2D SEISMIC REFLECTION DATA INTERPRETATION INTEGRATED WITH RESERVOIR CHARACTERIZATION OF MIANO AREA USING SEISMIC AND WELL LOG DATA

BY

MUHAMMAD MUDASSIR

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DEPARTMENT OF EARTH SCIENCES

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The search for knowledge is a sacred duty imposed upon every Muslim. Go in search of knowledge, even to China.

CERTIFICATE

This dissertation submitted by ***MUHAMMAD MUDASSIR*** S/O ***MUHAMMAD NABI*** 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 BS degree in Geophysics.

RECOMMENDED BY

SIR ANEES AHMAD BANGASH ____________________

(Supervisor)

DR. MONA LISA ____________________

(Chairperson Department of Earth Sciences)

EXTERNAL EXAMINER ____________________

Department of Earth Sciences
Quaid-i-Azam University, Islamabad
Pakistan

ABSTRACT

In this dissertation, focus is placed on the structural interpretation of the Miano block-20 in order to demarcate the probable zone for the accumulation of hydrocarbons. This thesis work includes preparation of synthetic seismogram of Miano-09 well. Analysis of geophysical borehole logs provides one of the best approaches to characterizing rocks within boreholes. So Facies analysis is also done in order to identify lithologies.

For the interpretation of the seismic lines, three reflectors are marked by correlating synthetic seismogram on seismic section. As the area of study lies in the Lower Indus Basin, horst and graben geometry in this region is common which is confirmed by fault polygon and time and depth contours made from time and depth grid respectively.

Facies modeling is one of the reliable tool for the confirmation of lithologies. In this dissertation, with the help of facies analysis of Miano-09 well, we came to the result revealing sand as the reservoir lithology.

Petrophysics is the one of the most reliable tools for the confirmation of the types of the hydrocarbon and for marking of the proper zone of the interest of the presence of the hydro carbon 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.

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MUHAMMAD MUDASSIR

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Chapter#01

1.1 Introduction to Miano Area

The Miano area is located approximately 62km southeast of Sukkur, Pakistan. The Miano gas field is located in the Central Indus Basin having a total area of 814.02 sq. km Tectonically the block lies on Panno-Aqil graben between two highs i.e. Jacobabad-khairpur and Mari-Kandhkot Thar Desert lies in its south and Delhi Aravalli range is in its east.The length of the field is approximately 42km along strike. The southern most well in the field is less than 10km from the Kadanwari field to the south and 45km from the Sawan field to the southwest. Two of largest gas fields found in Pakistan, the Mari and Sui gas fields productive from the Eocene limestone, are found 75km and 150km to the north respectively. Eight wells have been drilled to appraise the Miano field targeting the Lower Cretaceous-aged Lower Goru Formation. The Miano gas field is located in the Thar Desert 62km southeast of Sukkur province. It is thought to extend from the southern block boundary in a north-northeastrly direction and lies north of the Kadanwari gas field. The in lines and cross lines are in the range from 2080 to 3735 EW and 2524 to 3523 NS.Satellite image of Miano is shown in Fig 1.1.

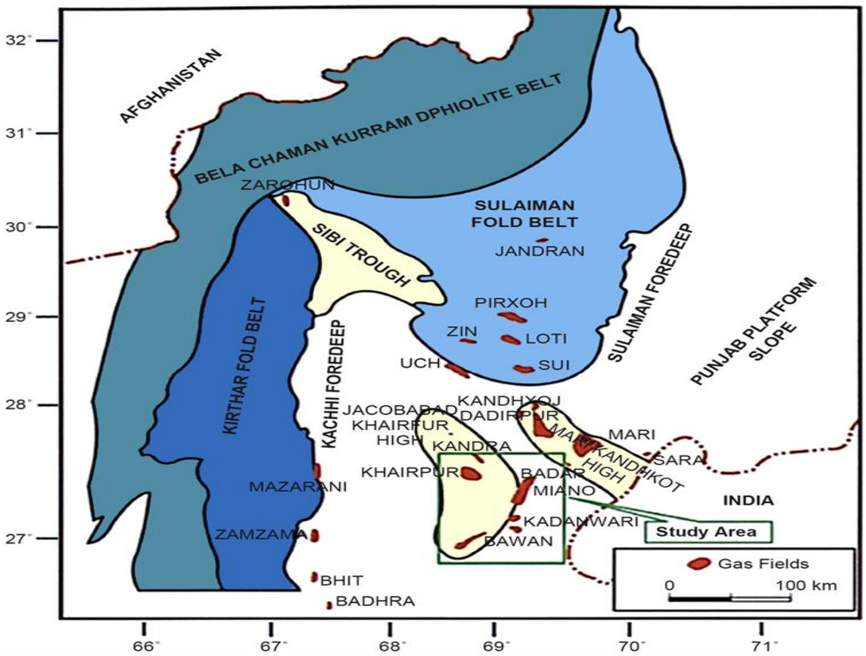


Figure 1. Generalized regional tectonic map with location of major oil and gas fields in the study area (modified after Ahmed et al., 2013)

1.2 Exploration History of Study Area

Miano field is located in Sindh Province. It is a joint venture between OMV (Pakistan) Exploration G.m.b.H (Austria), Eni Exploration and Production Limited (Italy), Pakistan Petroleum Limited and Oil and Gas Development Company Limited. Pakistan Petroleum Limited share in the joint venture is 15.16%. A total of eleven wells have been drilled in the lease area. As per Joint Utilization Agreement executed between Miano and Kadanwari Joint Venture and Government, Miano raw gas is being processed at Kadanwari gas processing plant, which has been upgraded. At present, Kadanwari plant is processing on an average 185 MMscfd of sales gas from Miano and Kadanwari, out of which the average gas sales from Miano field is 145 MMscfd. Miano-8 well has been tied-in to the production facilities in June, 2005. Currently six well are on production and an average gas sale is around 145 MMscfd. The average daily sale during 2004-05 (up to May 2005) from the field was 141.22 MMscfd of purified gas, and 104 barrels of condensate.

1.3 Objectives

The main objectives of this dissertation based on interpretation of seismic section are:

- Detailed seismic structural interpretation for identification of structures favorable for hydrocarbon accumulation.
- Seismic attribute analysis provides some qualitative information of the geometry and confirms the seismic interpretation.
- Identification of the possible hydrocarbons bearing zones by means of Petrophysical analysis by using available well data.
- Rock physics analysis for determining the mechanical properties within the reservoir depths by using well log data.
- Facies analysis to investigate the depositional environment and helps in identifying the lithologies of the reservoir zone..

1.4 Data used

Data used for this dissertation:

- Seismic data in SEG-Y format
- LAS file(well log data)
- Navigation file

1.4.1 Seismic Data

The data used for current research includes 3 seismic lines and one well Miano-9 The orientation of Seismic lines and the well are listed in the table 1.1. three lines and one well (in bold) are assigned to me for the completion of this research work.

Table 1.1 Data used for research work

Line	Orientation	Shot points	nature	well
P2094-214	**E-W**	**102-1175**	strike	Miano 09
P2094-219	**N-S**	**102-1140**	dip	Miano 09
P2094-221	**N-S**	**102-1142**	dip	Miano 09

1.4.2 Well Data

Information about the well used in this research is given below in table 1.2

WELL	MIANO-9
LATITUDE	**027.371747**
LONGITUDE	**069.311478**
KB	**80.00**
TOTAL DEPTH	**3385.0000(m)**
STATUS	**DEVELOPMENT**
EXPLORATION	**GAS**
SOURCE	**VIBROSEIS**
COMPANY	**OMV(PAK.)**
FORMATION TOPS	**DEPTH(m)**
Siwalik	000000.0
Kirthar Formation	000497.0
Drazinda Member	000497.0
Pirkoh Member	000572.0
Habib Rahi Member	000742.0
Ghazij Member	000871.0
Laki	000871.0
Sui Main Limestone Member	001512.0
Ranikot Formation	001697.0
Phar Formation	001860.0
Upper Goru	001930.0
Goru	001930.0
Shale Unit	002261.0
Lower Goru	002261.0
D Interval	003089.0
C Interval	003167.0
B Interval	003331.0

1.5 Software used

Software's used in this research are;

- IHS Kingdom
- Microsoft Office
- Snagit Editor

1.6 Base Map

Base map usually shows the seismic lines orientations, wells locations and seismic shot points along with the concession boundaries (Sroor, 2010) as shown in Figure 1.3. three Lines i.e. one strike P2094-214, two dip lines P2094-219 and P2094.221 and one well Miano-9 are assigned to me. In Figure 1.3 Base map is shown with Highlighted lines which are assigned to me for this research work.

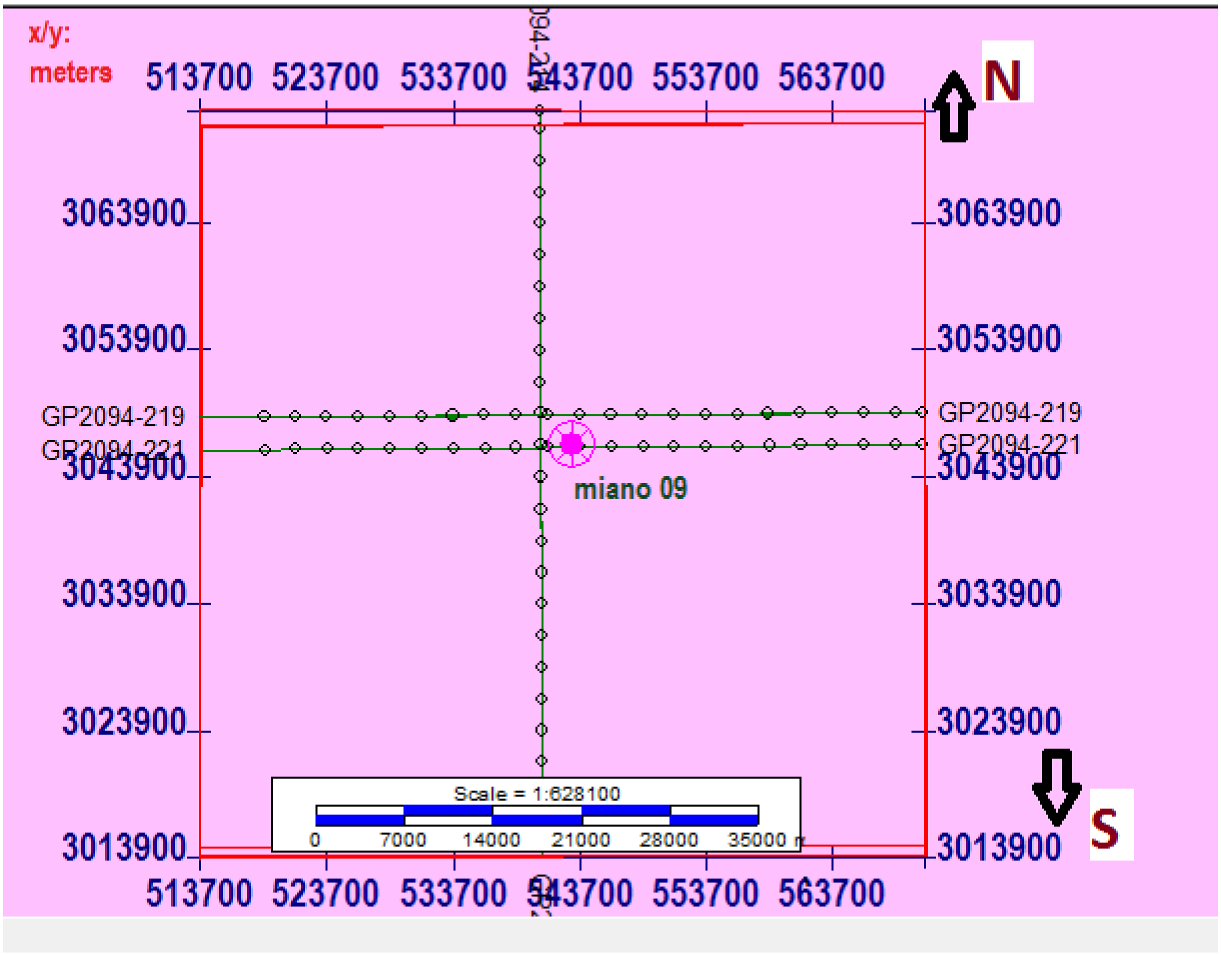


Figure 1.3 Base map of study area.

1.7 Workflow of Dissertation

Base map is prepared by loading seismic data in SEG-Y format and navigation data in (X,Y) horizons and faults identify in seismic section to generate fault polygon and grid of marked horizons then two way time contour map and depth contour map are generated, Petrophysical analysis, Estimation of rock properties of reservoir and Facies analysis are performed by using well log data.

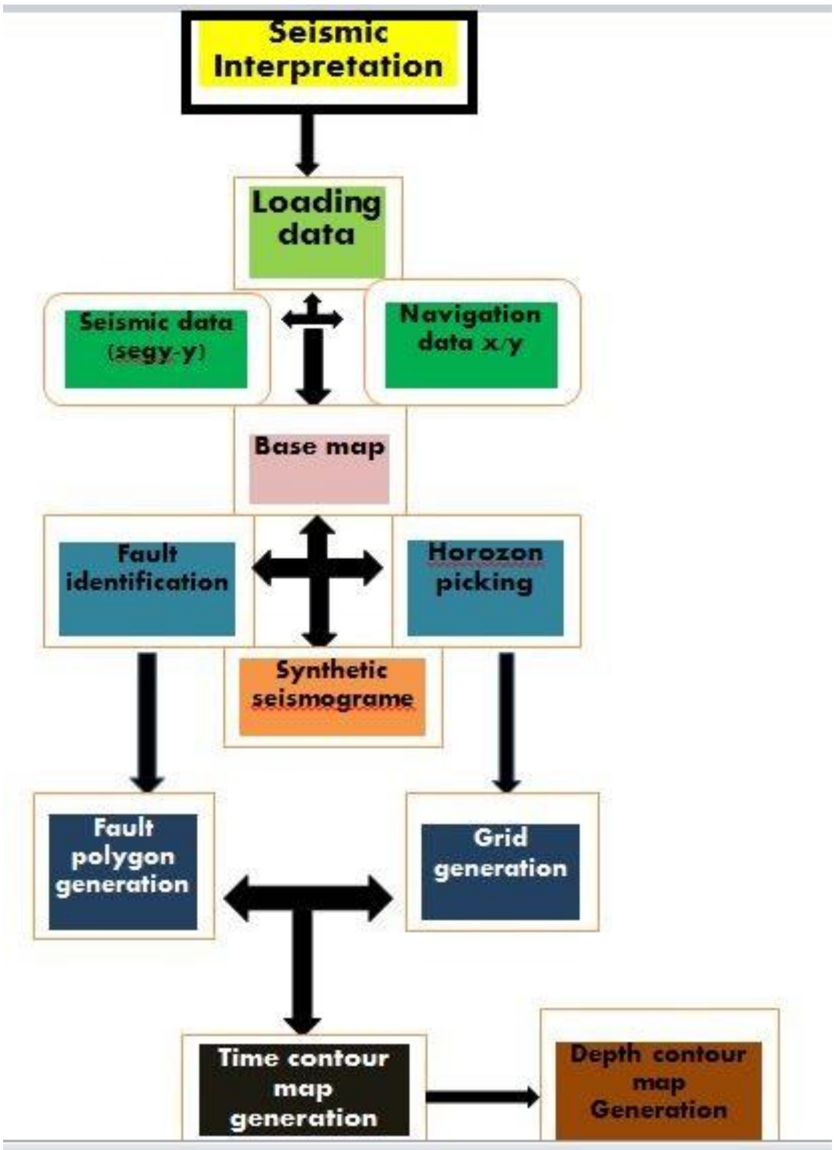


Figure 1.4 Workflow of Dissertation.

CHAPTER# 02

GEOLOGY AND TECTONICS OF AREA

2.1 Introduction

The information about the geology of an area plays an important role for precise interpretation of seismic data, because some velocity effects can be generated from formation of different ideologies and different velocity facts can be generated some lithological horizons. So, as if we don't know geological formations in an area we don't recognize the different reflections appearing in the seismic section. The studied area is a part of the Potwar plateau where the topography is undulating and characterized by a series of parallel ridges and valleys. Generally, they trend in E-W direction. Geologically it forms part of the Foreland zone of the NW Himalayan fold and thrust belt. This Foreland zone, comprising of Salt range, Potwar plateau, Kohat plateau and Hazara ranges, is an area bounded by the Salt range thrust in the south and the Panjal - Khairabad fault in the north. At its easternend is the nearly N-S running left lateral Jhelum Fault (Kazmi & Jan, 1997).

2.2 Regional Geological Settings

The Indian Ocean and the Himalayas, two of the most pronounced global features surrounded the Indo Pakistan subcontinent, have a common origin. Both are the product of the geodynamic processes of sea-floor spreading, continental drift and collision tectonics. A plate of the earth's crust carrying the Indo-Pakistan landmass rifted away from the super continent Gondwanaland followed by the extensive sea-floor spreading and the opening up of the Indian Ocean. Propelled by the geodynamic forces the Indian plate traveled 5000 Km northward and eventually collided with Eurasia. The subduction of the northern margin of the Indian plate finally closed the Neotythes and the Indian Ocean assumed its present widespread expanse. This collision formed the Himalayas and the adjacent mountain ranges (Kazmi & Jan, 1997).Pakistan has been divided into two broad geological zones, which are mentioned below

- **Gondwanaland Domain.**
- **Tethyan Domain.**

Pakistan is unique in as much as it is located at the junction of these two diverse domains. The southernpart of Pakistan belongs to Gondwanian Domain and is sustained by the Indo-Pakistan Crustal Plate. The northern most and western region of Pakistan fall in Tethyan Domain and present a complicated geology. The collision of the Indian plate with Asia, which is continuing at a rate of 5mm/a, has produced a remarkable variety of active fold- and-thrust wedges within Pakistan. These zones extend from the Kashmir fold-and-thrust belt in NE Pakistan, southwestward through the Salt Range-Potwar Plateau folds' belt, the Sulaiman fold belt, and the Makran accretionary wedge. This collision 9 between the Indian and Eurasian plates began during the middle to late Eocene in association with Late Cretaceous-Cenozoic spreading along the Carlsberg-southeast Indian Ocean Ridge. Sea-floor reconstruction indicates that about 2000 km of convergence has occurred between India and Eurasia since the collision began. In northern Pakistan, the Himalayan ranges are divided into four major subdivisions. North of the Main Karakoram thrust lie the Karakoram Range and Hindukush, terrains of Gondwanaland affinity sutured to Eurasia (Turan block) in the Late Triassic-Middle Jurassic. South of the Main Karakoram thrust and north of the Main Mantle thrust lies the Kohistan block, a terrane believed to have been formed as an island arc, which docked with Eurasia in the Late Cretaceous toearly Eocene. It is suggested that the Main Mantle Thrust locked approximately 15 Ma ago, subsequent to rapid uplift north of the fault between 30-15 Ma. During the early Miocene, deformation propagated southward near the Main Boundary thrust, where non-metamorphosed lower Tertiary rocks are thrust over Neogene molasses. In the latest phase in Pakistan, thrusting transferred to the Salt Range thrust, where deformation as young as 0.4 Ma has been documented. I n the Lesser Himalaya of northern Pakistan (Hill Ranges), detachments at upper crustal levels occur along a series of south-verging thrusts. (Kazmi, A.H, 1979)

2.3 Tectonic and Depositional Setting

The Jurassic Rifting and breakage of Gondwanaland in part of the Indus basin, presently Southern Indus Basin, resulted in the submergence of platform and produced deep-water sedimentation of Shrinab and Chiltan Formation. In early Cretaceous, the actual separation of Gondwanaland (Indian-Antarctica-Australia) from the western Gondwanaland started, the time when Sembar/Goru was being deposited. The whole Cretaceous represents shallow water while northern floor of the southern arm of the Tethys was subducting beneath the Iran–Afghanistan micro-continent and northern Tethys were subducting beneath the Tibetan plateau.

At the end of Cretaceous and in Early Tertiary, the northward drift of the Indian Plate accelerated (16cm/yr). The collision of Indian and Eurasian Plate resulted in submergence of numerous local areas throughout the Tertiary in the Lower Indus Basin, which is marked by various phases of transgression and regression. In early transgression phase Khadro Formation was deposited in the low areas of Central Sulaiman and the Kirthar regions while the elevated parts of the basin did not receive sediments The transgression was followed by a short-lived regression before the main Paleocene (Ranikot) sea transgressed and covered the whole Indus Basin. In Central Indus Basin rocks of Paleocene age are almost entirely of marine origin. Dominant lithology is limestone with subordinate marls and varying proportions of shale, sandstone and conglomerate. The sandstone/shale ratio decreases away from the Indian shield and of shale increases abundantly in Ranikot Nala, Tangi Sar section and also in Sui area.

Facies changes across the Indus basin represent widespread carbonate platform and shale basins. Central Pakistan is unaffected by collisional events. However subsidence with Mesozoic rift basin is continued during the Paleocene. The Indo-Pakistani continental margin in the Lower Indus Basin was very active during the Paleocene, being affected only by subsidence and minor localized up lifts.

Paleohighs such as Kairpur-Jacobabad and Mari-Kandkot, which had formed during the Mesozoic when adjoining areas rifted apart, were subaqueous Islands in an otherwise stable carbonate platform environment. Carbonate sedimentations was essentially affected by sea level changes. Terrigeneous input in Central Pakistan was limited to marine trangressive events when the carbonate. Eocene marks the initial contact of the Indo-Pakistan subcontinent with Chitral/Ladakh island arc system or the southern continental margin of Eurasia. As the north movement of India slowed down, it begun to rotate counterclockwise. This caused the widespread and stable shallow water carbonate plateform with a few depressions in Sulaiman Basin.

2.4 Sedimentary Basins

The basin is an area characterized by regional subsidence and in which the sediments are conserved for longer periods of time. In a basin, a receptacle or container, which is the basin's substratum is called the Basement. The container is filled or contained, which is the accumulation of sediments resting on the basement, is called sedimentary cover. The progressive settlement of the basin is called subsidence. The point of maximum sedimentary accumulation is called the Depocenter. The detachment may not correspond to the maximum subsidence. Pakistan includes three sedimentary basins as shown in figure 2.2.Geographically upper Indus basin is located from MBT in the north to Sargodha High in the South, central Indus basin from Sargodha high to Mari Kankot High and lower Indus basin from Mari Kankot High to Nagar Parker High. Following are the basins classification of Pakistan. (Raza, A.H. 1990)

- **Upper Indus Basin**
- **Southern Indus Basin**
- **Central Indus Basin**
- **Lower Indus Basin**
- **Baluchistan Basin.**
- **Kakar Khorasaan Basin or Pishin Basin**
- **Indus offshore basin**

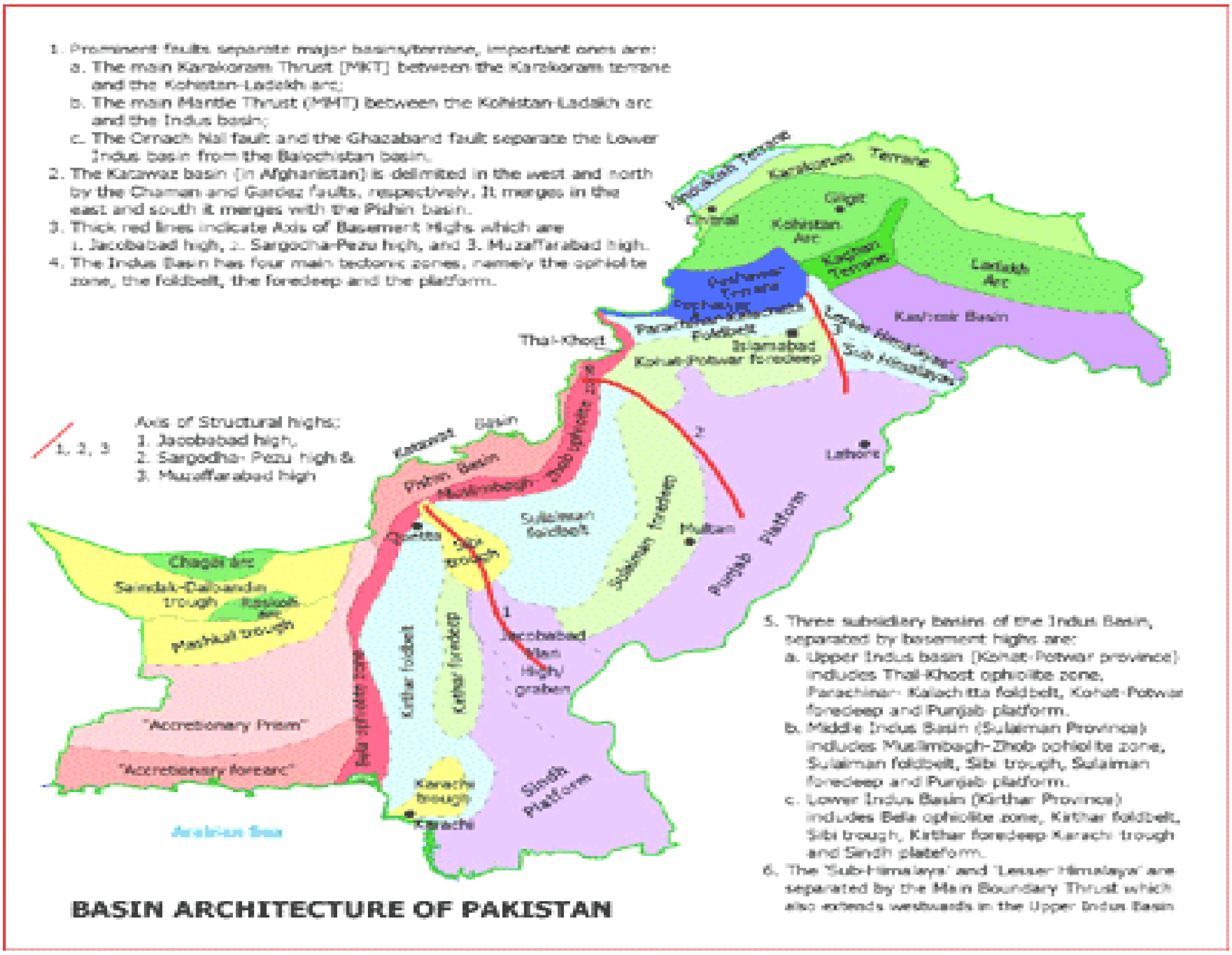


fig 2.1 basin of pakistan

2.4.1 Central Indus Basin

Central Indus basin is located in south of Sukkur Rift which divides the Lower Indus basin into Central and Southern Indus basin. Area is bounded by Marginal zone of Indian plate in west, Sukkur Rift in south and in East Indian Shield is present shown in Figure 2.3.

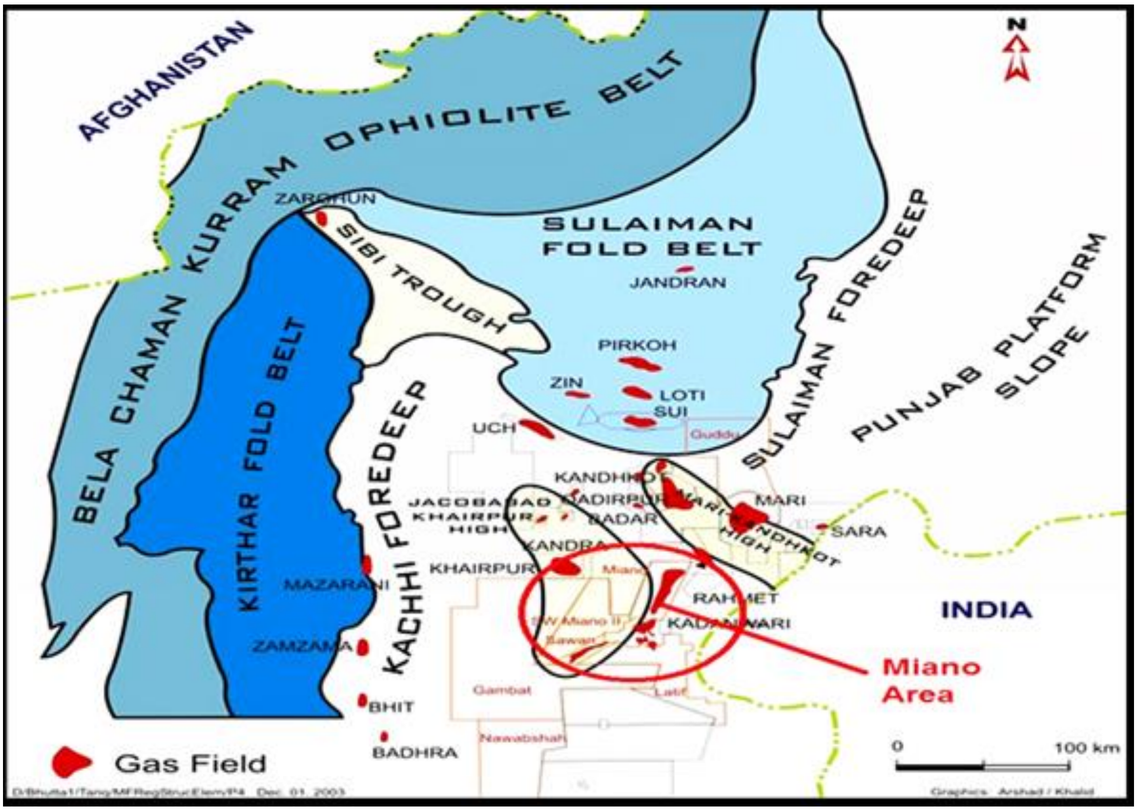


Figure: 2.2 Regional tectonic framework of Miano Field within Central Indus Basin (Mehmood et al., 2004).

2.4.1 Boundaries of Central Indus Basin

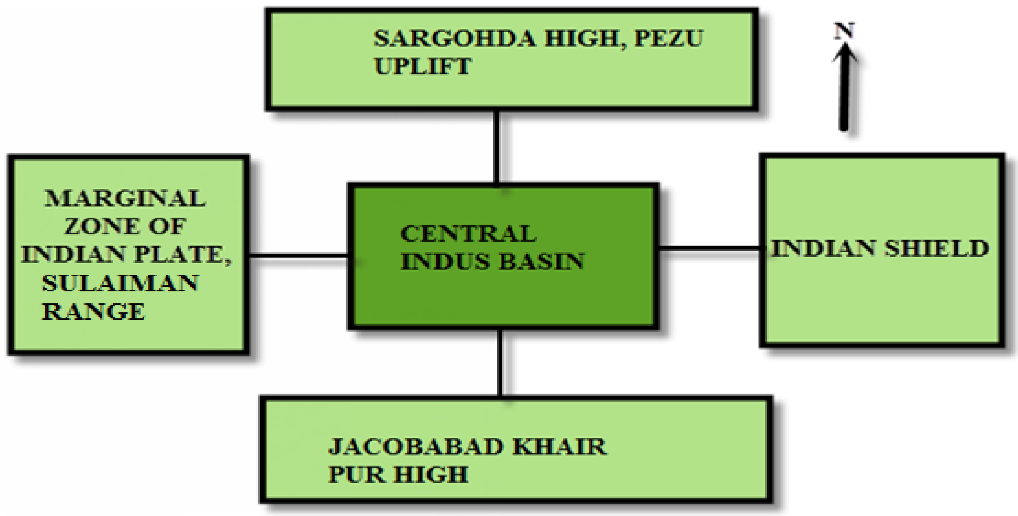


Figure 2.3 Boundaries of Central Indus Basin.

2.4.1 Geological Boundaries of Miano Area

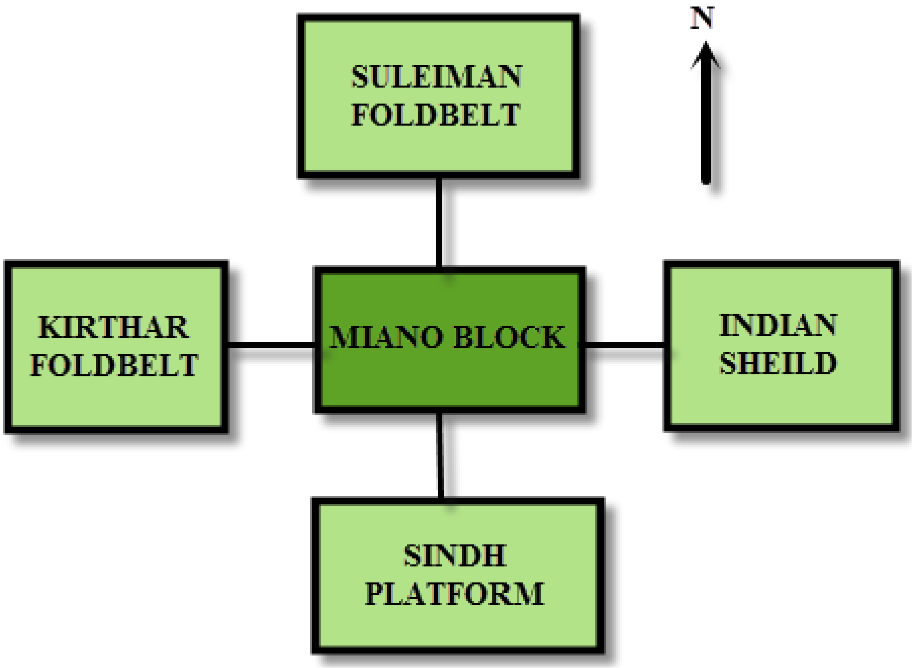


Figure 2.5 Tectonic boundaries of Miano Block-20.

2.5 Stratigraphy of the Study Area

The sedimentary section of the study area lies in central Indus basin mainly comprises of Permian to Mesozoic rocks and overlying by strong angular unconformity of late Paleozoic age. The Mesozoic progradational sequence is deposited on eastward inclined gentle slope. In the Thar slope areas all of Mesozoic sediments are regionally plunging towards the west and are truncated unconfirmabaly by volcanic rocks (basalts of Khadro formation). 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 (Kadri, 1994). Stratigraphic chart of study area is shown in Figure 2.6.

2.6 Structure

Structural basement comprises thick Chiltan Formation of Middle and Upper Jurassic age. Miano field (study area) lies in extensional regime usually show normal faulting in NNW-SSE direction shown in Figure 2.7. Structure formed in the study area is Horst and Graben in nature.

2.7 Petroleum Play

In geology a petroleum play is a group of oil fields or prospects present in the same region that are controlled by the same set of geological circumstances (Stoneley, 1995). Lower Indus is the main hydrocarbons producing basin of the Pakistan 37% hydrocarbons of the Pakistan are extract from the lower Indus basin (Kadri, 1995). Within a basin the presence of play elements plays important role in hydrocarbon accumulation.

- Mature Source rock
- Migration pathway
- Reservoir rock

- Trap
- Seal or Cap rock
- Appropriate timing

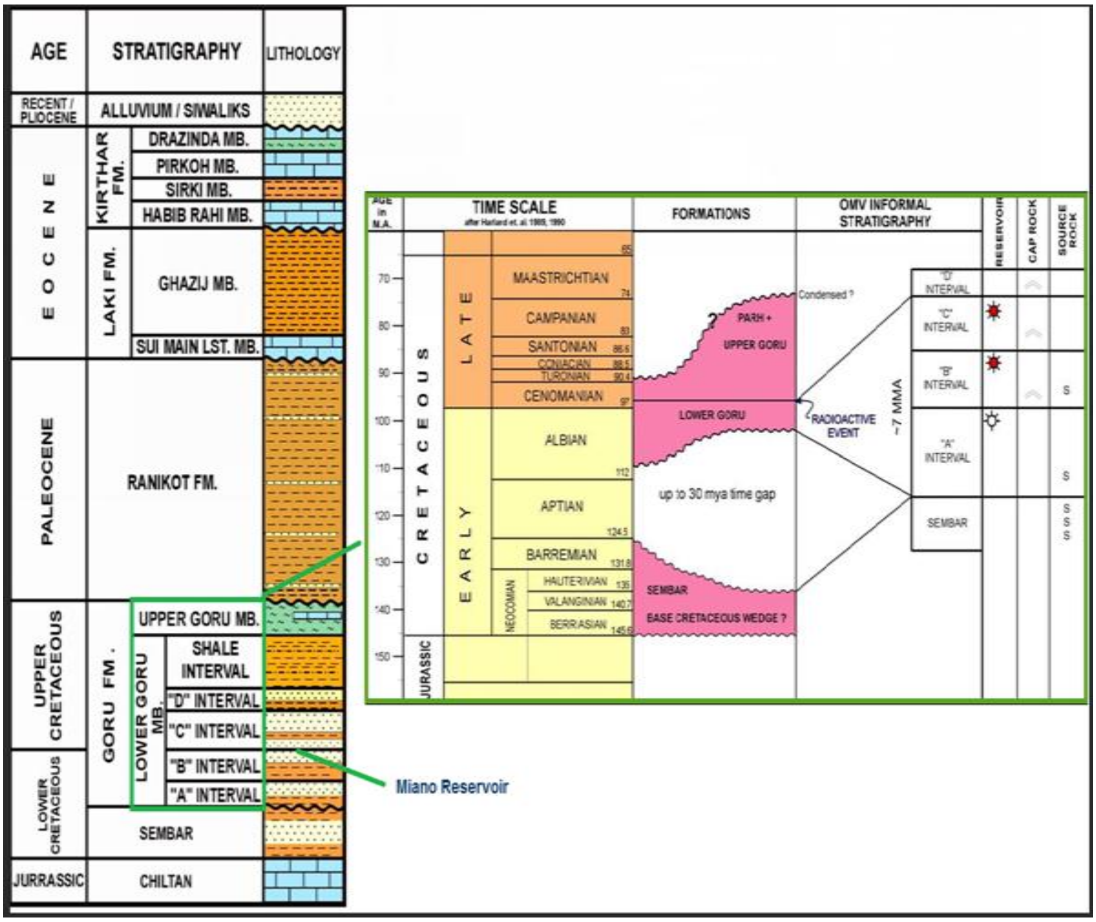


Figure 2.6 Stratigraphic column of study area (Mehmood et al., 2004).

2.7.1 Source Rock

Source rock is the productive rock for hydrocarbon. The Formations which act as a good 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. Potential of a reservoir also occurs within the sandstone part of the formation.

- **C-Interval of Lower Goru Formation**

As interbedded shale and sandstone layers are present in Lower Goru formation and shale act as a good source rock so in this assigned area lower Goru formation is divided into different interval and C Interval is one of the good source rocks of the study area.

All of the possible source rocks of the study area Sember is the best source for the largest production of oil and gas fields in Indus basin (Iqbal and Shah, 1980).

2.7.2 Reservoir Rock

B-interval of lower Goru is considered as good reservoir rock of this area. Usually the depositional environment of the Lower Goru "B" sands in the Miano field is tide dominated and formation's lithology is the sandstone with the occasional beds of shale. Sandstone is white, yellowish brown in color. Its porosity ranged between 10-15% and patchy yellowish to bluish white fluorescence.

2.7.3 Seal Rock

Seals act as a barrier for the flow of hydrocarbons. In the Central Indus Basin Upper Goru shale and interbedded shales of Sui Main Limestone of Cretaceous are acting as a seal but in study area C-interval of Lower Goru formation is acting as a good seal rock (Kadri, 1995). Thin beds of variable thickness act as an effective seals in producing fields.

2.7.4 Traps and Seals

Most of the fields discovered in the Kohat-Potwar geological province to date are overturned faulted anticlines, popup structures, or fault-blocking traps. In this zone, anticline structures generally strike east-northeast to west- southwest and are approximately parallel to the collision-plate area. The last booster traps started at about 5 and 2 Ma (Jaswal et al., 1997). Seals include fault truncations and inter bedded shales, as well as shales and thick clays of the Siwalik group of the Miocene and Pliocene .The Kuldana (Eocene) formation serves as a cap for the Eocene Chorgali reservoirs and Sakesar (Eocene) limestones in the Potner-Foreland Basin (SRPFB). Clays and shales of the Murree Formation also provide effective vertical and lateral sealing to the Eocene reservoirs of the Potwar Foreland Basin (SRPFB), where ever it is in contact.

CHAPTER#03

SEISMIC INTERPRETATION

3.1. Interpretation of 2D Seismic Data

Interpretation of the seismic section is done for the large area the area mostly done the structure interpretation and marks the prominent faults. Reflector is marked where the reflector is strong and clear, in such a way sequence is marked. A fracture is caused in the subsurface caused by the tectonic force called fault. Faults are basically the discontinuities that are cause because of the tectonic forces (Bakker, 2002).

As the seismic data is interpreted, then we are able to interpret the subsurface geologic structure such that fault, fold, horizons and the stratigraphic analysis. This is done to get information for the deposits of the hydrocarbon. Structural Interpretation of 2D seismic data of Block-20 Miano area is deals in this chapter. On the basis of seismic data interpretation following analysis can be made.

3.2 Basic Work flow of Seismic Interpretation

Following are the major interpretation steps that are taken to interpret the 2D seismic data

- Preparation of the base map of the area
- Faults marking on seismic section
- Interpretation of the Horizons
- Fault polygons construction
- Preparation of the contour map
- Basic flow chart of geophysical interpretational processes is shown in Figure 3.1.

3.2.1 Area Base Map Preparation

The Base map is formed by loading the latitude & longitude of the study area into the interpretation software. The seismic data may be the 2D or 3D. This will comprise the dip and the strike lines according to the structure of the area. The wells in the study area are loaded and displayed on the base map in Figure 3.1.

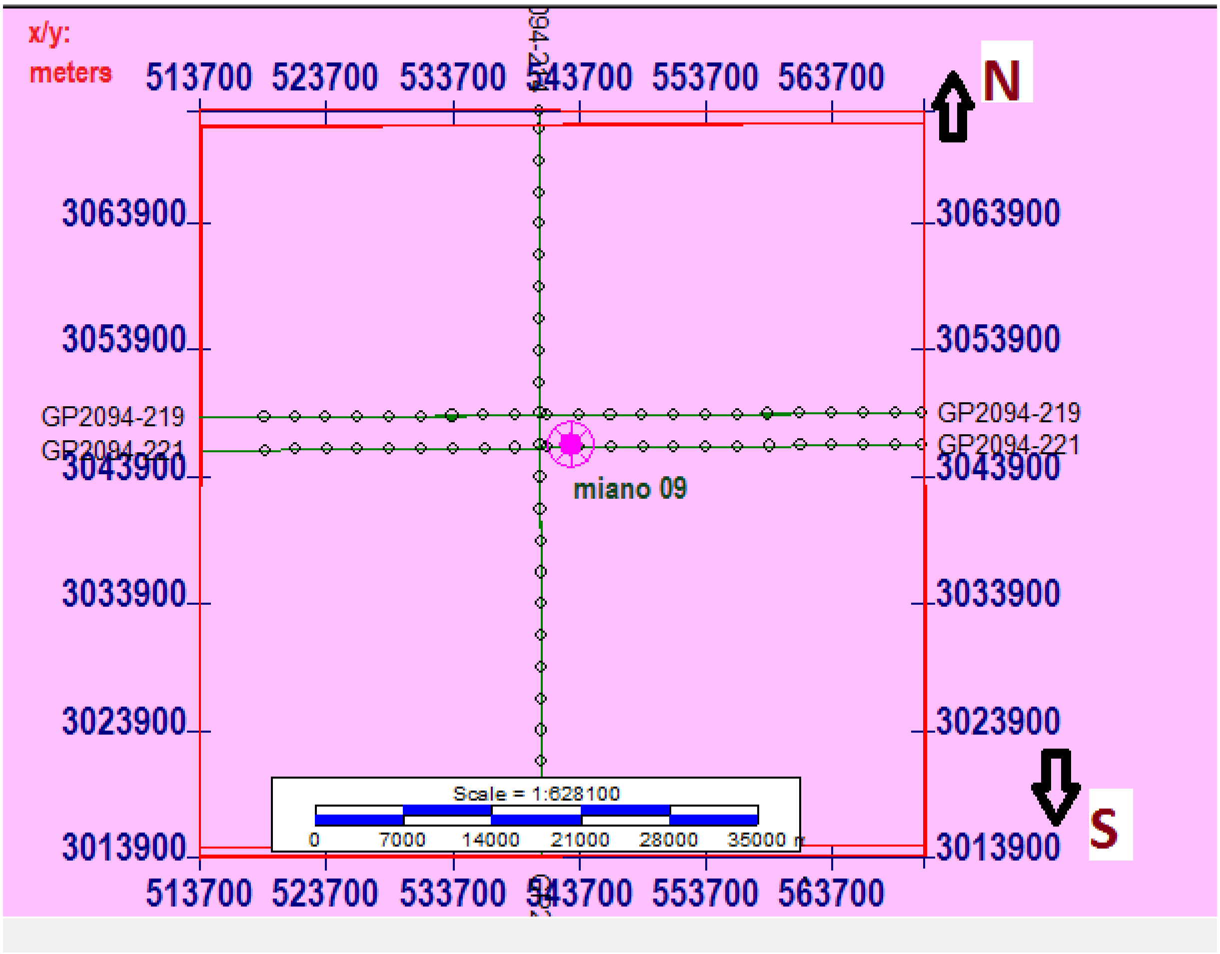


Figure 3.1: Base Map of Miano Area

3.2.2 Marking of Faults on Seismic Section

Faults are interpreted on seismic section where there is certain discontinuity or breakage in the beddings. Certain steps are necessary to identify the faults in the study area. The steps are

- Geology of area
- Faults correlation

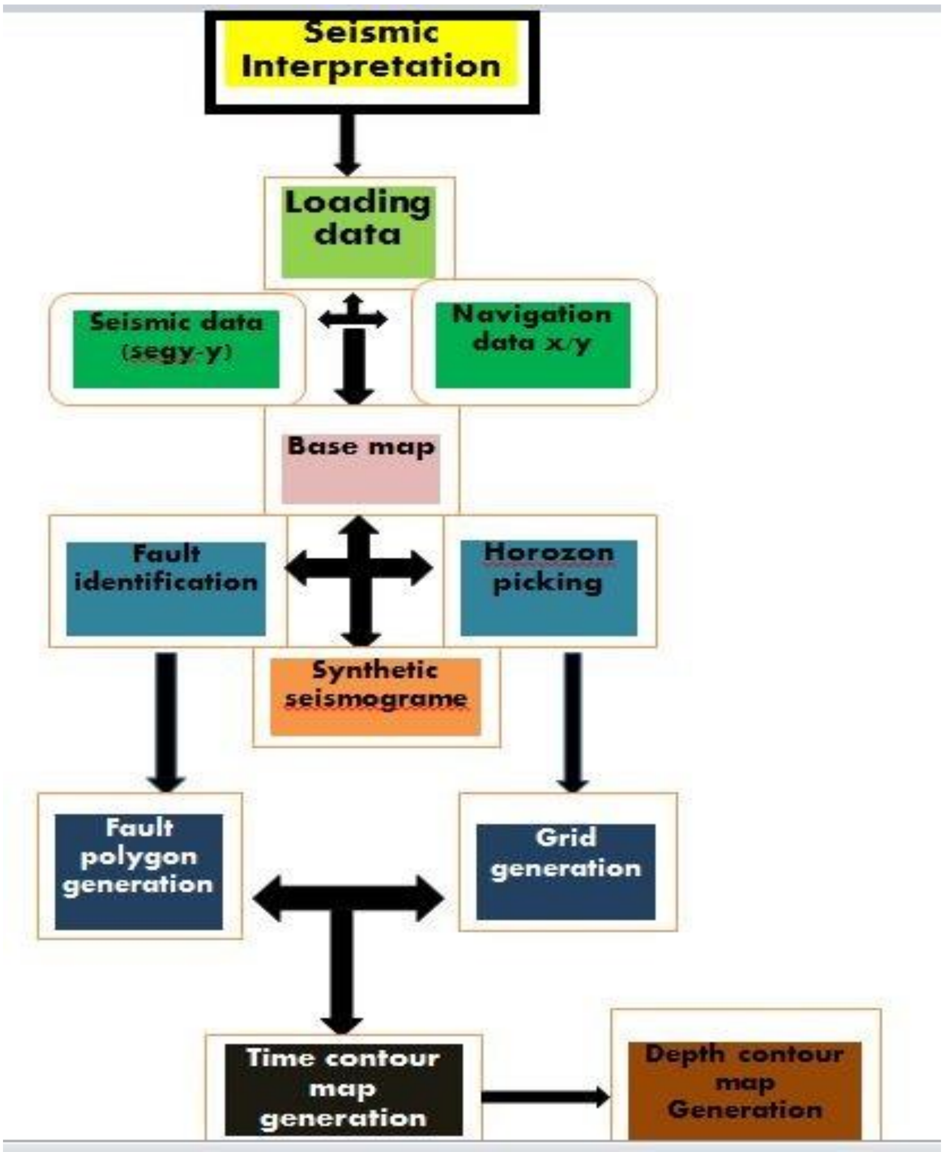


Figure 3.2: Flow chart Seismic Interpretation

3.2.2.1 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 al so used the constant density for that area. With the help of Miano- 09 the synthetic seismogram was constructed showen 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 them laterally along the seismic line (Handwerger et al., 2004).

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. Open 1D forward modeling Project and select the well logs.
3. Integrate the sonic log to rescale from depth in meters to two - way travel time in seconds.
4. Compute velocity from sonic log for P and S waves.
5. Create a TD chart for the well from the velocity logs.
6. Compute Acoustic impedance log using velocity and density log.
7. Compute the reflection coefficients from the time- scaled velocity log.
8. Compute a first- order Ricker wavelet as a digital filter with two millisecond increments of
9. Two- way travel time; using a frequency in Hertz (35 Hz frequency is used in this study)
10. 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 .Basically we have the limited log data only miano - 09 is the only well in our available data that having 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 f ormation tops of the Miano- 09 we marked the C- interval, top of the Lower Goru and the Ranikot formation. The display of the synthetic seismogram is showen in the Figure (3.2)

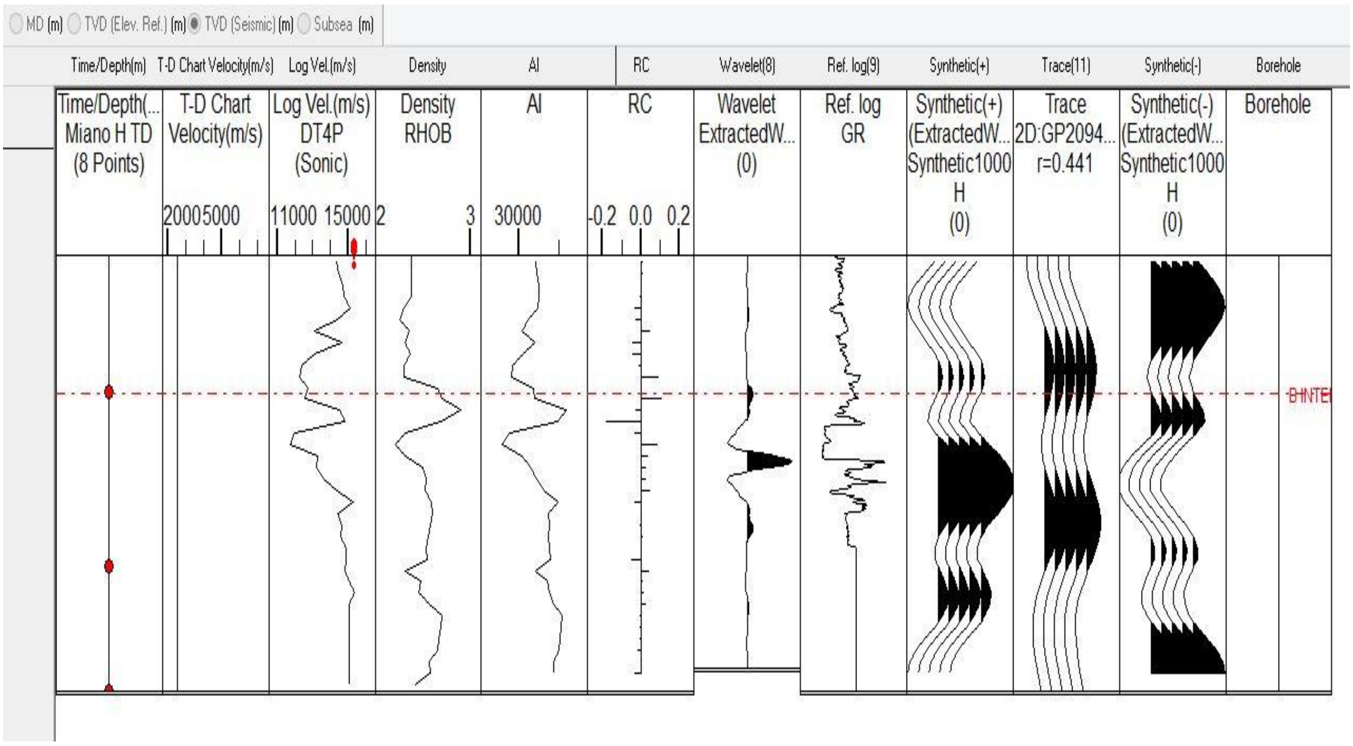


Figure 3.2 Synthetic Seismogram of the well Miano- 09 on line GP2094- 221

3.2.2.2 Geology of Area

The study about the stress regime like compressional or tensional helps us to identify the patter of the faults. Mostly in compressional regime reverse faults are dominant with minor normal faults but in extensional regime we observe normal faulting. Also previous knowledge of study area helps about the age of the faults so primary and secondary features are easy to understand. Miano area is extensional regime where we observe horse and graben structures. Major fault extend into the basement while splays along the major fault terminate to it. Geology of the area is important to purpose us the possible structure of the area.

3.2.2.3 Fault Correlation

The extension of the fault can be defined with the help of the fault correlation. It also defines the heave and throw of the faults and also network of the fault from where it passes through the different formation.

3.2.3 Horizon Interpretation

Interpretation of different horizon on the seismic section is the basic task of seismic data interpreter. The interpreter should have knowledge about the structures present in the area and also about the stratigraphy. The well tops are correlated with the seismic to mark the exact location of the horizons on the seismic section On the basis of well tops of Miano-09, three horizons are interpreted. The names of these horizons are:

- Lower Goru Formation
- C-sand
- B-sand

3.2.4 Construction of Fault Polygon

The faults are interpreted on many sections so the faults correlate with each other and also to generate the fault polygon. The polygons can be constructed Manually and the Auto-generation.

3.2.5 Contour Maps Preparation

Final stage of Interpretation is the contour map generation. Contours are lines that join the points of equal time, elevation or depth. For contour map, Grid of the horizons is generated and then contour is generated on such a Grid. In seismic interpretation, first we prepare the TWT contour maps and then depth contour maps are prepared.

Three seismic horizons are marked on the seismic lines. These horizons were marked through the same steps and all the section are correlated at their respective tie points. The reflectors are strong enough to be picked because contrast in the acoustic impedance that is ultimately caused by changes in lithology. Normally the VSP data is used for naming the marked. In this study, six prominent reflectors are marked other wells of Miano area.

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 GP2094-221 are marked first because it is nearer to the well Miano-9. 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 miss tie that may be removed later on. Taking seismic line P2094-223 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

In the first step the prominent reflector are picked and correlated with the well tops of miano-09 and the reflectors are identified. Also the lines are correlated with the synthetic seismogram of this well. Using tie of seismic lines from P2094-221 the other lines used in the study are marked. Three horizons are marked on the seismic section that is used in the study area and the horizons are named, with the help of the well data. The marked Horizons are assigned with different color. Horizon 1 is the Top of lower Guru Formation of Cretaceous age (green). Horizon 2 is the C-interval of sand in lower Goru Formation (orange). Horizon 3 is the B-interval of sand in lower Goru Formation (red). 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 lines are strike lines and on strike lines the faults cannot be clearly observed so the fault tie points from dip lines were highlighted on these lines. The base map of the lines used for the study along with the well location is shown in Figure 3.2. 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.

The seismic lines P2094-219 and P2094-221 are the dip lines. All of the above mentioned horizons are marked as shown in figure 3 and figure 4 normal faults are marked on both the section forming major horst structures. Five are the major faults. The time of the horizons on seismic sections is given as; Top of Lower Goru is at 1.61 to 2.089 seconds. 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.The horizons marked on the five faults are marked forming a graben. The interpreted seismic sections of the lines P2094-219 and P2094-221 are shown in Figure 3.4 and Figure 3.5 respectively.

3.4.1 Interpretation of the seismic Strike line GP2094 -214

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

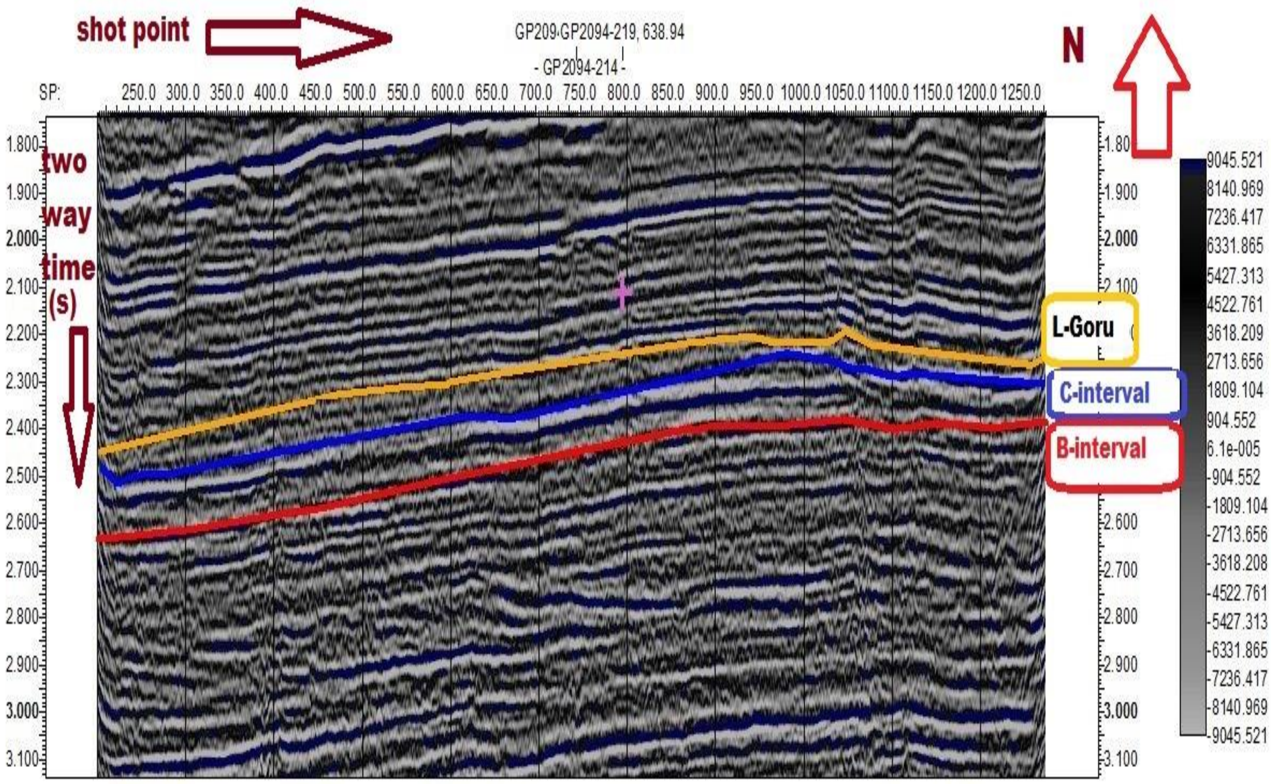


Figure 3.4: Interpreted seismic section of GP-2094-214.

3.4.2 Interpretation of the seismic Dip line GP2094 -221

After marking the seismic strike line GP2094- 214 we digitized this strike line with dip line GP2094- 221 because this strike line was crossing all the dip lines which are showen in the base map in chapter- 01. After digitizing the strike line with this dip line we marked the horizon and removed the miss tie. The faults were already marked on this seismic section. When faults and horizon were marked then the horst and Graben geometry formed as shown in fig.

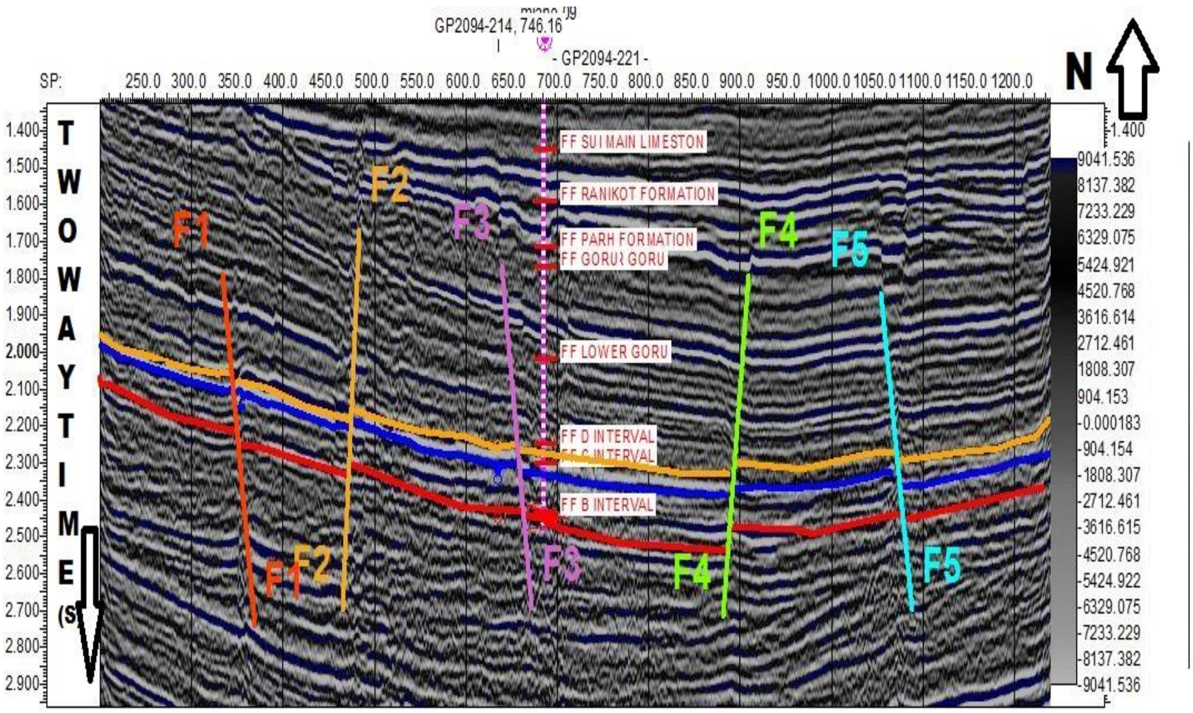


Figure 3.5: interpretation of seismic lines p2094-221.

3.4.2 Interpretation of the seismic Dip line GP2094 -219

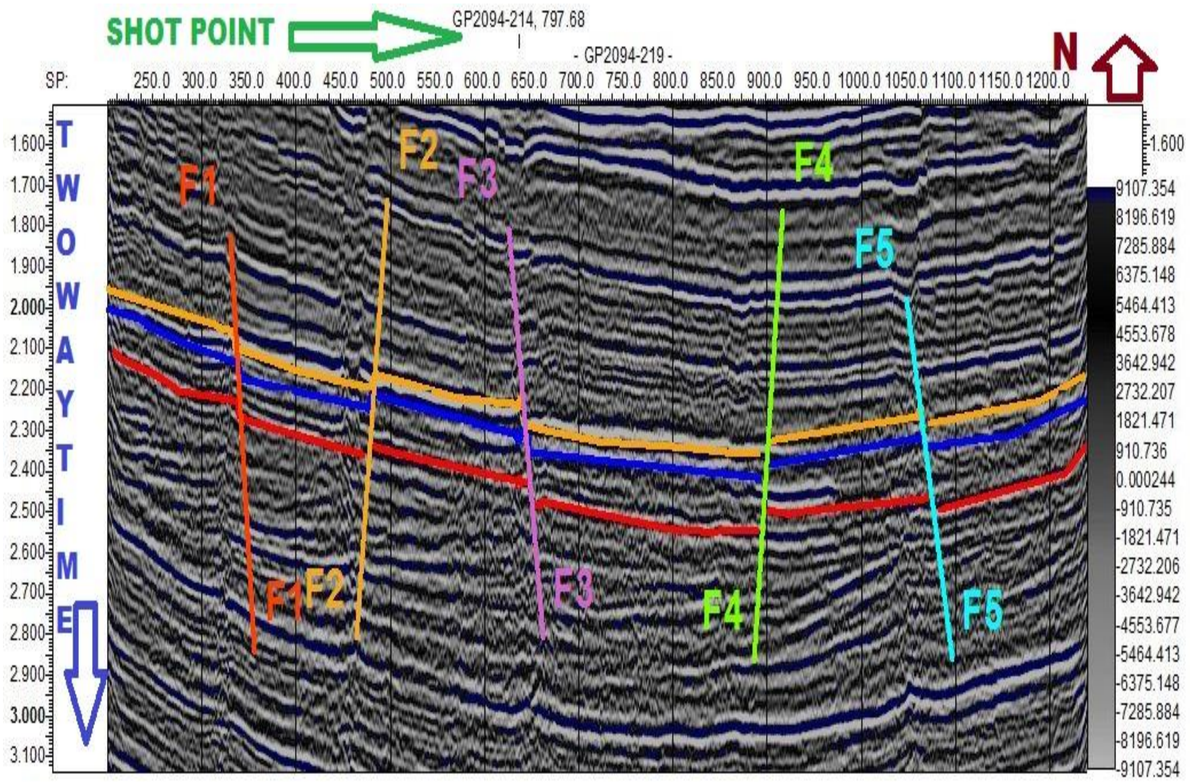


Figure 3.6: interpretation of seismic lines p2094-221.

3.5 Fault Polygon Generation

A fault polygon represents the lateral extent of dip faults or strike faults having same trend. Fault polygons show the sub-surface discontinuities by displacing the contours. To generate fault polygons, it is essential to identify the faults and their lateral extent by looking at the available seismic data. If one finds that the same fault is present on all the dip lines, then all points on base map can be manually joined to make a polygon. Figures show that after construction of fault polygons, the high and low areas on a particular horizon become understandable. Moreover, the linked color bar helps in giving information about the dip directions on a fault polygon if dip symbols are not drawn. Fault polygons are constructed for all marked horizons and these are oriented in E-W direction.

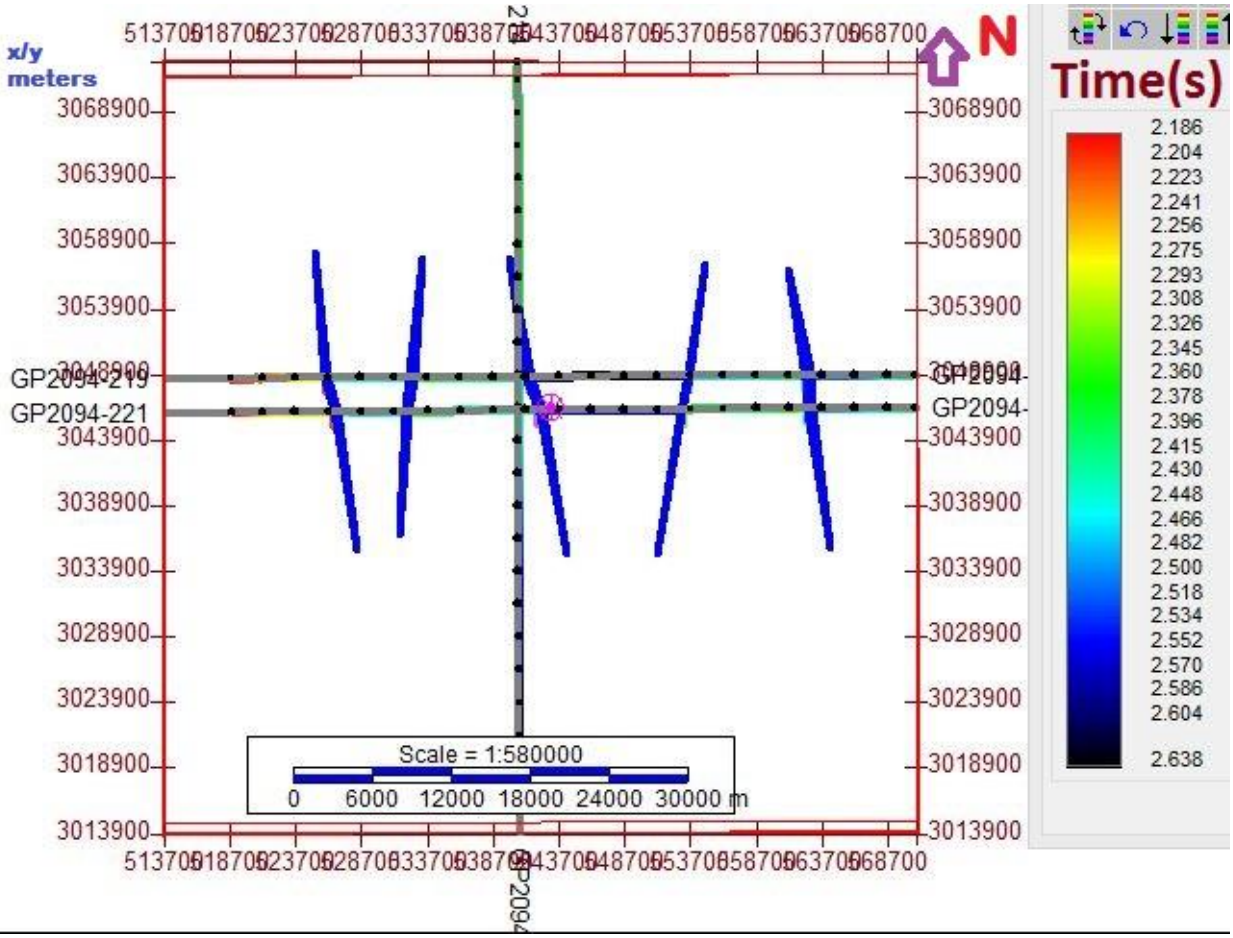


Figure 3.7 fault polygon of b interval.

3.6 Time Contour Maps

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

3.6.1 Time contour map of b interval:

TWT contour map of the B-interval has been prepared with contour interval of 75 milliseconds (0.075 seconds) as shown in Figure 3.7. Five major faults F1, F2, F3, F4 and F5 are considered in mapping. F1, F3 and F5 have dip direction NW-SE while F2 and F4 have dip direction of NE-SW. These faults are normal faults making the geometry of horst and graben. F3 and F4 are the left and right lateral faults making the horst and graben for the B . Those kinds of geometries represent the favorable sites for potential zones. The Figure 3.8 represent that there is very minor throw of the faults. The contours which are observed in the time contour map for the B-interval start from 2.188s and last contour has time 2.638s.Time contour map shows that B interval are shallower in the West and deeper in the East. As the contour time increases the response of the reflection is from the lager depth rather than the contour having the smallest time. The main objective of the time contouring is to get information about undulation in the time horizon due to folding and faulting.

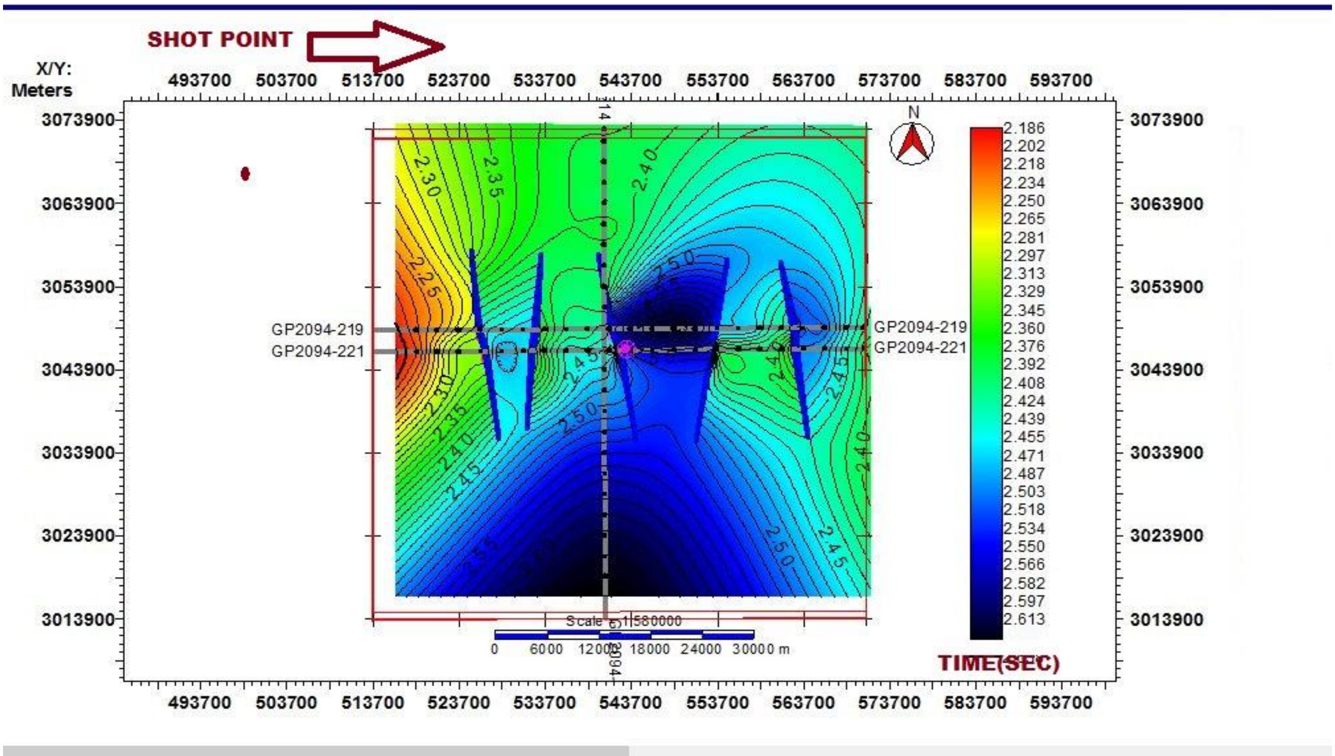


fig 3.8: Time contour map of B-interval.

3.7 Depth contour Maps

As the data is in the two way travel time, gives information about the subsurface structure. The depth contour map is prepared that truly related to the subsurface structure. Starting depth for B interval is 1930.530m and it ends up to 2743.805m depth. We have five faults having same directions as in the time contour maps. Formations are shallower in the West having depth of 1767.605m and deeper in the East with the depth of 2607.503m. Depth of the horizons is plotted against the Northings and Easting of the survey. Depth contour maps of the horizons are shown in the Figure 3.8.

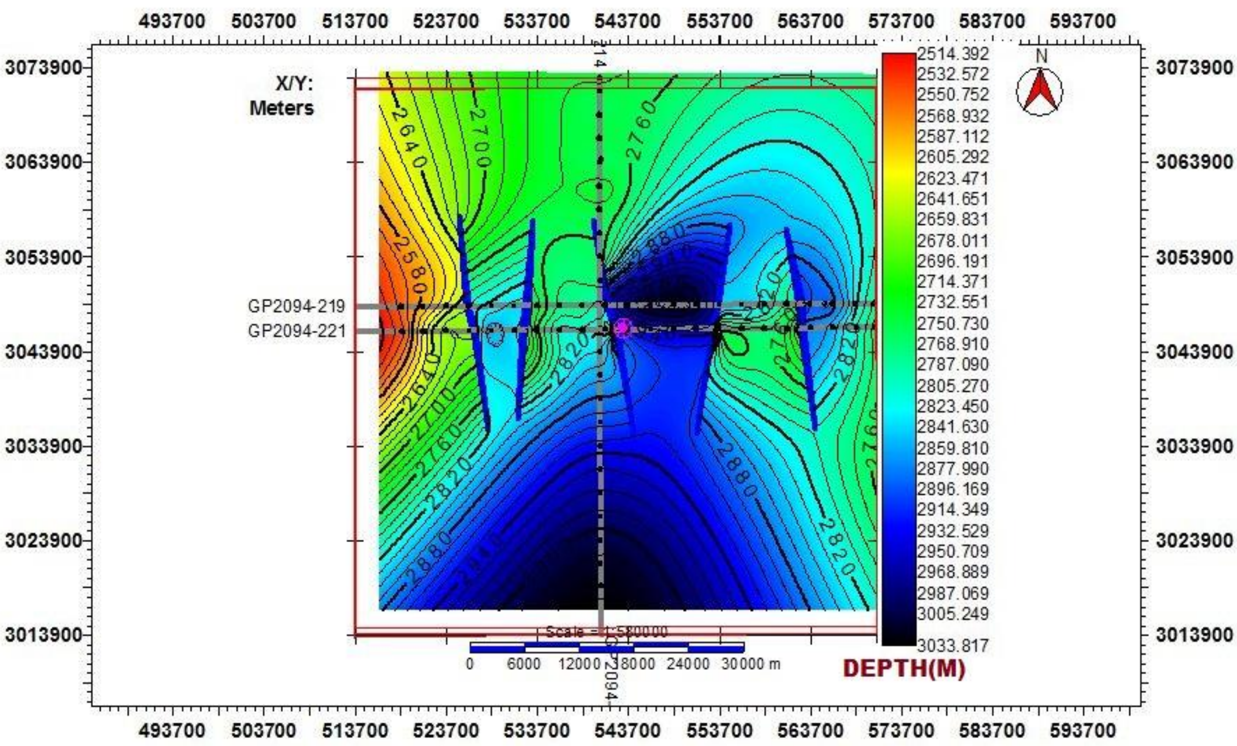


Fig 3.9 depth contour map of b interval.

Chapter#04

4.1 Introduction

Well logging is tool to measure the properties of the earth's subsurface. Through this process, various physical, chemical, electrical or other properties of rock /fluid mixtures penetrated by drilling a well into the earth are recorded. Petrophysics is the study of the physical and chemical properties that describe the occurrence and behavior of rocks, soils and fluids (Rider, 1996). This also defined "The petrophysics is description of physical properties relating the occurrence, behavior of rocks and fluids inside the rocks." (Asquith et al., 2004). Petrophysics uses well logs (caliper, resistivity, GR, DT, RHOB, Neutron logs etc.) and all pertinent information is obtain by use these well logs. Every well log has its own importance and these logs play very important role in quantifying the precise reservoir parameters such as porosity, permeability, net pay zone, fluid content and shale volume. Petophysical interpretation generally has less concern with the seismic and more concerned with using well bore measurements to contribute to reservoir description. (Krygowski,2004).

4.2 Classification of geophysical well logs

Geophysical well logs can be classified into three categories

- Lithology logs
- Resistivity logs
- Porosity logs

4.2.1 Lithology Logs

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

Lithology logs are

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

a) Caliper (CLAI)

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

b) Gamma Ray Log

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

$$Igr = \frac{GR_{LOG} - GR_{min}}{GR_{max} - GR_{min}}, \qquad (1)$$

Where GR_{min} is minimum value and GR_{max} is the maximum value of the gamma ray, Igr is the gamma ray index and GR_{LOG} represent the gamma ray log. Gamma ray logs are used to identify lithology, the volume of the shale and the correlation between the formations. (Asquith and Krygowski, 2004).

4.2.2 Resistivity well logs

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

Resistivity well logs are

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

a) Deep laterolog (LLD)

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

b) Shallow laterolog (LLS)

Shallow laterolog measure the resistivity of in the invade zone (R_i).In water-bearing zone, the shallow laterolog records a low resistivity because mud filtrate resistivity (R_{mf}) is approximately equal to mud resistivity (R_m), (Asquith and Krygowski, 2004).

4.2.3 Porosity well logs

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

Porosity well logs are

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

a) Sonic/Acoustic (DT)

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

Relation for the calculation of the porosity from the sonic log

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

$$\emptyset_S = \frac{\Delta t_{log} - \Delta t_m}{\Delta t_f - \Delta t_m} \qquad \textbf{(2)}$$

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

b) Neutron Porosity (Φ_n)

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

c) Density (RHOB)

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

Relation for the calculation of the porosity from the Density log ($\emptyset_d$)

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

$$\emptyset_d = \frac{\rho_m - \rho_b}{\rho_m - \rho_f}, \quad (3)$$

Where, $\emptyset_d$ represent porosity derived from the density log, $\rho_b$represent bulk density of formation, $\rho_m$represent matrix density and for sandstone it is 2.65 and ρ_f represent density of fluid. The main purpose of present petrophysics is to obtain calculation about porosity, saturation of water and hydrocarbon.

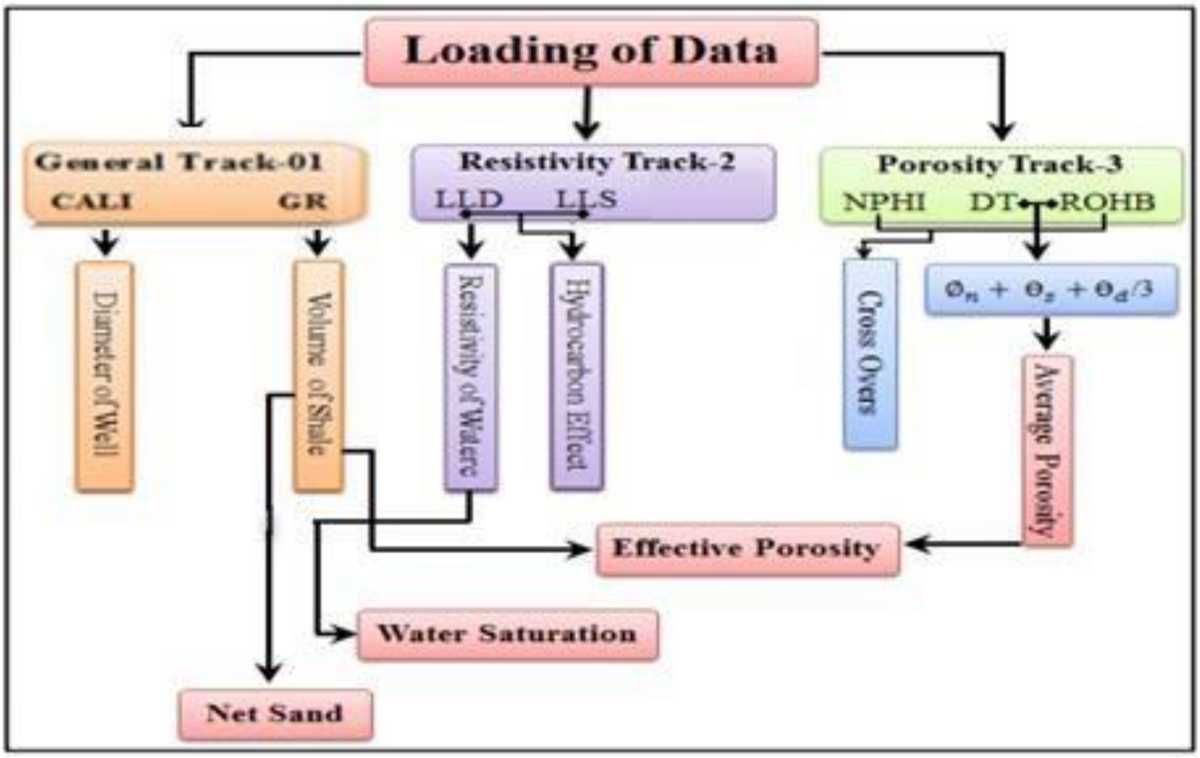


Figure 4.1: Methodology adopted for petrophysical interpretation.

4.3 Average porosity calculation

Sum of the porosities that are obtained from the different logs divided by number of logs from which porosity is calculated. Here Lower Goru formation is reservoir of cretaceous age for which the average porosity is calculated, to zone of interest reservoir, all the logs are interpreted. The relation is given below through which average porosity is calculated.

$$\emptyset_{avg} = \frac{\Phi n + \emptyset d + \emptyset s}{3}, \qquad (4)$$

Where $\emptyset_{avg}$ is the average porosity calculated from the available porosities, Φn represents neutron porosity, $\emptyset_d$ represent the density porosity and $\emptyset_s$ represent the sonic porosity.

4.4 Effective porosity ($\emptyset_e$)

This will define as "the ratio of the volume of interconnected pore spaces in a rock unit to the total volume of the rock by removing shale effect that rock unit". The zone which rich in the shale, effective porosity will be zero. Effective porosity is used to mark the saturated zone. The effective porosity can be calculated by the following formula. (Asquith and Gibson. 2004).

$$\emptyset_e = \emptyset_{avg} \times (1 - Vsh), \quad (5)$$

Where $\emptyset_e$ effective porosity which to be calculated, $\emptyset_{avg}$ represent the average porosity and Vsh

represents volume of the shale.

Mathematical relation for Water Saturation (S_w)

Water saturation in the formation can be defined as "The percentage of the pore volume filled by water in the formation". The saturation of water in the formation can be calculated by the following Archie equation

$$S_w = \sqrt[n]{\frac{F \times R_w}{R_t}}, \quad (6)$$

Where F is formation factor which is

$$F = \frac{a}{\emptyset^m} \quad (7)$$

R_w represent the resistivity of water, R_t represent the true formation resistivity ,n represents the saturation exponent ,a is the constant and its value is 1 in case of sand, ∅ represent effective porosity and m represents the cementation factor and it value is taken 2 for the sandstone.

Mathematical relation for Hydrocarbon Saturation (S_h),

$$S_h=1-S_w \quad (8)$$

Hydrocarbon saturation can be defined as "the pore in formation is filled with hydrocarbon". It can be calculated by using the following mathematical relation

Where S_w represent Hydrocarbon saturation, S_h represent hydrocarbon saturation.

4.5 Interpretation of well log

IHS Kingdom software is used for the analysis of Miano-09 well; within the depth Range of the B-sand 3331 m to 3390 m. Due to collapsing of wellbore Ruguosity effect will be occur. Therefore in the depth ranges, if there is Ruguosity, the value of the other log is not consistent. GR log, Caliper log are displayed in track-1.LLD and LLS log are displayed in track 2. DT, NPHI and RHOB are displayed in track-3.The crossover of NPHI and RHOB is important, if depth of NPHI is remain same but value of the RHOB is changed within that depth, it indicate fluid contact (Figure 4.2). Depth scale is shown in track-4. Volume of shale

V_{sh} is displayed in track-5. Shale and sand can be separated by applying 40% cut-off value. Below this cut-off value, there is a sand and above this cut-off, there is a shale. Density porosity is displayed in track-6, calculated from DT4P.Average porosity (PHIT) is displayed in track-7 and actually is the sum of NPHI and DT4P divided by 2. Effective porosity is displayed in track-8 after removal of the shale effect. Water saturation (SW) is displayed in track-9 and Hydrocarbon saturation is calculated from the water saturation.

B-sand petrophysics is done to depth from (3331 m) to (3390 m).In this way, interest zone that called the reservoir is from 3338 m to 3346 m defined where sandstone is encountered. The calculation parameter is displayed in the table.

Table 4.1 Calculated parameters for B-sand in Miano-09 Well.

Serial Number	**Calculation Parameter**	**Percentage % (3331-3385)m**	**Percentage % (3338-3346)m**
1	**Average Volume of Shale= Vsh_{avg}**	**44**	**24**
2	**Average Porosity Obtained From Density log= $Ø_{davg}$**	**11.3**	**18**
3	**Average Porosity in(PHIT) Percentage= $Ø_{avg}$**	**11.8**	**12**
4	**Average Effective Porosity in Percentage= $Ø_{eavg}$**	**6.4**	**8**
5	**Average water Saturation in Percentage=S_{wavg}**	**51.7**	**38**
6	**Average Hydrocarbon in Percentage=** [illegible]	**47.2**	**62**

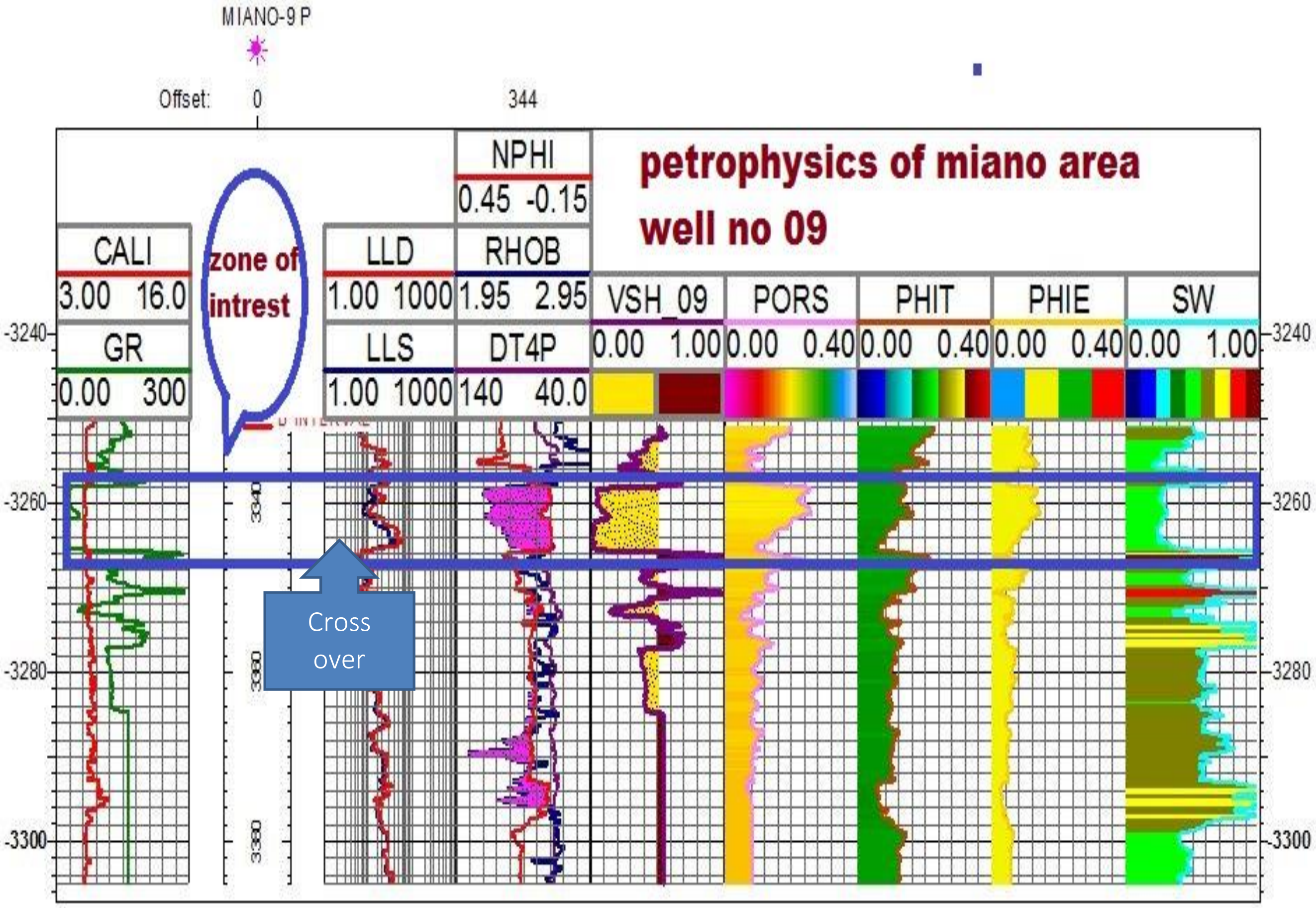


Figure 4.2: Petrophysical analysis of B-sand Miano well-09.

Chapter#05

5.1 Introduction

In geology, a facies is a body of rock with specified characteristics (Ravia et al., 2010). Ideally, a facies is a distinctive rock unit that forms under certain conditions of sedimentation, reflecting a particular process or environment. Sand-shale investigation has constantly been challenged for geoscientist. Key challenge is to classify and identify the facies, from logs or cores, degree to which shale content affect the reservoir properties. This feature is chief factor in illustrating the reservoir productive zones (Kurniawan, 2005). This leads us to identify different cross-plots that have relationship between reservoir properties and log response (Naji et al., 2010).

All these facies are releated to the certain sedimentary depositional environments. The depositional environment is a specific type of place in which sediments are deposited, such

as a stream channel, a lake, or the bottom of the deep ocean. They are sometimes called sedimentary environment .The different types of sedimentary depositional environment are showen in below Figure5.1.

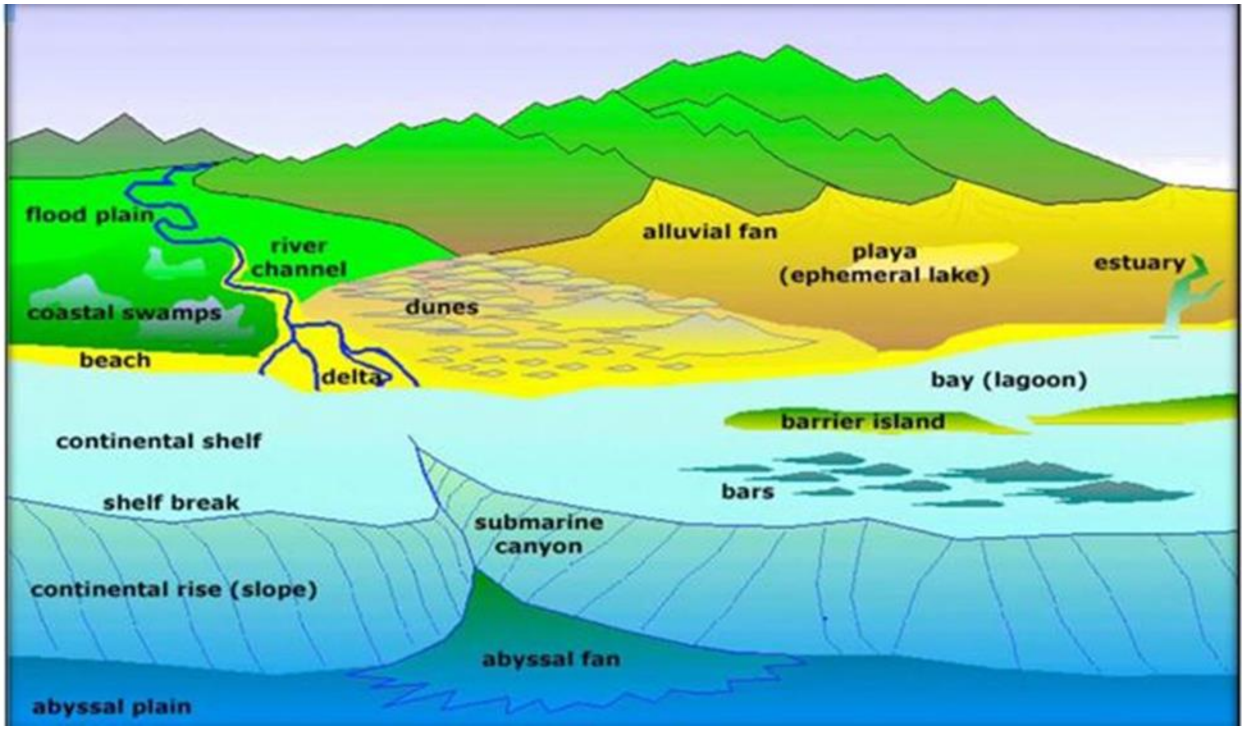


Figure 5.1 Different types of sedimentary environment (Elsevier, 1974)

5.2 Types of Facies

5.2.1 Sedimentary Facies

Sedimentary facies Sedimentary facies are bodies of sediment recognizably different from adjacent sediment deposited in a different depositional environment, as shown in figure 5.2 given below.

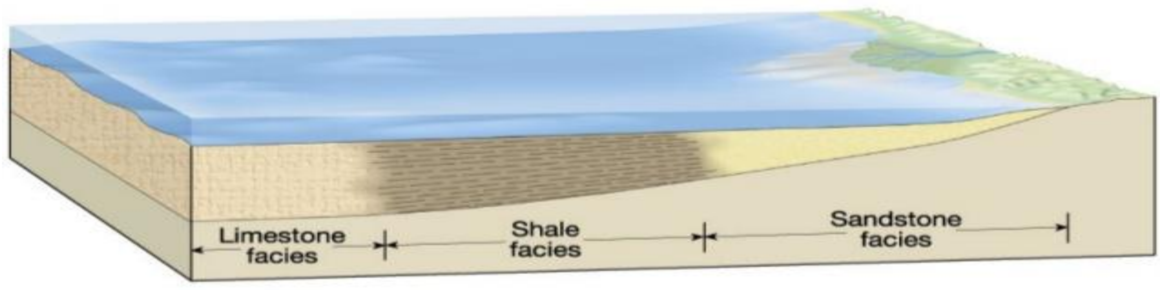


Figure 5.2 Sediment deposited in a different depositional environment (Naji et al., 2010).

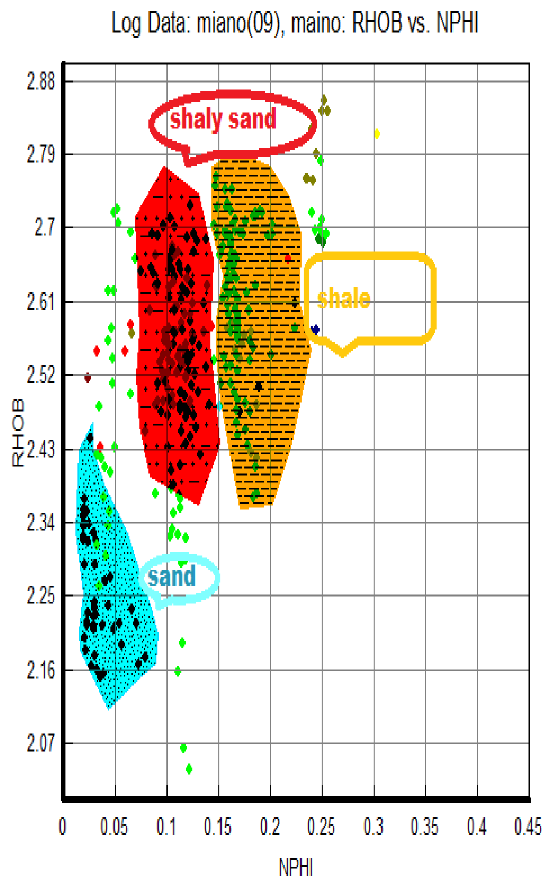
5.2.2 Metamorphic Facies

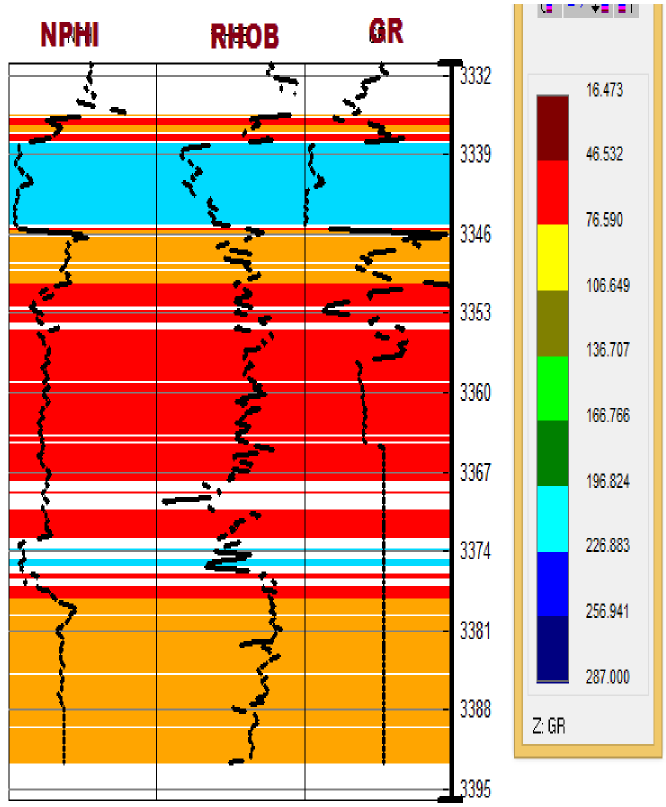
The sequence of minerals that develop during progressive metamorphism define a facies series.

5.3 Facies Analysis of the Lower Goru

Lower Goru is frequently inter-bedded sandstone and shale in different extents and is restricted mainly to the southern area of the Thar platform and the adjacent offshore (Quadri.and Shoaib, 1986). Lower Goru is typically composed of B, C and D intervals of sands. In the project area, B interval is acting as reservoir rock but evidence of hydrocarbon also exist in other intervals. Each porosity log behaves different in shales and also shaly sands. Cross-plot practice is appropriate for the analysis of porosity log response for sand-shale characterization. Crossplot are plotted that can help to identify the lithology in a qualitative way.

5.5 NPHI,RHOB and GR cross plot





Conclusion and Discussion

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

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

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

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