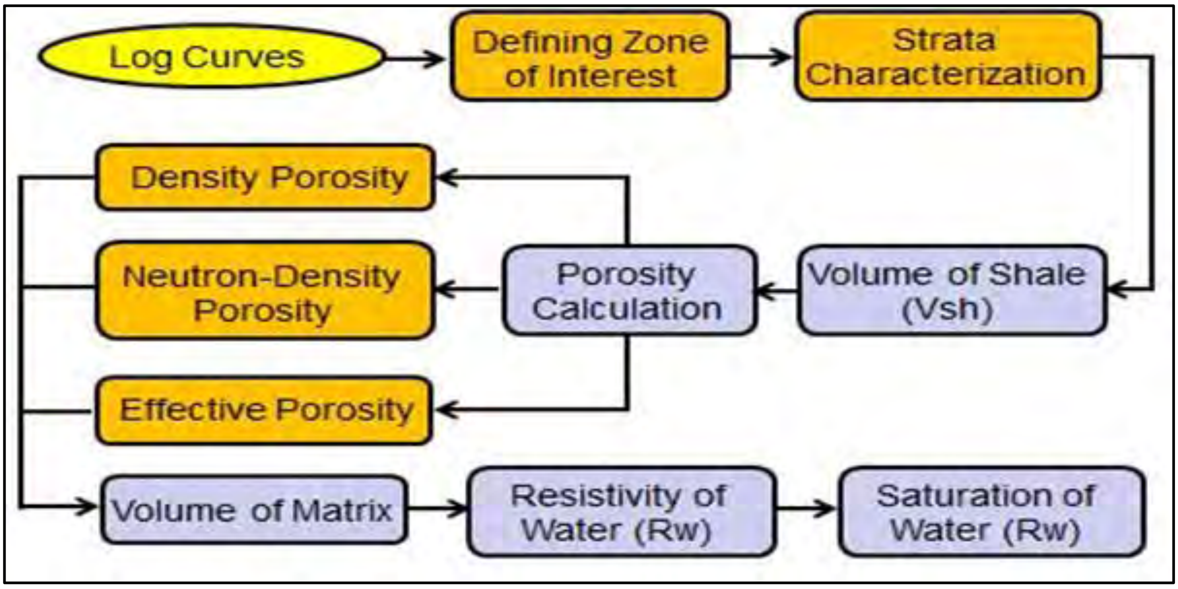

Figure 4. 1 Methodology followed to estimate petrophysics parameters

4.3 Estimation of Volume of Shale

Volume of shale can be calculated from different logs like neutron-density combination, resistivity log, SP log and gamma ray log. In this study due to unavailability of other logs only gamma ray log is used to calculate shale volume, which measures the natural radioactivity of the formation as gamma rays are emitted in the form of photons or electromagnetic energy and due to the collision of photons with electrons energy is transferred to electron exhibiting Compton scattering. These emissions are counted as well as displayed as count per second which is called a gamma ray log. Apart from its various uses, the basic purpose of gamma ray log is to separate sand and shale (Fischetti , 2002).

4.3.1 Gamma Ray Log

Gamma ray logs can be used to calculate volume of shale in porous reservoirs. It is used to analyze shaley sands because shale is more radioactive than sand or carbonate (George and Gibson, 1982).

By calculating volume of shale we can infer whether a formation is good or poor reservoir rock. Higher the volume of shale lower will be the reservoir potential of a reservoir formation. Lower the volume of shale higher will be the reservoir potential of a reservoir formation.

Following equation was used to calculate the gamma ray index.

$$V_{sh} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad \dots\dots\dots\dots\dots\dots (4.1)$$

Where

V_{sh}= *volume of shale*

GR_{log}= *gamma ray reading of formation*

GR_{max} = *maximum gamma ray (in shale)*

GR_{min}= *minimum gamma ray (clean sand or carbonate) (Schlumberger, 1974).*

The Gamma ray log shows maximum value when shale is encountered and shows a minimum value when clean lithology like sand is encountered. These values are calculated from given log response and then volume of shale is estimated by using (Asquith and Gibson, 2004) equation.

The volume of shale calculated in Miano-05 well in Lower Goru formation is 28% and in B-Sand formation is 33 %.

4.5 Estimation of Porosity

Porosity is the ratio of volume of voids to total volume of rock. Porosity is calculated for different zones of interest by using the following logs, sonic log, neutron log, density log.

4.5.1 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 reaches 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).

Sonic log is also used in with combination with other logs to achieve our desired goals. The various combinations are given below.

- Lithology identification (with neutron or density)
- Synthetic seismogram (with density)
- Mechanical properties of formation (with density).

4.5.1.1 Calculation of Porosity Via Sonic Log

To evaluate porosity of consolidated rocks from sonic log, a mathematical relation given by (Kahraman and Yeken , 2008) is used. For unconsolidated sandstone, a compaction factor Cp = (Δtsh*C)/100 (Kahraman and Yeken , 2008) should be added to this equation. Moreover, for calculation of vuggy or secondary porosity in carbonates, sonic porosity subtracted from total porosity (i.e. derived from density or neutron log).

$$\emptyset_{\text{sonic}} = \frac{\Delta t_{\text{log}-}\Delta t_{\text{ma}}}{\Delta t_{\text{f}} - \Delta t_{ma}}$$

Where

$\emptyset_{\text{sonic}=}$sonic derived porosity

$\Delta t_{\text{log}=}$interval transient time of formation

Δt_{ma} =interval transient time of matrix

$\Delta t_{\text{ma}=}$ interval transient time of fluid (fresh mud=189 & salt mud=185)

Values used for transient time of matrix (sand stone) and fluid (fresh mud) are 55µsec/ft and 189µsec/ft respectively (Schlumberger, 1974).

Presence of hydrocarbons may increase the interval transient time called as hydrocarbon effect. This effect should have to be removed as it can increase sonic derived porosity (Mabrouk, 2008).

4.5.2 Density log

The logging tool which is used to record the bulk densities of the formations along the borehole is called density log. An increase in counting rate causes a decrease in bulk density of formation and vice versa. Bulk density from the density log is considered to be sum of density of fluid times its relative volume ($\emptyset$) plus density of matrix time its relative volume (1- $\emptyset$). However, density log separately and also along with other logs used to achieve various goals. On availability of data some of which are used in this study especially for prospect generation (Asquith and Gibson, 1982; Bertozzi et. al., 1981).

4.5.2.1 Calculation of Porosity from Density Log

As density reading is a function of both porosity and rock type. If the rock type is known, then porosity can be calculated. In this research, rock type in zone of interest is known from gamma ray which is sandstone. Therefore, porosity can be calculated by using following relation (Asquith and Gibson, 1982).

$$\emptyset_{\mathrm{den}} = \frac{\rho_{\mathrm{ma}} - \rho_{\mathrm{b}}}{\rho_{\mathrm{ma}} - \rho_{\mathrm{f}}}$$

Where

$\emptyset_{den}$=density derived porosity

ρ_{ma}=matrix density

ρ_{b}=formation bulk density (value from log)

ρ_{f}=fluid density (Salt mud = 1.1 fresh mud = 1)

Values used for density of matrix (sand stone) and fluid (mud) are 2.65g/cm3 and 1.0g/cm3 respectively (Schlumberger, 1974).

4.5.3 Neutron log

Neutron log reading give the direct estimation of porosity. It is basically a porosity log which measure hydrogen ions (concentration) in the formation. From a chemical source, neutrons are continuously emitted, and when these neutrons collide with nuclei in the formation, results in some loss of some energy. As we know that, Hydrogen atom has the same mass as that of neutron so as a result maximum loss of energy occurs when neutron collide with hydrogen atom.

In clean formation (shale free formation), it measures the liquid filled porosity because the porosity is filled by oil or water. Neutron porosity will be very low when instead of oil or water pores in the formation are filled with gas because the concentration of ions (hydrogen) is less in the gas as compared to water and oil. The decreasing of neutron porosity due to presences of gas is termed as gas effect (Asquith and Gibson, 2004).

4.5.4 Total Porosity

The total porosity is the sum of all the porosities calculated from different logs divided by the number of logs used for calculating porosities. The total porosity is calculated for the reservoir which is Lower Goru in this case. The mathematical relation is used for this purpose is given below.

$$\emptyset_{total} = \frac{\emptyset_n + \emptyset_d + \emptyset_s}{3}$$

Where,

$\emptyset_{total}$= average porosity.

4.6 Estimation of Water Saturation

Water saturation is the percentage of pore volume in rock that is occupied by water of formation. If it is not confirmed that pores in the formation are filled by hydrocarbons, it is assumed that these are filled with water. To determine the water and hydrocarbon saturation is one of the basic goals of well logging. To calculate saturation of water in the formation, a mathematical equation was developed by Archie shown below. All the parameters of Archie equation can be calculated from resistivity and spontaneous potential logs.

Water saturation of reservoirs is calculated from following Archie equation,

$$S_w = \left\{\frac{a * R_w}{\emptyset^m * R_t}\right\}^{1/n}$$

Where,

S_{w}=water saturation

R_t= deep resistively

R_w= resistivity of the formation water

$\emptyset$= porosity log (Nphi)

n= saturation exponent

a= tortuosity factor which is equal to 1 (Rider, 2002).

The values of the constants m & n are kept 2 respectively (Rider, 2002).

4.7 Estimation of Resistivity of Water (R_w)

The resistivity of water is calculated by Spontaneous potential log. The formula used for calculating resistivity of water is given below.

$$SSP = SP_{clean} - SP_{shale}$$

SSP = static spontaneous potential.
SP_{clean} = spontaneous potential for sand.
SP_{shale} = spontaneous potential for shale.
After calculating all these parameters we use Archie equation for calculating saturation of water stated above.

4.8 Estimation of Hydrocarbon Saturation

The fraction of pore spaces containing hydrocarbons is known as hydrocarbon saturation. The simple relation used for this purpose is given below.

$$S_h = 1 - S_w$$

Where,
S_h = Hydrocarbon saturation
S_w= Water saturation
The saturation of hydrocarbons is percentage of pore volume occupied by hydrocarbons. It can be evaluated after calculating the saturation of water because the remaining pores also contain hydrocarbons. Hence this is an indirect method and estimates hydrocarbon saturation quantitatively.

4.9 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 (Ridder, 1996). B-interval is interpreted as reservoir zone after considering all the above explained results and logs.

4.10 Interpretation of Entire B interval (3256-3268m):

Depth range of B interval varies from (3331-3386m) in well Miano-05. It consist 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

4.11 Interpretation of Zone of Interest:

Only one main zone of interest is marked. Depth range Zone of interest or reservoir varies from 3256- 3268 m in well Miano-05. Shale volume for whole depth range is 24 %. Effective porosity is about 7% and hydrocarbon potential of 60%. This is only one pay zone in where high net pay is expected. This zone bear relatively low values of GR, high resistivity and high porosity.

4.12 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 3256-3268 m. Because there was low value of GR which is clear cut indication that it is reservoir zone. Now in 2nd track we run the LLD, LLS, these are resistivity log now their 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 hydrocarbon 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 4.2.

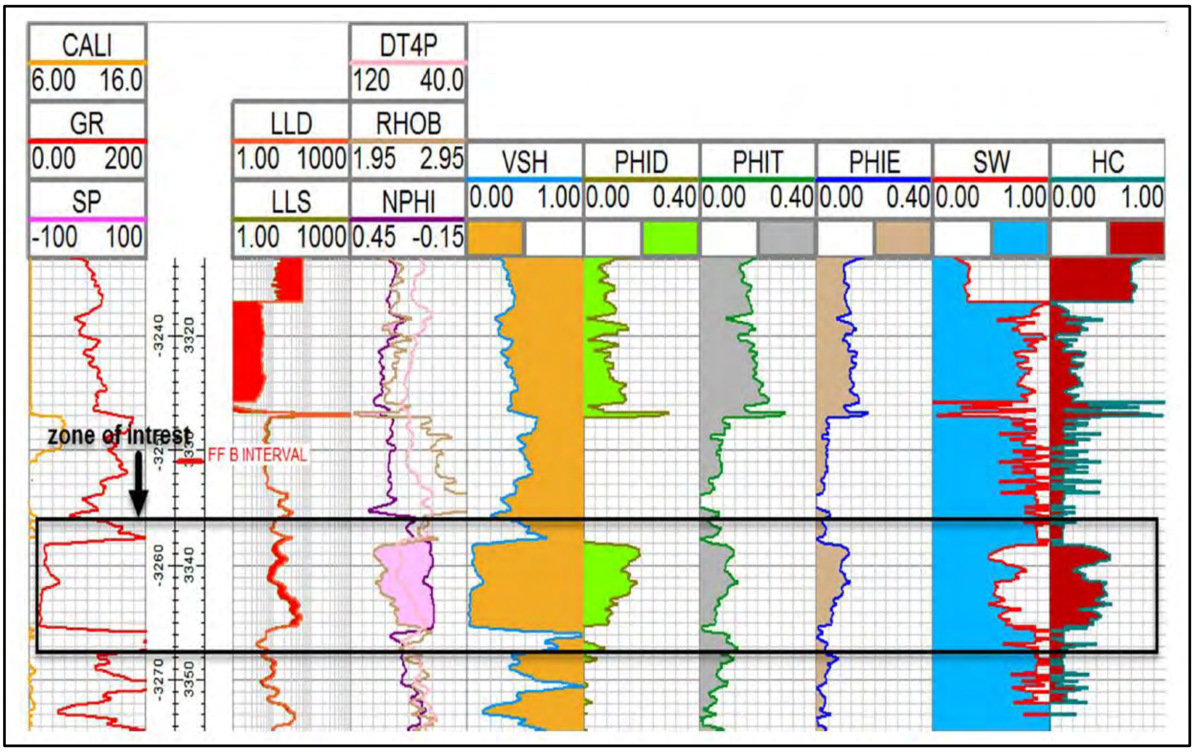

Figure 4. 2 Petrophysical analysis of well Miano 5 with interest depth is shown by rectangle

4.13 Discussion and Conclusions

Three horizons are marked on the basis of available well log data.

- The whole interpretation is based on the seismic and well data available for the dissertation. Miano (Block-20) is in the area where there is influence of both structure and stratigraphy which make the interpretation more interesting, complex and challenging.
- In case of stratigraphy,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.
- The Chiltan Limestone is overlain and down lapped by a Late Jurassic to Early Cretaceous regressive strata comprising bottomsets, foresets and topsets that prograde towards west from the Indian craton. In lithostratigraphic terms the argillaceous foresets to these prograde are called the Sembar Formation which is an important source rock in the basin. The Sembar Formation was deposited over large area of the Indus Basin in marine environment; it consist mainly of black shale with subordinate amounts of siltstone. B-sands of lower goru is the major producing reservoir in the study area. . Shales and tight sands within the C-Interval of Lower Goru Formation act as lateral and bottom seals.
- Based on seismic and well data, reflectors are marked i.e. Lower Goru, B- Sand and C-Sand. B-Sand is acting as reservoir in the study area. Four major faults are marked and their orientation is N-S. 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-05 well which shows the highest porosity and hydrocarbon prospect zone in the depth range (3256-3268 m) of Lower Goru. It exhibits Shale volume 24 %. Effective porosity is about 7% and hydrocarbon

saturation of 60%. The calculations performed for the petrophysical analysis elucidated that the reservoir zone of the Lower Goru Formation have good hydrocarbon potential.

References

- Ahmad, N., Mateen, J., Chaudry, K. S., Mehmood, N., & Arif, F. (2013). Shale gas Potential of lower Cretaceous Sembar formation in middle and lower Indus basin, Pakistan. Pakistan Journal of Hydrocarbon Research, 23, 51-62.
- Archie, G.E. (1942), Classification of carbonate reservoir rocks and petrophysical considerations. AAPG Bulletin, V. 36, P. 278–298.
- Asquith, G. B. (2004). Basic Well Log Analysis, Volume 1. American Association of Petroleum Geologists.(n.d.).
- Badley, M. E. (1985). Practical seismic interpretation. International Human Resources Development Corporation.
- Bender., (1995). Geology of Pakistan. Berlin: Gerbruder Borntraeger
- Coffeen, J.A., (1986), Seismic Exploration Fundamentals, PennWell Publishing Company,Tulsa, Oklahoma.
- Davis, I. D., Chen, W., Jackson, H., Parente, P., Shackleton, M., Hopkins, W., ... & Cebon, J. S. (2004). Recombinant NY-ESO-1 protein with ISCOMATRIX adjuvant induces broad integrated antibody and CD4+ and CD8+ T cell responses in humans. Proceedings of the National Academy of Sciences, 101(29), 10697-10702.
- Kadri I. B., (1995), Petroleum Geology of Pakistan, Published by Pakistan Petroleum
- Kazmi A. H. & Jan, M.Q, (1977), Geology & Tectonics of Pakistan", Graphic Publishers,,Karachi, Pakistan. 540-560.
- Kearey, P., Brooks, M., & Hill, I., (2002). An Introduction to Geophysical Exploration.Blackwell Science Ltd.
- Kemal, A., Zaman, A.S.H., and Humayon, M., (1991), New directions and strategies for accelerating petroleum exploration and production in Pakistan. Proceedings, International Petroleum Seminar, Islamabad, Pakistan, Ministry of Petroleum and Natural Resources,16–57.
- Krois, P., Mahmood, T., & Milan, G. (1998, November). Miano field, Pakistan, A case history of model driven exploration. In Proceedings Pakistan Petroleum Convention 98, Islamabad 25–26 November (pp. 112-131). Islamabad, Pakistan: Pakistan Association of Petroleum Geoscientists (PAPG).
- Krygowski, D. (2004). Basic Well Log Analysis 2nd Edition. Amer Assn of Petroleum Geologists.
- Longwell, C.R., (1949). Sedimentary facies in geologic history. Geological Society ofAmerica.
- Raza, H. A., (1990) petroleum geology of khirthar sub-basin and part of kutch basin, Pakistan journal of hydrocarbon research vol, 2, No. 1.

- Robinson ES, & Coruh, C., (1988), “Basic Exploration Geophysics”, John Wiley & Sons,New York, 25-70p
- Russell, B. H. (1990). Introduction to seismic inversion method.
- Schlumberger, (1974),”Log Interpretation”, Vol. 1, P. 87-96.
- Shah, S.M.I., (2009). Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoirs,v.22.
- Sroor, M. (2010). Geology and Geophysics in Oil Exploration.
- Taner, M.T., Schuelke, J.S., O'Doherty, R., and Baysal, E., (1994) Seismic attributes revisited.
- Tittman, J. & Wahl, J.S., (1965), "the physical foundations of formation density logging (gamma-gamma)," geophysics 30: 284-294.
- Wanderley, M. M., & Depalle, P. (2004). Gestural control of sound synthesis. Proceedings of the IEEE, 92(4), 632-644.
- Yilmaz, (2001). Seismic Data Analysis and Processing, Inversion and Analysis of Seismic Data, Society of Exploration Geophysics, Tulsa.
- Zaigham & Mallick, (2000), “Prospects of hydrocarbons associated with fossil rift structure of southern Indus basins”. AAPG Bulletin, November 2000, v. 84, p.1833-184