SEISMIC REFLECTION DATA INTERPRETATION, PETROPHYSICS, WELL CORRELATION AND FACIES MODELING OF BLOCK (20) OF MIANO AREA

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CERTIFICATE

This dissertation, submitted by Muhammad Asim S/o Muzammil Hussain is accepted in its present form by the Department of Earth Sciences,

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ABSTRACT

The study area is Block-20 Miano, and is located in Sindh province of Pakistan. It is present at the boundary of lower and central Indus Basin. The study area covers 2D vintage (1992) seismic time profile data of 8 migrated seismic lines (SEGYFormat) and seven wells (LAS files). The area has been identified as extensional regime. The main reservoir in the area is Lower Goru Formation especially its B Sand interval. Geophysical study includes the interpretation of seismic time profiles.

Six horizons i.e. Sui Main Limestone, Rani Kot, Upper Goru, Top of Lower Goru, C-sands, B-sands are marked on the seismic sections with the help of well top data and synthetic seismogram of Miano-08 well. On the interpreted seismic sections, the horst and Garben structures are observed, Time and depth contours and surface of Rani Kot Formation are formed.

Well log correlation and facies Modeling is also performed to determine the behavior of deposition. Petrophysical studies of include the determination of the porosities, resistivity of water, saturation of water, porosity,. The results show the presence of clean Sandstone and which may have ability to act as reservoir.

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CHAPTER # 01

INTRODUCTION

Introduction:

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

Latitude: 27° 14' N to 27° 32' N

Longitude: 69° 12' E to 69° 28' E

Location Map of the study area is shown in Figure (1.1).

Figure (1.1) Location Map of the study area (google-earth)

Introduction to lines:

In 1992, 2D seismic data was acquire the block-20 Miano Area. 2D seismic reflection data of Line P2092-110 and P2092-114. Detail of these lines is given in (Table 1.1).

S.NO.	LINE NO.	NATURE	LINE ORIENTATION
1	P2092-110	Dip	SW-NE
2	P2092-114	Strike	S-N

(Table 1.1) showing seismic lines

1.1 Data Formats:

- Navigation Data
- Las Data
- SEG-Y
- Well Data

1.2BASIC SEISMIC AQUISTION PARAMETERS:

The following basic parameters were in the acquisition of the seismic data shown in Table (1.2).

Area	Miano
Company	OMV
Crew	S.S.L
Nominal Fold	60
Party Number	115
Recoder Type	SN368
Record Length	5Sec
Sample Rate	2ms
Recording Filter	LC OUT; HC 125 Hz
Format	SEG-Y
Source	Vibrosies
No. of Sweeps per vibrater	8
Array Length	88.75M
VP Interval	50M
Geophones Group Distance	50M
Geophone Type	SM4 UB 10Hz
Geophones per Group	36
String Spacing	3M
Geophone Spacing	4.16M
Traces	120

Table (1.2) Basic Seismic Acquisition Parameters

1.3. BASE MAP:

Base map generally shows the well locations, concession boundaries, orientations of seismic survey lines and seismic surveys shot point. The base map also contains cultural data such as buildings and roads with a geographic reference like latitude and longitude or Universal Transverse Mercator (UTM) grid information. As shown in figure (1.2).

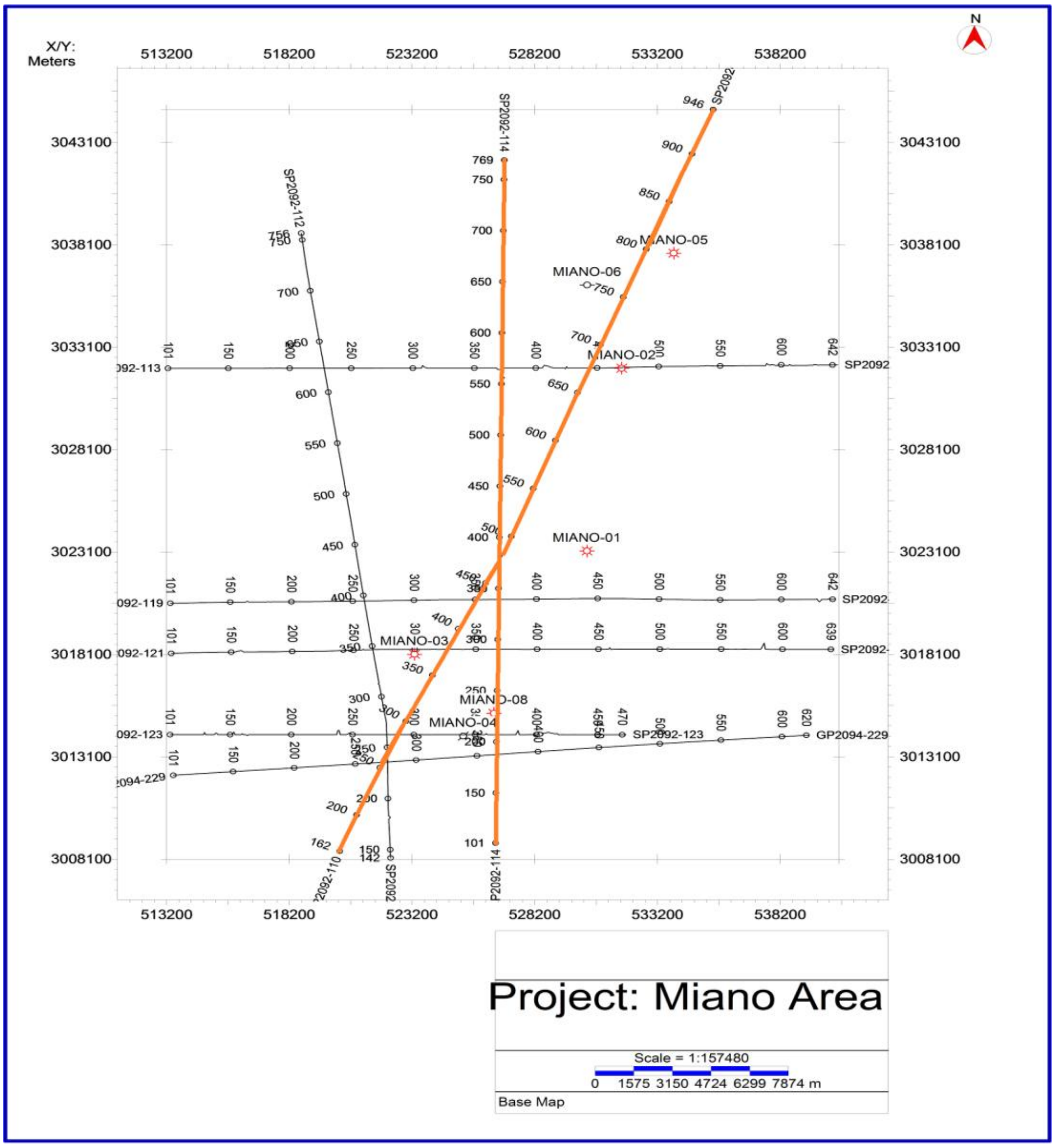


Figure (1.2) Base Map

CHAPTER # 02

GEOLOGY OF THE AREA

GEOLOGY OF THE AREA

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

2.1 Structure and Tectonic Settings:

Tectonically Pakistan comprises of two domains of large landmasses, i.e. Tethyan and Gondwanian Domains and is continued by the Indo-Pakistan crustal plate. The northern most and western regions of Pakistan fall in Tethyan Domain, which have complicated geology and complex crustal structure, While the Indus basin consists of the gondwanian domain. The Indus basin is the largest basin in Pakistan, oriented in NE-SW direction including the 25,000 square kilometers of SE part of Pakistan. Tectonically Indus basin is much stable area as compared to other tectonic zones of Pakistan (Kazmi & Jan, 1997).

It is further divided into three parts which are;

- Upper Indus basin
- Middle Indus basin
- Southern Indus basin

The Miano Field is located on the eastern part of a regional high, named as Jacobabad-Khairpur High, which is the major feature identified on the regional seismic lines in the Basin. The study area lies at the boundary of Middle Indus Gas Basin and southern Indus basin. The uplift episode occurred near cretaceous-tertiary (K-T) boundary established as the base of Tertiary unconformity against which many of the deep basement related and shallower wrench-tectonics related faults terminate. The second major phase of inversion in the eastern platform part of the Middle and Lower Indus basin took place in late Eocene time. Miano field shows a series of faults that trend in a nearly N-NW to S-SE, These faults are normal and strike slip in nature similar to the faulting found in the other fields in the area. These faults have some throw so these faults could isolate some of the sand reservoirs in the field. The Tertiary faults may have resulted from bending of the crustal plate due to collision and rebound relief or tensional release. Seismic studies and fault plane solution indicates that these are extensional features. Middle Indus basin is generally characterized by passive roof complex type structures (Kadri, 1995).

Regional Tectonic setting of the area is shown in the figure (2.1).

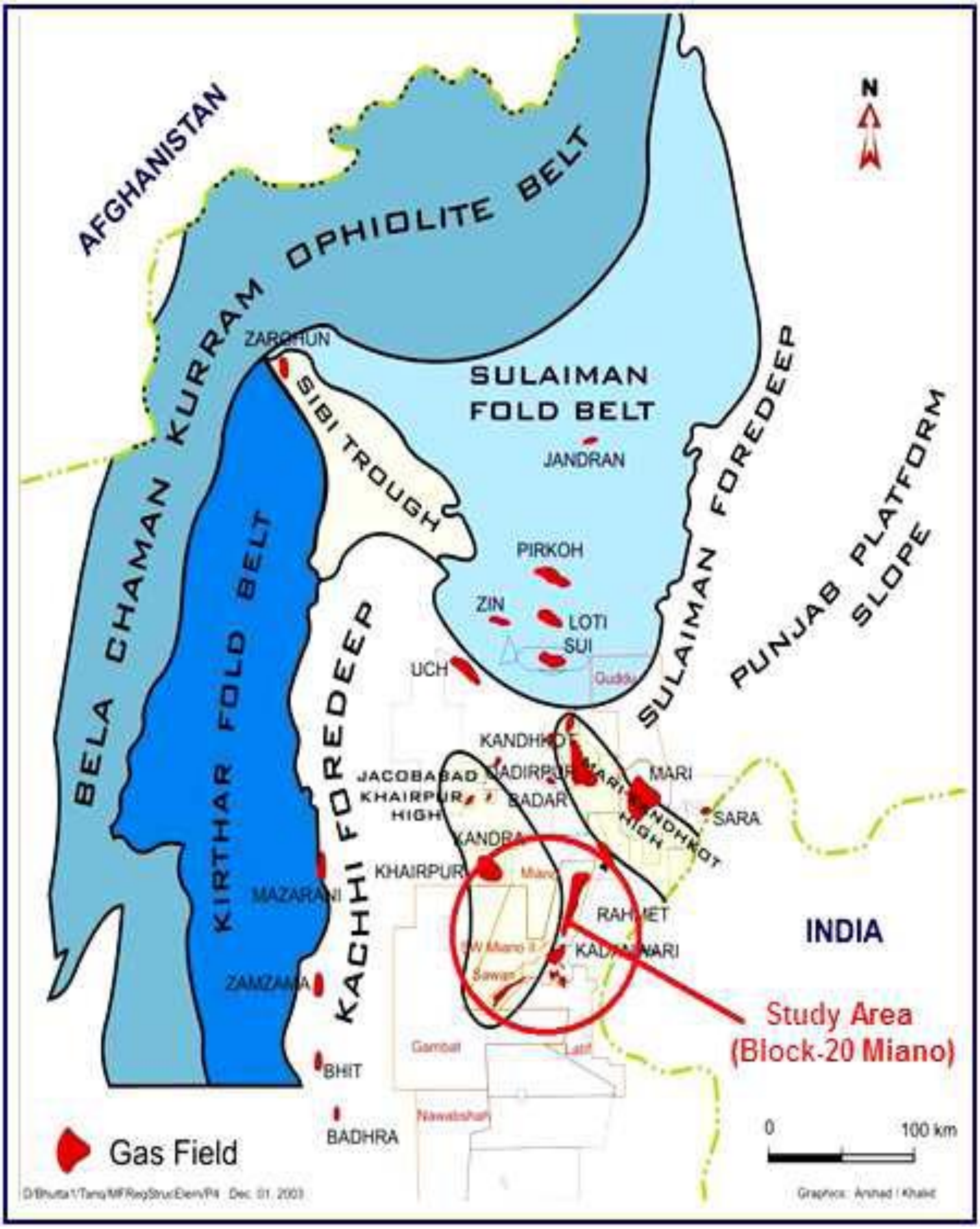


Figure (2.1). Regional tectonic map of Block-20 in the Middle Indus Basin (Mehmood et al. 2004)

2.2 STRATIGRAPHY

The sedimentary section of the study area in central Indus basin comprises mainly of Permian to Mesozoic sediments overlying, a strong angular unconformity of late Paleozoic age. The whole of area of study is thickly overlain by alluvium deposits as such no out crops are present at the surface, which can yield a direct evidence of the stratigraphic succession. The Mesozoic progradational sequence is deposited on eastward incline gentle slope. Every 10 prograding time unit represents lateral facies variation from continental to shallow marine in the west to the east. In the Thar slope areas all of Mesozoic sediments are regionally plunging to the west and are truncated unconfirmabaly by volcanic rocks (basalts of Khadro formation) and the sedimentary rocks of Paleocene age. Permain, Triassic and early Jurassic sedimentary rocks in the study area consists of inter-bedded sandstone, siltstone and shale of continental to shallow marine origin. The sedimentary cover in the study area consists mainly of Permian to Mesozoic sedimentary rocks overlying a strong angular unconformity of possibly late Paleozoic age (Kadri, 1995).

The early to middle Jurassic aged Chiltan Limestone in the Middle Indus Basin forms a prominent seismic reflector, which has a smooth planar character. Flattening seismic sections on this horizon helps to remove the complexity of Tertiary structural tilting and faulting, a process that better resolves depositional architecture. The Chiltan Limestone is overlain and down lapped by a Late Jurassic to Early Cretaceous regressive strata comprising bottomsets, foresets and topsets that prograde towards west from the Indian craton. In lithostratigraphic terms the argillaceous foresets to these prograde are called the Sembar Formation which is an important source rock in the basin. The initial topsets to the progrades have been called the Chichali Formation, while the younger topsets are called the “A” Sand Member of the Lower Goru. No name has yet been given to the sandy submarine fan systems associated with this prograding complex (Sturrock and Tait, 2004). The Sembar Formation was deposited over large area of the Indus Basin in marine environment; it consists mainly of black shale with subordinate amounts of siltstone, sandstone and argillaceous limestone. The Sembar Formation is considered to be the primary 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. The organic matter in the Sembar Formation is type-III kerogen which is capable of generating gas, but type-II kerogen is also present (Wandrey et al. 2004).

The Lower Goru Formation was deposited during the deposition of the latter part of Late Jurassic to Early Cretaceous regressive system.The LowerGoru “A”, “B”, “C” and “D” sequences were deposited during a gradual and long term 3rd order eustatic or tectonic-eustatic sea level rise. The deposition is punctuated by high-frequency 4th and 5th order relative sea level fluctuations. These fluctuations led to the deposition of prograding clastic sand packages on a vast and widespread ramp. Balance between intermittent and slow addition of accommodation space and ample sediment supply from the east and E-SE maintained an overall aggradational packages to slightly progradational profile on “A”, “B”, and “C” intervals’. The present-day eastward tilt of strata in the study area works with the westwards facies related shale-out of sands to provide stratigraphic trapping of hydrocarbons.

In the study area lateral (N-S) shale-out or corrosion in reservoir quality of the “B-sand” reservoir, towards west shale-out of sand to distal settings and to the east structural tilt provide combined structural-Stratigraphic trapping system (Krois et al. 1998). The generalized stratigraphic coloum of the indus basin is shown in figure (2.2).

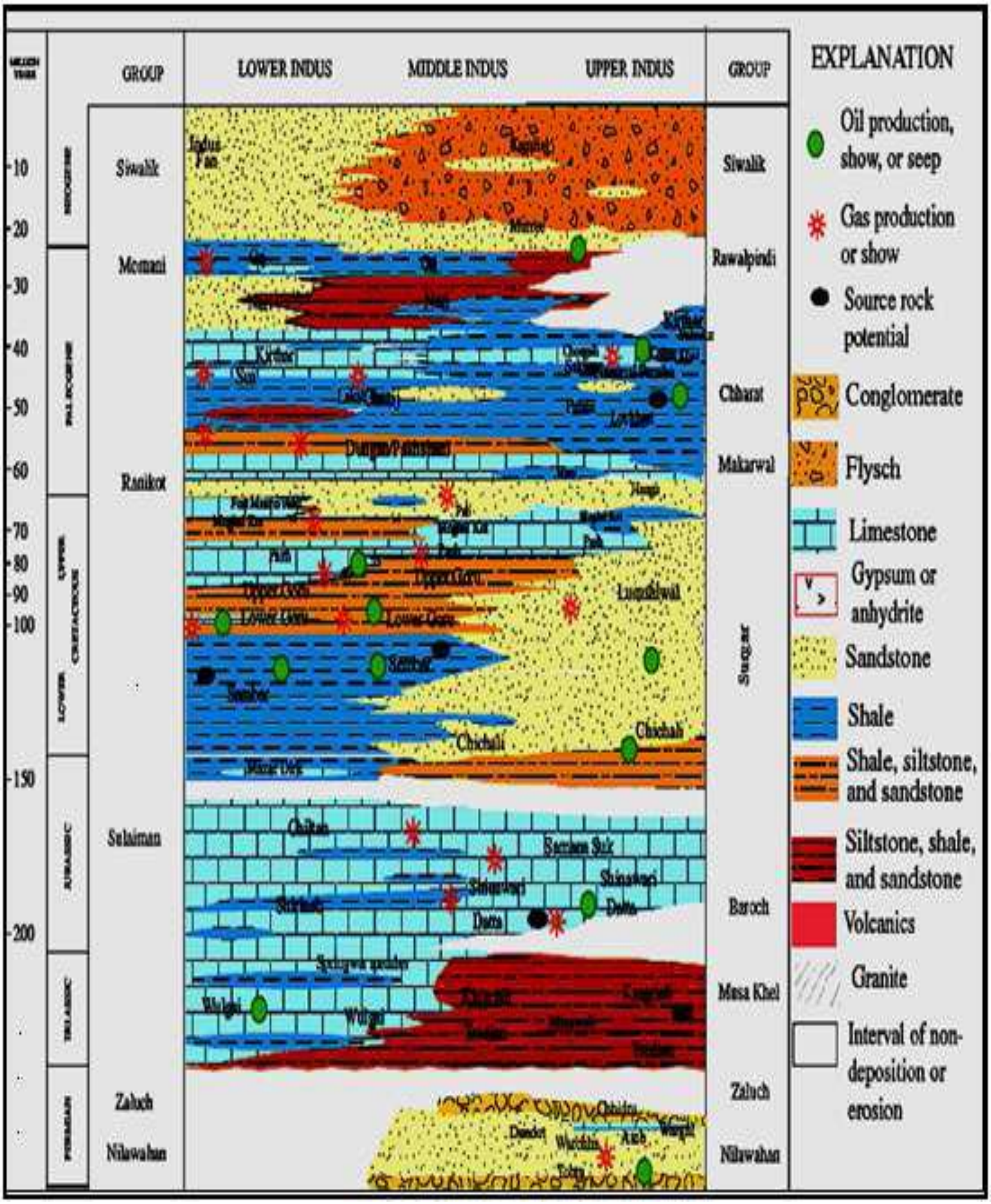


Figure (2.2) Generalized stratigraphic column of Indus basin (www.gsp.com.pk).

2.3 Petroleum Prospects:

Different gas fields like Kadanwari, Sawan, Miano and Tajjal are present in the area. The Stratigraphic column of the area shows different rocks act as Source, reservoir and Cap rock in the area.

2.3.1 Source Rocks:

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

- Sember Formation:

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

- Ranikot Formation:

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

- Habib Rahi Limestone :

In the middle Indus basin source rock analysis of early Eocene rock indicate the presence of organic matter. Middle Eocene aged Habib Rahi limestone member of Kirther Formation contains the maximum reported TOC's of 5.25%, It is appears to be organic rich and burns when lit.

2.3.2 **Reservoir Rocks:**

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

2.3.3 **Cap, Seal and Trapping mechanism:**

The trapping Mechanism for the target reservoir in the study area is combination of structural and stratigraphic. An E-NE to S-SW trending isopach thick in the Lower Goru "C" Interval forms the structural trap, Supported by the horsts due to normal faulting. Towards the NE and SW trapping is caused by shaling out of the reservoir. The northwestern limit is defined by a facies controlled deterioration in reservoir quality, which creates an "effective zero reservoir" line. Transgressive shales of the Lower Goru "C" Interval directly, overlying the 'B' interval of reservoir sands, and thick shales and marls of the Lower Goru Formation form the regional top seal for the reservoir in the area. Shales and tight sands within the C-Interval of Lower Goru Formation act as lateral and bottom seals (Krois et al. 1998).

CHAPTER #03

SEISMIC DATA AQUISITION

3.1 Introduction

The fundamental purpose of seismic surveys is accurately to record the ground motion caused by a known source in a known location. The record of ground motion with time constitutes a seismogram and is the basic information used for interpretation through either modeling or imaging. The essential instrumental requirements are to:

- Generate a seismic pulse with a suitable source
- Detect the seismic waves in the ground with a suitable transducer
- Record and display the seismic waveforms on a suitable seismograph

The general methodology of examining hidden structures by studying their effects on artificially generated acoustic or seismic waves has an enormously wide range of applications covering a wide range of spatial scales.

3.2 Field Operations

3.2.1 Energy Source

Seismic exploration uses sound produced artificially at or near the surface of the earth. There are a great many ways that the sound can be produced. An explosive detonated in a hole in the ground is a particularly good source. A controlled vibration imparted to the earth can be used in cities without disturbing the inhabitants.

Explosive Source

For much of the history of seismic exploration, almost the only type of energy source used was an explosive in a hole in the ground. This is still one of the most common type for shooting on land. Seismic source used for the line of study was also explosive (dynamite). When a charge is to be fired in a hole, the hole is normally drilled by a rotary drill which is usually mounted on a truck. After the hole is drilled, it is usually loaded with explosive by the drillers. For use in hole explosives are packaged in one piece plastic tubes, threaded on both ends so tubes can be screwed together to make up larger charges.

3.2.2 Geophone

Seismic energy is a form of mechanical energy. Seismic receivers convert this mechanical energy into electrical energy (see figure 3.1(a)). Different devices to perform this conversion must be used, depending on the environment and physical quantity to be measured. In land operations the quantity being measured is ground motion.

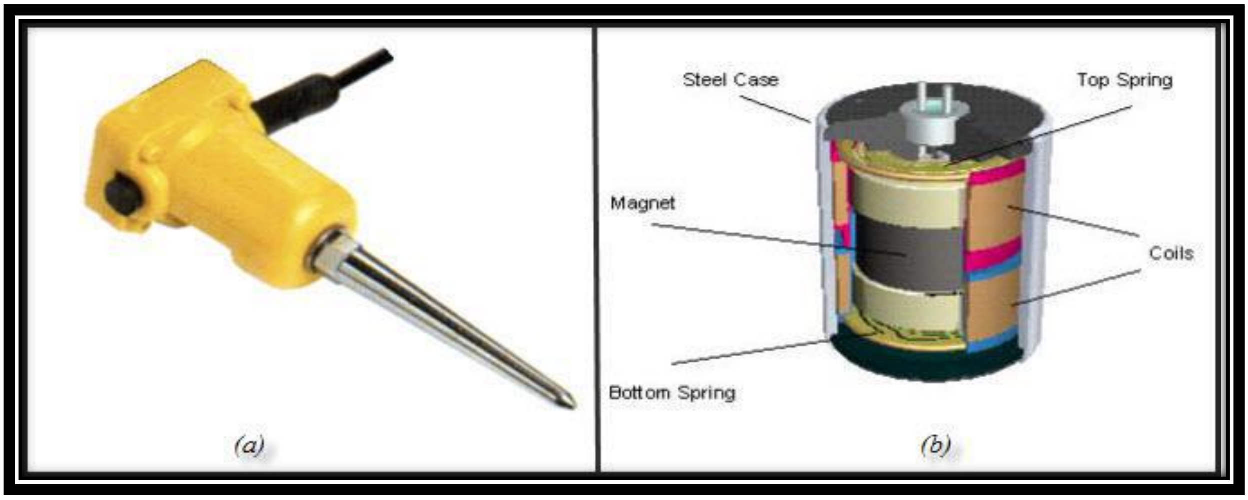


Figure (3.1). (a) Geophone, (b) Internal Structure of Geophone

Principle and Working

The type of geophone generally used in seismic exploration on land is consists of a powerful permanent magnet and a coil of wire around the magnet, all in a rugged case. The magnet is attached rigidly to the case, which also serves as a retainer for the magnetic field. The coil, made of fine copper wire is connected to the case by a spring (see figure 3.1(b)). The geophone is placed in firm contact with the ground. Then any shaking of the ground will shake the case and magnet. Relative movement between magnet and coil generates electric current. The bits of current generated by the movements of the magnet make up the signal from the geophone.

3.2.3 Cables

On most land crews, geophones are spread out in a line, connected by a cable to the recording equipment. The data from each geophone group is transmitted along one pair of wires, so the cable has many pairs of wires as there are geophone groups: 24, 48, etc. At intervals, the cable has takeouts, pairs of wires to be connected to the group of geophones.

3.2.4 Recording

A seismic source produces sound that goes into the earth, is reflected from rock layers, and arrives at the surface of the earth. The geophones convert some of that sound into electrical energy, which the cable conveys to the recording equipment.

3.2.5 Spread Geometries

An array is a group of two or more elements (sources or receivers) arranged in a geometrical pattern. The pattern may be one or two-dimensional (linear or areal). The function of arrays is to do spatial filtering. An arrays response depends upon wavelength or wave number of seismic energy produced or received. There are different types of spread configurations used during seismic data acquisition.

Symmetric Spread Configuration

The spread configuration used during the acquisition of the data for the line of study was symmetric spread. In this type of configuration source and receivers are placed in a single line and source is placed at the middle of the line and on both sides of the source equal number of geophone is placed. As shown in figure (3.2).

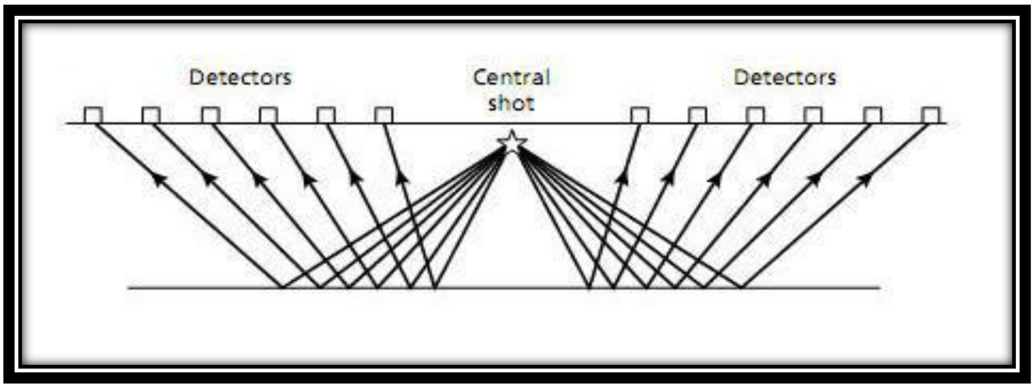


Figure (3.2): Symmetric Spread

3.3 Recording Systems

Recording a seismogram is a very difficult technical operation from at least three key aspects:

- The recording must be timed accurately relative to the seismic source.
- Seismograms must be recorded with multiple transducers simultaneously.
- The electrical signals must be stored for future use.

Seismic data can be recorded by two types of recording systems:

- Analog System
- Digital System

3.4 Recording Format

Most seismic data is recorded on half-inch wide magnetic tape in 9-track format, that is, with nine pieces of information in the width of the tape. The tape recorder has nine recording heads in that half inch of width.

3.5 Seismic Recorder

Seismic Recorder picks seismic signals (vibrations) from geophone and sensors record them on magnetic media in a digital format. It consists of multiple channels, each connected to a geophone group. As shown in figure (3.3).

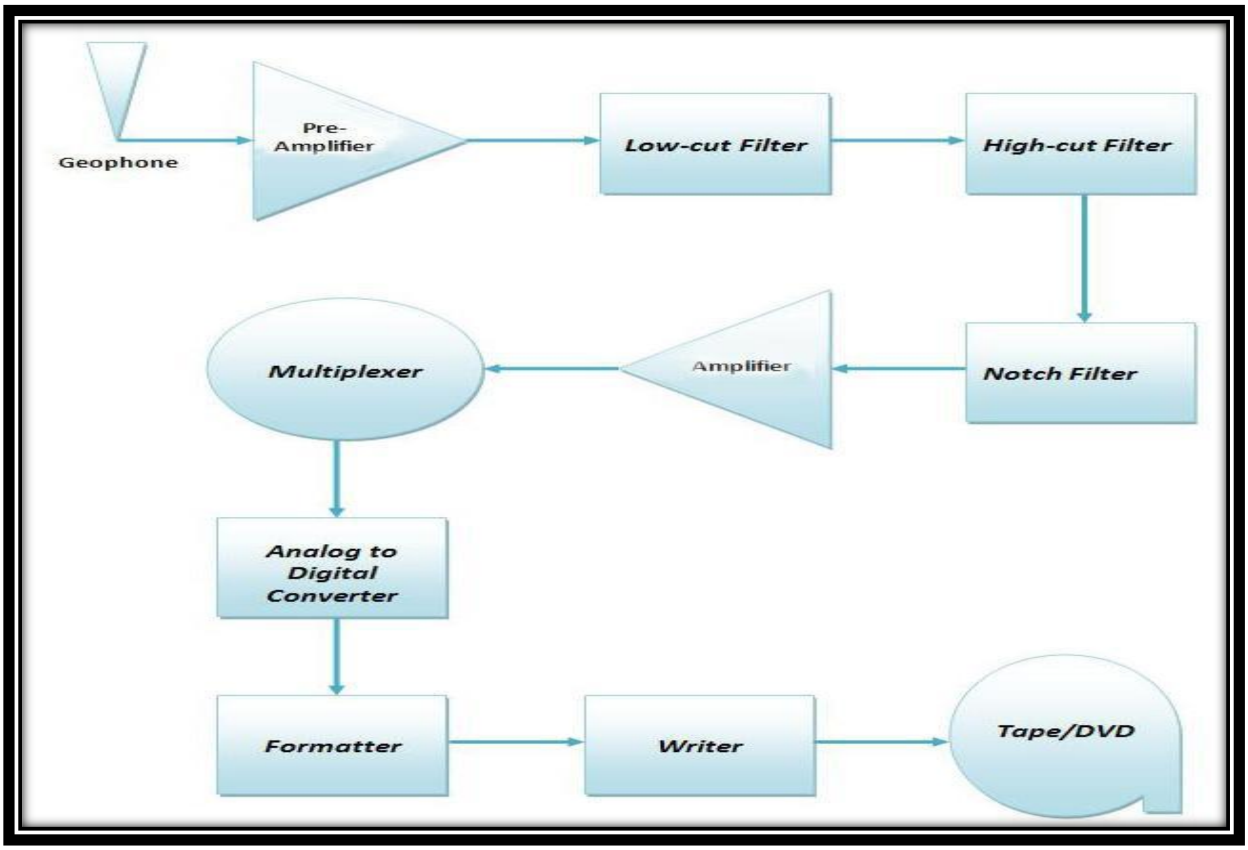


Figure (3.3) Seismic Recorder

3.5. Seismic Data Processing:

Processing is a sequence of operation, which are carried out according to the pre-defined program to extract useful information Data from a set of raw data as an input-output system (Al. Sadi, 1980). Seismic processing flow chart is shown in figure (3.4).

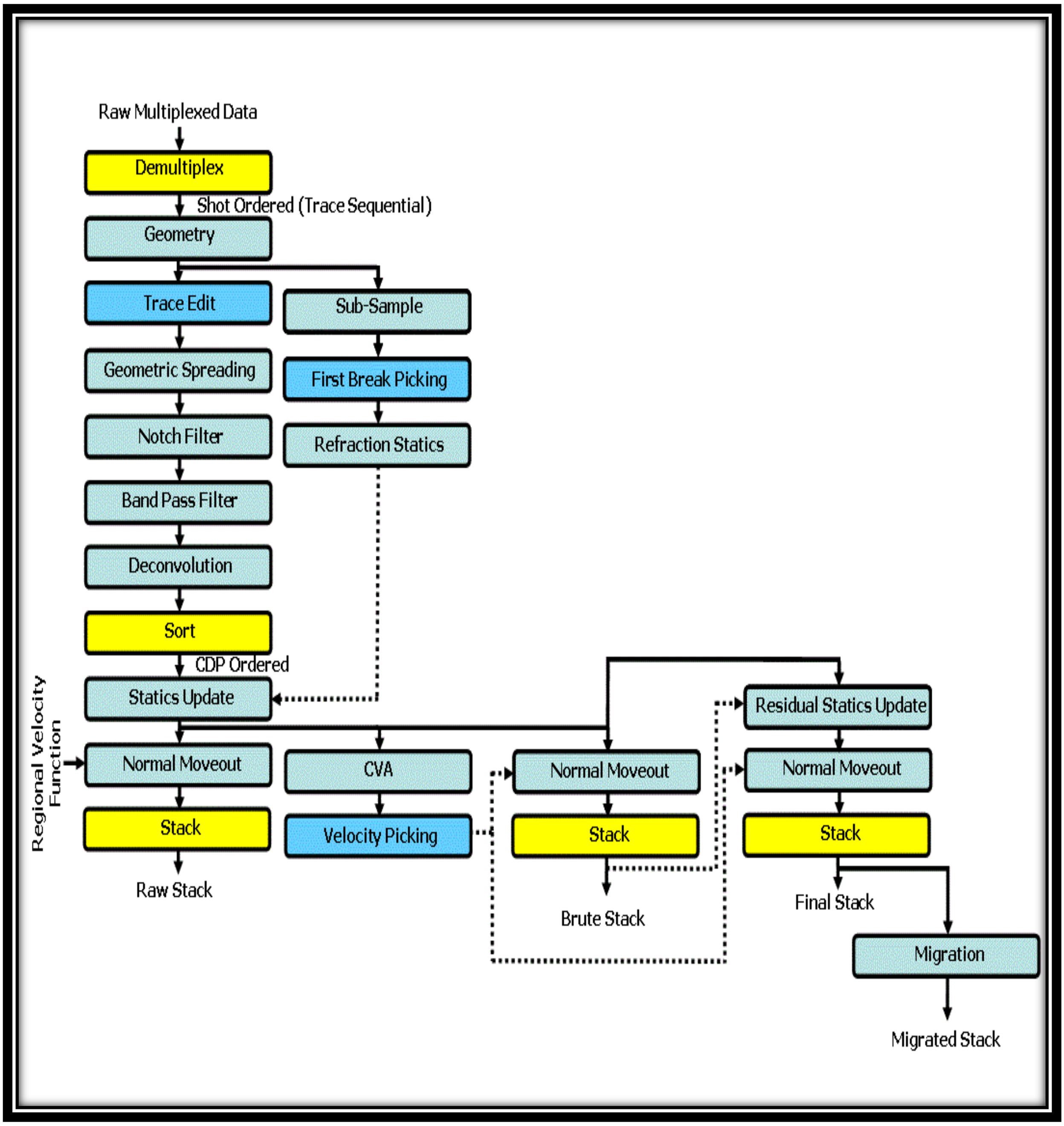


Figure (3.4). Seismic processing flow chart.

CHAPTER # 04

SEISMIC VELOCITIES

4.1. INTRODUCTION

In seismic prospecting, we deal with a medium, which is made up of a sequence of layers of different velocities, so it is necessary to specify the kind of velocities that are used. In Geophysics the word velocity refers to several different concepts. The most common concepts of velocity are briefly the following:

- Root Mean Square velocity
- Average velocity
- Interval velocity

4.1.1 VELOCITY DETERMINATION

Velocity measurement can be direct, requiring the existing of a borehole, or indirect, based on time differences observed on the surface and estimate of reflector depth or layer thickness. Various methods are used for velocity determination. In seismic Prospecting two main approaches are available for the velocity measurements.

- By use of exploration oil well, this is a direct method. A velocity function is computed from the continuous velocity survey.
- By use of reflection travel time during processing, this is an indirect method.

4.1.2 USES OF SEISMIC VELOCITIES

The seismic velocities may be used to establish the following

- True depth.
- Stacking of seismic data.
- Migration of seismic data.
- Possible lithology determination.
- Possible porosity estimates.
- Overpressure-zone

4.1.3 SOLVING THE VELOCITY TIME PAIRS

The Root Mean Square Velocity functions given on a seismic section were processed by using excel sheet to compute interval & average velocity functions using Dix equation.

$$V^2_{int,n} = V^2_{rms,n}T_n - V^2_{rms,n-1}T_{n-1} / T_n - T_{n-1}$$

The input velocity functions are Root Mean Square (RMS) velocities, from these RMS velocities excel computes Interval and Average Velocities.

Average velocities are further used for time to depth conversion to see the depth of reflectors, the variation in average, interval and R.M.S can be seen with respect to time on the sections below. Along Y axis we have time in (Milliseconds) and along X axis we have velocities of line P2092-110 and 114 respectively. These graphs shows the variation of velocities with increasing time.

These graphs show the variation of RMS velocity with increasing time of both seismic lines. As shown in figures (4.1a) and (4.1b) respectively.

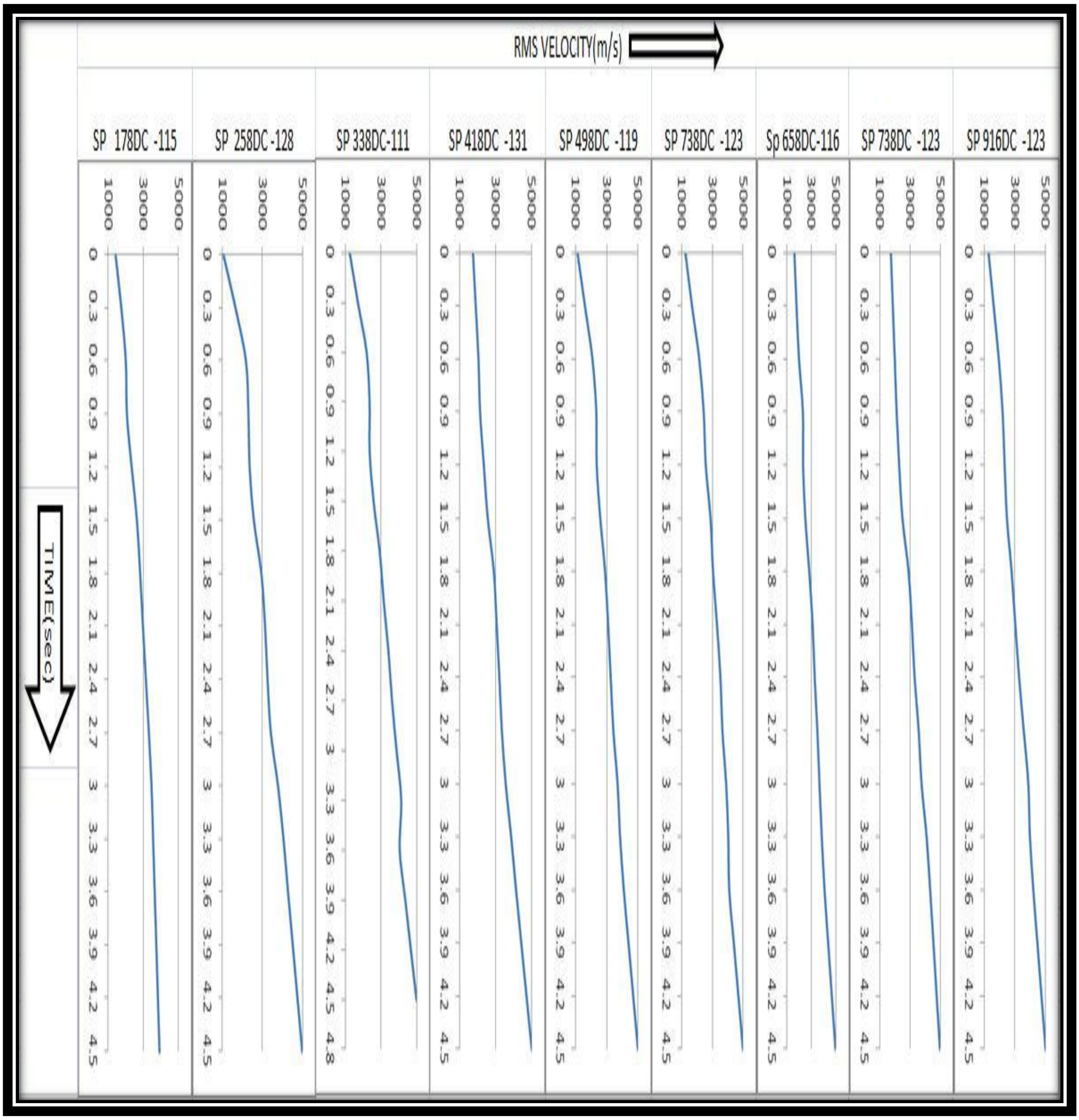


Figure 4.1(a) RMS velocities of Line P2092-110

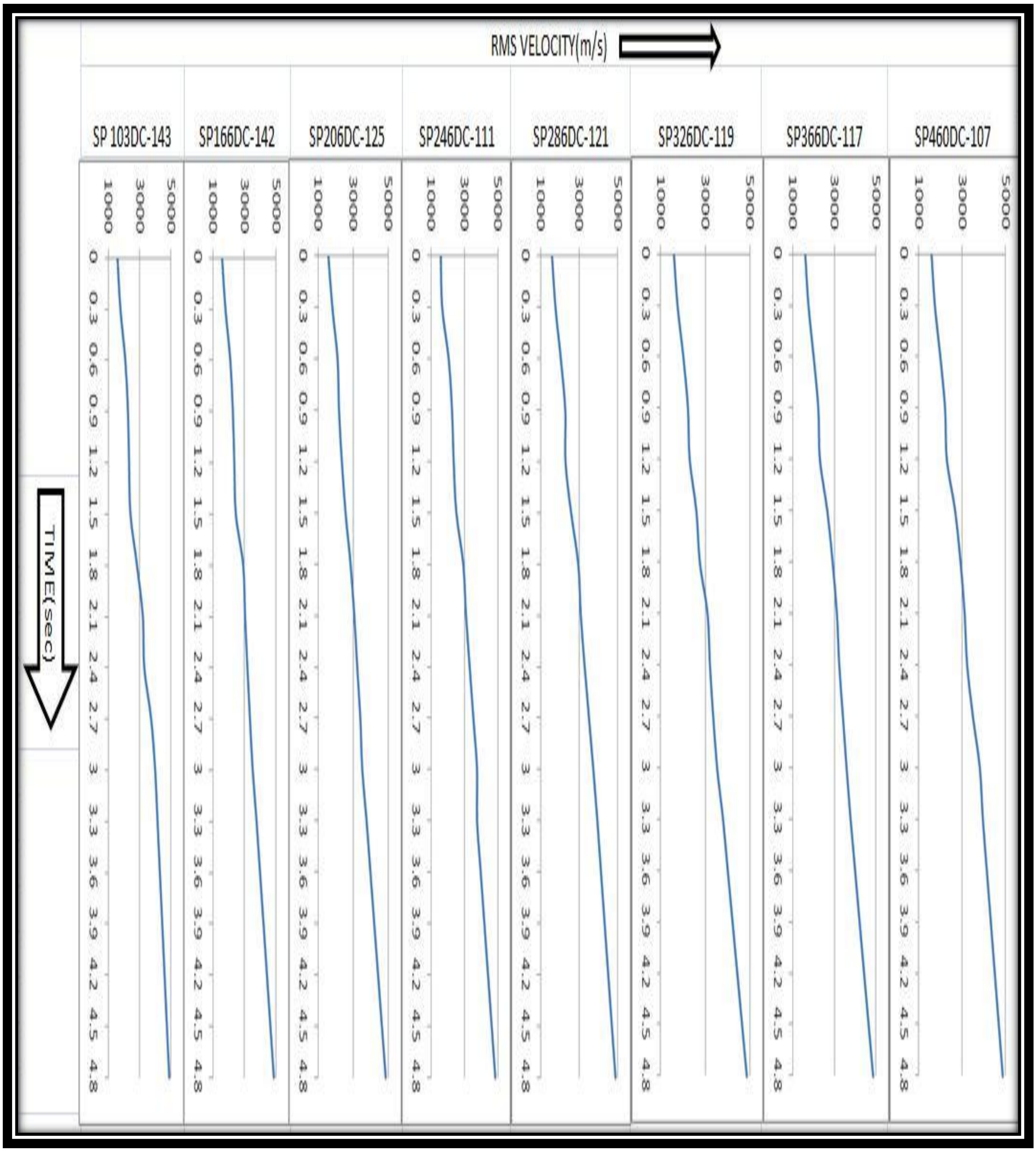


Figure 4.1(b) RMS Velocities of P2092-114

Figures (4.2a) and (4.2b) show the variation of average velocities with increasing time of both seismic lines.

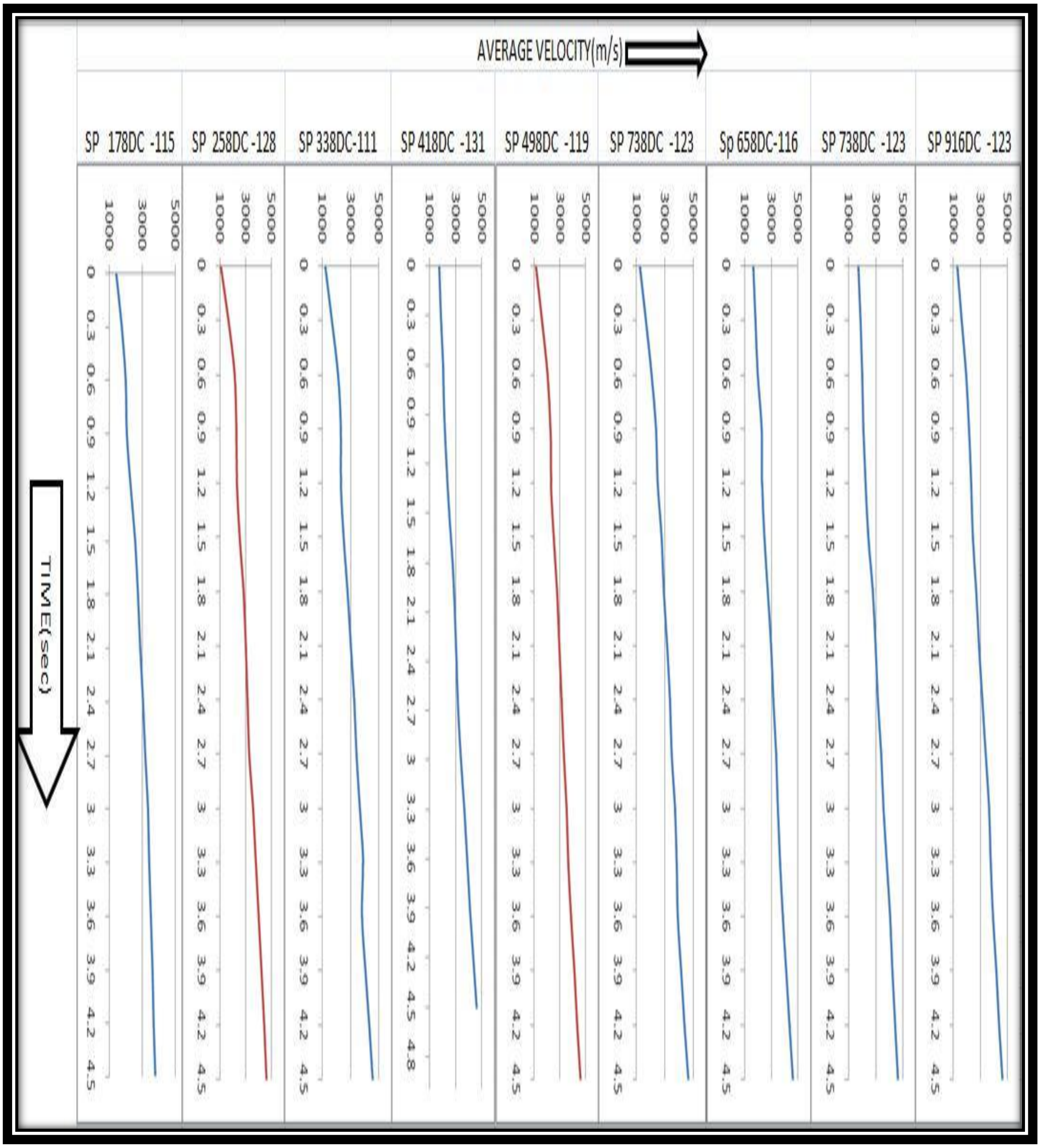


Figure 4.2(a) Average Velocities P2092-110

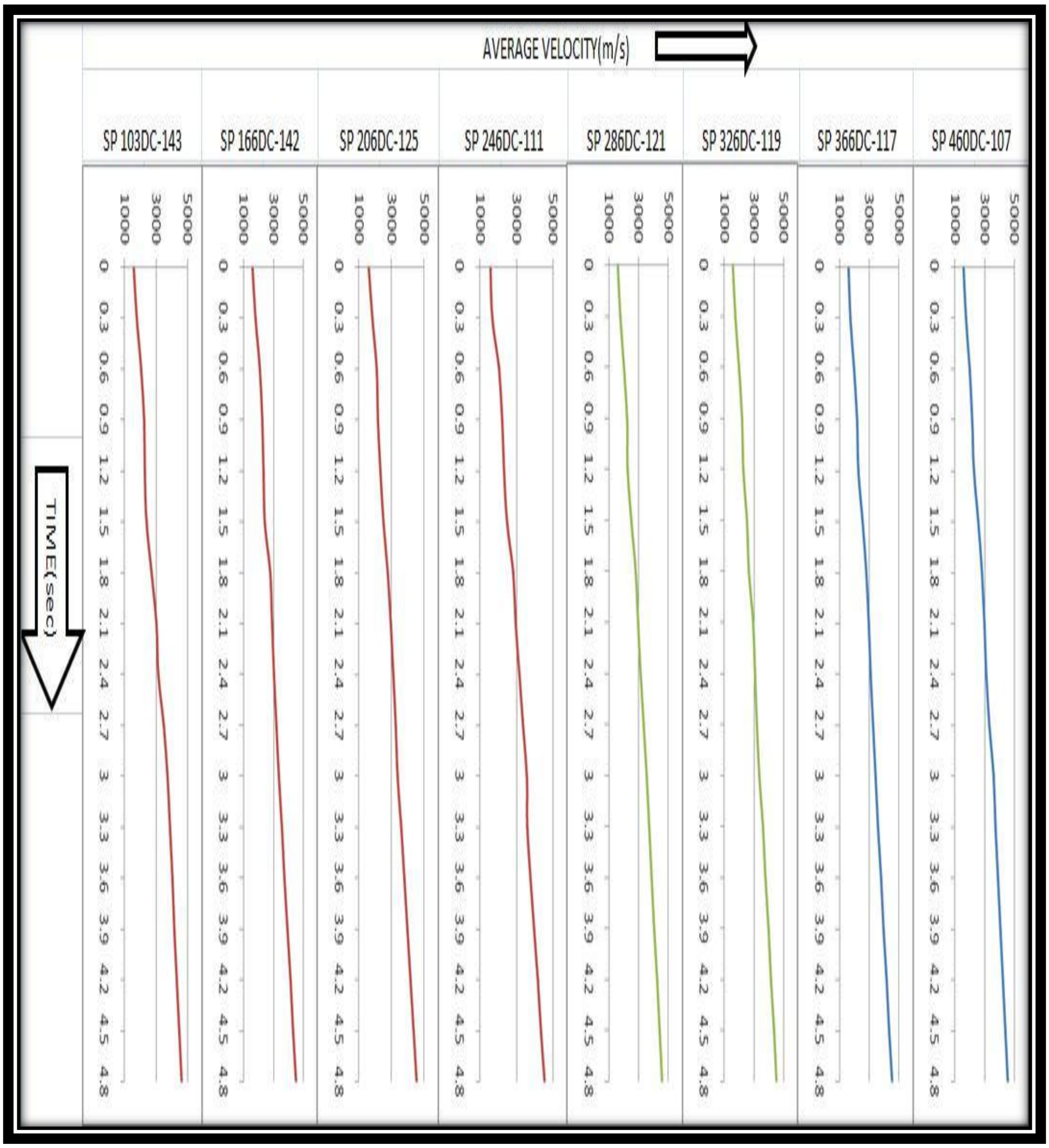
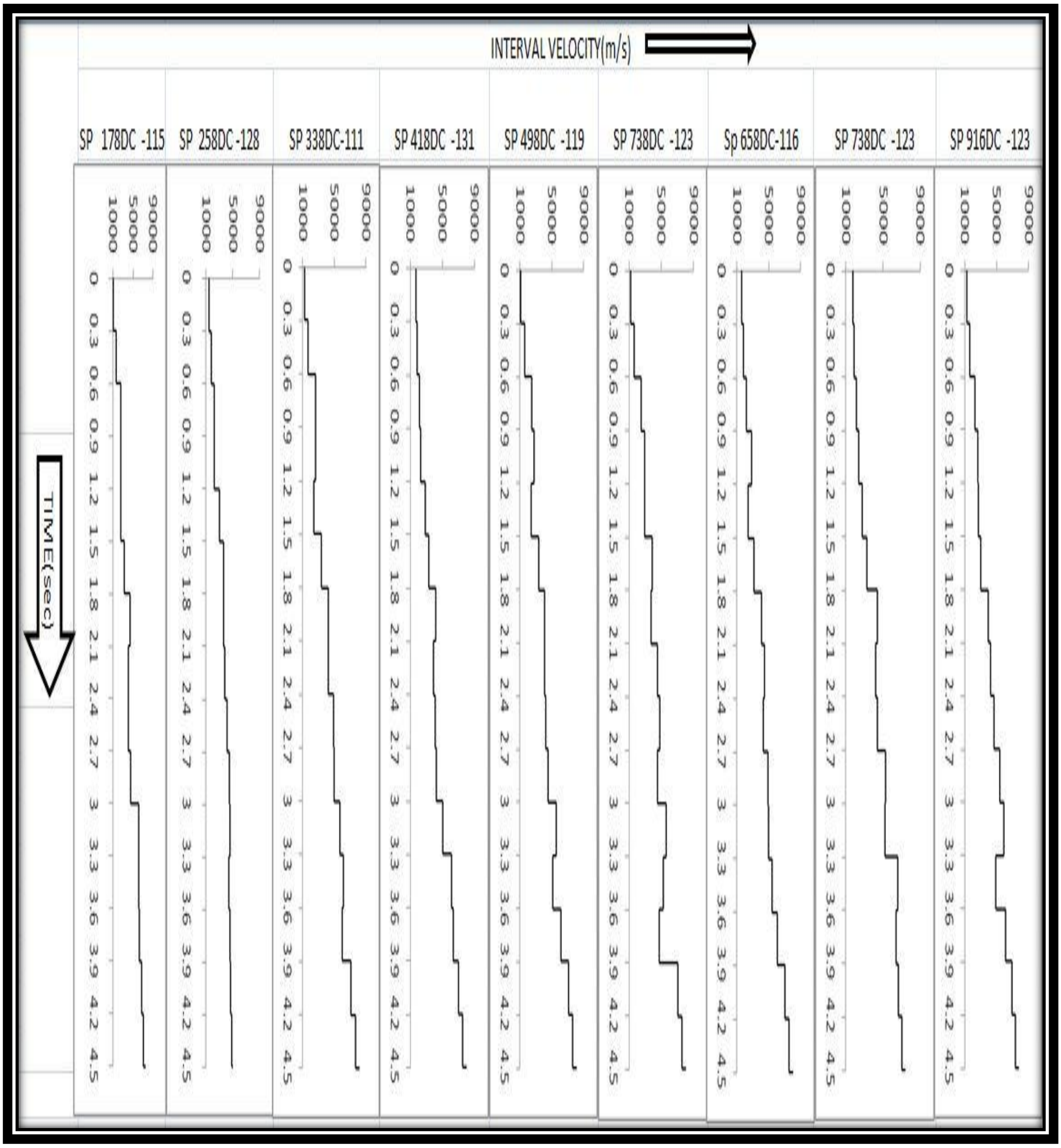


Figure 4.2(b). Average Velocities of Line P2092-114

Figurs (4.3a) and (4.3b) shows the behaviour of Interval Velocities with increasing time. An interval velocity is the velocity of particular layer.



Figures 4.3(a).Interval Velocities of Line P2092-110

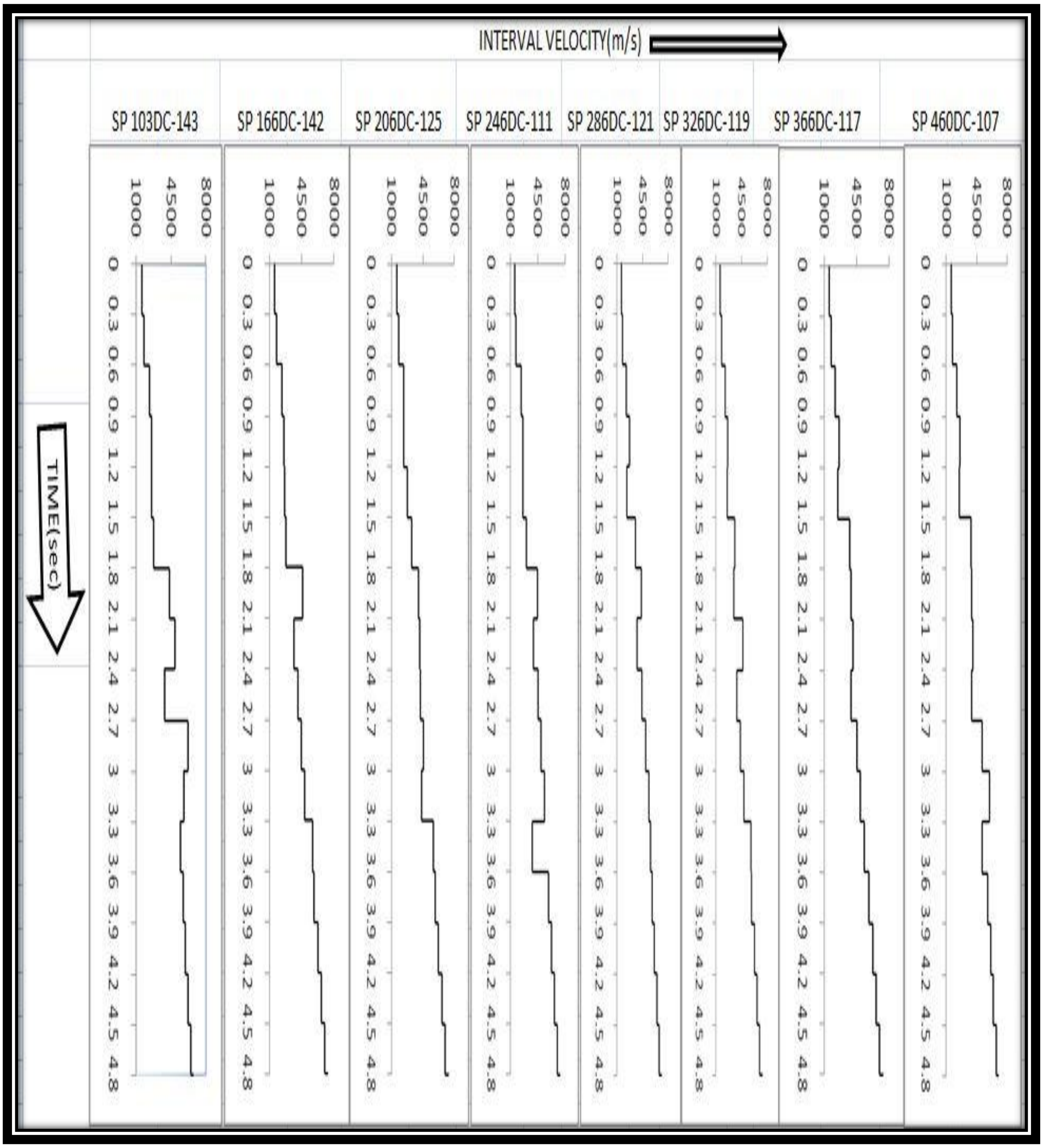


Figure 4.3(b) Interval Velocities of line P2092-114

4.2 Mean Average Velocity Graphs

Mean Average velocity graph shows the variation of velocity with time which is the mean of the velocities of all CDP‟s having same time. It shows the overall trend of velocity with respect to time. As depth increases mean average velocity also increases smoothly. The plot of mean average velocity with respect to is shown in figures 4.4(a) and 4.4(b) respectively.

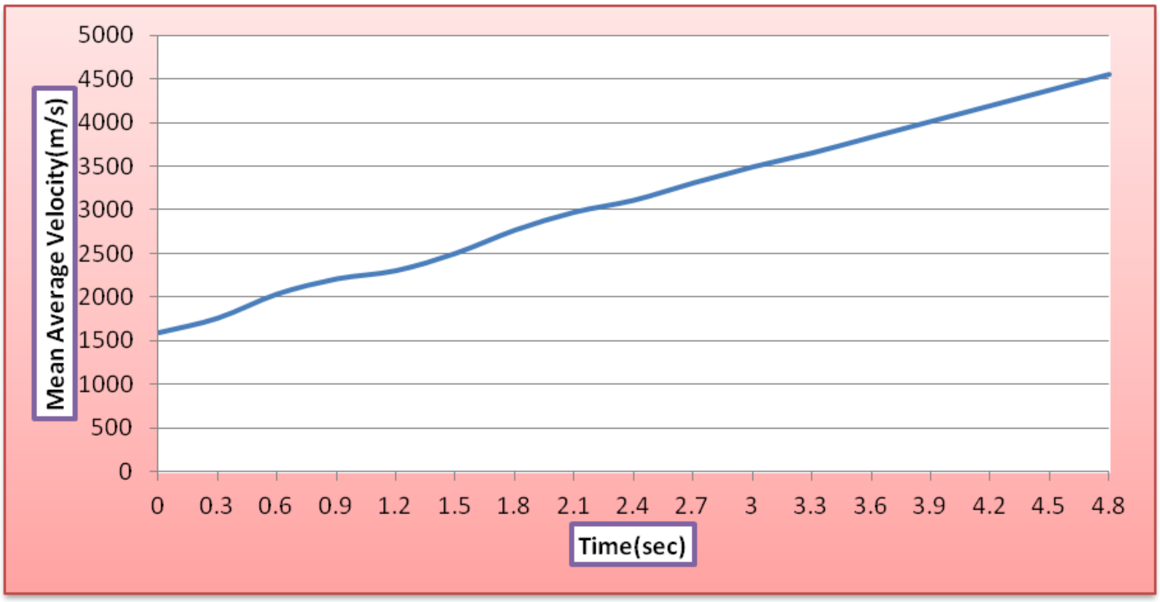


Figure 4.4(a).Mean Average Velocities of Line P2092-114

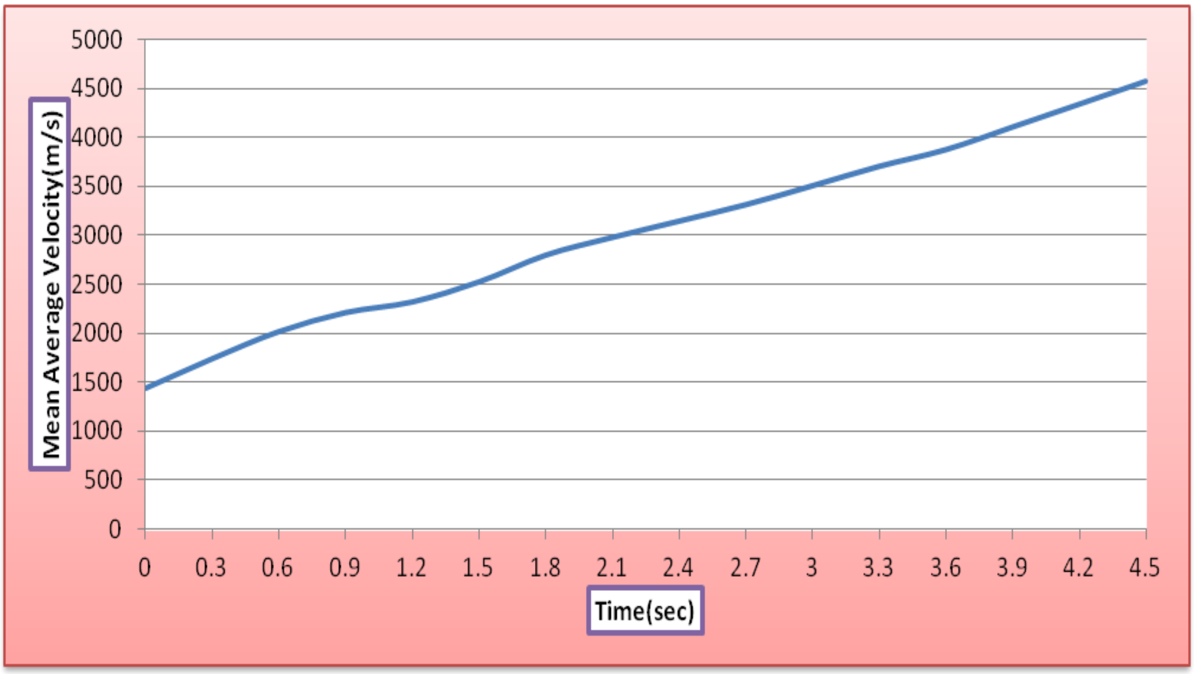


Figure 4.4(b).Mean Average Velocities of Line P2092-110

4.3 Iso-Velocity Map

The aim of generating the iso-velocity map is to observe the lateral and vertical velocity variations in the area. Iso-velocity map of the line P2092-114 was generated by creating grid of CDP, time and velocity data in Golden Software Surfer and plot it in that software a figure (4.5).

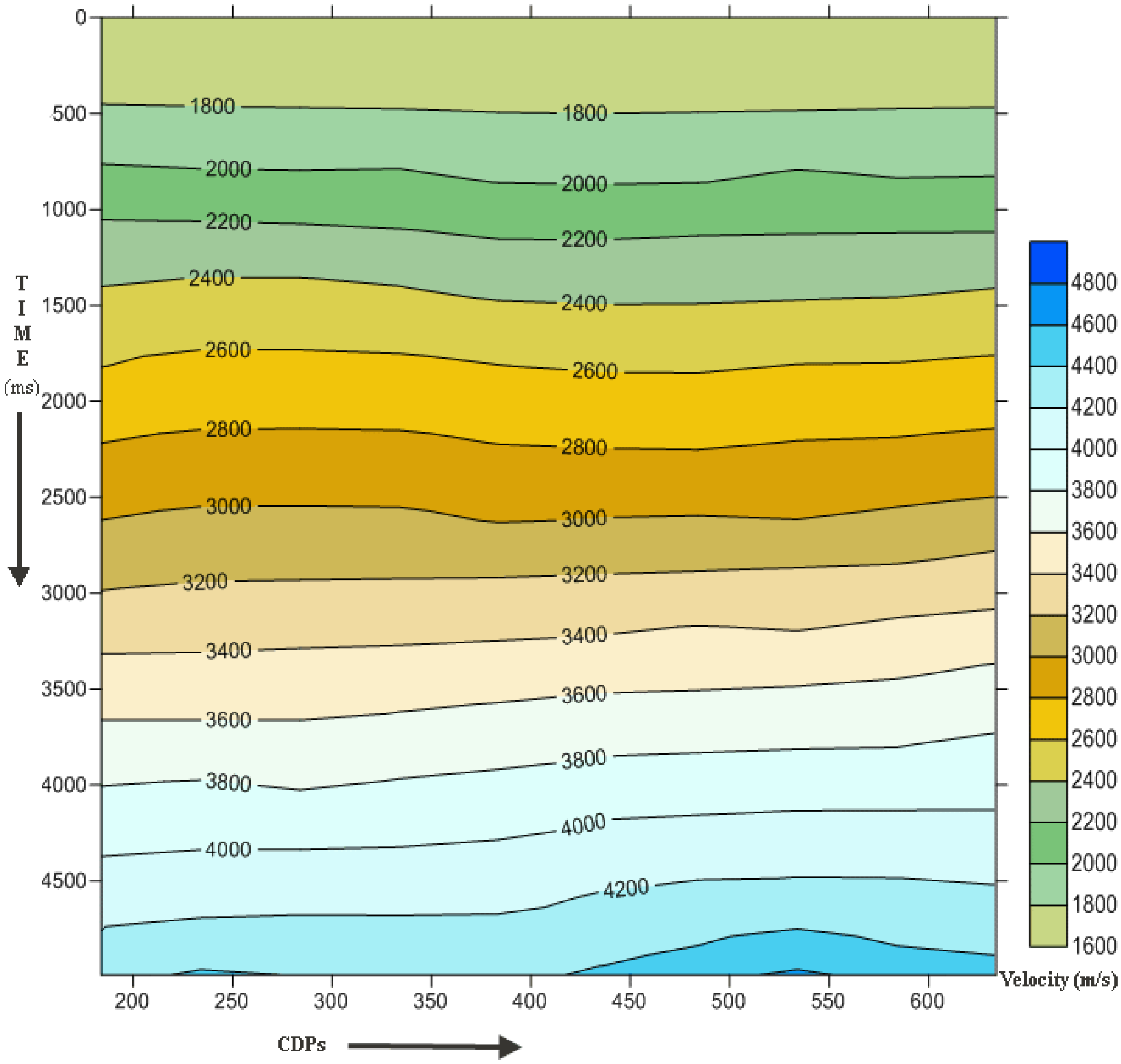


Figure (4.5). Iso Velocities Map of Line P2092-114

CHAPTER # 05

SEISMIC INTERPRETATION

SEISMIC INTERPRETATION

This chapter deals with the structural Interpretation of 2D seismic data of Block-20 Miano area. Seismic interpretation is the transformation of the 2Dseismic reflection data to a Geological image by the application of corrections, migration and time to depth conversion.

The seismic reflection data interpretation usually involves calculating the position and identifying geologically hidden interfaces or sharp transition zone formed seismic pulses return to ground surface by reflection. The impact of varying geological condition is brightened along the profiles to transform the irregular recorded travel time in to acceptable sub surface models. This is very important for confident approximation of the depth and geometry of the bed rock or target horizons.

The main approaches for the interpretation of the seismic section.

- *Structural analysis*
- Identification of structural features
- *Stratigraphic analysis*
- Identification of stratigraphic boundaries

5.1 Structural Analysis

This type of analysis is very suitable in case of Pakistan, as most of the hydrocarbons are being extracted from the structural traps. Structural interpretation of a 2-D seismic reflection data includes marking of the horizons and the faults. Using these marked structures one tries to interpret a structural trap, which is the consequence of the structural dynamics that have large extension in the geological history. So the structural interpretation would also include the study of the geological history of the area. (Sheriff, 1999).

Structural interpretation usually includes the identification of the following from conventional seismic sections:

- Horizons
- Faults and folds

5.2 Stratigraphic Analysis

Stratigraphic interpretation is usually concerned with the identification of Lithology, age and depositional environment of the picked horizons and using these concepts to develop a play for the area on a regional scale.

Seismic stratigraphy is used to find out the depositional processes and environmental settings, because genetically related sedimentary sequence normally consists of concordant strata that show discordance with sequence above and below it. It also helps to identify formations, stratigraphic traps and unconformity. This method also facilitate for the identification of the major pro-gradational sedimentary sequences which offer the main potential for hydrocarbon generation and accumulation. Stratigraphic analysis therefore greatly enhances the chances of successfully locating hydrocarbon traps in sedimentary basin environment.

5.3 Marking and identification of seismic horizons:

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

The first step of Seismic data interpretation is to mark the prominent reflectors also called horizons on the seismic sections. A reflector (Horizon) is defined as "an interface or boundary between two rock units (formations)".Those reflectors are selected which are real, show strong character ,continuity and can be followed throughout the seismic line and also can be correlated at tie points of other seismic lines of the area (Badely, 1985).

Seven prominent horizons are marked on the Seismic lines. These horizons were marked through the same steps and all the sections are correlated at their respective tie points. The reflectors are strong enough to be picked because of contrast in acoustic impedance that is ultimately caused by changes in lithology.

Normally the VSP data is used for naming the marked horizons. But in this study due to the unavailability of VSP data the identification of Horizons has been done by using the depths of the formations from the well top data of Miano-08 and 6 other wells of Miano area. Also With the help the average thickness of strata from above mentioned well, depths can be calculated by using interval and average velocities derived during processing of seismic data.

In this study six prominent reflectors are marked.

- Sui Main Limestone
- Rani Kot Formation
- Upper Guru
- Lower Guru
- D sand Interval
- C sand Interval

5.4 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 P2092-114 are marked first because the well Miano-08 is exactly on the line. The tie points of the lines are confirmed from the base map, where tie points of the lines have been mentioned. At the tie point of both intersecting seismic lines have same horizons at the same time. If the horizon does not have same time then there may be mistie that may be removed later on. Taking seismic line P2092-114 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. In the same manner all the faults are correlated. Faults were marked on the line of study on the basis of discontinuity in reflections. As the area of study is an extensional regime so normal faults were identified on the seismic section.

5.4.1 Seismic Time Section

After marking seismic horizons and faults, the time of each reflector was noted at different shot points, and then the seismic time section was generated by plotting the two-way travel time of the reflectors and faults on y-axis against the shot points on x-axis. The seismic time section is simple reproduction of an interpreted seismic section. Time sections of lines P2092-114 and P2092-110 are shown in (Figure 5.1) and (Figure5.2) respectively. There is normal faulting, due to Horst and Graben structures suitable of Hydrocarbon accumulation.

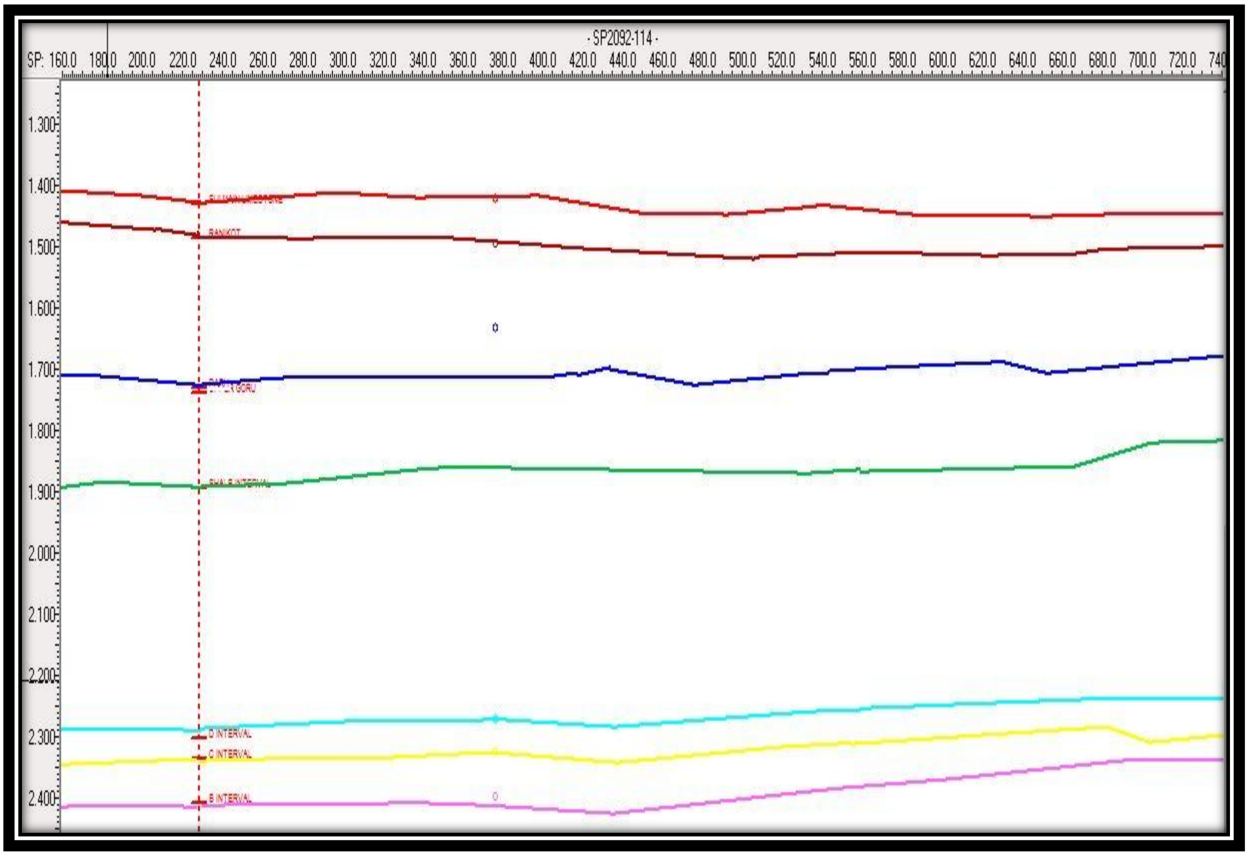


Figure (5.1) Time Section of Line P2092-114

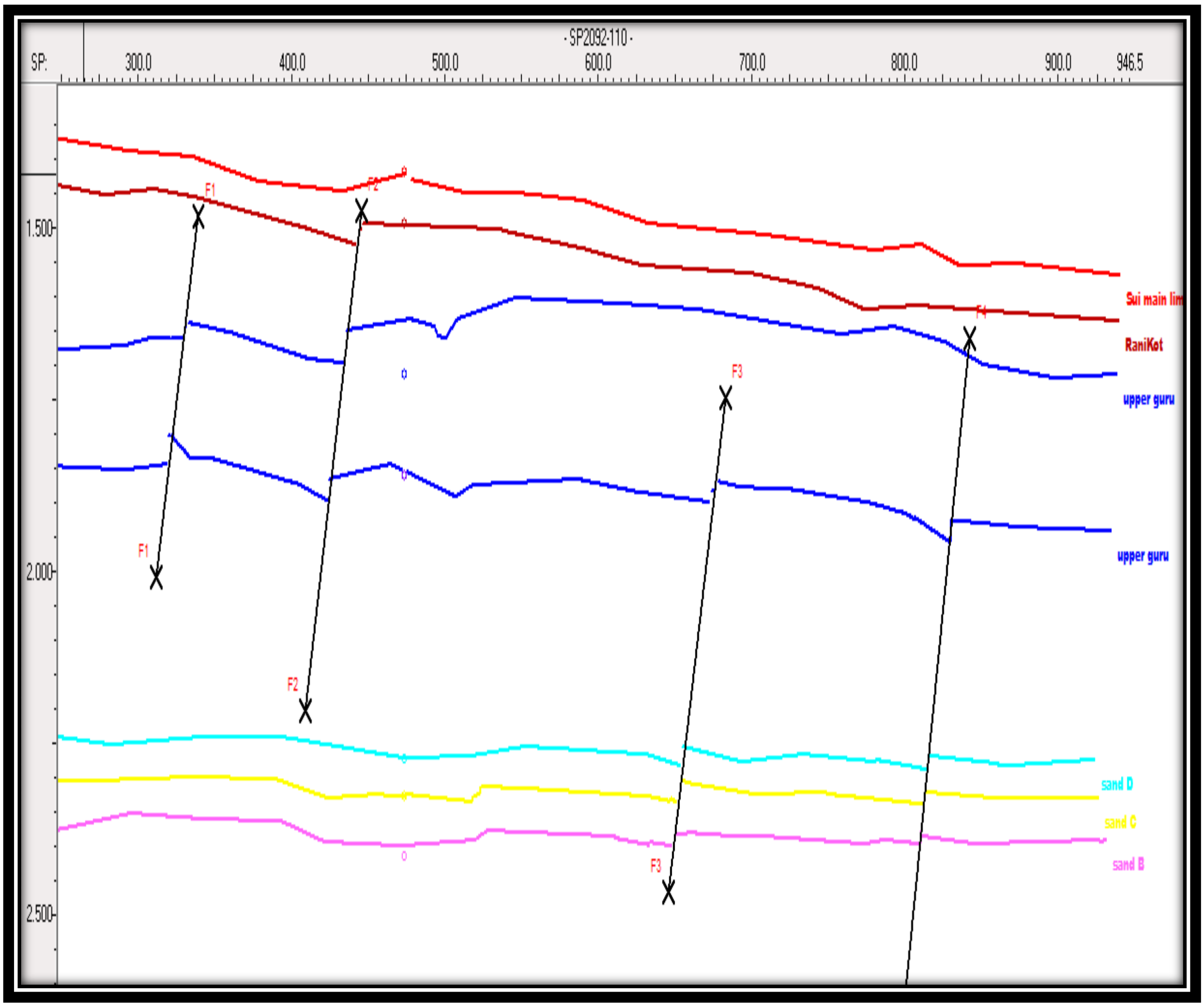


Figure (5.2) Time Section of line P2092-110

5.5 <u>Time Contour Maps</u>

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

5.5.1 Time Contour map of Rani Kot Formation

The range of two way time contours of the Rani Kot Formation is from 1.4 to 1.65s. This map shows that the displacement between contours lines along the faults on western side is negligible but when we move towards east this displacement is prominent which means faulting is extensive in the eastern side of the area as shown in figure 5.3.

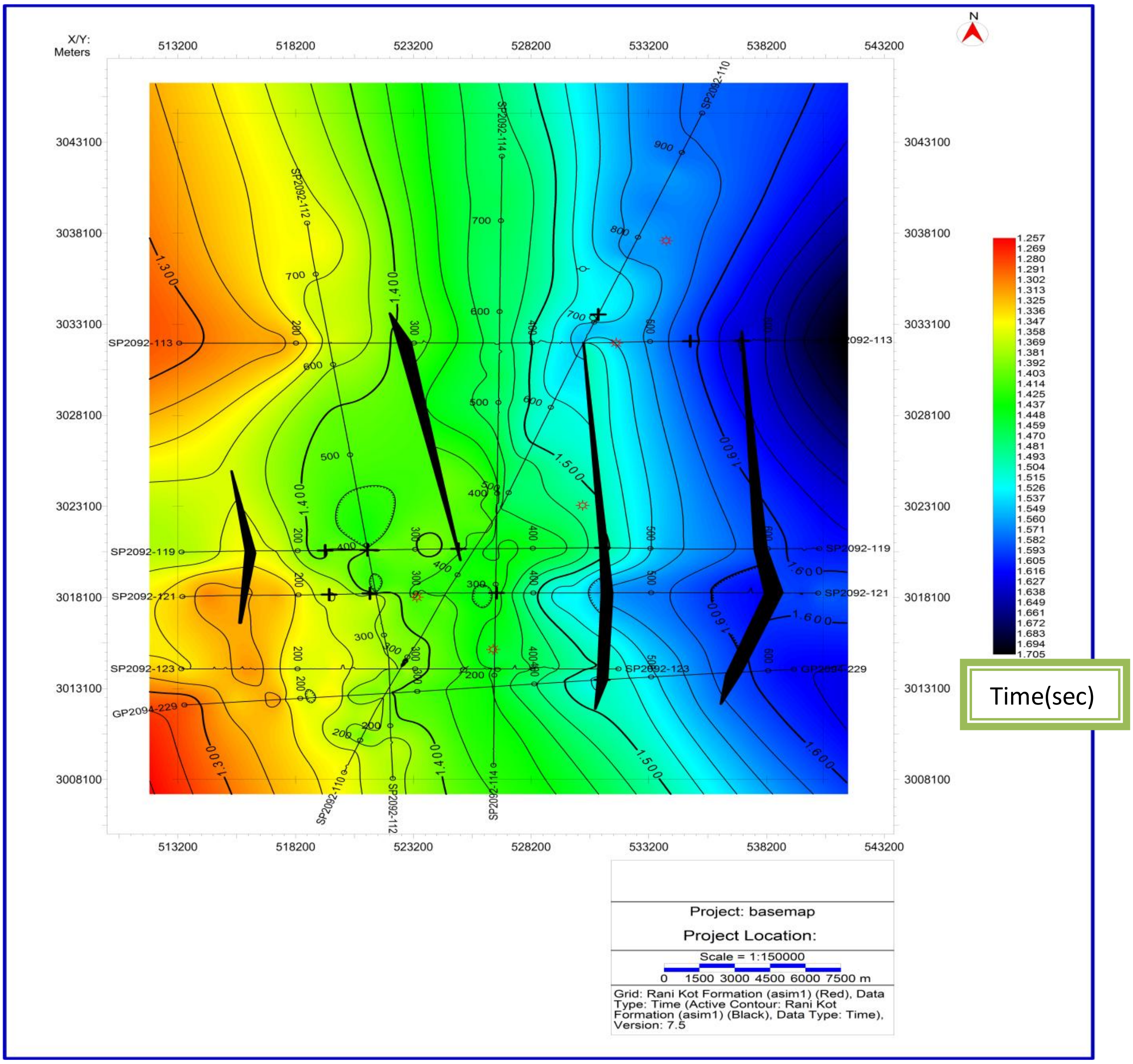


Figure (5.3) Time contour map of Rani Kot Formation.

5.5.2 3D Visualisation of Time contour maps of Rani Kot Formation

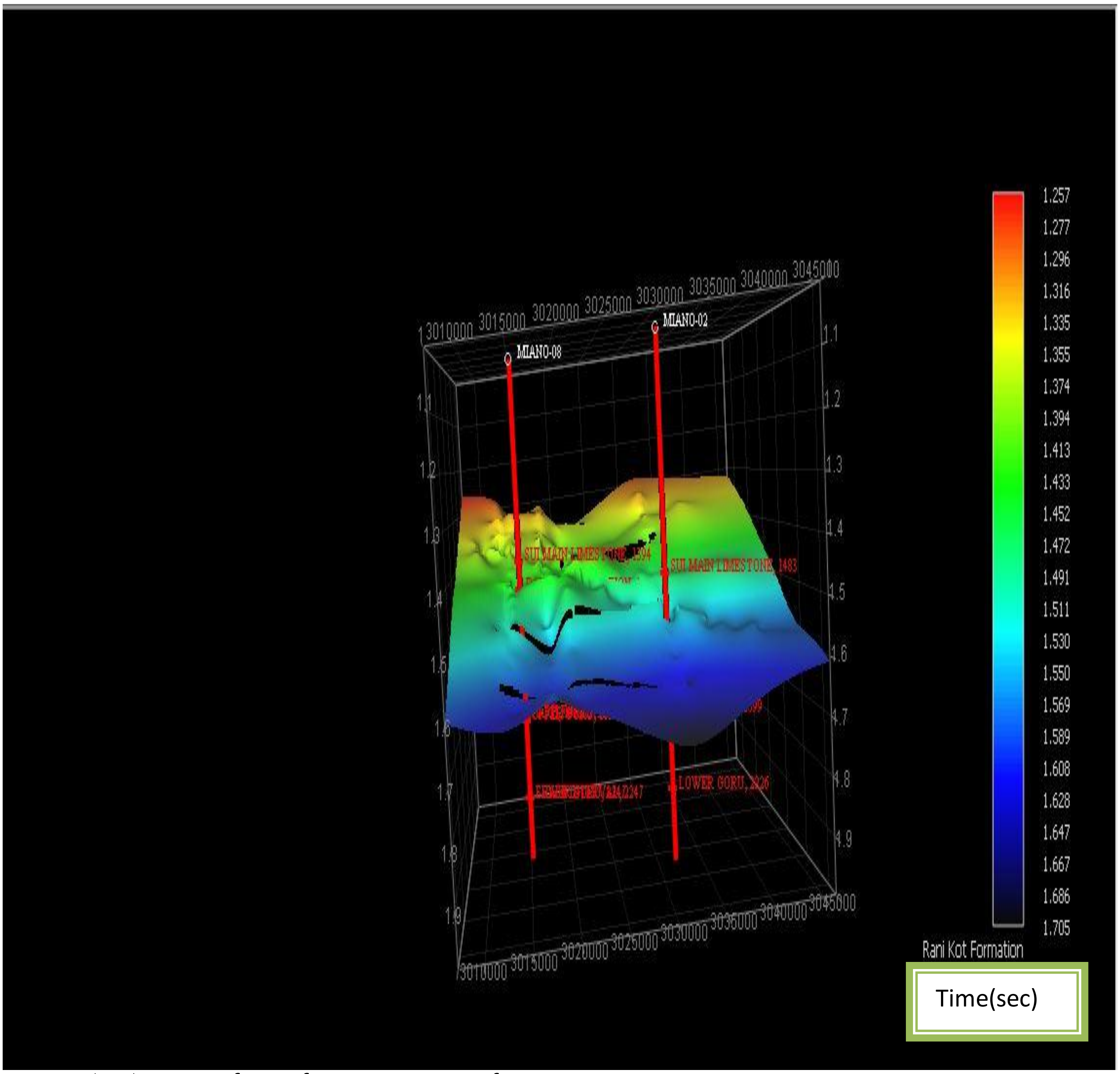


Figure (5.4) 3D Surface of Time Section of Rani Kot Formation

5.5.3 Depth Contour map of Rani Kot Formation

The range of depth of top of Rani kot Formation is from 1300m to 1800m. The depth contour map of Rani Kot Formation is shown in(figure 5.5). It is clear from the figure that the trend of depth contours is same as time contours and shows similar faults as formed during Time contour map.

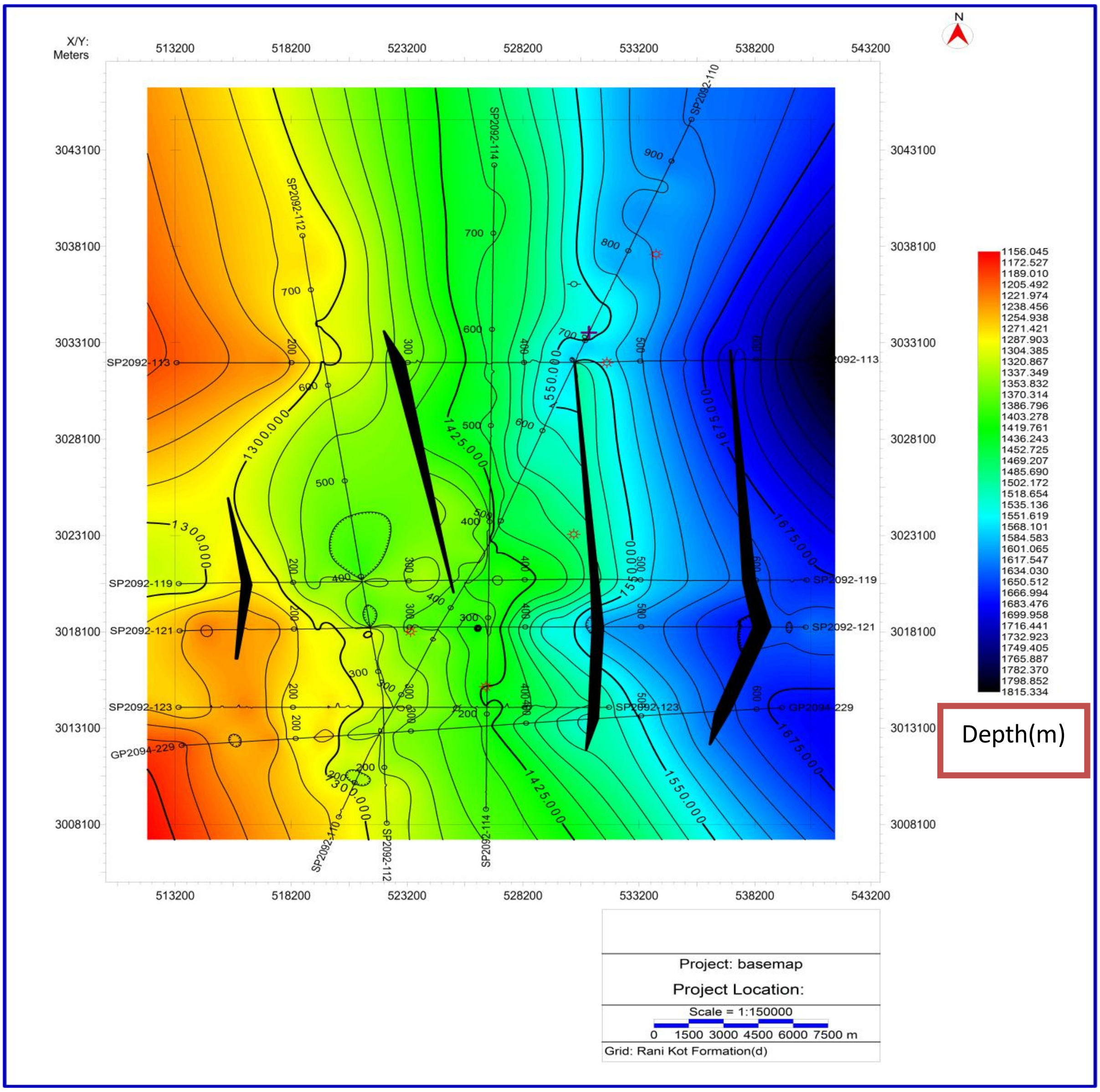


Figure (5.5). Depth Contour Map of Rani Kot Formation.

5.6. Seismic Synthetic Modeling

The seismic synthetic modeling is the result of forward modeling to predict the seismic response of the subsurface. A more common definition used by seismic interpreters is that a synthetic seismogram is a direct one-dimensional model of acoustic impudence energy traveling through the layers of the earth.

Synthetic seismogram or pseudo seismic section is a forward model of the earth that is constructed to mark the different geological horizon on the seismic section. The synthetic seismogram is generated by convolving the reflection coefficient derived from digitized sonic and density logs with the wavelet derived from seismic data, as describe in figure 6.1.

The quality of the tie between a synthetic seismogram and seismic data depends on well log quality, seismic data processing quality, and the ability to extract a representative wavelet from seismic data, among other factors. When the synthetic seismic response shows a good comparison to seismic section, the resultant model is considered to be representative of the true subsurface lithology (www.slb.com).

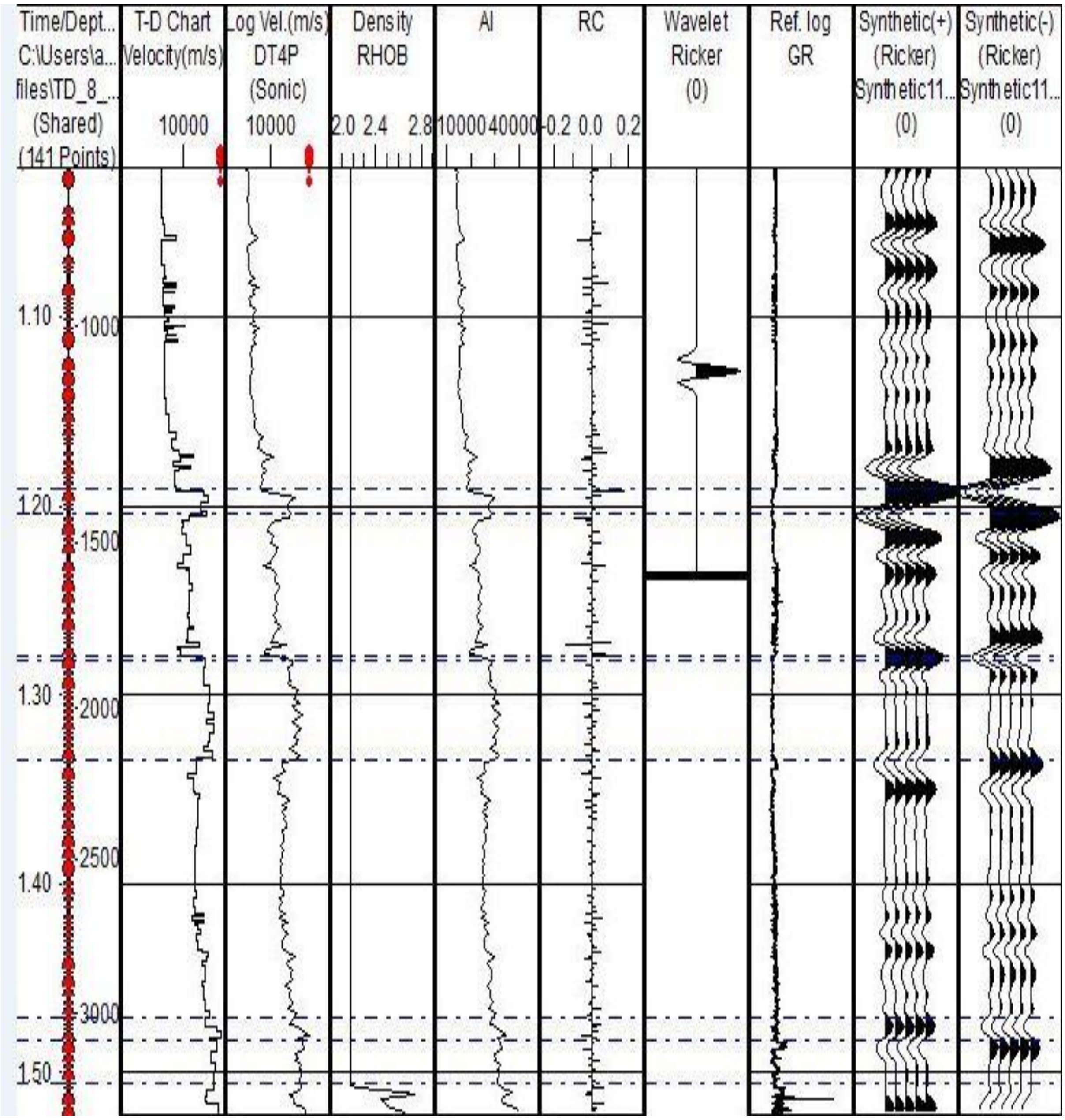
5.6.1 Procedure for Synthetic Seismogram generation

The Synthetic seismograms for the study area are generated on Kingdom software using the following procedure

1. Load the Las file of the well in the software.
2. Open synthetic generation from 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 two-way travel time; using a frequency in Hertz (35 Hz frequency is used in this study).

9. Convolve the reflection coefficient log with the Ricker wavelet to generate the amplitudes of the synthetic seismogram.

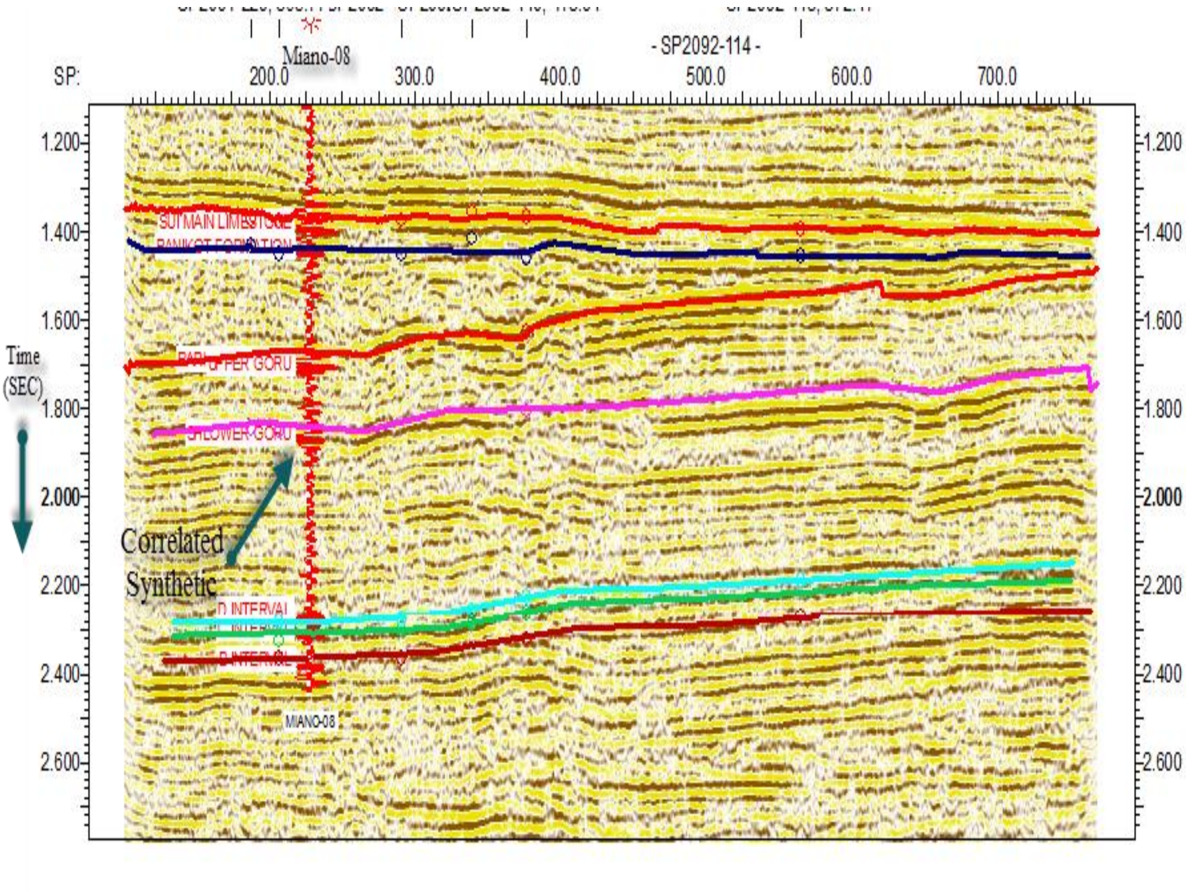
Synthetic seismogram contains very useful information like Elevation of Kelly bushy (KB), ground level, datum, information like time scale, traces per inch, sample interval. Band pass is filter used range of 10--50 Hz means it allows the waves that are in the frequency range of 10 to 50 Hz and rejects the waves that are below 10 Hz and Above 50 Hz, frequency greater than 60 must not use because the result saturates at this value. As shown in figure 5.6.



Figure(5.6) Synthetic Seismogram

Correlation of Synthetic with seismic:

The well Minao-08 lies on the Line P2092-114. Generated Synthetic Seismogram is correlated with the line to mark the horizons. Shown in figure (5.7).



Figure(5.7).Section correlated with synthetic seismogram.

CHAPTER # 06

WELL CORRELATION

6.1. WELL CORRELATION

6.1.1 Why we perform well correlation:

Correlation is used to determine the equivalency in time or rock stratigraphic units of the succession of strata found in two or more different places. The rocks of associated outcrops may be correlated through physical criteria and fossil content. Precise lithological correlations from well to well can be inferred by comparing the tops and bottoms of lithologies in each well, well tops data is used to perform this task.

6.1.2 How we generate cross section:

A wells correlation cross section map is generated by using the "Earth Pak tool" in kingdom software. Starting from the well miano-08, a profile is passed through all the wells that are correlated as shown in Figure (6.1). The software also provides the distance between each well along the profile. This information is used to create well correlation cross-section by placing the well columns at their appropriate position.

Information of wells that are used for correlation is given below in table:

Well name	Miano-02	Miano-05	Mian-08	Miano-01
Depth Reference	KB	KB	KB	KB
Elevation (m)	56.07	63.59	65.8	57.62
Total Depth(m)	3548.4	3400	3462	4030
Status	GAS	GAS	GAS	GAS

Encountered Lithologies and Corresponding Depths in Well Miano-08

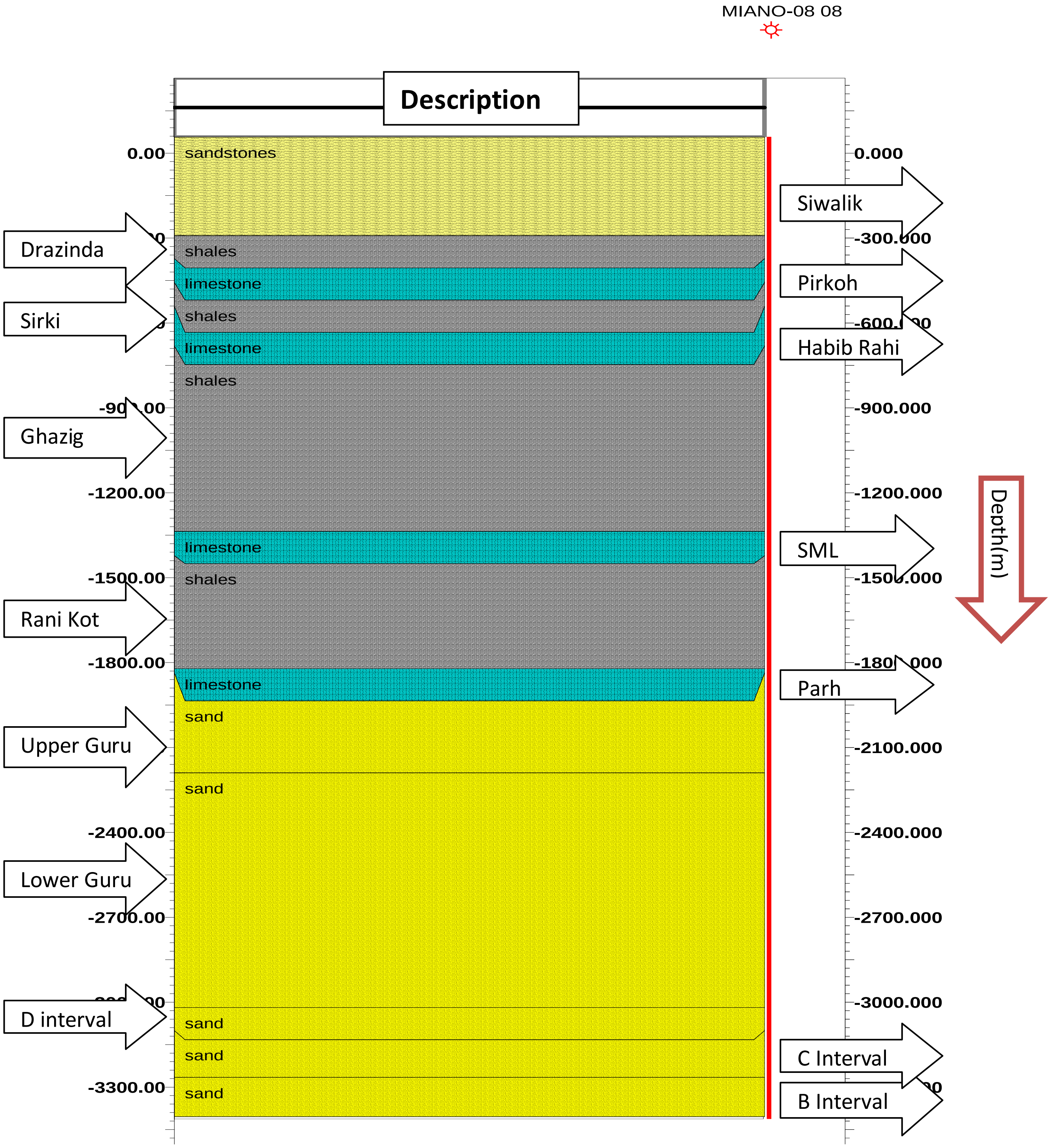


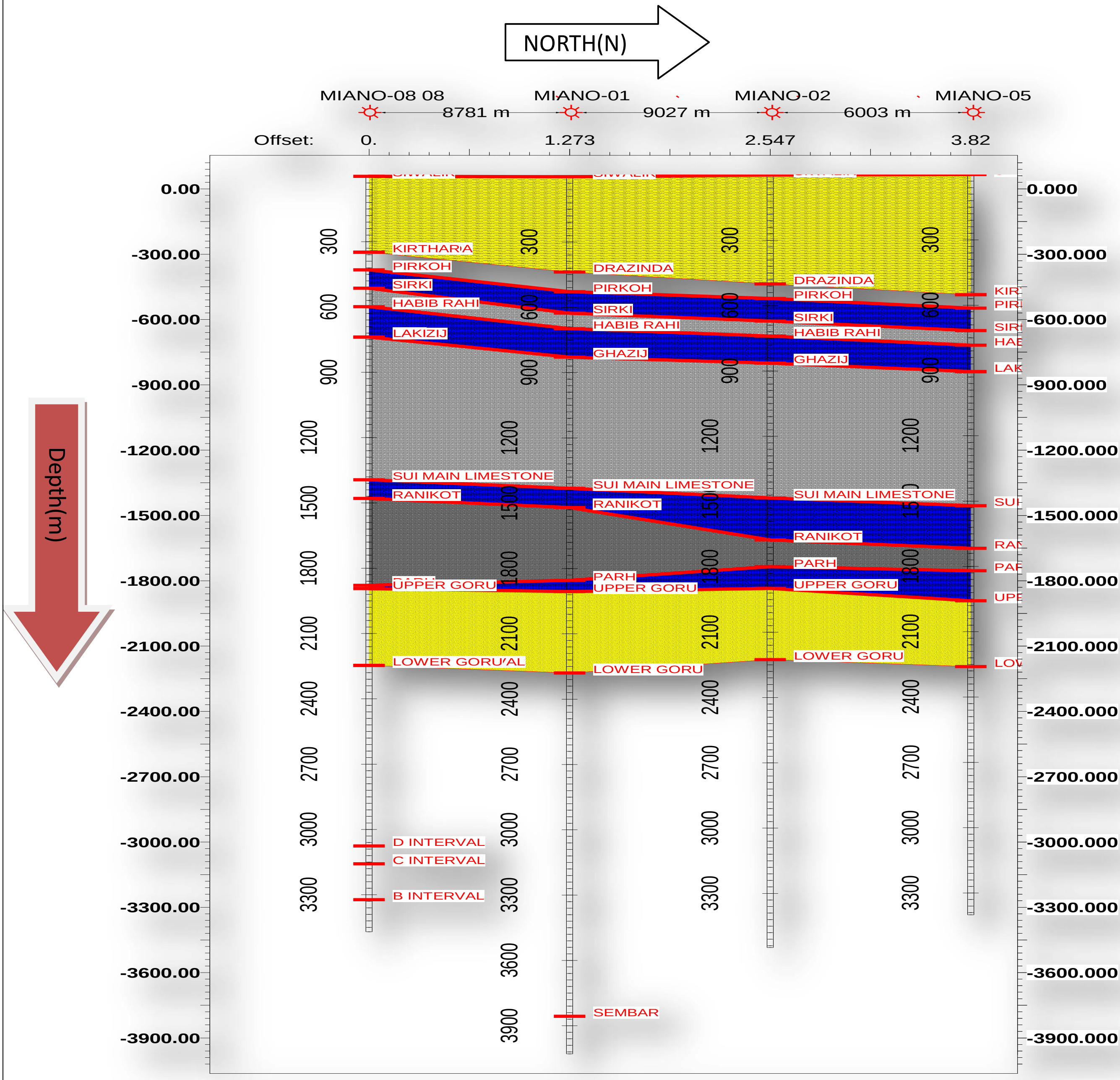
Figure (6.1). Encountered Lithologies and corresponding Depths in Well Miano-08

6.2 <u>Stratigraphic Wells Correlation:</u>

The interpretation of well log data is the primary method for development of a stratigraphic framework of the area. This framework can be used for mapping and delineation of reservoir intervals. The purpose of it is not only to establish the stratigraphic correlations of different wells in Miano Area but also to clarify the source of sediments and depositional centers during different geological time periods. This helps in identifying the maximum thickness zones of prospective formations in Miano Area and the direction of sediments flow in the basin during different geological periods. The thickness variations are due to the Erosion, over burden pressure and ancient high.

In Miano area the major cause of the thickness variation is due to overburden pressure. There is a horst and graben structures in this area.. Thickness variation is not very dominant throughout the wells except the thickness of Rani kot formation which is decreasing and of Parh limestone increases if we follow the well profile from Miano-08 to Miano-05. As we move towards north shaly material decreases and carbonated material increases which shows marine transgression and towards south limestone pinches out in well-08 which shows marine regression.

The depth variation of the formations also not prominent in the area if follow the well profile from (Miano-08 to Mian0-05) S-N except rani kot formation. , as it is clear from the figure (6.2) that the reflector Rani Kot on which I have focused is at the depth of 1500m to 1900m in both wells Miano-08 and Miano-01, but is at slightly deeper depth in Miano-02 and Miano-05 well. This is may be because of faulting or folding.



Figure(6.2). Correlation of wells

6.3. Well Log Correlations and Marking Zone of Gas production in the Miano Area.

The well log correlation of wells Miano-1, Miano-2, Miano-5 and Miano-8 is shown in the figure . This correlation shows Gamma ray and DT curve. As the gamma ray increases in shales and less in sandstones. There are some sand stones which show high value of GR because of radioactive materials in it so we use both GR and DT curves together. DT shows slowness of the sonic wave with increasing porosity. On the basis of this correlation the zone of interest is marked as shown in Figure. The producing reservoir is the area is B-sand interval of Lower Goru Formation the correlation confirms the behaviour of the reservoir in all the wells. This correlation shows that the strata are not so much disturbed in the area. As shown in figure 6.3.

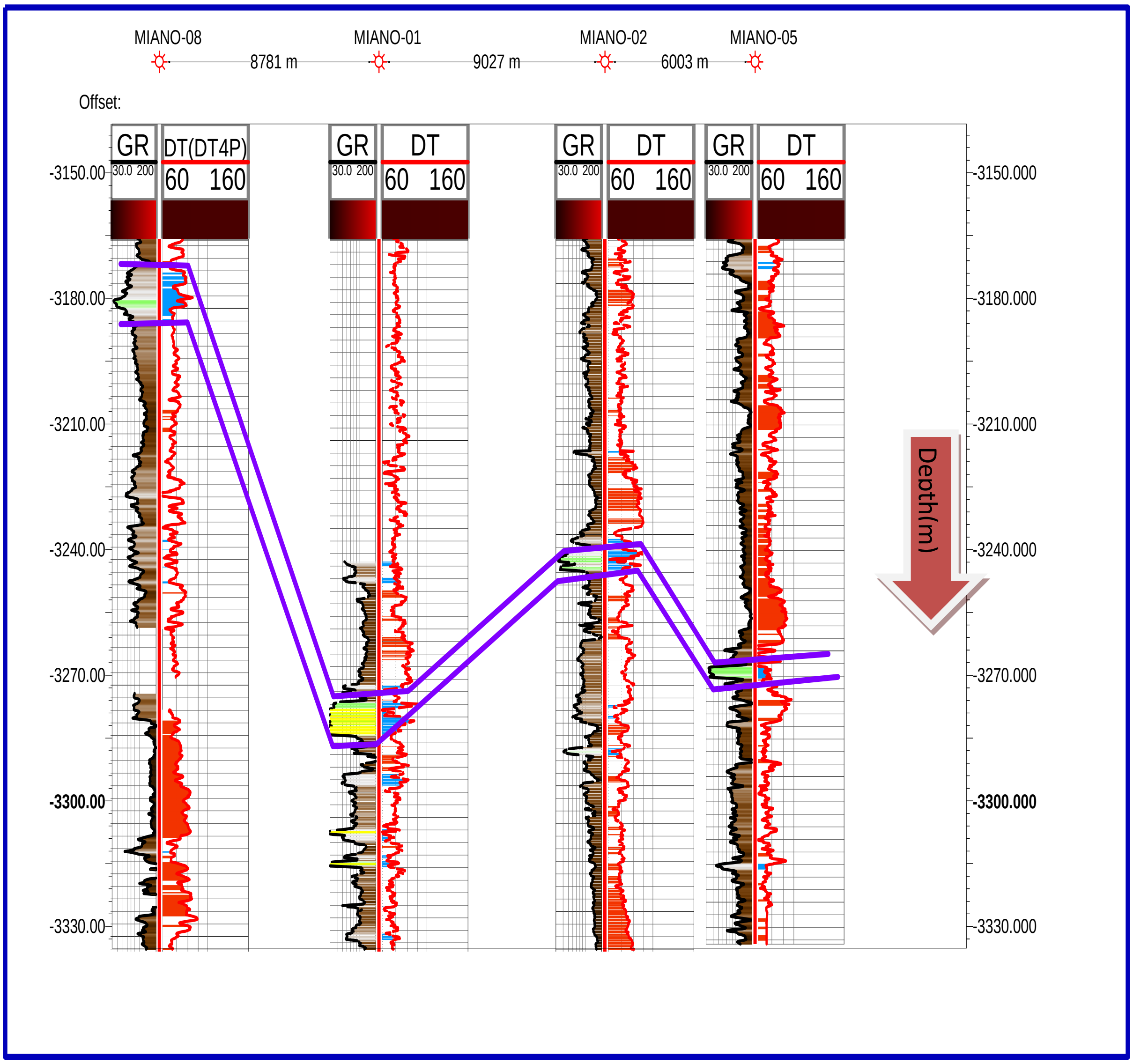


Figure (6.3). Composit log of DT(sonic) and GR(gamma ray).

CHAPTER 07

PETRO PHYSICS AND FACIES MODELING

7.1 <u>Introduction</u>

Rock Physics describes a reservoir rock by physical properties such as porosity, rigidity, compressibility; properties that will affect how seismic waves physically travel through the rocks. Different relations are established between the material properties and the observed seismic response.

7.2 <u>Rock Physics Properties Of Rani Kot Formation</u>

Following rock parameters and engineering properties of Rani Kot Formation were calculated using the data of Miano-8 well.

- P-wave velocity
- Density
- Bulk modulus
- Shear modulus
- Young‟s modulus
- Poisson‟s ratio

7.2.1 <u>P-Wave Velocity</u>

The sonic log measures interval transit time (Δt) of a compressional sound wave traveling through one foot of formation. Interval transit time (Δt) in microseconds per foot is the reciprocal of the velocity of a compressional sound wave in feet per second. A typical sonic log is shown in figure 7.1(a). P-wave velocity was calculated using this log by following formula:

$Vp = 1/\Delta t$

Where; = P-Wave Velocity (ft/s), Δt = Interval Transit Time (µs/ft).

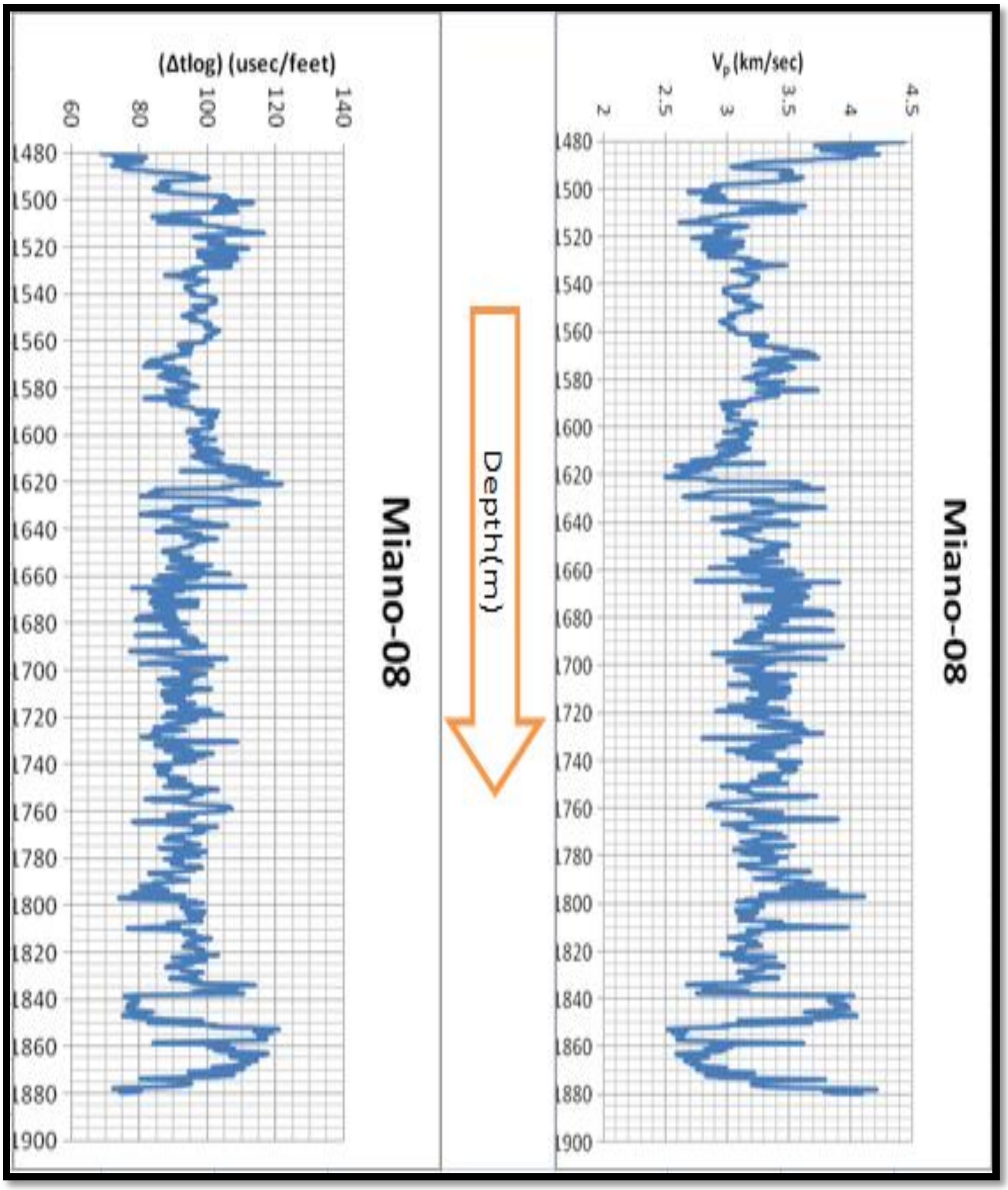


Figure 7.1: (a) Sonic Log, (b) P-Wave Velocity

In figure 7.1(b), the zone where Vp is high shows compact rock and at the other hand where Vp is low shows loose material. In this case compact material is sand of Rani Kot Formation and the softer portion indicates beds of shales.

7.2.2 S-Wave Velocity

Seismic S-Wave velocity was calculated using previously calculated P-Wave velocity by using following formula:

Vs =Vp − 1.36/1.16

Where;

Vs = P-Wave Velocity

Vp = S-Wave Velocity

S-Wave velocity is always less than P-Wave velocity.

7.2.3 Density

Density is a major property of the rock which describes the amount of solid part of the rock body per unit volume. Simply mass per unit volume is called density. Rocks of lower densities make the seismic velocity to drop down. Direct estimation of density from seismic velocities has been done by using the following relation:

density = 0.31*Vp0.25

Where;

Density

Vp= P-Wave velocity in m/sec.

Density is used in various moduli calculations. The density variations through out the Rani Kot Formation are shown figure (7.2).

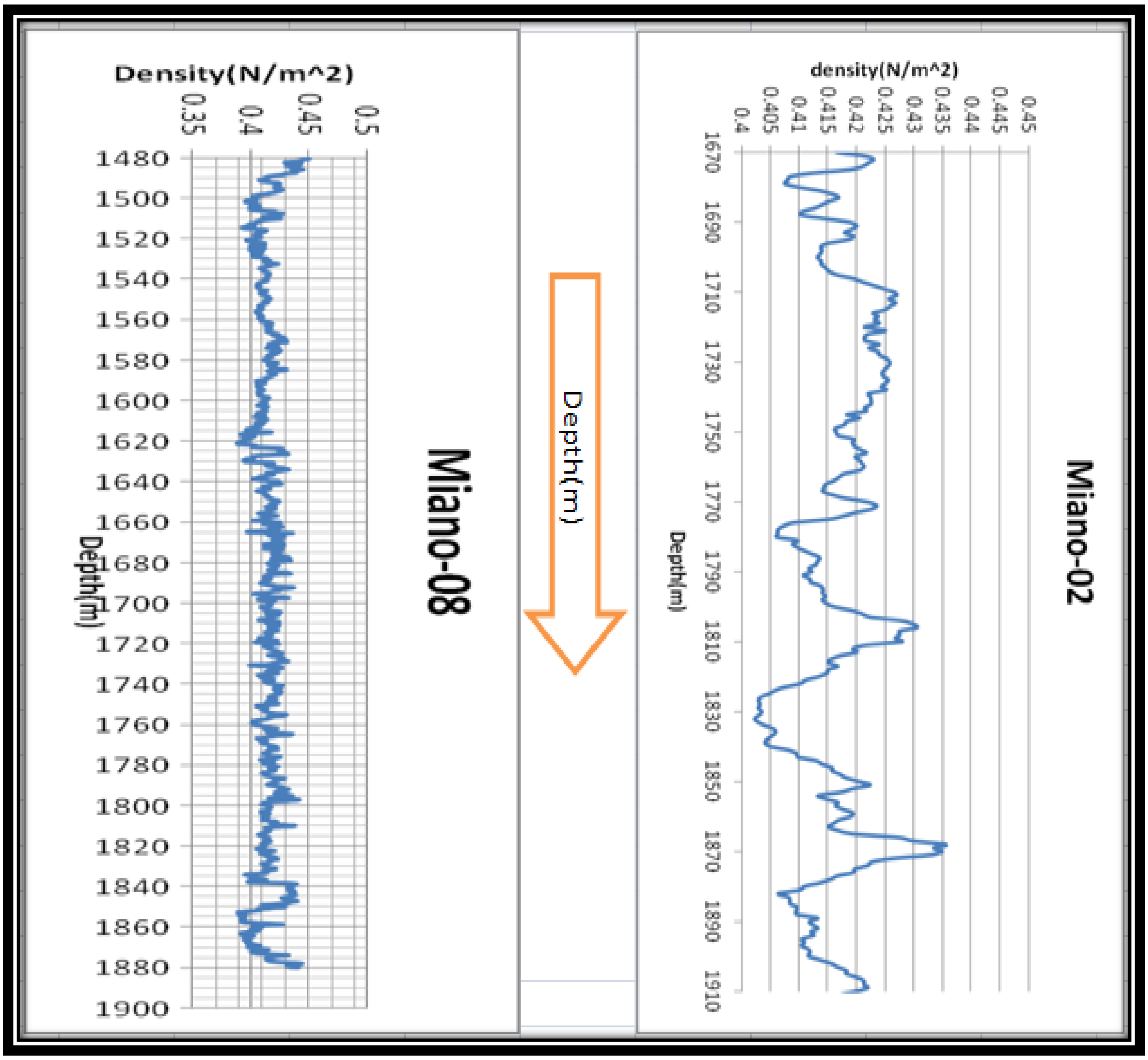


Figure (7.2) Density Graph of wells.

The figure shows the variation of density with depth,as the density of hydrocarbon is much low, so the zones of low density may indicate hydrocarbon or other less dense material(gas).

7.2.4 Bulk Modulus (K)

The bulk modulus (K) of a substance measures the substance's resistance to uniform compression. It is the ratio of volume stress to volume strain. It describes the material's response to uniform pressure.

The value of K is calculated by the following relation.K

K = density*(Vp2 −4/3)/Vs2

Where;

K = Bulk modulus

Vp = P-wave velocity

Vs = S-wave velocity

In figure (7.3), the zone of higher values of Bulk Modulus indicates that, there may be presence of resistive material, and less resistive material to stress may be present in the zone where bulk modulies have low values.

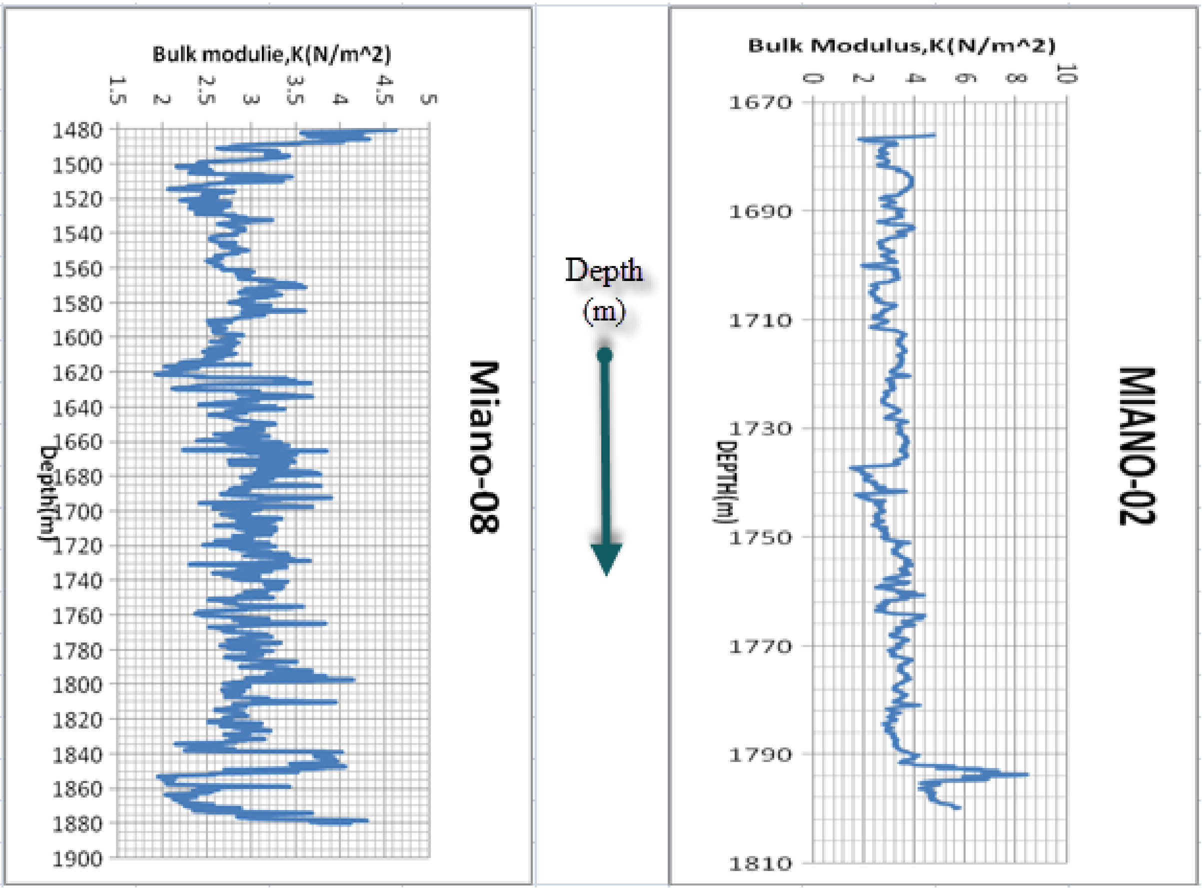


Fig 7.3. Comparison of Bulk Modulus of wells

7.2.5 <u>Shear Modulus (μ)</u>

Shear modulus or modulus of rigidity (μ), is defined as the ratio of shear stress to the shear strain (angle of deformation). It is concerned with the deformation of a solid when it experiences a force parallel to one of its surfaces while its opposite face experiences an opposing force (such as friction). It describes the material's response to shearing strains.

The value of young modulus is calculated by the following relation.

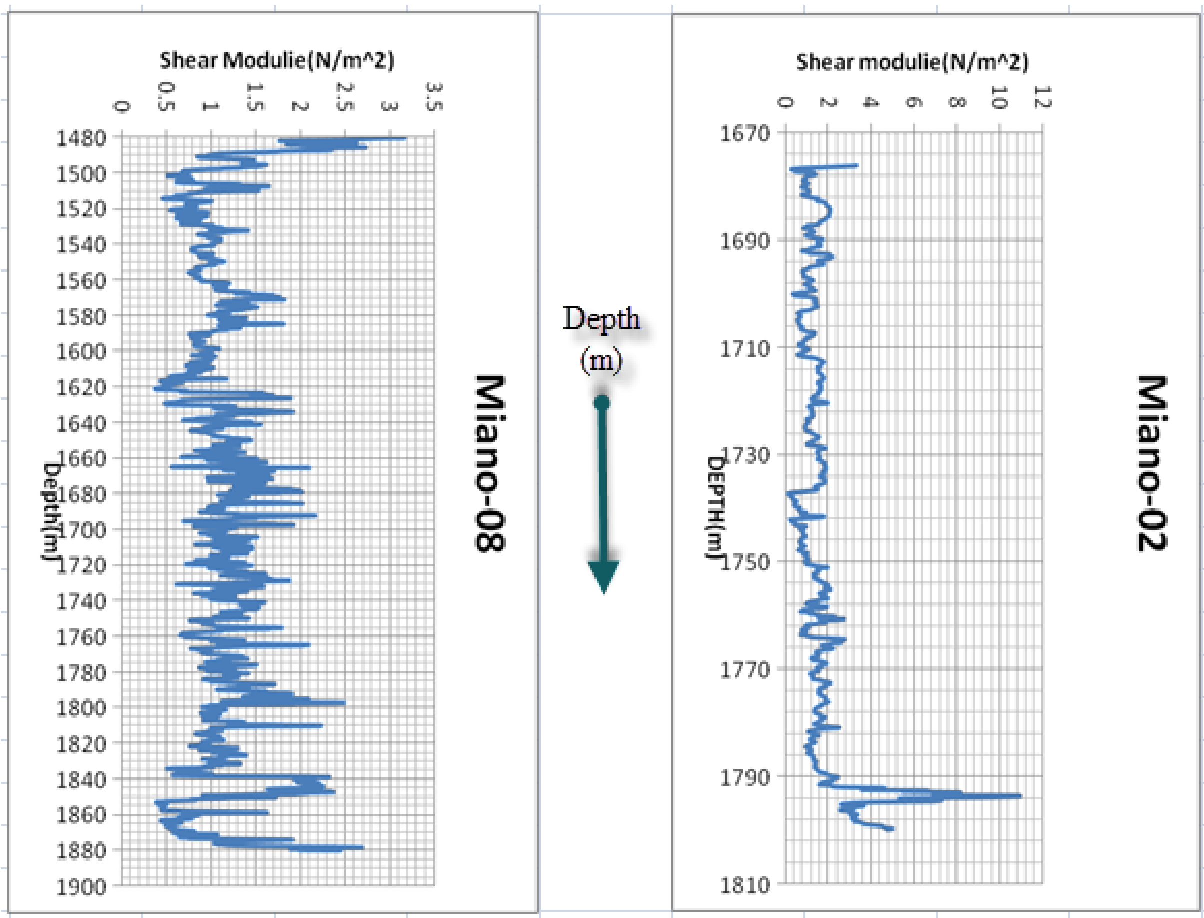
$\mu = (d*Vs^2)/2$

Where;

d = Density

Vs = Velocity of S-Wave

Figure (7.4) shows the graph between depth and shear modulus of Rani Kot Formation. The zone where shear modulus has high value it indicate the presence of stiff material (sand) and where less stiff material (shale) is present shear modulus has low value. If shear modulus is more than the rock unit is more fractured and more sheared.



Fig(7.4). Comparison of Shear Modulus of wells

7.2.6 Young Modulus (E)

Young's modulus or modulus of elasticity (E) is a measure of the stiffness of an isotropic elastic material. It is the ratio of the uni-axial stress over the uni-axial strain in the range of stress in which Hooke's Law holds. It describes the material's response to linear strain. The value of young modulus is calculated by the following relation.

$E = (9*K*\mu)/(3*k + \mu)$

Where;

E = Young modulus

K = Bulk modulus

μ = Shear modulus

Behavior of Young's modulus through out Rani Kot Formation is shown in figure. It is clear from figure 7.5 that the higher values of Young's modulus indicates the presence of sand and lower values predict the presence of shale in the Rani Kot Formation.

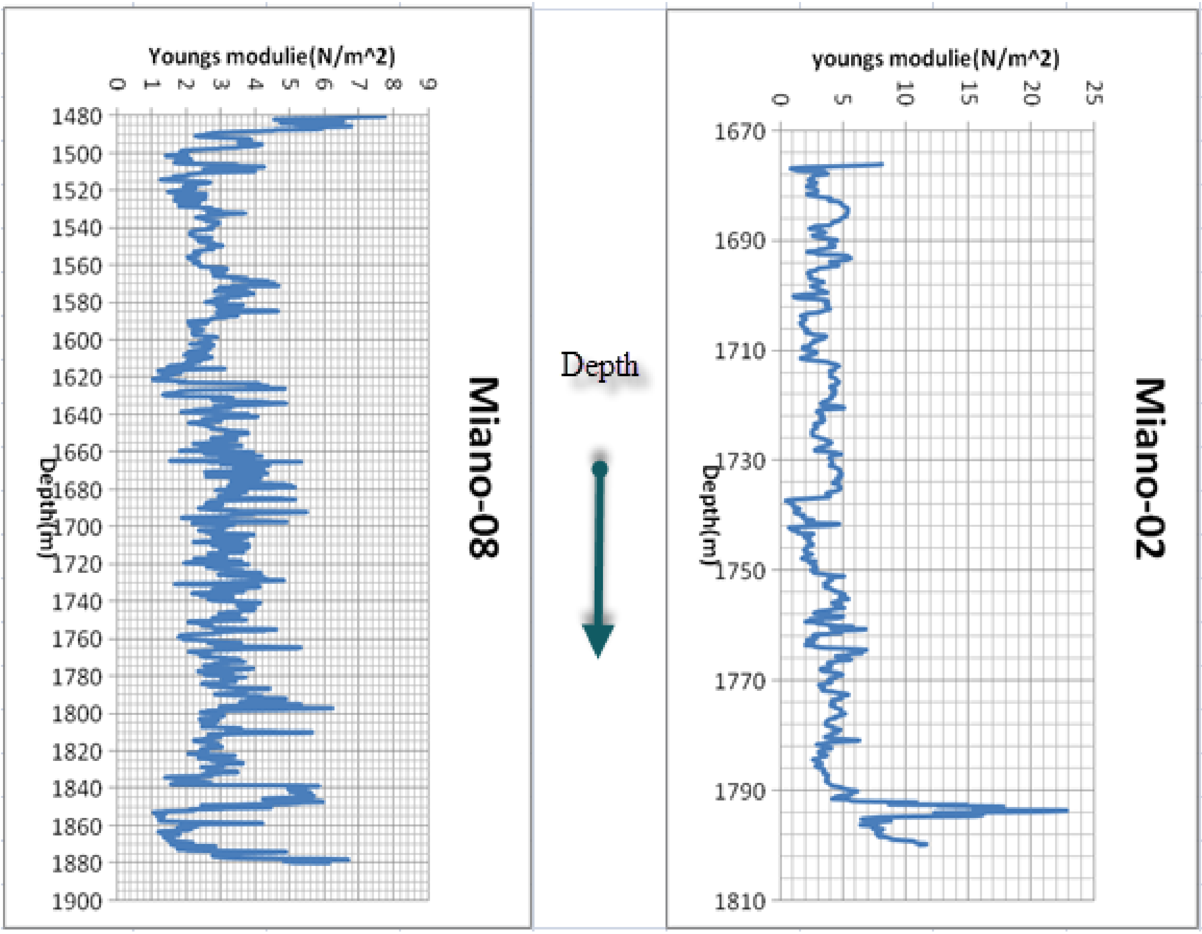


Figure (7.5) Young's Modulus of wells

7.2.7 **Poisson’s Ratio (σ)**

Poisson‟s ratio (σ) is defined as the transverse strain divided by longitudinal strain. This means that it is the measure of incompressibility of the rock body. Also Poisson‟s Ratio is more dependent upon P-wave velocity rather than S-Wave velocity (Telford, 1999). Estimation of Poisson‟s ratio from shear wave velocity and density has been done by using the formula:

$\sigma = 0.5*(Vp^{2} - 2* Vs^{2}/Vp^{2} - Vs^{2})$

Where;

σ = Poisson Ratio

Vp = P-Wave velocity in m/sec,

Vs = Shear wave velocity

In other words we can say that the Poisson‟s Ratio is the measure of the behavior of a seismic wave when it passes through the rock body. Behavior of Poisson‟ ratio through out the Rani Kot Formation. For hard rocks, the position‟s ratio has low values while soft rocks have higher values of position‟s ratio. Also the velocity of seismic waves depends upon the compaction of the subsurface material or hardness and softness of rocks and may be because of litho log so high value of Poisson‟s ratio indicates the compact sand and lower values infer the presence of soft material shale. Shown in figure 7.6.

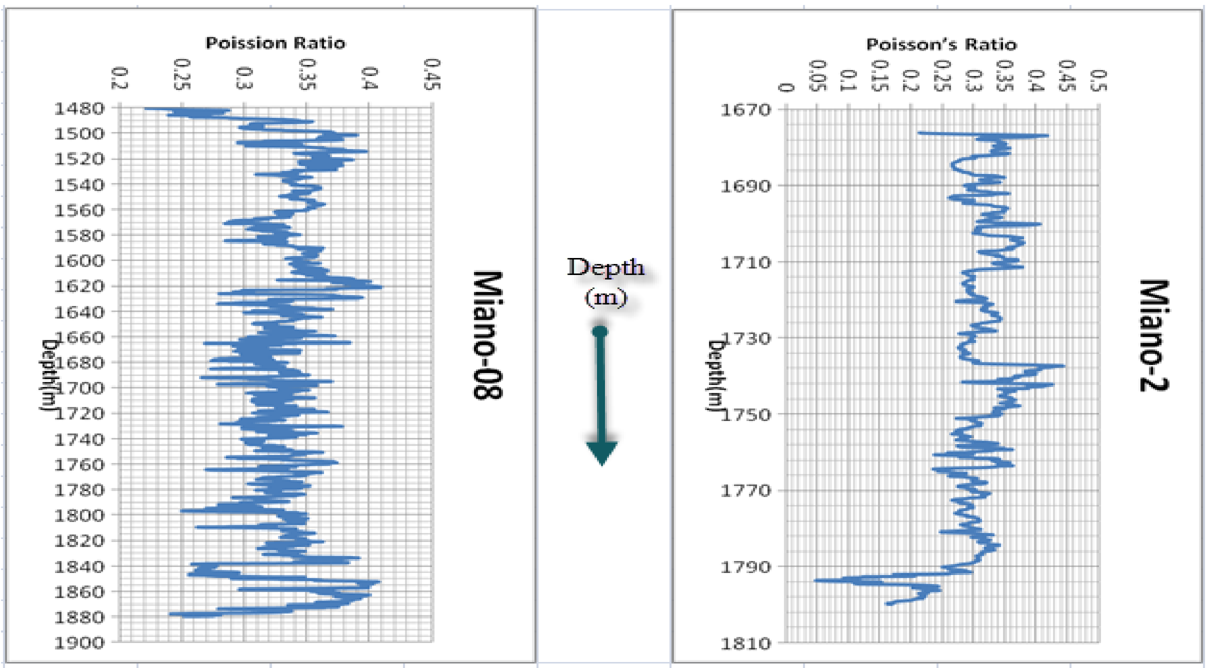


Figure (7.6) Comparison of Poision’s ratio of wells

7.3 Volume Of Shale

In order to characterize the reservoir , calculation of volume of shale is most important step. The gamma ray has been used as one of the independent shale indicators in the evaluation of shaly sand. Gamma ray log was used to calculate volume of shale of Rani Kot Formation.

Calculation of volume of shale was done by following process:

Calculation of gamma ray index is 1st step needed to determine the volume of shale from gamma ray log. Gamma ray index was calculated by using relation:

IGR =(GRlog – GRmin)/(GRmax− GRmin)

Where;

IGR = Gamma ray Index

GRlog = Measured Gamma Ray log reading

GRmax = Maximum Gamma Ray reading

GRmin =Minimum Gamma Ray

Volume of shale was then calculated by using Formula as:

[VShale= 0.083[2(3.7 * IGR) - 1]

The general trend of volume of shale throughout Rani Kot Formation is shown in figure 7.7

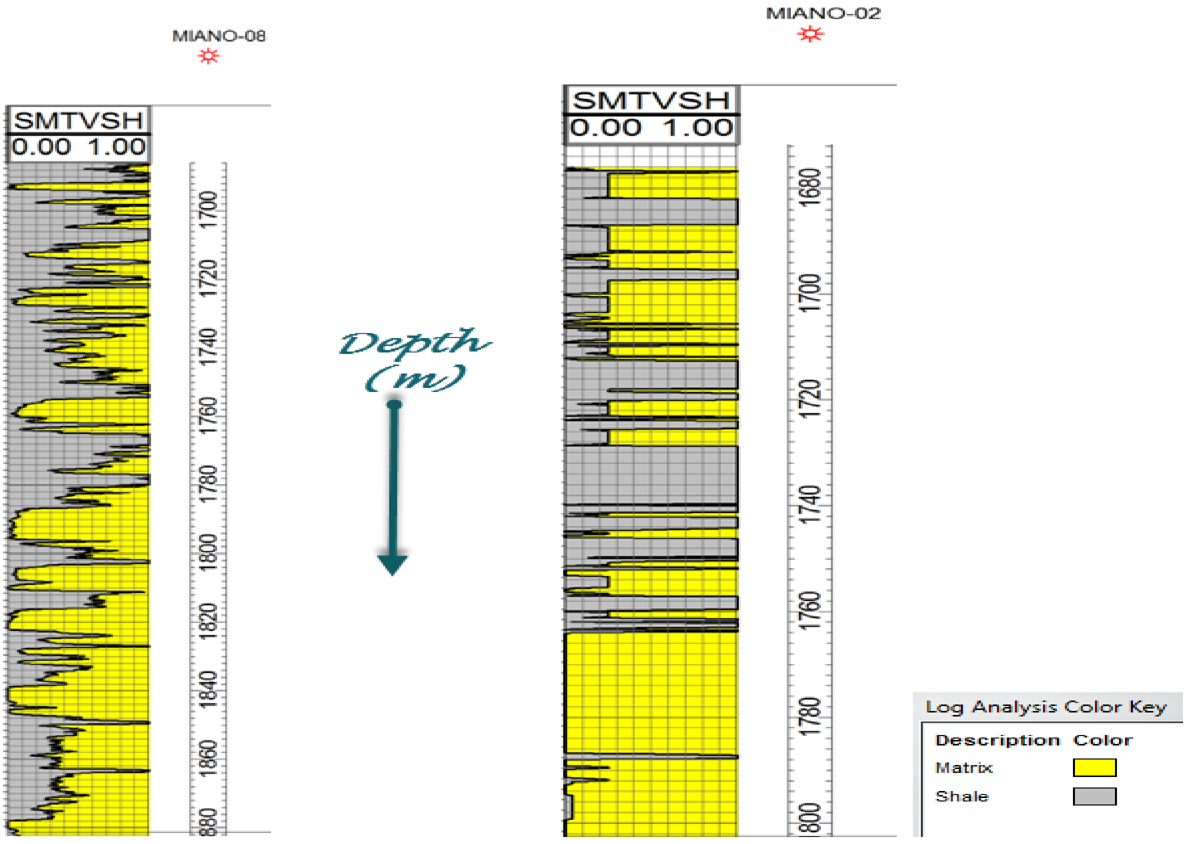


Figure 7.7 (volume of shale of two wells)

It is obvious from the figure that volume of shale present in Rani Kot Formation is average about 30 to 40 percent in Miano-08 where as it varies in Miano-02.As we move deeper volume of shale decreases which indicates the presence sand. In the upper part of this rock unit, lithology is mainly shale and little amount of carbonaceous material as confirmed by facies modeling. There is no doubt in saying that part of this rock unit is mainly composed of shales.

7.4 <u>Porosity</u>

Porosity is defined as the ratio of the volume of void spaces to the total volume of the rock. Porosity is the primary factor responsible for hydrocarbon storage in a reservoir rock. Estimation of porosity of any reservoir can be done using neutron, density and sonic logs. The behavior of porosity in Rani Kot Formation was measured by density log.

The trend of porosity throughout the Rani Kot Formation showed changes with depth and is shown in figure 7.8.

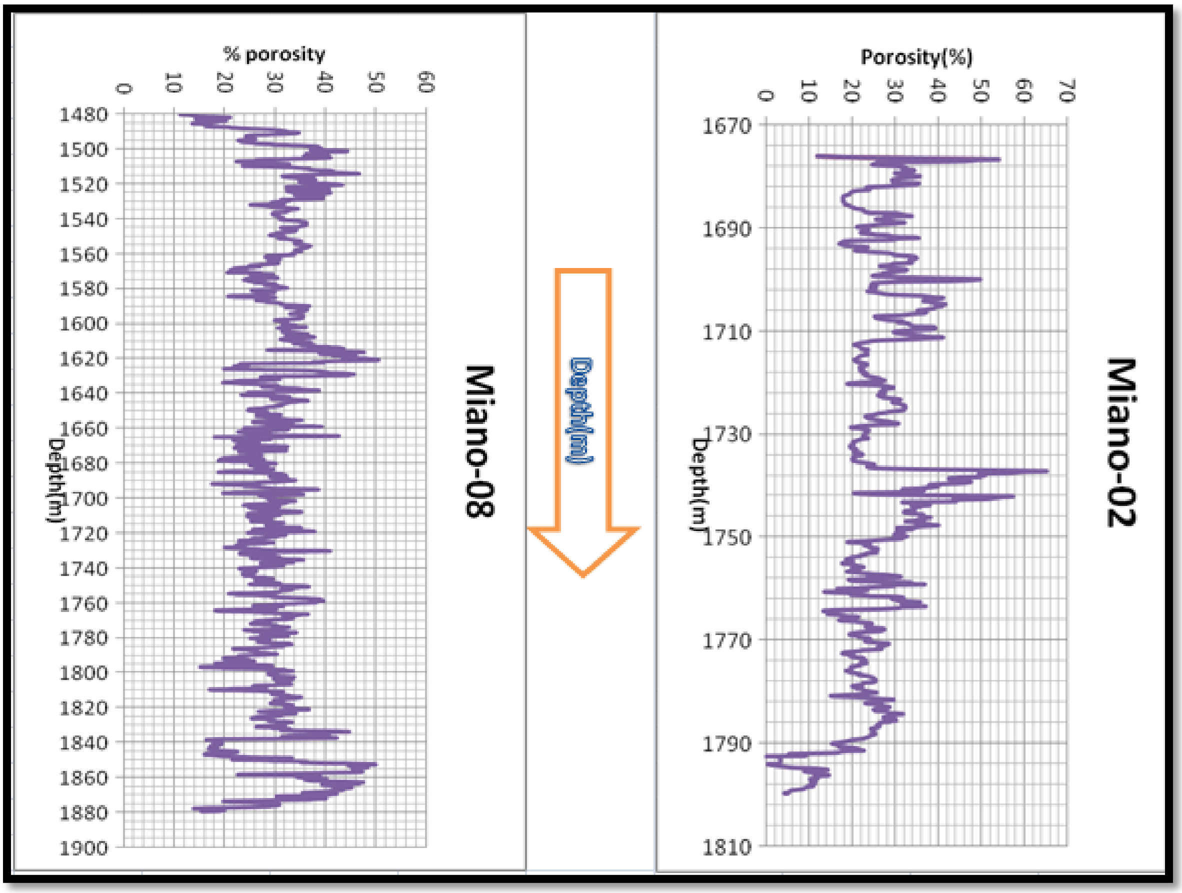


Figure (7.8) Porosity Comparison of Wells

It interpreted from the figure that porosity is comparatively low in upper portion of the rock unit but as we move down, variations in the porosity are observed.

7.5 <u>Pickett Plots for Resistivity of Water:</u>

Pickett plots are the cross plots of resistivity(LLD) and porosity (PHIE), It is almost impossible to calculate water saturations of a reservoir zone without resistivity measurements in cased well, a common situation in petrophysical analysis is when water resistivity (Rw) of a rock formation and/or the Archie Equation constants (a, m, n) are unknown. For this purpose Dick Pickett of the Colorado School of Mines determined that, since the values of Rw, a, and m are constant within a given reservoir unit, then there is a straight line relationship between log Ro (the resistivity of a reservoir which is completely saturated with formation water) and log Φ (porosity of the reservoir). The slope of the line is –m and the intercept is log aRw at log Φ = 0, If we plot these values on a log-log graph, this line represents Sw = 100%. Plotting measured Rt (measured resistivity) against porosity from the well log allows us to visually estimate the placement. The slope of this line in zones that contain both wet (Sw = 100%) and hydrocarbon intervals. Water zones tend to impinge on a linear barrier toward the lower left on the graph and hydrocarbon-bearing zones plot to the upper right.

BVW (bulk volume of water) of a zone is the product of porosity and water saturation (Sw * Φ). Since Swi (irreducible water saturation) is the water saturation at which all of the water in the formation is absorbed by the rock grains or held in capillaries by capillary overburden pressure, BVWi describes the combination of porosity and water saturation at which no formation water will flow, on a plot of Sw vs Φ, the zones which are at irreducible water saturation will tend to impinge on a barrier which describes this BVWi line. Later on the observation was made by G. E. Greengold, that this BVWi line could be plotted as a straight line on a Pickett Plot. Any data points that plot to the left of this line will produce some quantity of water and points that plot on the right side of Pickett Sw = 100% line will be fully saturated by water (Krygowski, 2003). The algorithm for the Sw Lines is (= 100%, 50%, 40%, 30%, 20% and 10%) The algorithm for the BVW Lines (= 0.2, 0.1, 0.08, 0.06, 0.05, 0.04, 0.03,) The Pickett cross plot of well Miano-02 of Miano area is generated and shown in the figure.(7.9)

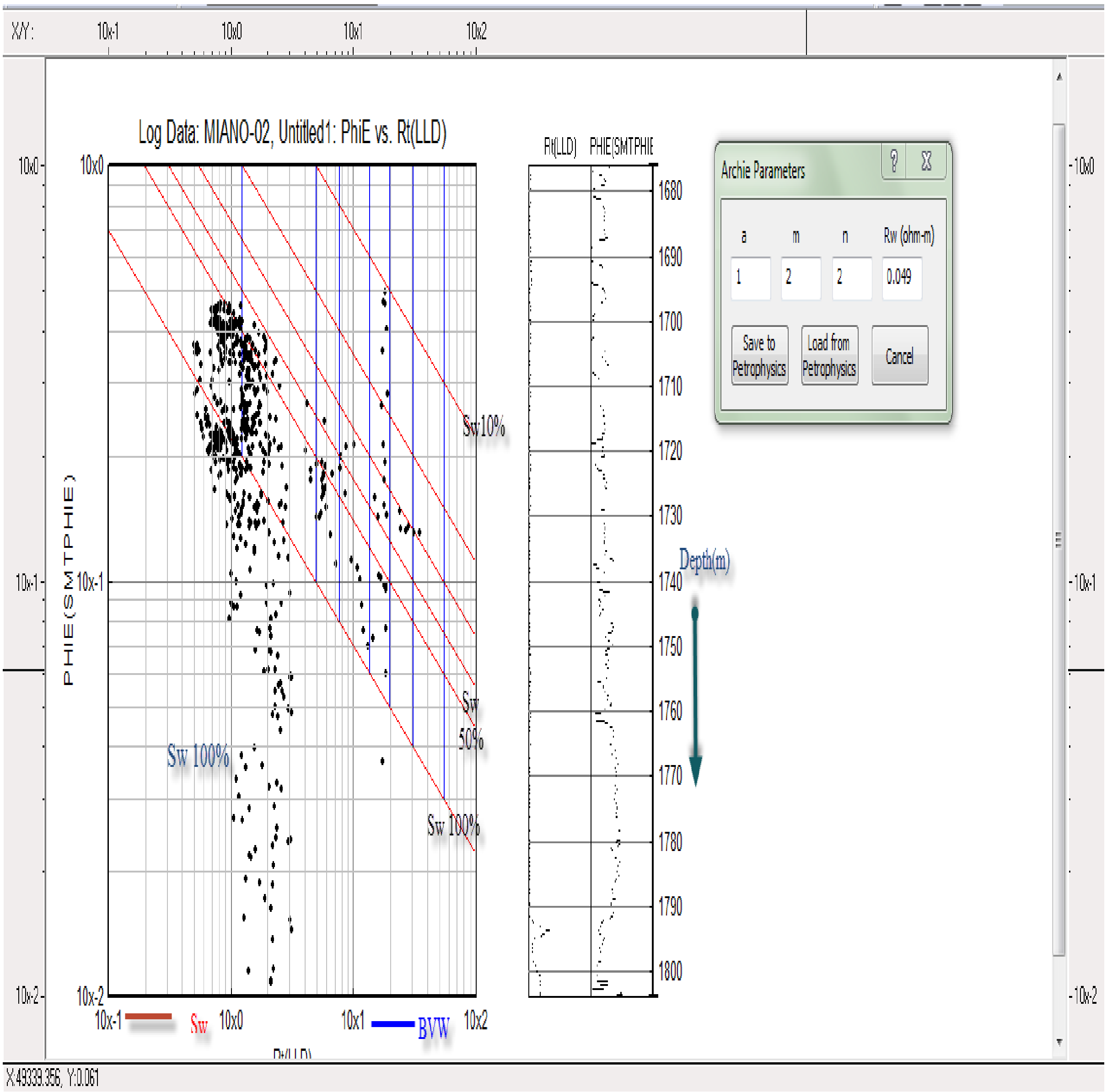


Figure 7.9 (Picket Plots)

7.6 Water and Hydrocarbons Saturation

Water saturation (Sw) and Hydrocarbon saturation for Rani Kot Formation Miano-02 and from following Archie equation, as well as from a selected model of sandstone.

Sw= (a*Rw/ϕm*Rt)1/n (Rider, 2002)

Where,

Rt: is the deep resistively (from LLD log).

Rw is the resistivity of the formation water (From Pickett plot).

ϕ is the porosity (NPHI log).

n is the saturation exponent.

a is the tortuosity factor which is equal to 1.

m is constant calculated from Pickett plot and its value is 2.

The composite logs of water saturation by Archie (SWAR), Formation water saturation by selected model (SW), Water saturation of flushed zone by selected model (SXO) and Total Porosity Miano-02 and Miano-08 wells are shown in figure 7.10. These logs show the water saturation of Rani Kot Formation of the above mentioned wells, where the portion of pore space that contain formation water high is probably not favorable for hydrocarbons. The remaining part of the reservoir pore spaces other than Water saturation (Sw) is taken as saturation of hydrocarbon. Now using this value of water saturation, we can calculate the hydrocarbon saturation (SH) using following simple relation: SH = (1 - Sw) (Rider, 2002).

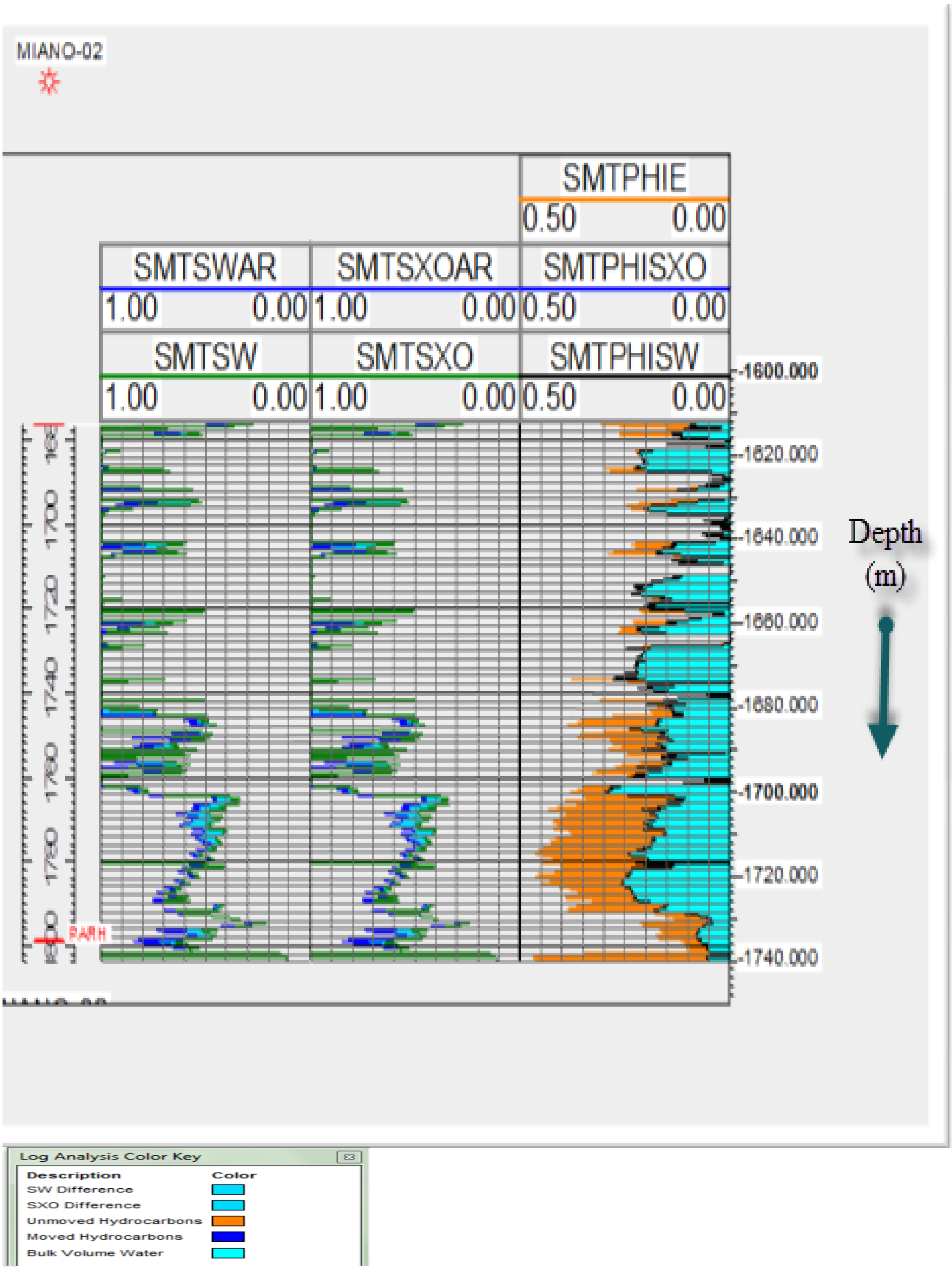


Figure 7.10 (Water Saturation of well Miano-02)

7.7 Facies Modeling

7.7.1 Facies

A facies is a body of rock with specified characteristics. Ideally, a facies is a distinctive rock unit that forms under certain conditions of sedimentation, reflecting a particular process or environment.

Types Of Facies

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

1. Sedimentary Facies

2. Metamorphic Facies

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

7.7.2Walther's Law Of Facies

Walther's Law of Facies states that the vertical succession of facies reflects lateral changes in environment. Conversely, it states that when a depositional environment "migrates" laterally, sediments of one depositional environment come to lie on top of another. A classic example of this law is the vertical stratigraphic succession that typifies marine transgressions and regressions. However, the law is not applicable where the contact between different lithologies is non-conformable (Lucia 1995).

Transgression

A marine transgression is a geologic event during which sea level rises relative to the land and the shoreline moves toward higher ground, resulting in flooding.

Regression

A marine regression is a geologic event during which sea level falls relative to the land and the shoreline moves toward lower ground and exposes former sea bottom.

7.7.3 **Facies Analysis**

Fundamental to all subsurface geologic studies is an analysis of depositional facies. Development of a facies classification scheme is a particular challenging interplay between capturing enough information for environmental interpretation yet remaining simple. Particularly important is the characterization of facies such that their recognition criteria relate to critical environmental threasholds such as sea level, norma wave base, and storm wave base. These physical environmental zones regulate sedimentary textures and biotic assembleges. A good understanding of paleoecology always strengthen the interpretation and such studies should be included as part of all depositional facies studies. Depositional textures in turn affect porosity-permeability in carbonates . The vertical and lateral organization of facies is an exercise essential to sequence stratigraphic interpretations. (Lucia 1995).As shown in figure (7.11).

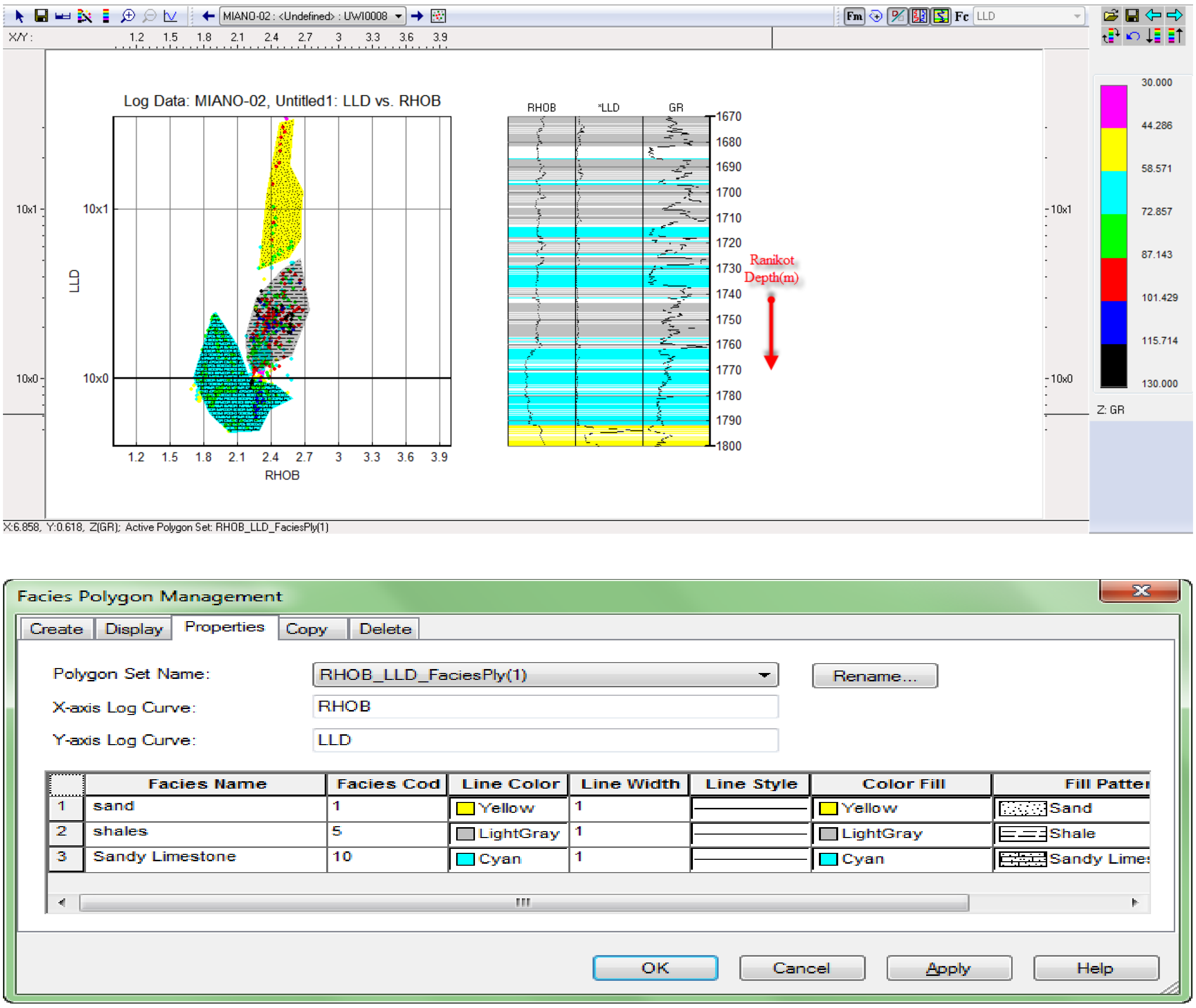


Figure (7.11) Facies Modeling

Conclusion:

- The study area is dominated by Normal faulting; these faulting in the area show that area is deformed by the extensional tectonics movement which results in Horsts and Graben structures.
- On the basis of general stratigraphic column present in the area and the formation tops of the Miano-08 well, six reflectors are marked on lines, first reflector is Sui Main Limestone and Rani Kot, Upper Guru, Lower Guru, Sand D,C and B intervals.

- Time and depth contour maps and 3-D surfaces of Rani Kot Formation helped to confirm the presence of horst and graben structures in the study area.

- Rock physics studies showed that both stiffer and softer lithologies are interbeded through out the Rani Kot Formation and softer material is dominant in middle portion.

- Petrophysical study and facies modeling of the Rani Kot Formation revealed that upper portion of rock unit is mainly composed of shales with interbeded limestone and lower portion about 10 to 20m thick may have gas. The Rani Kot Formation is partially saturated with water.

- Rani Kot formation consist of shales in upper portion with limestone and lower about 10 to 15m in Miano-02 portion consist of sand, it can be good source rock rather than a reservoir rock as previous studies reveals that initially gas production is from shallow depths.

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