# INTEGRATED WITH RESERVOIR CHARACTERIZATION OF MIANO AREA USING SEISMIC AND WELL LOG DATA

**BY**

***Abdur Rehman***

**M.Sc (Geophysics)**

**2017-2019**

**Department of Earth Sciences**

**Quaid-I-Azam University Islamabad**

بسم الله الرحمن الرحيم

*I commence with the Name of Allah - in whom all excellences are combined and who is free from all defects. The Compassionate One whose blessings are extensive and unlimited. The Merciful One whose blessings are inherent and eternal.*

# CERTIFICATE

This dissertation submitted by **Abdur Rehman** S/O **Muhammad Aslam** 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 M.Sc. degree in Geophysics.

## *RECOMMENDED BY*

**Dr. Muhammad Toqeer** ____________________

` (Supervisor)

**Dr. Gulraiz Akhtar** ____________________

(Chairperson Department of Earth Sciences)

**External Examiner** ____________________

Department of Earth Sciences

Quaid-I-Azam University Islamabad,Pakistan

# ABSTRACT

The present study pertains to integrated seismic, petro physical of Miano (Central Indus basin) area. This thesis work includes preparation of synthetic seismogram of Miano-09 well. Analysis of geophysical borehole logs provides one of the best approaches to characterize rocks within boreholes. So Facies analysis is also done in order to identify lithology.

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 of time and depth contour maps made from time and depth grid respectively.

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

# ACKNOWLEDGEMENT

First praise is to Allah, the most Beneficent, Merciful and Almighty, on whom ultimately we depend for sustenance and guidance. I bear witness that Holy Prophet Muhammad (PBUH) is the last messenger, whose life is perfect model for the whole mankind till the day of Judgment. I thank Allah for giving me strength and ability to complete this study.

I am especially indebted to my honorable supervisor Dr. Muhammad Toqeer for giving me an initiative to this study. His inspiring guidance, dynamic supervision and *constructive criticism*, helped me to complete this work in time.

I specially acknowledge the prayers and efforts of my whole family, especially my parents my brother for their encouragement, support and sacrifices throughout the study. My friends especially **Komal Rani, Muhammad Hamza**, **Umer Yasin**, **Shahzad Gul Baloch**, **Maryam Farooq**, **Erum Kurshid**, and my thesis mates **Mujassam Ali**, **Ali Hassan Shah**, **Muhammad Ijaz** who encouraged me with constant motivation and my parent's encouragement played a role of back bone throughout my academic carrier.

***Abdur Rehman***

M.Sc Geophysics (2017-2019)

# *DEDICATION TO*

**My Ma; my roots, my Pa; my stem**

**Dedicate my work to both of them**

# Contents

# Chapter: 01 Introduction

## 1.1 Introduction:

The Miano Block is located in the Sukkur district, Sind Province, Pakistan covering total area of 814.02 Sq. km. The block extends between the 27º14´N to 27º32´N latitude and 69º12´E to 69º28´E longitude. The field was discovered in 1993. OMV Pakistan, Oil and Gas Development Company Limited (OGDCL), ENI Pakistan Limited and Pakistan Petroleum Limited (PPL) are the operators in Miano development and production with working interest of 17.68%, 52.0%, 15.16% and 15.0% respectively (Jadoon et al. 2016).

Study area lies in the Central Indus Basin which is a part of an extensional regime exhibiting normal faulting, formed as a result of split of the Indian Plate firstly from Africa and then from Madagascar and Seychelles. Tectonically, the Miano Block lies on the Panno-Aqilgraben between two extensive regional highs i.e. Jacobabad-Khairpur High and Mari Kandhkot High (Jadoon et al. 2016).

The dominant feature of the area is extensional tectonics and the normal faults provide trapping mechanism for hydrocarbons. The producing formation in study area and its surrounding fields are Lower Goru Sandstone of Cretaceous age. The study area is gas prone and has structural as well as stratigraphic trap.

## 1.2 Objectives:

The main objective of dissertation is to present a subsurface model of study area and to characterize the reservoir potential in the zone.

- Detailed seismic interpretation for identification of the structures favorable for hydrocarbon accumulation.
- Petrophysical analysis for the identification of the reservoir types and various petro- physical and geo-mechanical properties of reservoir encountered in study area.
- Facies modeling for the identification of the lithology in the study area.
- Seismic attribute analysis for the confirmation of the seismic interpretation.
- Depositional environment by the sequence stratigraphy using the well log data.

## 1.3 Data used:

To achieve all the objectives, seismic and borehole data given in Table-1.1 and 1.2 is used, provided by Department of Earth Sciences, Quaid-I-Azam University Islamabad.

**Table 1.1 Seismic Data used in interpretation**

| No | Line Name | Orientation | Nature | SP Range |
|---|---|---|---|---|
| 1 | P2094-211 | E-W | Dip | 102 – 420 |
| 2 | P2094-213 | E-W | Dip | 102 – 740 |
| 3 | P2094-215 | E-W | Dip | 103 - 852 |
| 4 | P2094-217 | E-W | Dip | 102 -916 |
| 5 | P2094-219 | E-W | Dip | 102 -1140 |
| 6 | P2094-221 | E-W | Dip | 102 -1142 |
| 7 | P2094-223 | E-W | Dip | 102 – 1153 |
| 8 | P2094-216 | N-S | Strike | 102 – 1175 |
| 9 | P2094-220 | N-S | Strike | 102 – 785 |
| 10 | P2094-212 | N-S | Strike | 102 – 500 |

**Table 1.2 Well data used in the interpretation**

| Well Data obtained from DGPC for completion of Thesies work | | |
|---|---|---|
| **Well Name** | **TD(m)** | Type of well |
| **Miano-07** | **3429** | Development GAS |
| **Miano-09** | **3385** | Development GAS |
| **Miano-10** | **3610** | **Development GAS** |

## 1.4 Base Map:

Base map shows the well locations, concession boundaries, orientations of seismic survey lines and seismic surveys shot points. 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.

For a geophysicist a base map is that which shows the orientations of seismic lines and specify points at which seismic data were carried out (Sroor,M. 2010). The base map of the study area is shown in the Figure 1.1which contains 1strike lines and 2 dip lines and a well of Miano-09.

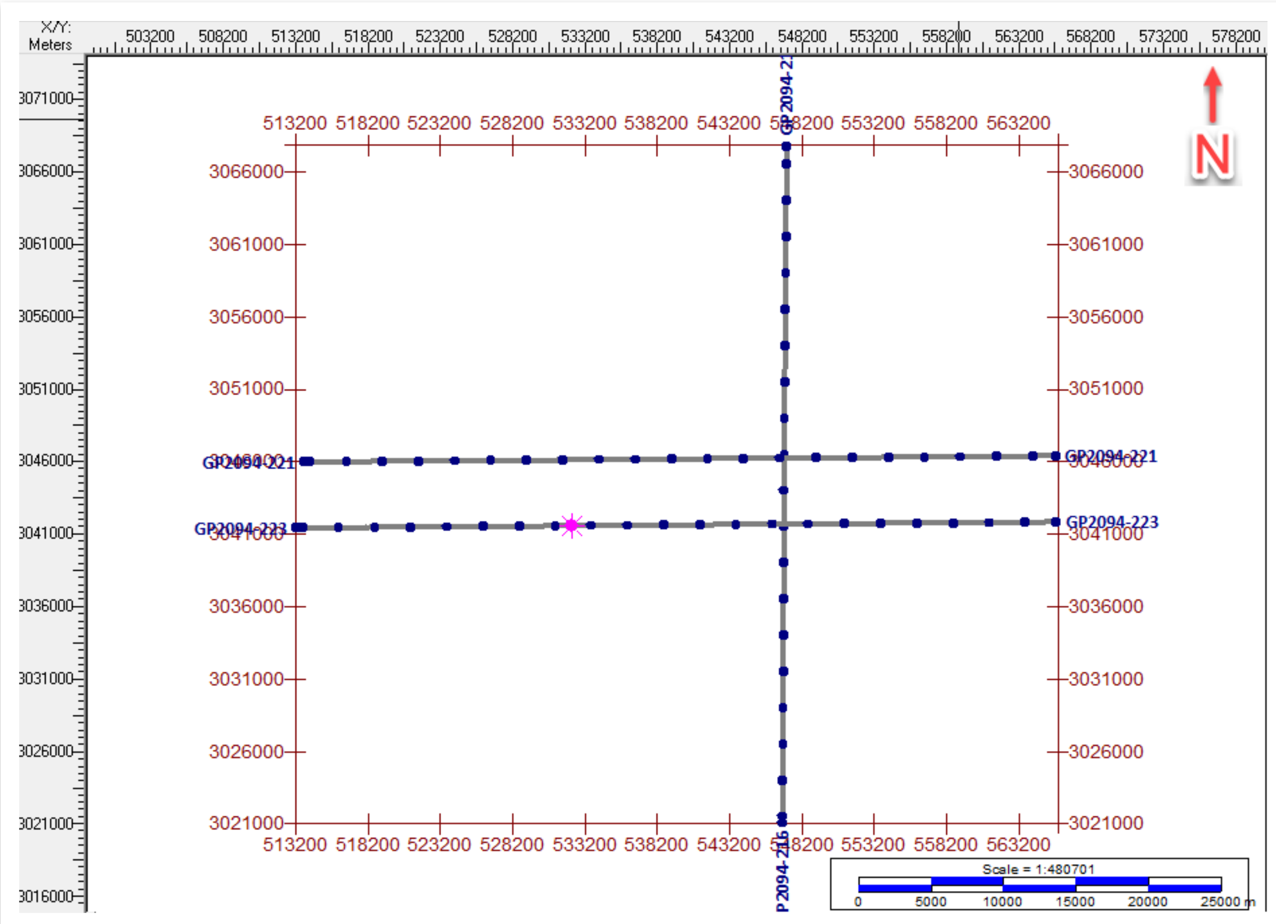


**Figure.1.1 2D Base Map of the study area**

## 1.5 Geographical Location:

The area of concern is Miano (Block-20), which is located approximately 62km 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 field 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. Geologically it is located at the boundary of Lower and Middle Indus Basin, between the Indian basement and the Kirthar Fold and Thrust belt. It is thought to extend from the southern blocks. The Geographic coordinates of the area are given as Latitude of area (27° 14' N to 27° 32' N) & Longitude of area (69° 12' E to 69° 28').

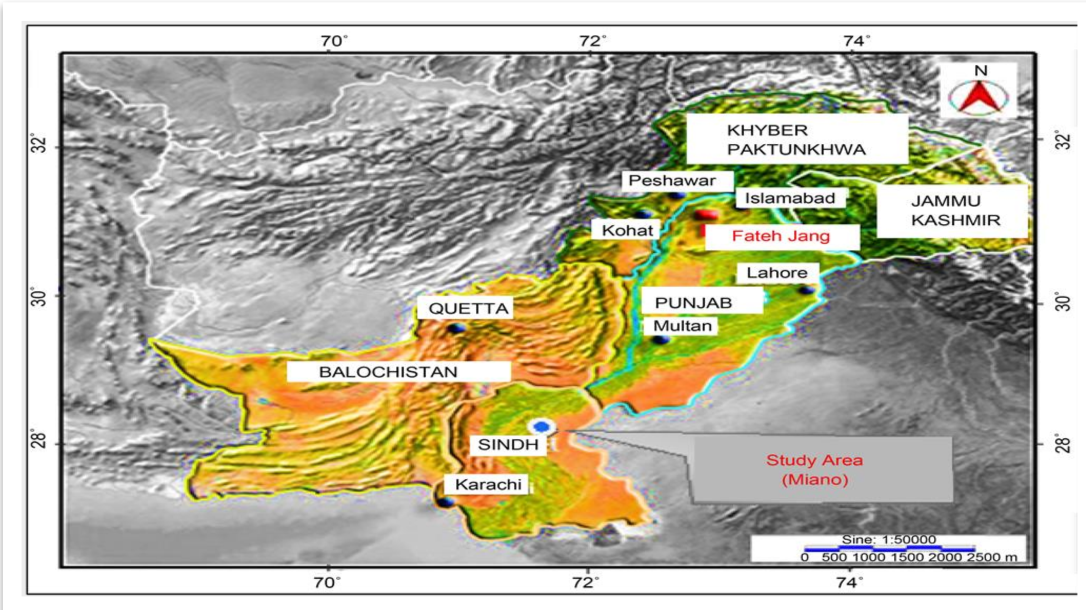


**Figure 1.2 Location of the Study area (Naqi and Siddiqui, 2006)**

## 1.6 Exploration History of the Miano Field:

OMV (Pakistan) started exploration activities in the desert of Sindh in 1991 and its first major breakthrough in 1993 was the discovery of a natural gas reservoir called 'Miano' in the Thar Desert, District Sukkur. In continuation of its efforts the Sawan gas field, in district Khairpur was discovered in 1998 which is presently the fourth largest gas producer. OMV (Pakistan) currently holds interests in five exploration blocks, of which three (South West Miano II, Gambat and Latif) are operated by OMV and two (Zamurdan and Sari South) as non-operating interest. The company's recent discoveries in early 2007 in its exploration licenses Latif and Gambat blocks in the northern Sindh Province have opened the potential for further discoveries in the vicinity. New acreage in Baluchistan has also been acquired. OMV has also promoted local companies to become partners in its international ventures.

A total of 18 wells have been drilled in the field, out of which seven wells are currently on production.

**Table 1.3 General information about Miano Gas field (Zaigham et al., 2000)**

| | |
|---|---|
| Recoverable Reserves | 615 Bcf gas; 0.316 MMbbl NGL |
| PPL Working Interest | 15.16 percent |
| Operator | OMV |
| Other Partners | PPL, OGDCL, Eni |
| Daily Average Production | 98 Mscf gas,52 barrels condensate |

## 1.7 Thesis Organization:

This thesis is divided into fourth chapters with this first chapter forming an introduction. Chapter 2 covers the Geologic setting and History of study. 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. Following are the methodologies adopted to complete this work.

- Collection of geological & Geophysical data
- Preparation of base map
- Identification of faults on seismic sections
- Determination of horizons by generating 1-D synthetic seismogram
- Determination of horizons by generating 1-D synthetic seismogram
- Finding velocity of horizon using well data
- TWT contour map generation
- Optimal time to depth conversion
- Depth contour map generation
- Geo-mechanical properties using Well-Logs
- Identifying the depositional sequence using sequence stratigraphy and facies modeling by kingdom

# Chapter: 02 Geology

## 2.1 Geology:

General geology and geological history of an area is very important for exploration of oil and gas. A geological history of basin can be compiled by considering basin forming tectonics and depositional sequence (Kingston et al., 1993).

## 2.2 Sedimentary basins:

Sedimentary basin is a low area in the earth's crust of tectonic regions, in which sediments accumulate. In terms of genesis and different geological histories, Pakistan comprises three main sedimentary basins

- Indus Basin
- Baluchistan Basin
- Pishin Basin

Indus and Baluchistan the basins evolved through different geological episodes and were finally welded together during Cretaceous/Paleocene along Ornach Nal/Chamman strike slip faults (Kazmi and Jan, 1997).The subdivision of the Indus basin is shown in figure 2.1.The main sedimentary basins of Pakistan (Abdul Fateh et al.,1984) are shown in figure 2.2.Our study area lies in the central part of Indus basin.

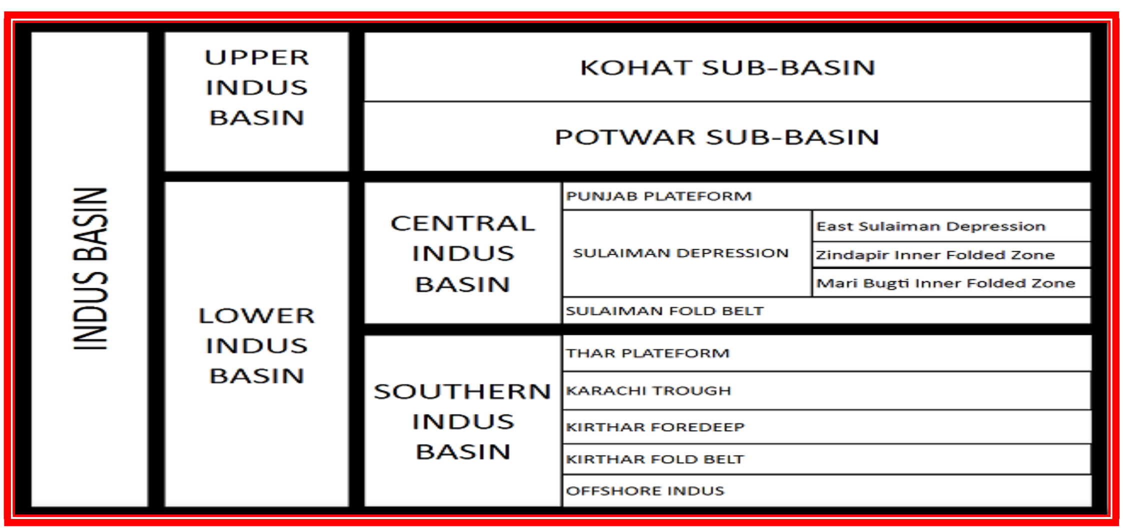


**Figure 2.1 Division of the Indus Basin (Kadri, 1995)**

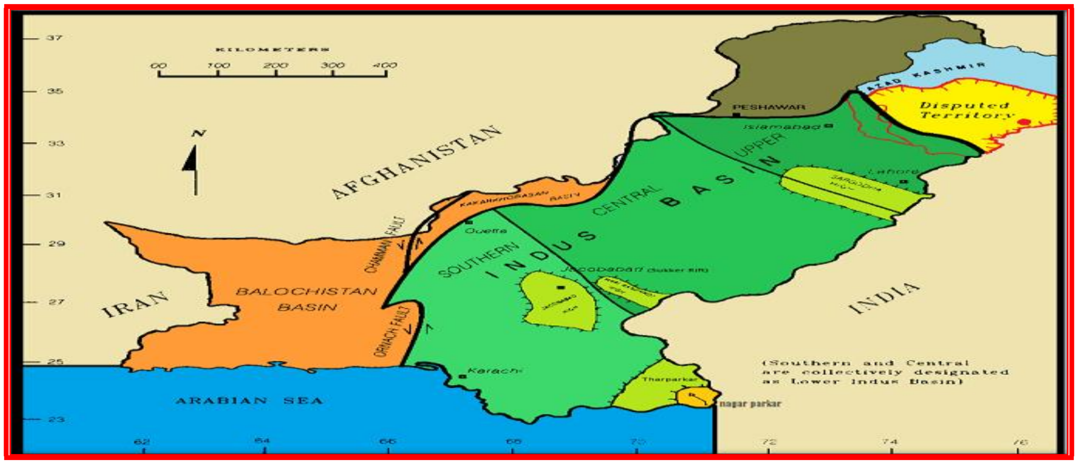


**Figure 2.2 sedimentary basin of Pakistan (Fateh et al., 1984)**

## 2.3 Structure and Tectonic Settings of the study Area:

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 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 (Nadeem et al., 2012). Seismic studies and fault plane solution indicates that these are extensional features. Regional Tectonic setting of the area is shown in the Figure.2.3

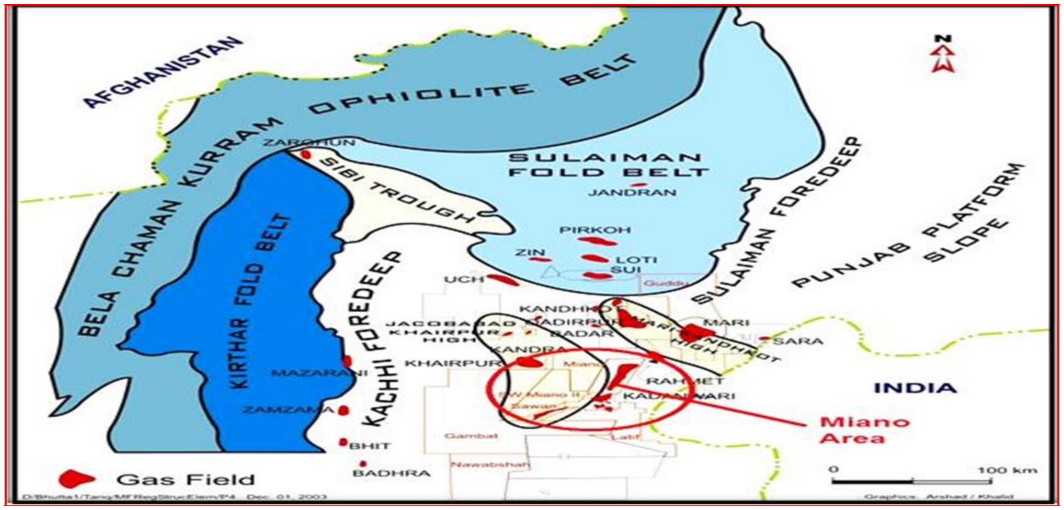


**Figure 2.3 Regional tectonic map of Block-20 in the Middle Indus Basin (Mehmood et al. 2004)**

## 2.4 Stratigraphy of the Area:

The main reservoir rock is Lower Goru Sand of cretaceous age. Sembar shale is source rock and Upper Goru marl acts as cap rock also having cretaceous age. Interbeded shale in Lower Goru formation also acts as barrier for hydrocarbons of Lower Goru sands (Shah et al., 1977). The sedimentary section of the study area in central Indus basin comprises mainly of Permian to Mesozoic sediments overlying, a strong angular unconformity of late Paleozoic age. The whole study area is thickly overlain by alluvium deposits as such no out crops are present at the surface, which can yield a direct evidence of the stratigraphic succession. The Mesozoic progradational sequence is deposited on eastward incline gentle slope. Every prograding time unit represents lateral facies variation from continental to shallow marine in the west to the east. In the Thar slope areas all of Mesozoic sediments are regionally plunging to the west and are truncated unconformable by volcanic rocks (basalts of Khadro formation) and the sedimentary rocks of Paleocene age (Nadeem et al., 2012).

Permian, Triassic and early Jurassic sedimentary rocks in the study area consists of inter- bedded sandstone, siltstone and shale of continental to shallow marine origin. The sedimentary cover in the study area consists mainly of Permian to Mesozoic sedimentary rocks overlying a strong angular unconformity of possibly late Paleozoic age. (Kadri I.B.,1994). The early to middle Jurassic aged Chiltan Limestone in the Middle Indus Basin forms a prominent seismic reflector, which has a smooth planar character.

Flattening seismic sections on this horizon helps to remove the complexity of Tertiary structural tilting and faulting, a process that better resolves depositional architecture. The Chiltan Limestone is overlain and down lapped by a Late Jurassic to Early Cretaceous regressive strata comprising bottom sets, foresets and top sets 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 initial top sets to the progrades have been called the Chichali Formation, while the younger top sets are called the "A" Sand Member of the Lower Goru. No name has yet been given to the sandy submarine fan systems associated with this prograding complex (Sturrock and Tait, 2004). The 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 3.5 percent in the area (William, 1959).

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).

## 2.5 Petroleum system:

The petroleum prospect of the Area tells about the source, Reservoir and seal Mechanism.

Different gas fields like Kadanwari, Sawan and Miano are present in the area. The Stratigraphic column of the area, figure 2.4 shows different rocks act as Source, reservoir and Cap rock in the area. The general description is given below.

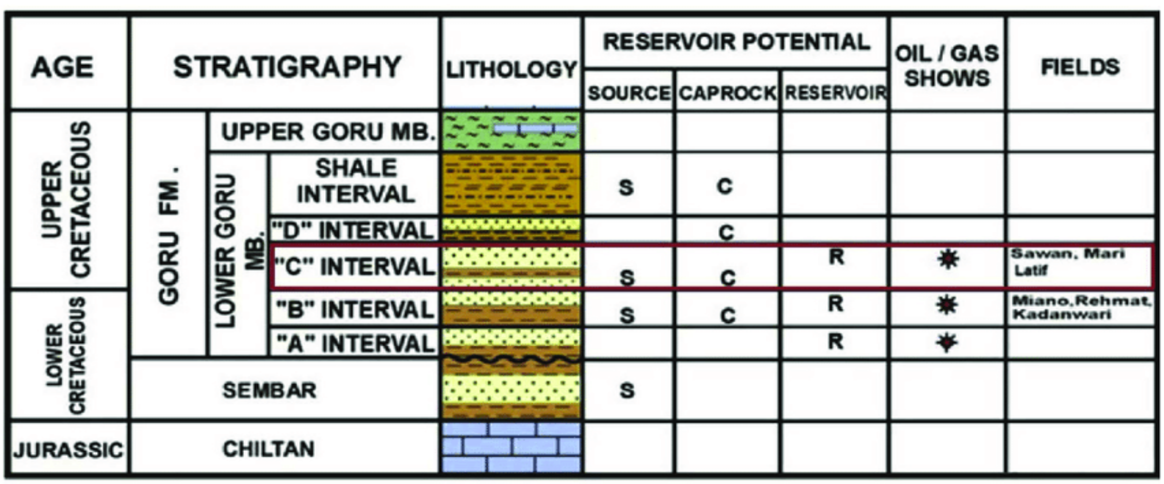


**Figure 2.4 Stratigraphic charts for the Sembar and lower Goru formation (Anwer et al., 2017).**

### 2.5.1 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 follow.

- **Sembar Formation:**

Sembar 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.

- **Ranikot Formation:**

Ranikot shale is considered as the main source for all the gas present in that region, these are the source for overlying Lakhi Formation.

### 2.5.2 Reservoir Rocks:

The main reservoir rocks in the study area are lower Goru and Parh formations. The deposition Environment of the Lower Goru "B" sands in the Miano field is interpreted as tide dominated lithology of sandstone with inters bedded shale. 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 as cemented, argillaceous, visual inter-angular porosity ranged between 10-15%, fair oil shows with scattered and patchy yellowish to bluish white fluorescence and very weak, pale yellowish white residual cut. The low acoustic impedance of seismic waves together with strong seismic amplitudes indicates the presence of reservoir quality sands. This type of reservoir quality sands are only present in the depositionally up dip, i.e. the shallowest marine part of the low stand wedge, as are found in the Sawan, Miano and Kadanwari Fields.( Yergin, Daniel, 1991)

### 2.5.3 Trapping mechanism:

The trapping Mechanism for the target reservoir in the study area is a 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 shale of the Lower Goru "C"

Interval directly, overlying the 'B' interval of reservoir sands, and thick shale and marls of the Lower Goru Formation form the regional top seal for the reservoir in the area. Shale and tight sands within the C - Interval of Lower Goru Formation act as lateral and bottom seals (Krois et al. 1998).

# Chapter: 03 Seismic Data Interpretation

## 3.1 Introduction:

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 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

## 3.2 Types of the Interpretation:

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

- Qualitative Interpretation
- Quantitative Interpretation

Qualitative interpretation is conventional or traditional seismic technique which is used primarily for mapping the sub-surface geology (Sheriff, 1999).

## 3.3 Interpretation Workflow:

The Interpretation was carried out using different techniques and steps. Each step involves different processes which were performed using the software tools. 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.

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

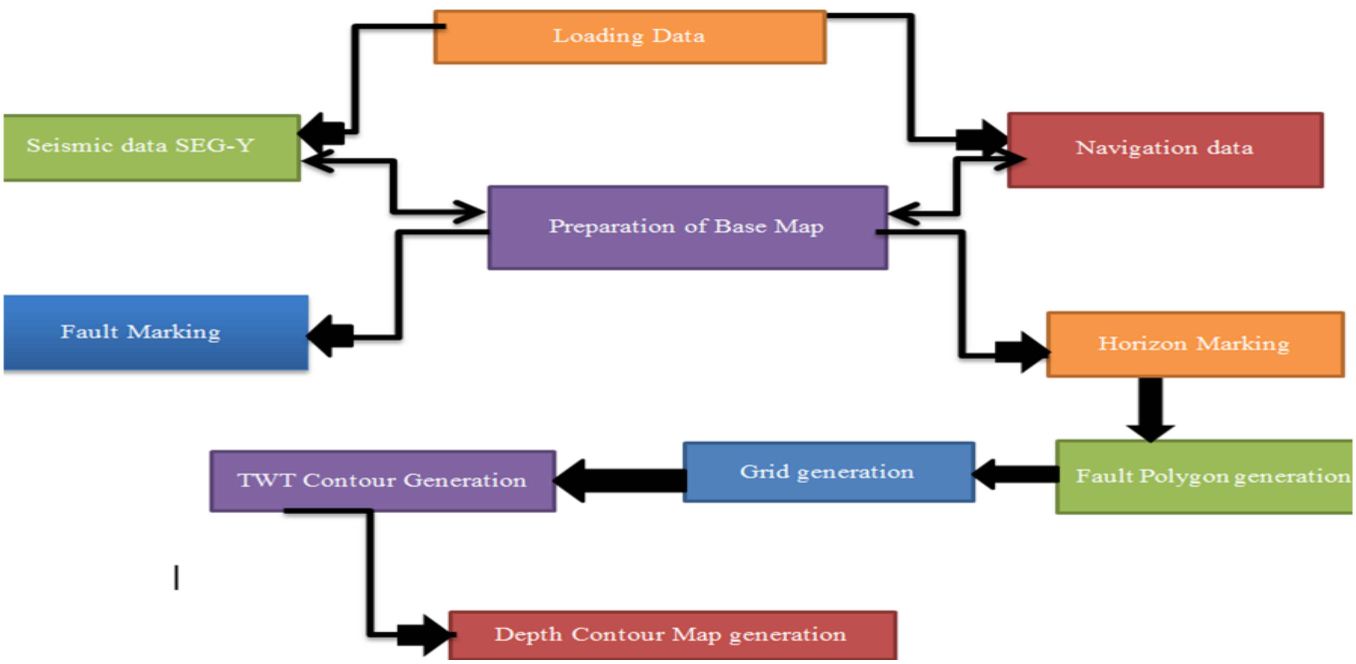


**Figure 3.1 Work flow adopted for the seismic data interpretation**

## 3.4 Interpretation of the seismic lines:

The primary task of interpretation is the identification of various horizons as an interface between geological formations. For this purpose, good structural as well as stratigraphic knowledge of the area is required (McQuillin et al., 1984). Thus during interpretation process, mark both, the horizons and faults on the seismic section by the information obtained from the synthetic seismogram generated from well miano-09. Mark the two horizons. The horizons are named on basis of well tops of the well miano-09. Hence the first step before the Marking of the horizons is the generation of the synthetic seismogram. The steps used in the generation of the synthetic seismogram are explained below.

For completion of this dissertation I have been assigned the following lines.

- GP2094-223………………… (Dip Line)
- GP2094-221………………… (Dip Line)
- GP2094-216…………………. (Strike Line)

## 3.5 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 well miano-09 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 lithologies and seismic reflection patterns (Handwerger et al., 2004). Reflection profiles are sensitive to changes in sediment impedance, the product of compression wave velocity and density. Changes in these two physical parameters do not always correspond to observed changes in lithologies. By creating a synthetic seismogram based on sediment petro-physics, it is possible to identify the origin of seismic reflectors and trace those laterally along the seismic line (Handwerger et al., 2004).

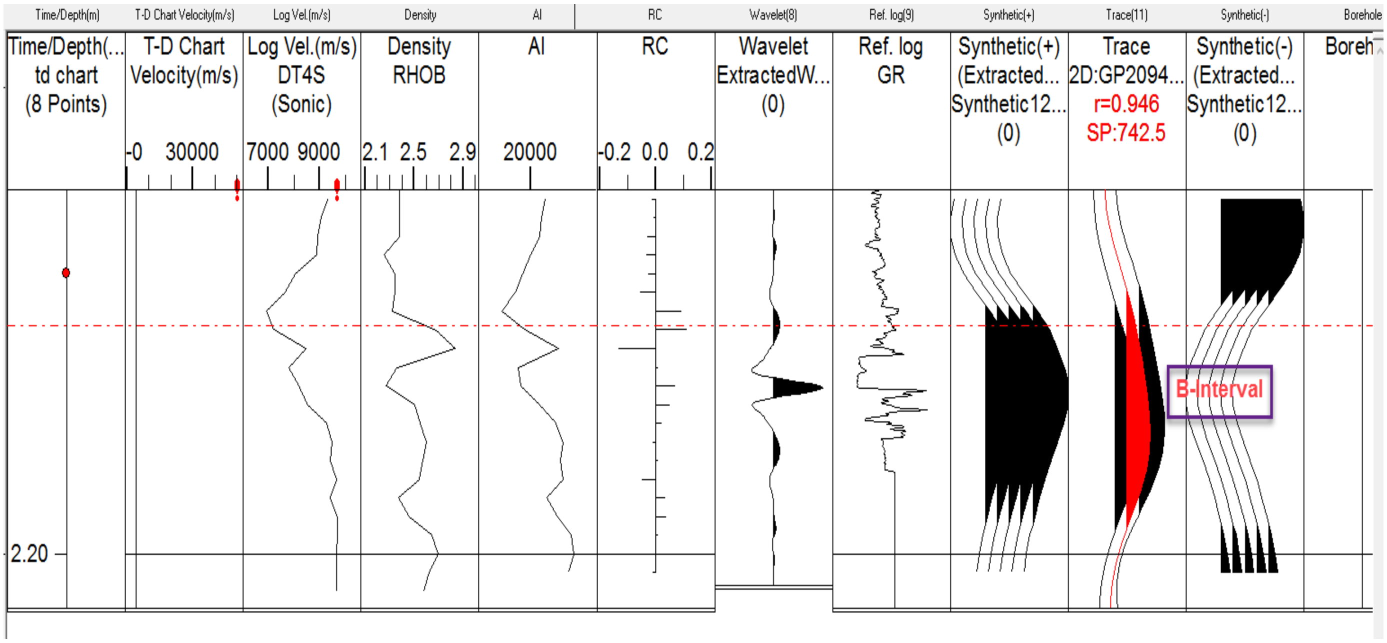


**Figure 3.2 Synthetic Seismogram of the well Miano-09 on line GP2094-23**

The following steps are adopted during the Generation of the synthetic seismogram using the IHS kingdom.

1. Load the Las file of the well in the software.
2. Integrate the sonic log to rescale from depth in meters to two-way travel time in seconds.
3. Compute velocity from sonic log for P and S waves.
4. Create a TD chart for the well from the velocity logs.
5. Compute Acoustic impedance log using velocity and density log.
6. Compute the reflection coefficients from the time-scaled velocity log.
7. Compute a first-order Ricker wavelet as a digital filter with two millisecond increments of two-way travel time; using a frequency in Hertz (35 Hz frequency is used in this study).
8. Convolve the reflection coefficient log with the Ricker wavelet to generate the amplitudes of the synthetic seismogram.

Now the generated seismogram is used to confirm the horizon. Miano -09 is the only well in available data that has the DT and ROHB log to generate the synthetic seismogram. Hence due to the limitation of the well data the generated synthetic seismogram only confirm the B-interval but on the basis of the formation tops of the Miano-09 the C-interval is marked, top of the Lower Goru and the Ranikot formation. The display of the synthetic seismogram is shown in the Figure 3.2

## 3.6 Fault marking

Fault marking on real time domain seismic section is quite a hard work to do without knowing tectonic history of area (Sroor, 2010). Faults are marked on the basis of breaks in the continuity of reflection. This Discontinuity of the reflector shows that the data is disturbed here due to the passing of the faults. The Miano block 20 is lying in extensional regime hence there is conjugate normal faulting due to which the clear cut horst and Graben are formed.

## 3.7 Horizon Marking:

Primary task of interpretation is identification of various horizons between geological formations. For this purpose, good structure as well as stratigraphic knowledge of the area is required. Horizons are marked on the time section on the basis of synthetic seismogram, well tops and prominent reflection.

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.

### 3.7.1 Interpretation of the of Dip line GP2094-223:

Figure 3.3 shows well tie with real time domain section. Mark horizons of B-interval, C-interval. Top of the lower Goru and the Ranikot formation on the basis of the change in the acoustic impedance also confirmed by the synthetic seismogram .The following color scheme is used to mark the horizon.

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

The main purpose was to show the favorable structure for petroleum accumulation. The horst sand graben structures are considered good structural trapes for the petroleum accumulation.

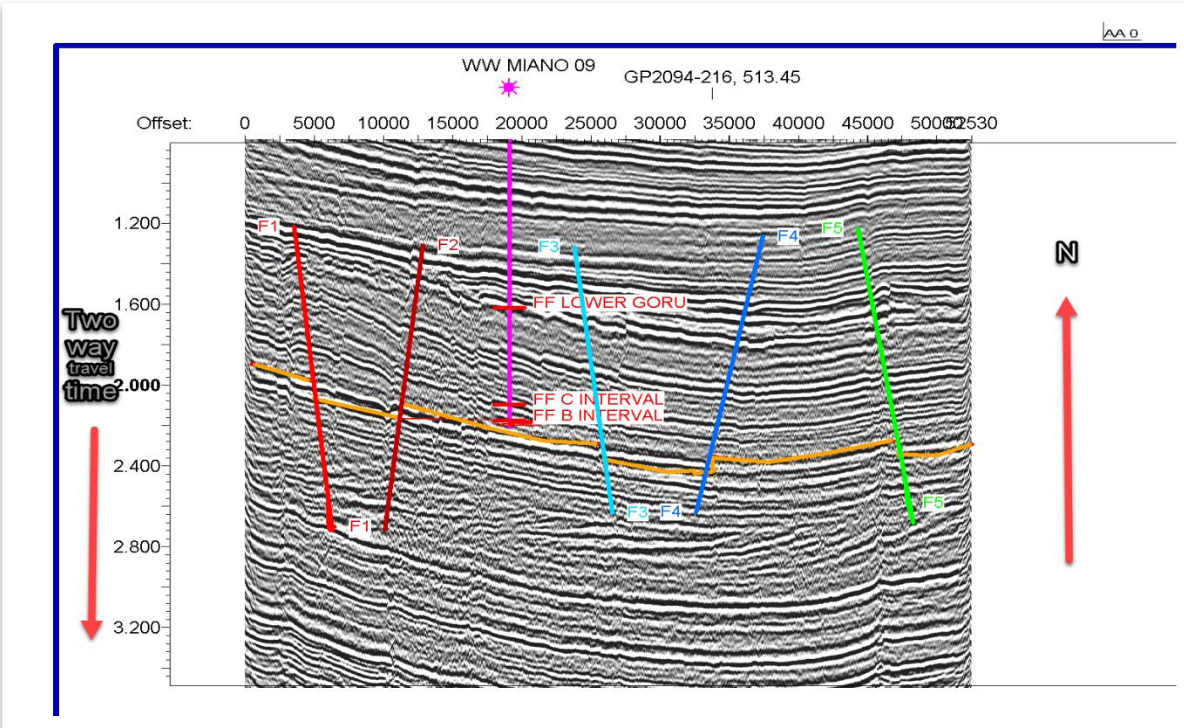


**Figure 3.3 Well tie and interpretation of Dip line GP2094-223**

In the interpretation of the line GP2094-223 the conjugate normal faulting can be seen. Due to this conjugate normal faulting the horst and graben structures are formed. These structures are considered favorable for the hydrocarbon accumulation in the extensional regime as in the Miano area.

Location the formations are picked at the following intervals of the time and depth shown in table 3.1.

**Table 3.1 TD chart for two marked Horizon**

| SN | ***Formation Name*** | ***T(sec)*** | ***Depth(m)*** |
|---|---|---|---|
| 1 | C-interval | 2.08 | 3152 |
| 2 | B-interval | 2.1706 | 3319 |

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

Using IHS kingdom digitize the seismic line GP2094-223 with the strike line GP2094- 216 shown in figure 3.4. Then remove the misstie however, in the given seismic section doesn't show any faults. The reason behind is that the given line is a strike line and the orientation of the line is against the basin configuration.

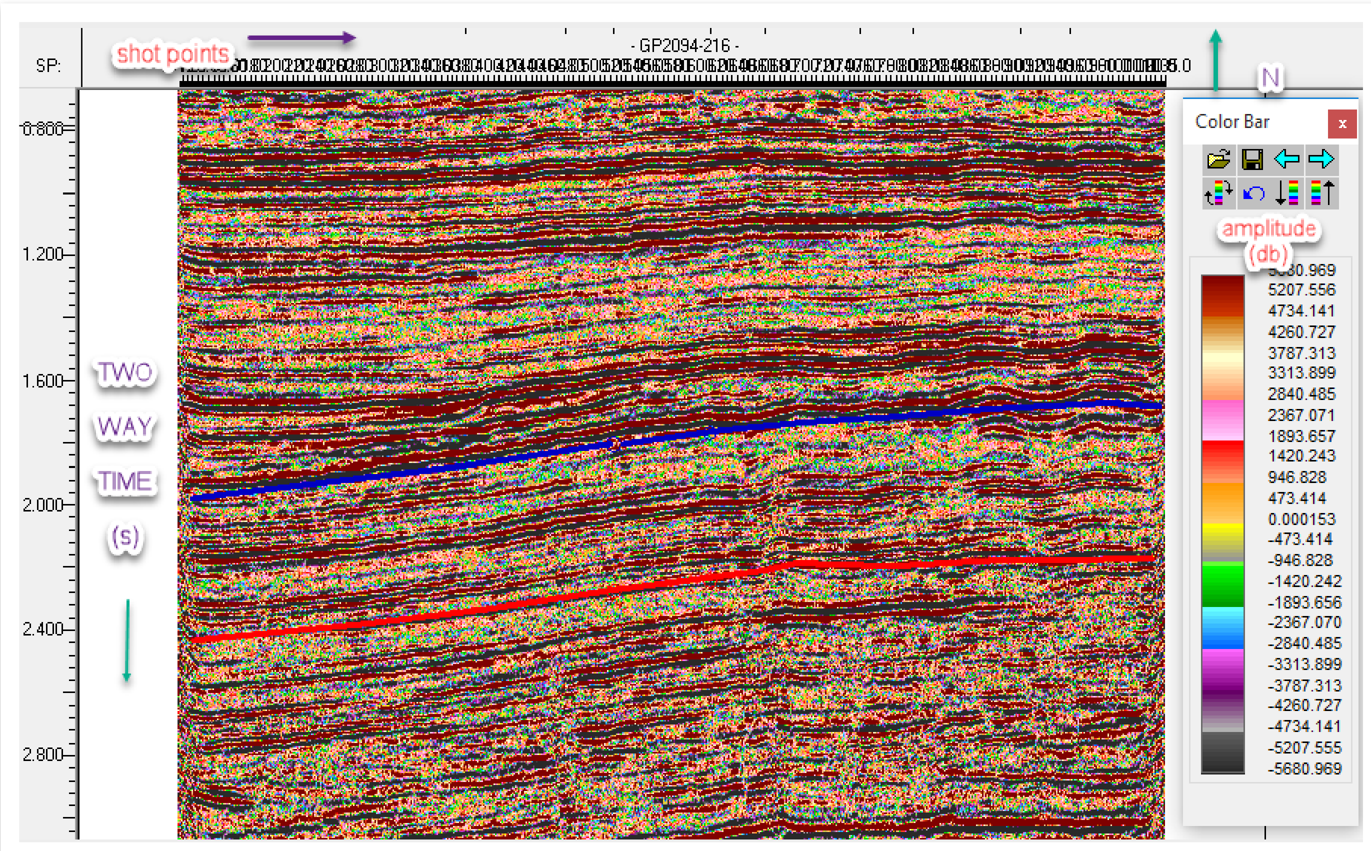


**Figure 3.4 Interpretation of the seismic Strike line GP2094-216**

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

Mark the seismic strike line GP2094-216 then digitize this strike line with dip line GP2094-221 because this strike line was crossing all the dip lines which are shown in the base map in chapter-01. Digitize the strike line with this dip line then mark the horizon and removed the miss tie. The faults were already marked on this seismic section. When faults and horizons were marked then horst and graben geometry is formed as shown in the below figure 3.5.

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.

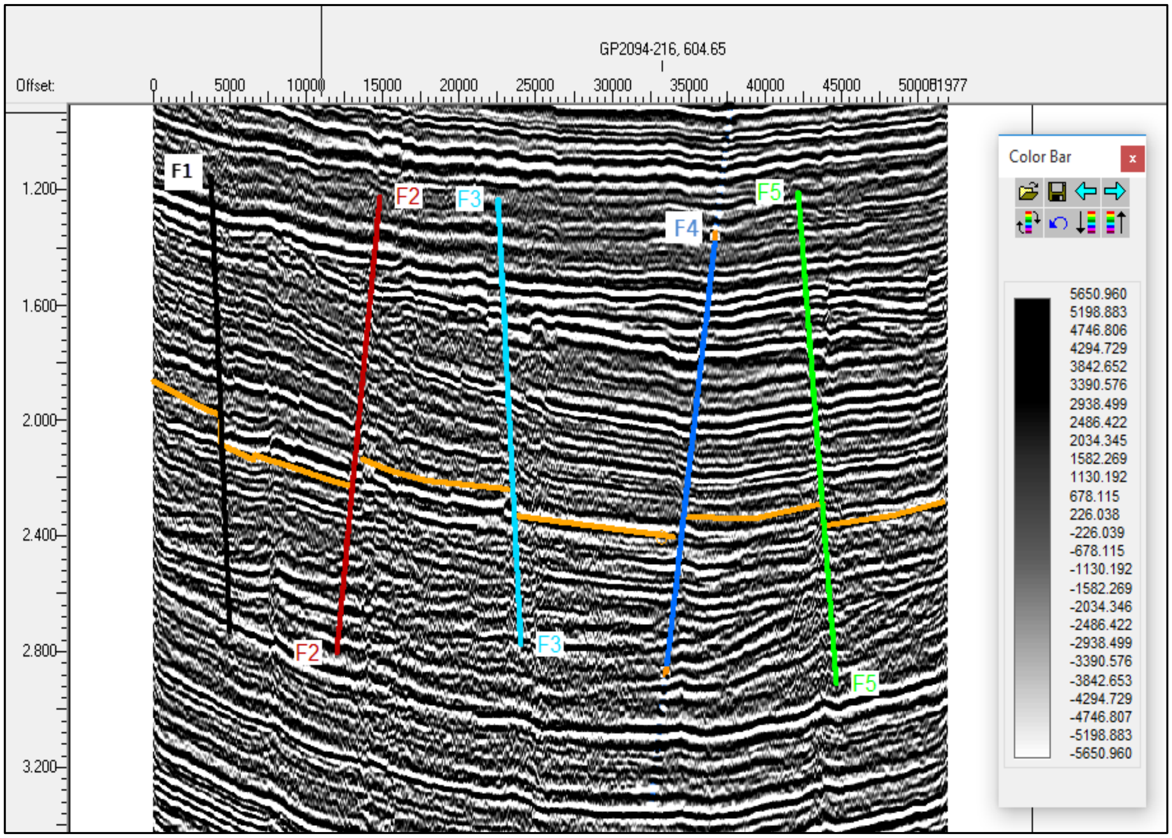


**Figure 3.5 Interpretation seismic Dip line GP2094-221**

## 3.9 Fault polygon construction:

Pick the fault on seismic section and find it at the other seismic lines. The fault in seismic section is called Fault Segment and the fault on map view is called Fault Polygon (Sroor, 2010). In any software for mapping an area all faults should be converted in to polygons prior to contouring. The reason is that if a fault is not converted into a polygon, the software doesn't recognize it as a barrier or discontinuity, thus making any possible closures against faults represent a false picture of the subsurface. I construct the fault polygon at B-interval level and at C-interval level. Because the B-interval is acting as reservoir in this study area and C-interval is acting as seal. The fault polygon on both these level are shown in the figure 3.6.

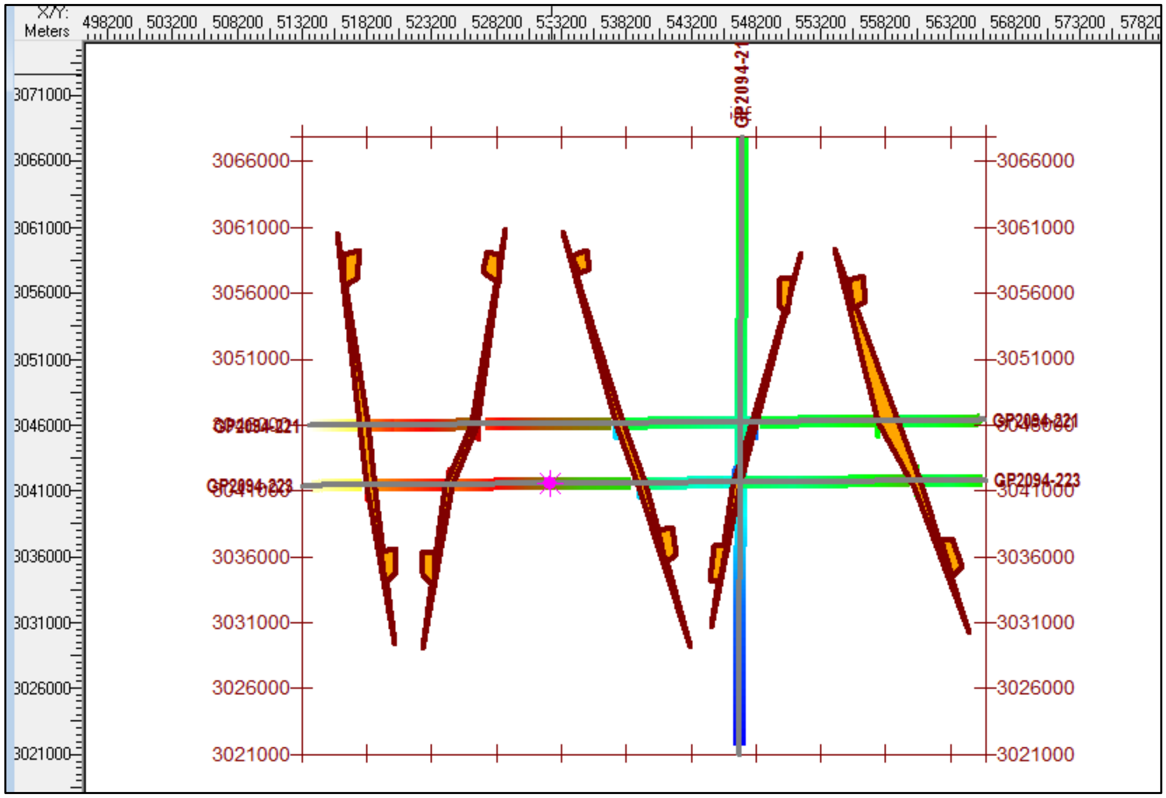


**Figure 3.6 Fault polygon constructed at B-interval level**

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

## 3.10 Contour Maps:

The final products of all the seismic exploration are the contour maps, time or depth. Mapping is part of the interpretation of the data, the one on which the entire operation depends for its usefulness. The contours are the lines of equal time or depth wandering around the map as dictated by the data (Coffeen, 1986).Contouring represents the three-dimensional Earth on a two dimensional surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip and any faulting and folding. The interpreted seismic data is contoured for producing seismic maps which provide a three-dimensional picture of the various layers within an area which is circumscribed by intersecting shooting lines. These time and depth contour maps have been generated with the help of Seismic Micro Technology IHS (Kingdom 8.8).

## 3.11 Time contour Map of the B-interval of the lower Goru:

Time contour map gives the information about the subsurface structure. It cannot show the structure directly but gives the idea about the structure and also give the information about the horizons. The contour maps are generated by the HIS Kingdom software. The time contour maps for the Lower Goru Formation and B-Sand is generated.

From the time contour map it is clear that the red color represent the low time and the blue color represent the high time as shown in figure 3.7.

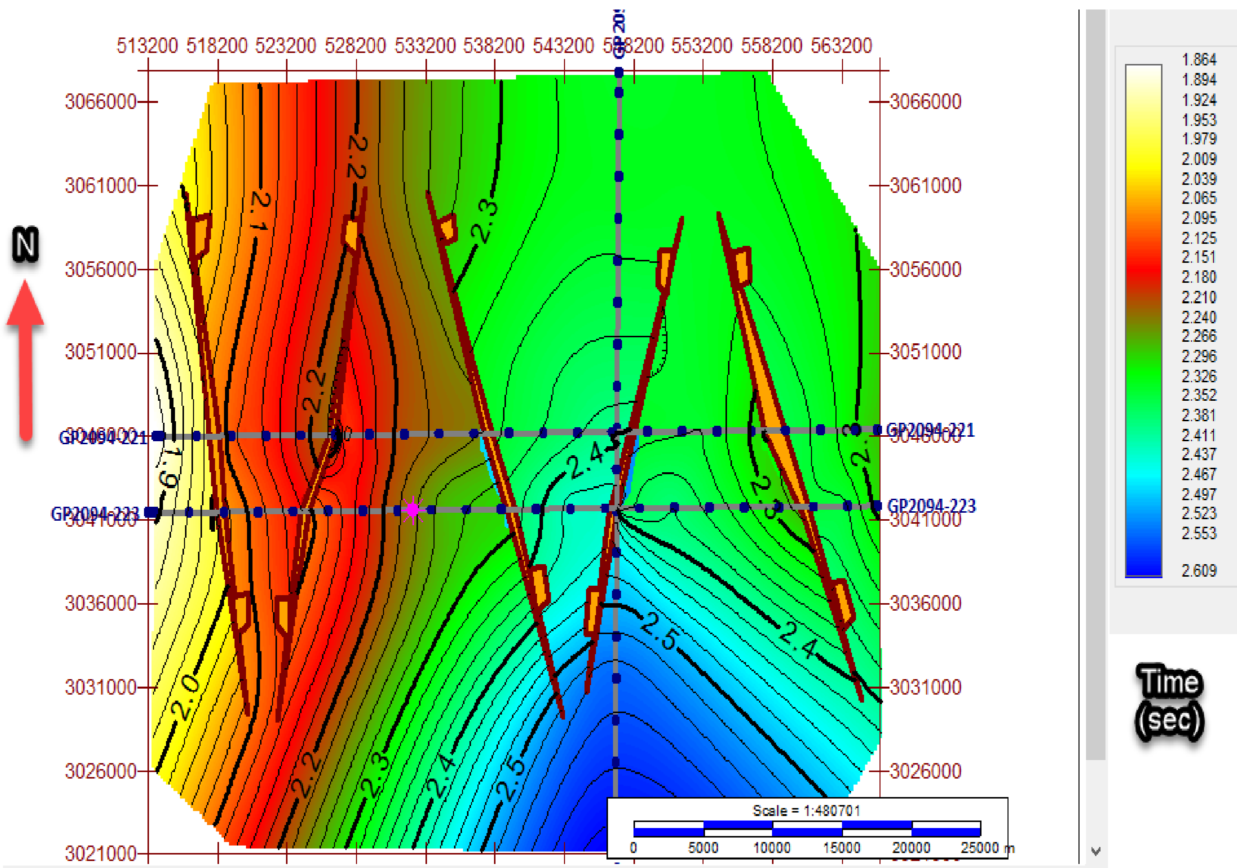


**Figure 3.7 Time contour Map of the B-interval of the lower Goru**

## 3.12 Depth contour Map of the B-interval of the lower Goru formation:

As the data is in the two way travel time, gives information about the subsurface structure. The depth contour map is prepared that truly related to the subsurface structure. Starting depth for B interval is 2159.85m and it ends up to 2726.151m depth. We have eight faults having same directions as in the time contour maps. Formations are shallower in the West having depth of 1767.6m and deeper in the East with the depth of 2807.5m. Depth of the horizons is plotted against the Northings and Easting of the survey. Depth contour maps of the horizons are shown in the Fig 3.8.

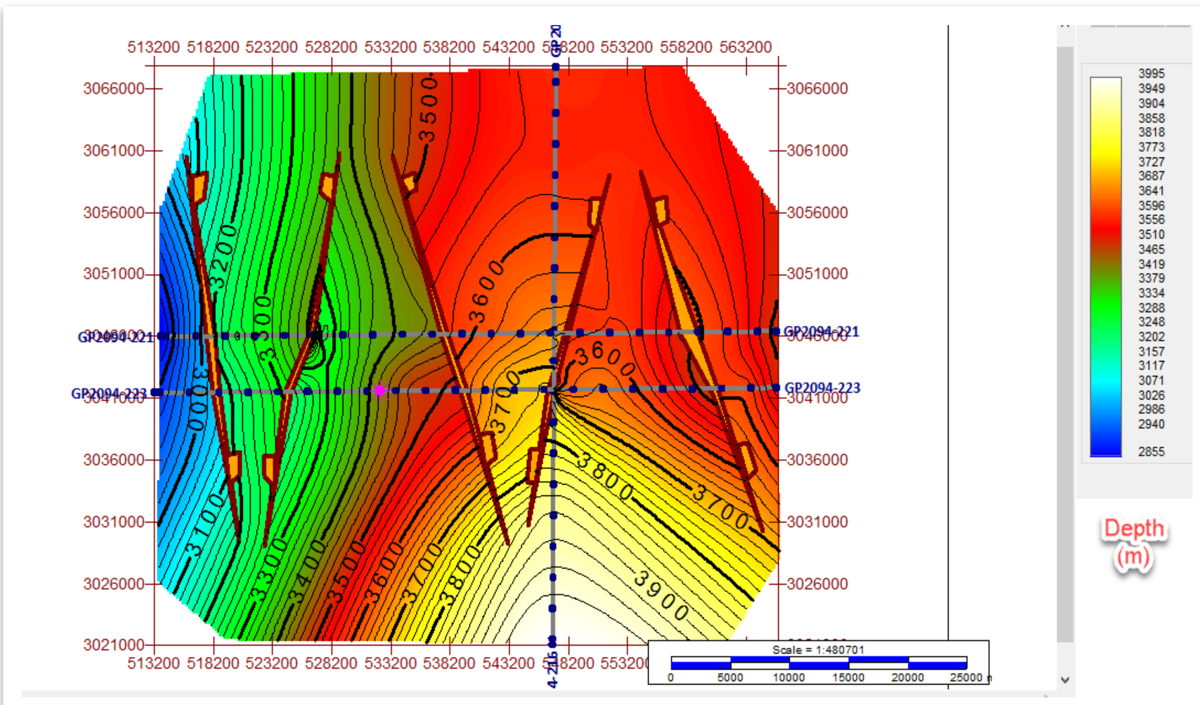


**Figure 3.8 Depth contour Map of the B-interval of the lower Goru formation**

## 3.13 SEISMIC ATTRIBUTES:

### 3.13.1 Introduction:

The Components of seismic date which are obtained by calculation are seismic attributes, seismic attributes are established in 1970s as a part of seismic interpretation. Any information that can be obtained from seismic is seismic attribute.

## 3.14 Classification of Seismic Attributes:

The Seismic Attributes are classified basically into two categories.

- Physical Attributes
- Geometric attributes

### 3.14.1 Physical Attributes:

Physical attributes are directly related to lithology, wave propagation etc. The physical attributes can be pre stack or post stack. The sub classes of physical attributes are instantaneous and wavelet .instantaneous attributes are evaluated at every instant of sample (Marfurt, 2008).

### 3.14.2 Geometrical Attributes:

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

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

Trace envelope attribute represent mainly the acoustic impedance contrast, hence reflectivity strength. It always remains positive whether the reflection coefficient is positive or negative. This attribute is mainly useful in identifying (Chopra et al.,2005).

- Bright spots gas accumulation
- Sequence boundaries, major changes or depositional environments
- Major changes of lithology
- Local horizontal changes indicating faulting

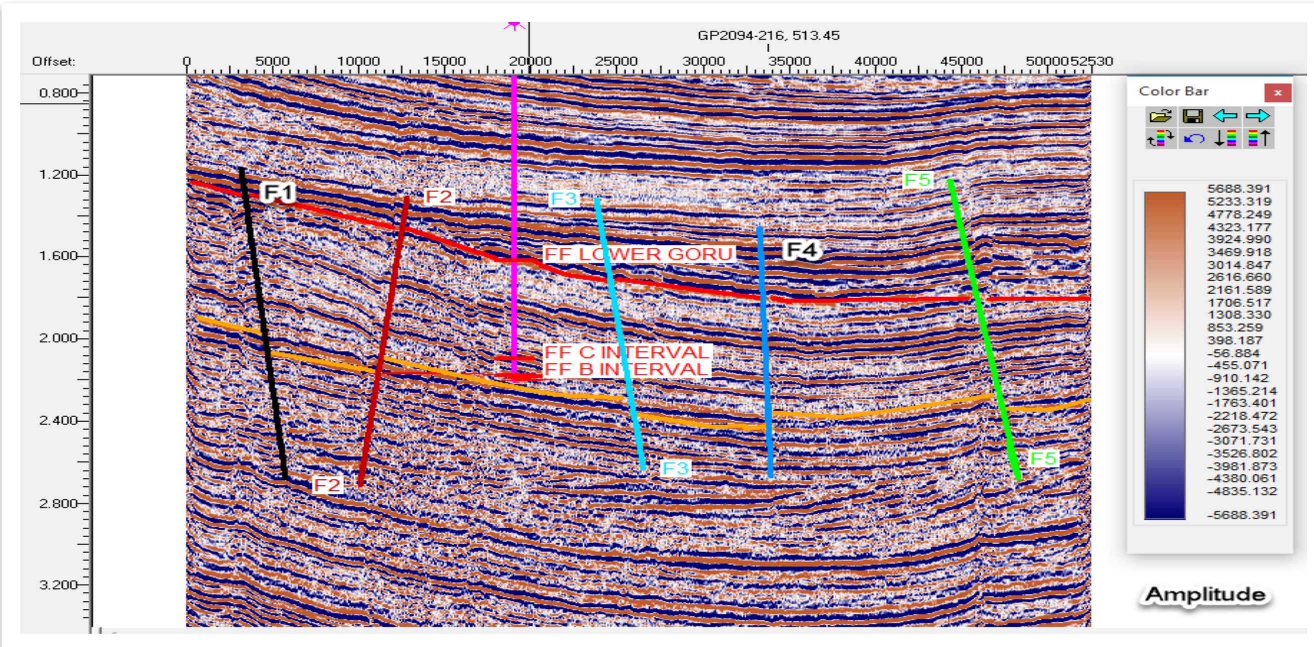


**Figure 3.9 Trace envelope attribute line GP2094-223**

## 3.16 Instantaneous phase:

Instantaneous phase is measured in degrees ($-\pi,\pi$). It is independent of amplitude and shows continuity and discontinuity of events. It shows bedding very well. Phase along horizon should not change in principle; changes can arise if there is a picking problem, or if the layer changes laterally due to “sink-holes” or other phenomena.

This attribute is useful as (Chopra et al., 2005)

- Best indicator of lateral continuity.
- Relates to the phase component of the wave propagation.
- Has no amplitude information, hence all events are represented
- Detailed visualization of bedding configuration.
- Used in computation of instantaneous frequency and acceleration

This attribute is marking clear cut continuity of the reflector as shown in the below figure.

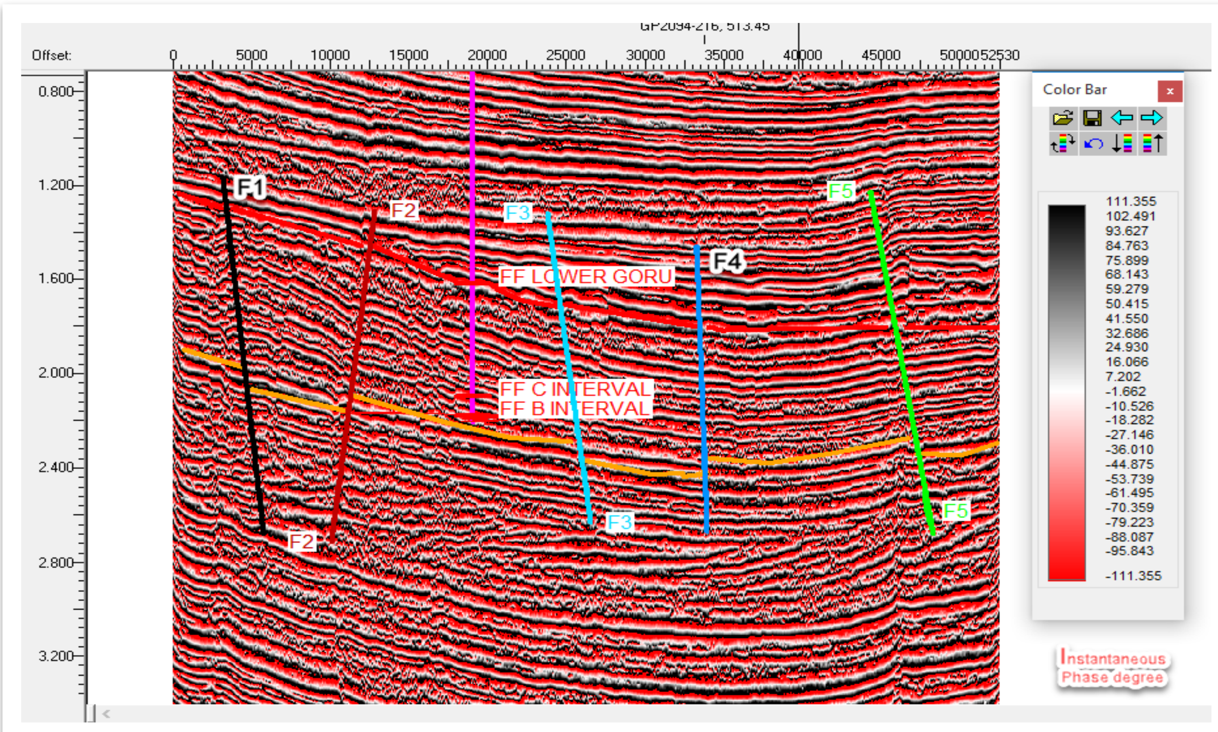


**Figure 3.10 Instantaneous phase line GP2094-223**

## 3.17 Instantaneous frequency:

Instantaneous frequency is the time derivative of the phase, i.e., the rate of change of the phase

$$F(t) = d(\phi(t))/dt$$

Instantaneous frequency represents the mean amplitude of the wavelet. This attribute is useful in identifying abnormal attenuation and thin-bed tuning (Chopra et al, 2005). These attributes are mainly direct Hydrocarbon indicator by low frequency anomaly in high resolution 3D data because this effect is sometimes accentuated by unconsolidated sands due to the oil content of the pores. Fracture zone indicator, since fractures may appear as lower frequency zones best thickness indicator. Higher frequencies indicate sharp interfaces such as exhibited by thinly laminated shale, lower frequencies are indicative of more massive bedding geometries, e.g. sand-prone lithologies (Taner, 2001). From figure 3.11 at marked horizons are low frequencies indicating presence of hydrocarbon in the zone whilst as move downward, and time increases instantaneous frequency increases i.e. at greater depth.

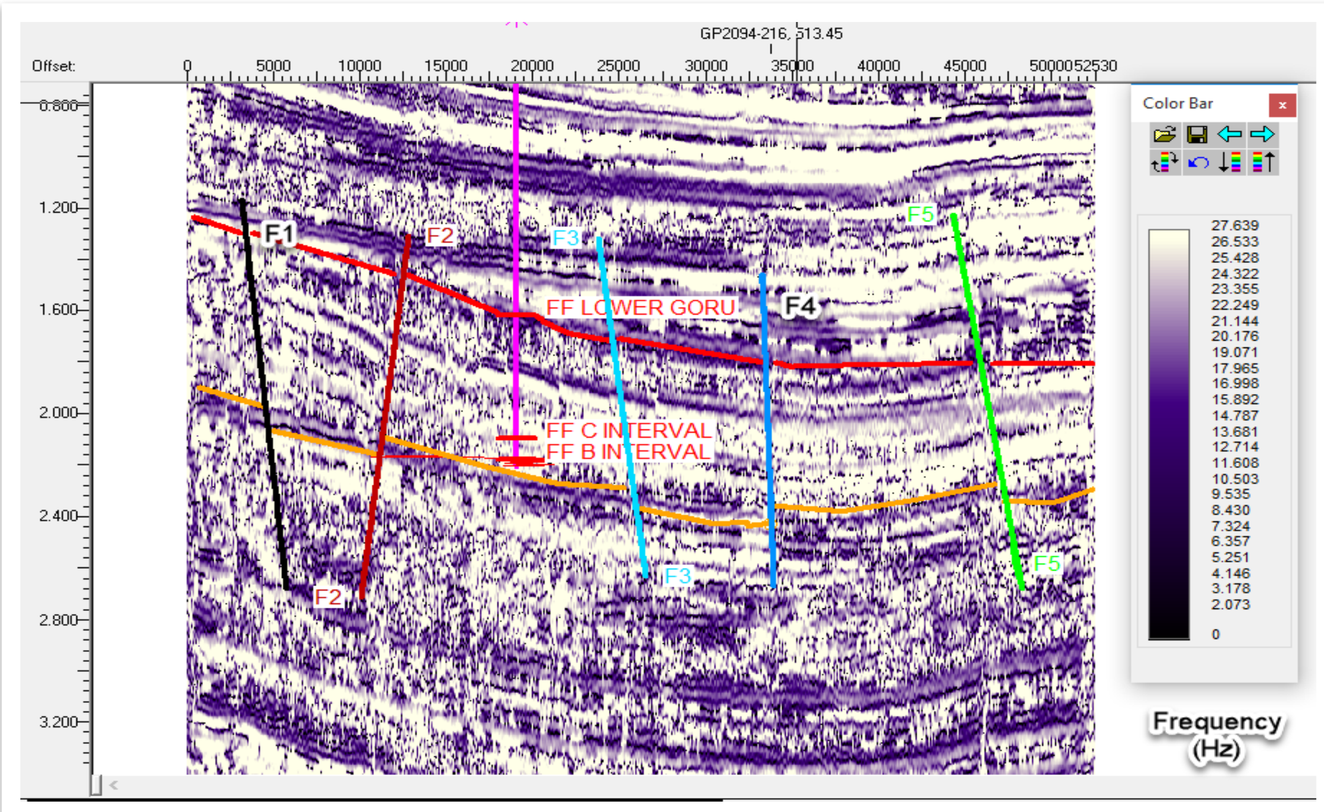


**Figure 3.11 Showing Instantaneous frequency attribute applied on seismic line GP2094-223**

## 3.18 Conclusions:

After 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 2D models show clear horst and Graben structures which can act as 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: 04 Petrophysics and Facies Modeling

## 4.1 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 (Cosgrove et al., 1998). Petrophysics is one technique used for the reservoir characterization. This study facilitates in identification and quantification of fluid in a reservoir. Knowledge of reservoir physical properties like volume of shale, porosity, 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 is apprehensive with using well measurements to subsidize reservoir depiction (Daniel, 2003).

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 properties 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.

## 4.2 Data set:

The Petrophysical analysis has been carried out for reservoir characterization of Miano area. For this purpose the data of the drilled borehole, well Miano-09 used. The log curves of the borehole is used i.e. Spontaneous potential (SP) log, Gamma ray (GR), Sonic log (DT), Lateral log deep (LLD), Lateral log shallow (LLS), Neutron log, Density log (RHOB), and Photoelectric effect (PEF) etc. For petrophysical analysis, the following parameters are determined on the basis of these log curves.

- Volume of shale
- Water saturation
- Hydrocarbon Saturation

In order to calculate these properties, we should be familiar with the different types of the logs and their characteristics.

## 4.3 CLASSIFICATION OF GEOPHYSICAL WELL LOGS:

The logs are explained according to the tracks in which they run.

### 4.4 LITHOLOG Y TRACK:

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

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

#### 4.4.1Gamma ray (GR):

This log is actually a measurement of the natural radioactivity of the formation. Gamma radiations are emitted in the form of electromagnetic energy called photon. When photon collides with electrons, some energy is transferred to electron called Compton scattering. These scattered radiations reached the detector and are counted after absorption of gamma rays from natural radioactive source present within the layer. These emissions are counted and displayed as count per second which is termed as gamma ray log. This log is very important and used for various purposes however, its basic purpose is to differentiate between sand and shale **(**Asquith and Gibson, 2004).

#### 4.4.2 Spontaneous Potential log (SP):

The ‘SP’ log is a record of the naturally occurring potential in the well bore. This log utilizes a single moving electrode in the bore hole and a reference electrode at the surface, located in the mud pit. The ‘SP’ curve therefore is a record of the potential difference, which exists between the surface electrode and the moving electrode in the bore hole (Asquith and Gibson, 2004).

This log can be used for the following purposes (Daniel, 2003).

- To identify the permeable and impermeable zone.
- To detect the boundaries of bed.
- To determine the volume of shale.
- To determine the resistivity of formation water.
- Qualitative measure of permeability.

### 4.4.3 Caliper Log:

Caliper log is used to measure the borehole size. This log helps us to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. Because if there is any 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.

## 4.5 Porosity Logs Track:

Porosity logs measure the percentage of pore volume in a bulk volume of rock. These logs are also helpful to provide data to distinguish between oil and gas and, in combination with resistivity measurements and calculate water saturation.

### 4.5.1 Porosity log include:

- Sonic log (DT)
- Density log (RHOB)
- Neutron Porosity log (NPHI)

### 4.5.2 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).

### 4.5.3 Density Log:

Gamma rays collide with electrons in formation and scattered gamma rays (Compton scattering) received at detector and counted as indicator of formation density. 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 plus density of matrix time its relative volume. However, density log separately and also along with other logs used to achieve various goals (Tittman and Wahal, 1965).

### 4.5.4 Neutron log (NPHI):

This is the porosity log which measure concentration of hydrogen ions in the formation. Neutron is continuously emitted from a chemical source in neutron logging tool. 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 neutron collide with hydrogen atom. Hydrogen is usually indication of presence of fluids in pores, so energy loss is related to the formation porosity.

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

## 4.6 Electrical Resistivity Logs Track:

Basically there are different types of electrical Resistivity logs, which measures the subsurface electrical resistivity. This helps to differentiate between formations filled with salty waters and those filled with hydrocarbons. Resistivity and porosity measurements are used to calculate water saturation. Resistivity logs includes

- Lateral log Deep (LLD)
- Lateral log Shallow (LLS)
- Micro- Spherically Focused Log (MSFL), But MSFL was not present in my Data of Miano-09.

### 4.6.1 Laterolog Deep (LLD):

Lateral log is used for deep investigation of the undisturbed zone (Uninvaded zone) and it is called Lateral log 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. LLD having deep penetration as compared to the (LLS).

**4.6.2 Laterolog Shallow (LLS):**

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

## 4.7 Workflow for Pertophysical Analysis:

Petrophysical interpretation is carried out by making use of HIS Kingdom software. Raw log curve are loaded and step by step different rock properties are calculated. Number of mathematical equations and Schlumberger charts have been involved in calculations. Workflow is illustrated in Figure 4.1.

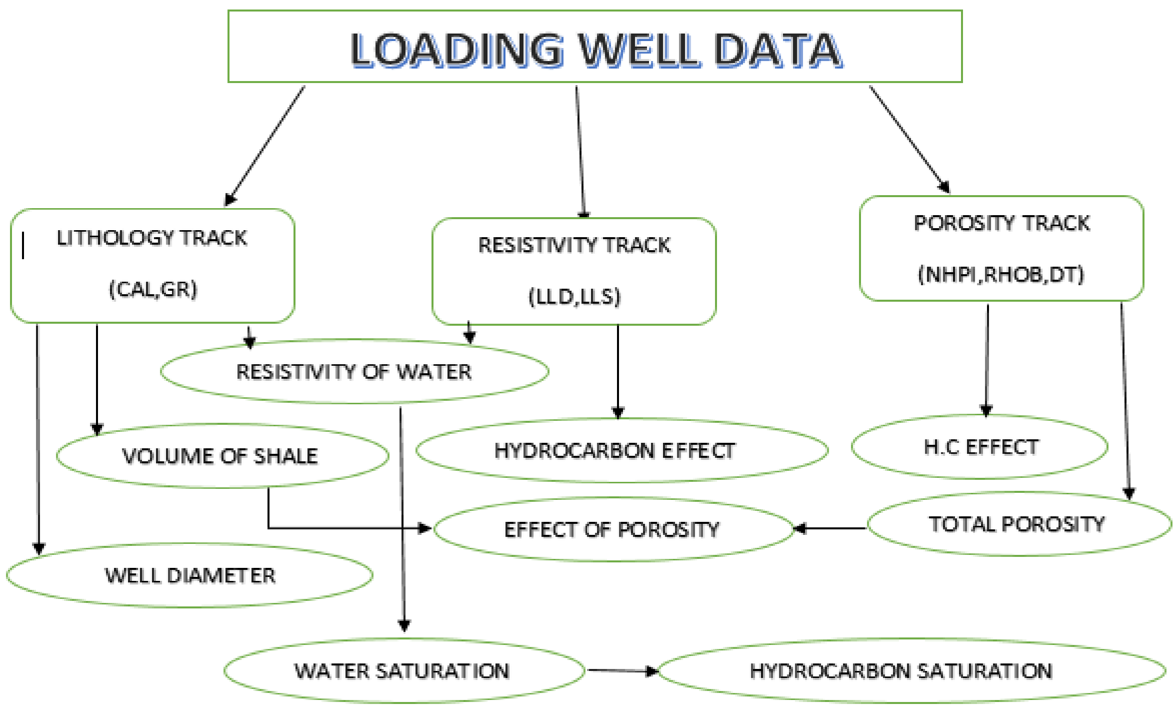


**Figure 4.1 Petrophysical interpretation work flow**

Raw log curves have been used for the petrophysical analysis of Miano-09. Main reservoir in Lower Indus Basin is Lower Goru of Cretaceous age. Sand intervals (A, B, C and D) of Lower Goru are acting as reservoir in different areas of Lower Indus Basin. In study area, B interval is most productive. Top and bottom depth of B interval is defined for petrophysical analysis. Also the zones of importance are defined within the reservoir for more specific interpretation of reservoir. These raw log curves include Gamma Ray (API), SP (mv), Caliper(Inches), LLD (ohm-meter), LLS (ohm-meter), RHOB (g/cm3), DT (us/ft) and NPHI (v/v decimal).

## 4.8 Calculation Of Rock Properties:

Many of the rock properties can be derived from geophysical well logs. Different equations that can be used to calculate the rock properties are given below (Table 4.1).

**Table 4.1 Different equations for calculating rock properties (Asquith et al., 2004)**

| | *PROPERTIES* | *MATHMATICAL FORMULAS* |
|---|---|---|
| 1. | VOLEUME OF SHALE (Vsh) | $V_{SH} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$ |
| 2. | DENSITY POROSITY (PHID) | $\varphi_d = \frac{\rho_m - \rho_b}{\rho_b - \rho_f}$ |
| 3. | SONIC POROSITY( PORS) | $\emptyset_s = \frac{\Delta t - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$ |
| 4. | TOTAL POROSITY (PHIT) | $\emptyset_t = \frac{\emptyset_d + \emptyset_n + \emptyset_s}{3}$ |
| 5. | EFFECTIVE POROSITY (PHIE) | $\emptyset_e = (1 - V_{sh}) \times \emptyset avg$ |
| 6. | STATIC SPOTANIOUS POTENTIAL (SSP) | SSP=$SP_{clean} - SP_{shale}$ |
| 7. | FORMATION TEMPRATURE (FT) | $T_f = \frac{d(BHT - T_s)}{T_d + T_s}$ |
| 8. | SATURATION OF WATER (Sw) | $S_w = \left[\frac{R_w \times F}{R_t}\right]^{\frac{1}{n}}$ |
| 9. | HYDRO CARBON SATURATION (HS) | $S_h$= 1-Sw |

## 4.9 Volume of Shale:

Shale volume is calculated by Gamma Ray log (GR). It measures the natural radioactivity that is emitted from formations and hence a very useful tool to identify lithology. Carbonate and sandstone have low value of GR value while shale has maximum GR value because radioactive materials are concentrated in shale. It is recorded in lithology track along with Caliper and SP (Asquith and Gibson, .2004).

This will lead us to a result that volume of shale value is used to distinguish between reservoir and non-reservoir rock (Asquith and Gibson, 2004). Volume of shale is estimated by using the equation (Rider, 1996) given in Table (4.1).

## 4.10 Calculation of Porosity:

Porosity is estimated by using neutron, density and sonic log. Sonic log is acoustic measurements while neutron and density logs are nuclear measurements. Combination of these logs gives accurate estimations of porosity. These Logs are explained above .Now the combination of these logs give some other types of the porosities which are given below.

### 4.10.1 Average Porosity:

Average porosity is the sum of all porosities logs divided by number of logs used for calculating porosity. Its mathematical equation (Schlumberger, 1989) is given in Table 4.1.

### 4.10.2 Effective Porosity:

Effective porosity is the ratio of linked pore volume to the total volume, calculated after removing the effect of shale. Effective porosity is used for the estimation of water saturation. It can be calculated using the mathematical relation (Schlumberger, 1989) given in the Table 4.1.

Now to calculate the Water saturation required the Resistivity of the water of formation.

## 4.11 Resistivity of formation water (Rw):

After the calculation of volume of shale, effective, total and sonic porosities, the next step is the calculation of resistivity of water. Computing water resistivity is the vital step in finding the saturation of water.

The following steps lead to the calculation of resistivity of water.

***Step 1:*** After noting the values of surface temperature (ST), maximum recorded temperature (BHT) and resistivity of the mud filtrate (Rmf1) from well headers, very first step is to find the static spontaneous potential (SSP) from the relation in Table 4.1(Rider, 1996).

***Step 2:*** Formation temperature is calculated by using the relation same Table 4.1 (Rider, 1996).

***Step 3:*** Finding the resistivity of mud filtrate by using the relation given in Table 4.1.

***Step 4:*** Now for finding the resistivity of mud equivalent (Rmfeq), the relation is given in Table 4.1.

***Step 5:*** Rweq (Resistivity of the water equivalent) determination from $E_{ssp}$ (Static spontaneous potential)

After calculating the value of Rmfeq, the next step is to derive the value of resistivity of water equivalent against the value of Rmfeq at SSP value and BHT.

***Step 6:*** Rw versus Rweq and formation temperature. The value of resistivity of water (Rw) is derived against the values of Rweq and formation temperature. After using all the relations of finding the resistivity of water by SP chart method, the next step is the computation of saturation of water by using Archie Generalized Water Saturation equation (Archie, 1942) Table 4.1.

$$S_w = \left(\frac{a \times R_w}{R_t \times \emptyset^m}\right)^{\frac{1}{n}}$$

## 4.12 Saturation of Hydrocarbon:

To calculate hydrocarbon saturation, just subtract the saturation of water from the pore spaces, the rest will be hydrocarbons saturated pore spaces.

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.

The principal use of resistivity logs is to detect and quantify hydrocarbon. That is, resistivity logs are used to give the volume of oil/gas in a particular reservoir, or, in petrophysical terms, to define the water saturation (Sw).When Sw is not 100%, then hydrocarbons are present there. Higher values of resistivity usually indicate the presence of hydrocarbons or fresh water. If separation between LLD and LLS is reported, that is quite possibly 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 2.9 g/cm3. But somewhere at the reservoir level, very high density corresponding to low resistivity is noted. It may be due to the Presence of some heavy minerals like gluconate, Chlorite, Chamosite Siderite etc. (Fareed et al 2003).

Neutron and Density logs when combined with each other, their cross over possibly the best clue of presence of hydrocarbons (Rider, 1996). Considering all the above factors, B interval is interpreted and few petrophysical properties are quantified. Which are given in table 4.4.

### 4.12.1 Interpretation of Entire B interval (3331-3385m):

Depth range of B interval varies from (3331-3386m) in well Miano-09. It consist of alternate layers of shale and sand. Values of GR ranges are given below.

- GR Minimum ………… 12.52 API
- GR Maximum…………..286.43 API

Shale volume for whole depth range is 44% and water saturation is 51.7%. A prominent zone is marked through the well section in Figure 4.2, where high net pay is expected. A prominent LLD and LLS separation is observed. This zone bears relatively low values of GR, resistivity and high porosity the detail of this zone is explained below. The zone B which is generally called the bassel sand is main productive zone in Miano field. Calculated the petrophysical properties of this entire zone and then zone of interest which lies in the zone B of bassel sand as shown in the figure 4.2.

### 4.12.2 Interpretation of Zone of interest:

Only one main zone of interest is marked. Depth range Zone of interest or reservoir varies from 3338-3346 m in well Miano-09. Shale volume for whole depth range is 24 %. Effective porosity is about 8% and hydrocarbon potential of 62%. 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. Petrophysical properties of these zones are given in the Table 4.2.

## 4.13 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 3338-3346m. Because there was low value of GR which is clear cut condition that it is reservoir zone. Now in 2$^{nd}$ 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 4.2.

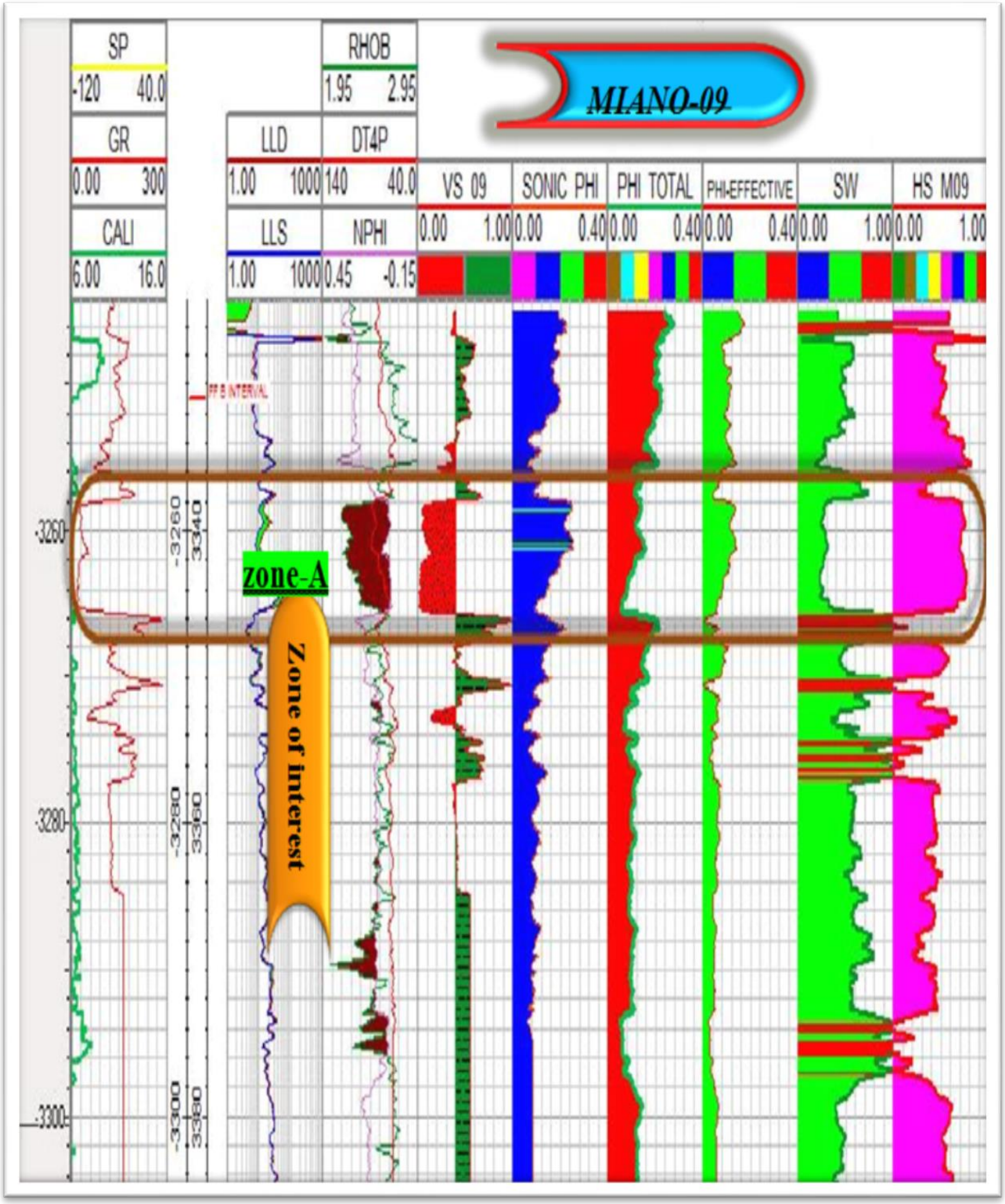


**Figure 4.2 Well log interpretation of Miano-09 by IHS kingdom**

**Table 4.2Rock Properties Of The Zone-A And Zone-B Miano-09**

| Sr No | Zone/Rock Properties | Entire B interval 3331-3385 | Zone of interest(zone-A) 3338-3346 |
|---|---|---|---|
| 1 | Average Volume Of Shale | 44% | 24% |
| 2 | Average Sonic Porosity | 11.3% | 18% |
| 3 | Average Porosity | 11.8% | 12% |
| 4 | Average Effective Porosity | 6.4% | 8% |
| 5 | Average Saturation Of Water | 51.7% | 38% |
| 6 | Average Saturation Of HC | 47.3% | 62% |

## 4.14 Facies Modeling:

### 4.14.1 Introduction:

In geology, a facies is a body of rock with specified characteristics (Ravia et al., 2010). Ideally, a facies is a distinctive rock unit that forms under certain conditions of sedimentation, reflecting a particular process or environment. Sand-shale investigation has constantly been challenged for geoscientist. Key challenge is to classify and identify the facies, from logs or cores, degree to which shale content affect the reservoir properties. This feature is chief factor in illustrating the reservoir productive zones (Kurniawan, 205). This leads us to identify different cross-plots that have relationship between reservoir properties and log response (Naji et al., 2010).

All these facies are related to the certain sedimentary depositional environments. The depositional environment is a specific type of place in which sediments are deposited, such as a stream channel, a lake, or the bottom of the deep ocean. They are sometimes called sedimentary environment.

### 4.14.2 N-PHI, DT and GR cross plot:

The cross plot of the N-PHIE and GR is obtained from Miano -09 for B-interval shown in figure 4.5. Cross plot in the figure reveals that there is an inverse relationship between DT and NPHI. Sand intervals are marked by high values of DT and low value of the NPHI comparatively to shale and low value of GR. The low value of NPHI in gas bearing reservoir is called the gas effect as in our reservoir area. Shale has direct relation with GR but low values of DT and PHIE. The GR is marked on the Z-axis with color dots. Yellow color is representing the sand while the Cyan color is representing the shale.

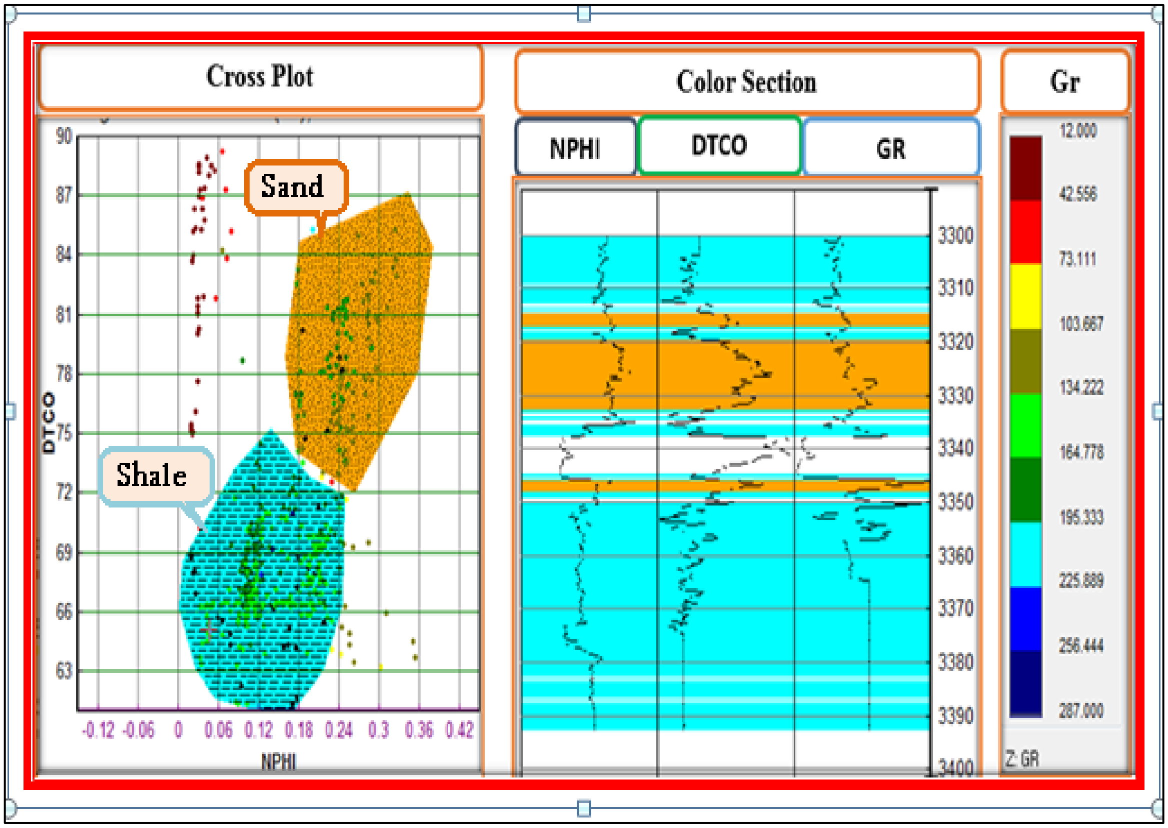


**Figure 4.3 N-PHI, DT and GR cross plot B-interval Miano-09**

### 4.14.3 GR, LLD and Depth cross plot:

A cross-plot of GR, LLD and depth of B- interval in Miano-09 is shown in Figure 4.4. An inverse relationship is observed between GR and LLD. For higher value GR and low value of LLD, lithology is marked as shale while in case of sand GR is low and LLD is high. Resistivity in reservoir zone is chiefly high as hydrocarbon are poor conductor of electricity. Pay zones listed in petrophysical section can easily be correlated.

### 4.14.4 GR, PHI-E and Water saturation cross plot:

There is direct relation between GR, and shale because there is higher value of GR in shale and lower value in sand. While PHIE having quite opposite relation in the shale and sand. There is higher value of the PHIE in sand and lower value of PHIE in shale. The relationship is built between GR, PHIE and Sw shown in figure 4.5. Effective porosity (PHIE) is plotted along horizontal axis, water saturation along vertical axis while GR is analyzed by colored dots lying between both the axes. Figure shows the decline of porosity when water saturation.

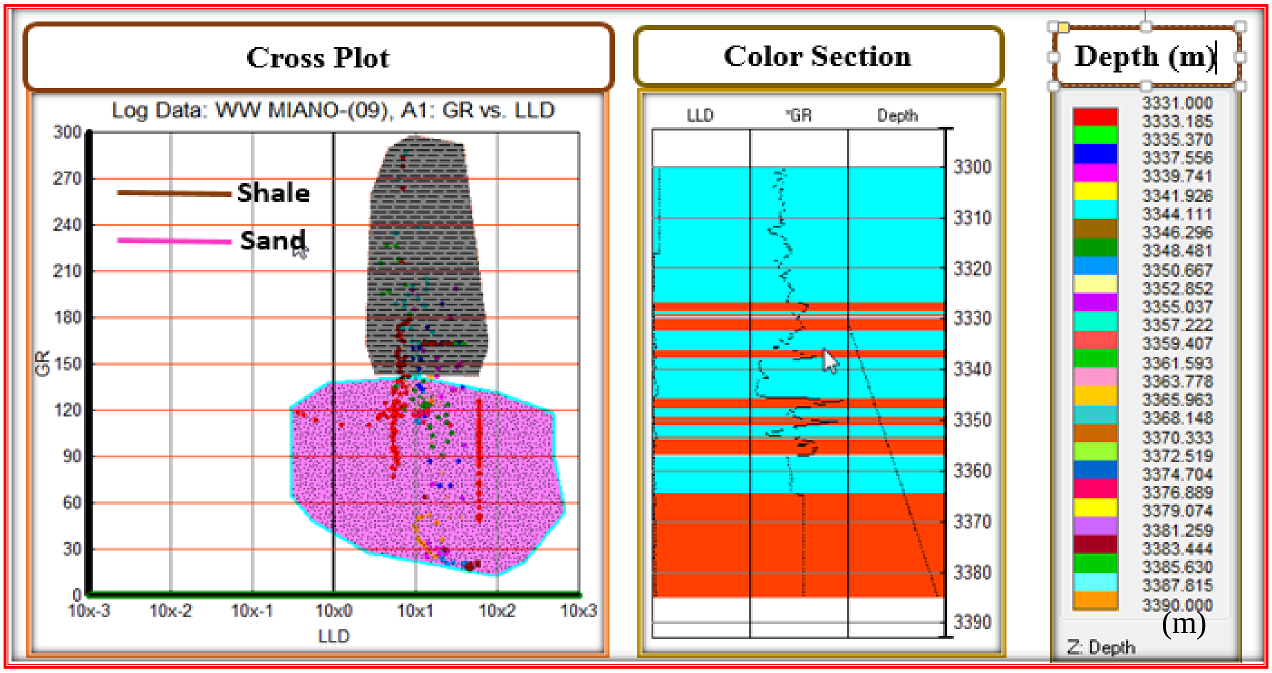


Figure 4.4 GR, LLD and Depth cross plot on B-interval Miano-09

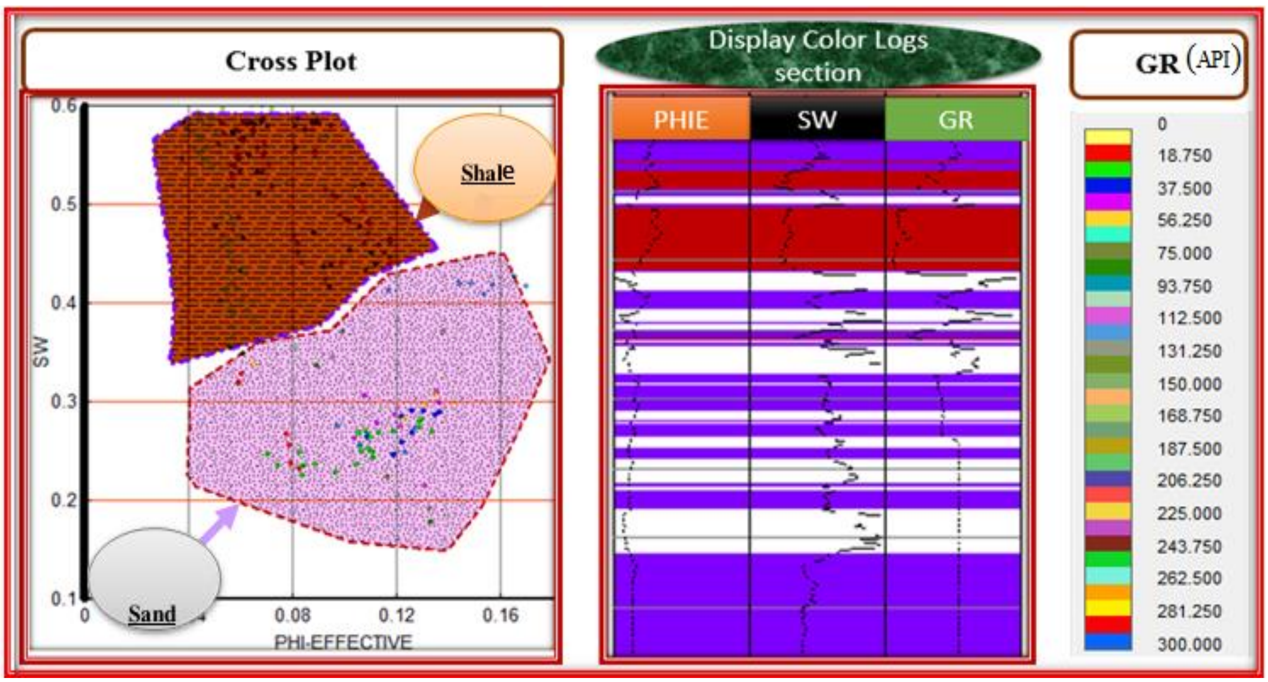


Figure 4.5 GR, PHI-E and Water saturation cross plot for B-interval Miano-09

## 4.15 Marking the variation of Facies By lithofacies Coloum using well logs interpretation Miano-09:

Lithofacies may refer to: Map able subdivision of a designated stratigraphic unit, distinguished from adjacent subdivisions on the basis of lithology, a facies characterized by particular lithological features (C. Kerans,1997)

Basically the lithofacies Coloum are impotent in order to see the clear variation of lithologies which cannot be explained in more clear form in the cross plots as explained above .The litho facies Coloum of Miano -09 is constructed on the basis of different logs behavior which are displayed in the different tracks behind the lithofacies Coloum. Basically we marked the sand, shaly sand, sandy shale and shale.

The first clear cut indication is the GR log response which having higher value in front of the shale and lower value in front of the sand. But some time GR value can also be greater in Sand due to the excess of element i.e. thorium (Th) and uranium (U). These break down to form a sequence of radioactive daughter product (Daniel, 2003). Hence simply on the basis of the Gamma ray value we can't say with full confident that this is sand and this is shale. Hence we moves towards the other logs.

The DT and the NPHI logs give the important result about the sand and shale variation Shale has a direct relation with GR but low values of DT and hence we can mark the sandy and shaly zone. Similarly we calculated the volume of the shale and then marked the cut off on 40% i.e. below 40% we have the sand and above it we have the shale. Similarly there will be the higher value of the effective porosity in front of the sand and lower value in front of the shale and medium value in front of the sandy shale and shaly sand (Asquith et al., 2004). Hence on the basis of all these properties we Marked the Lithofacies in the Litho facies Coloum for Miano-09 which are shown in the below figures 4.6.

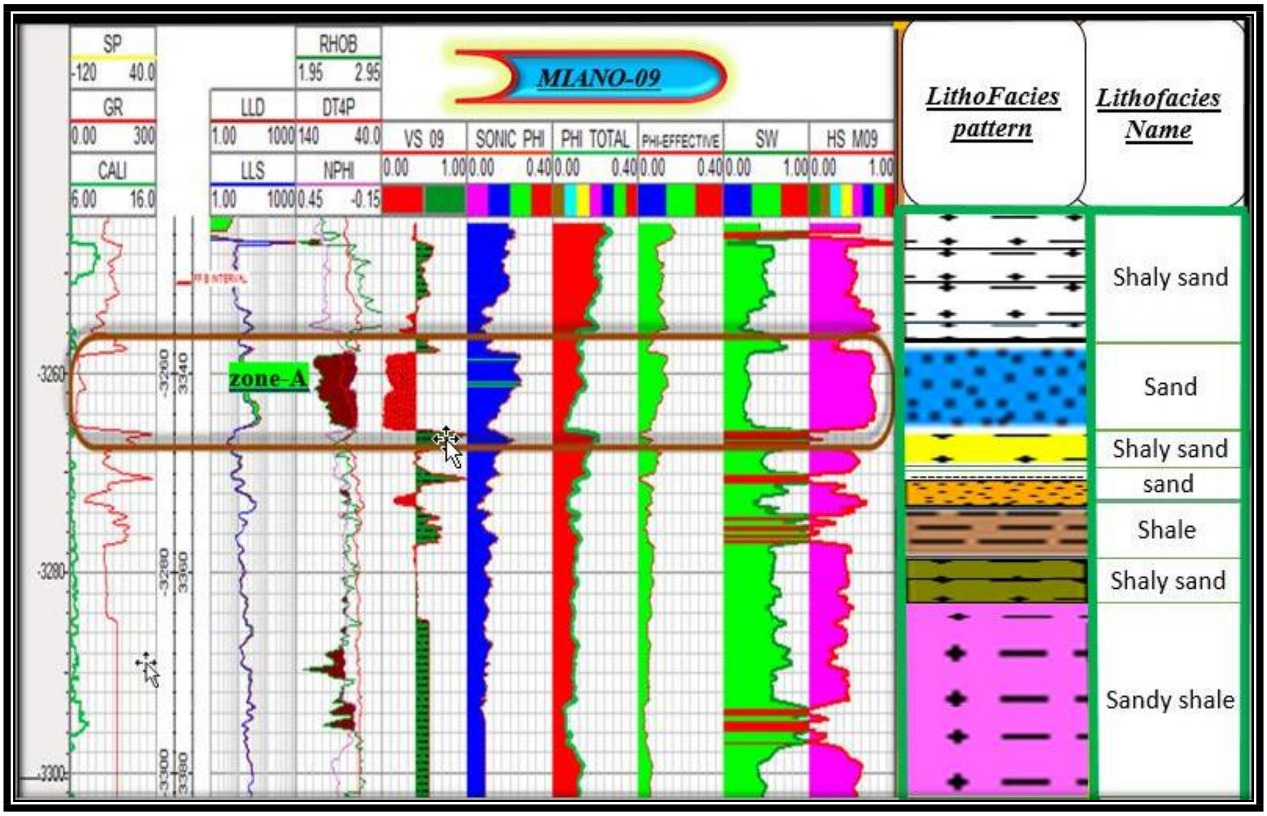


**Figure 4.6 Lithofacies Colum of Miano-09 B-interval**

# CONCLUSIONS & RECOMMENDATIONS

Following conclusions can be made from this study:

- Normal Faulting in the study area confirms that there is an extensional regime in the area.
- There is horst and grabben geometry in the area, the major horst block present between oppositely dipping faults at all levels.
- There is horst and graben geometry in the area. For generation of hydrocarbons, grabens are mainly kitchen area. High temperature gradient in graben also provides proper temperature for maturation of hydrocarbon. For generation of hydrocarbon, overburden in access as a result of subsidence providing sufficient pressure is required. The tilted fault blocks similar to a bookshelf model as a result of extensional forces facilitate petroleum system by providing migration pathway for hydrocarbons.
- Well bore data was interpreted to describe the physical properties and behavior of rocks, soils and fluids, focusing mainly on the calculation of hydrocarbon potential of the area. With the help of the well data average porosity, volume of shale, hydrocarbon saturation and water saturation were calculated for sands of the potential reservoir mainly Lower Goru sands. The overall trend indicates a good hydrocarbon potential in the area.
- The average shale volume in Miano-09 of Lower Goru Formation is 44%, total porosity is 11.3%, average water saturation of reservoir is 38%, average hydrocarbon saturation of reservoir is 62%. The calculations performed for the petrophysical analysis elucidated that the reservoir zone of the Lower Goru Formation have good hydrocarbon potential.

## References:


- Batzle, M. L., and Wang, Z., 1992, Seismic properties of pore fluids: Geophysics, 64, 1396-1408.
- Berryman, J. G., 1999, Origin of Gassmann's equation: Geophysics, 64, 1627-1629.
- Bust, V. K., Majid, A. A., Oletu, J. U., & Worthington, P. F. (2013). The petrophysics of shale gas reservoirs: Technical challenges and pragmatic solutions. Petroleum Geoscience, 19(2), 91-103.
- Chopra, Satinder, and Kurt J. Marfurt. "Seismic attributes a historical perspective." Geophysics 70.5 (2005): 3SO-28SO.
- Coffeen, J.A., 1986, Seismic Exploration Fundamentals, PennWell Publishing continental rise and shelf of Prydz Bay, Antarctica. Proc. Ocean Drill. Prog, Sci. Res. Vol. 188. 2004.
- Daniel, 2003,2004; Dobrin and Savit. 1988, Geophysical Exploration, Hafner Publishing Co.
- Elsevier, 1974, Fareed et al 2003
- Handwerger, D. A., et al; Jadoon et al.2016.
- Kadri I.B., (1995), "Petroleum Geology of Pakistan'', PPL, Karachi, Pakistan.p143-154.
- Kazmi, A.H., & Jan, M.Q., (1997). "Geology & Tectonics of Pakistan".
- Keary, Philip, MichaelBrooks, and Ian Hill. "An Introduction to geophysical exploration". John Wiley & Sons, 2002.
- Kemal. A. (1991). Geology and new trends for petroleum exploration in Pakistan
- Kingston, D. R., Dishroon, C. P., & Williams, P. A. (1983). Global basin classification system. AAPG bulletin
- Kumar, Dhananjay. 2006, a Tutorial on Gassmann Fluid Substitution: Formulation, Algorithm and Matlab Code, Chevron Energy Technology Company, California.
- Lucia, F. J., 1995, Carbonate reservoir characterization: New York, Springer-Verlag, 226 p.
- Marfurt, 2008; McQuillin, R., Bacon, M., and Barcaly, W., 1984 An introduction to seismic interpretation, Graham & Trotman Limited Sterling House, 66 Wilton Road London SW1V 1DE
- Nadeem et al., 2012; Naji et al.,2010; Powell, C. (1979). A speculative Tectonic history of

Pakistan and surroundings: some constrains from Indian Ocean: In SA Farah and K.A Dejong (Editors), Geodynamics of Pakistan, Geol. Survey of Pakistan, Quetta.p 5-24; Naqi and Siddiqui, 2006.

- Ravia et al ,.2010; Rimstad, K., Avseth, P., & Omre, H. (2012). Hierarchical Bayesian lithology/fluid prediction: A North Sea case study. Geophysics, 77(2), B69-B85.
- Rehman, K., Manawer, M., & Ahmed, S. (2013). Delineation of seismic reflectors in Miano area. Journal of Himalayan Earth Sciences, 46(2), 25-34, Asquith and Gibson, 2004
- Russell, B. R., Hedlin, K., Hilterman, F. J., and Lines, L. R., 2003, Fluid-property discrimination with AVO: A Biot Gassmann perspective: Geophysics, 68, 29-39.
- Shah et al., 1977; Smith, T. M., Sondergeld, C. H., and Rai, C. S., 2003, Gassmann fluid substitutions: A tutorial: Geophysics, 68, 430-440.
- Sroor, M. (2010). Geology & Geophysics in Oil Exploration (p. 33).
- Taner, M.T., Koehler,F. and Sheriff, R.E., 1979, Complex Seismic Trace analysis, Geophysics, Vol. 44(6), pp.1041-1063.
- Telford, W. M., Sheriff, R. E., and Geldart, L. P. (1990). Applied geophysics. Cambridge University Press.
- Telford, William Murray, and Robert E. Sheriff. "Applied geophysics". Vol. 1. Cambridge university press, 1990.
- Titman and Wahal, 1965; Wang, Z., 2001, Fundamentals of seismic rock physics: Geophysics, 66, 398-412
- Yergin, Daniel, 1991; Yilmaz. 2001, Seismic Data Analysis and Processing, Inversion and Analysis of Seismic Data, Society of Exploration Geophysics, Tulsa.
- Zaigham, N. A., & Mallick, K. A. (2000). Prospect of hydrocarbon associated with fossil-rift structures of the southern Indus basin, Pakistan. AAPG bulletin, 84(11), 1833-1848.