2D-SEISMIC REFLECTION DATA INTERPRETATION, PETROPHYSICAL ANALYSIS AND SEISMIC ATTRIBUTE ANALYSIS OF KHIPRO AREA, LOWER INDUS BASIN, PAKISTAN

BY

DANIAL SHAHZAD SATTI

BS (GEOPHYSICS)

2016-2020

DEPARTMENT OF EARTH SCIENCES

QUAID-I- AZAM UNIVERSITY ISLAMABAD, PAKISTAN


In the name of Allah, Most Gracious, Most Merciful

CERTIFICATE

This dissertation submitted by Danial Shahzad Satti S/O Shahzad Iqbal 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

Dr. Tahir Azeem

____

(Dissertation Supervisor)

Dr. Aamir Ali

____

(Chairman Department of Earth Sciences

EXTERNAL EXAMINER

____

ACKNOWLEDGEMENT

In the name of Allah, the most Beneficent, the most Merciful. All praises to Almighty Allah, the creator of universe. I bear witness that there is no God but Allah and Holy Prophet Hazrat Muhammad (P.B.U.H) is the last messenger of Allah, whose life is a perfect model for the whole mankind till the Day of Judgment. Allah blessed me with knowledge related to Earth. Without the blessing of Allah, I could not be able to complete my work as well as to be at such a place.

I am especially indebted to my dissertation supervisor Dr. Tahir Azeem for giving me an initiative to this study. His inspiring guidance, dynamic supervision, and constructive criticism, helped me to complete this work in time. Heartily thanks to whole faculty of department of Earth Sciences especially the teachers and senior students of Department of Earth Sciences whose valuable knowledge, assistance, cooperation and guidance enabled me to take initiative, develop and furnishing my academic carrier. I would like to thank Jamal Abdul Nasir and Abdullah Abbasi who helped me in studies whenever I needed. My friends and my parent's encouragement played a role of back bone throughout my academic carrier

Danial Shahzad Satti

Bs Geophysics

2016-2020

DEDICATION

I would like to dedicate this thesis work to my sweet parents, teachers and friends whose love, encouragement, guidance and prays make me able to achieve such success and honor.

ABSTRACT

The present study pertains to the structural and stratigraphy interpretation, attributes analysis, petrophysical analysis and estimation of rock physics of Khipro area. The data used for this study consists of SEG –Y data, navigation data and well logs data. Khipro area is prominent in the Lower Indus Basin for its hydrocarbon structural traps. This thesis work includes preparation of synthetic seismogram of Naimat Basal-01 well, which was then later used for seismic to well tie for the seismic lines in order to mark the horizon of interest, along with demarcating faults associated in the study area. Since the study area lies in the extensional regime as confirmed by the geology of the study area from literature, we encounter horst and graben structures, and normal faulting. Time and depth contours maps of the three horizons are generated which delineates the horst and graben structures that confirms normal faulting in the study area. Naimat basal-01 well is drilled on the horst area in Khipro area. Seismic attributes analysis of seismic section helps in identifying the different lithological boundaries and confirmed the structural disturbance. By using well data estimation of petrophysical analysis are also possible for identification of accumulation of hydrocarbons. Low volume of shale, high effective porosity, low water saturation and high hydrocarbon saturation in zone of interest are the indicator for hydrocarbon presence and the porous reservoir formation, which is suitable for hydrocarbon accumulation, also for quantitative interpretation averages of the different petrophysical logs are calculated.

Contents

CHAPTER 01

INTRODUCTION

1.1 Introduction

The purpose of this dissertation is to interpret the subsurface structures based on seismic reflection data. We try to transform the whole seismic information into structural or stratigraphical model of the earth through the seismic interpretation. As seismic section represents the geological model of earth, we try to find out the final zone of anomaly by interpretation. According to Sheriff (1999) it is very rare that we can make sharp boundary of correct or incorrect interpretation because actual geology is rarely well known. The test of good interpretation is consistency rather than correctness. Good interpretation be consistent with all the seismic data, but it is also important to know all about the area, including gravity and magnetic data, well information, surface geology as well as geologic and physical concept (Sheriff, 1999).

Seismic methods are the most important and commonly conducted geophysical survey technique used in the oil and gas exploration industry. Seismic measurements can be used to gain knowledge about geological structures in the ground. The oil industry uses seismic measurements to locate oil-and gas reservoirs. Identification of subsurface structure, petrophysical analysis and estimation of rock properties are the most important tools to identify hydrocarbons.

1.2 Objective

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

- Structural interpretation to find out the structural traps and horizons of the formation.
- Generation of synthetic seismogram to mark horizons.
- Petrophysics, to understand the rock properties of the reservoir.

1.3Data used

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

1.3.1 Seismic Data

All data sets used were provided by Directorate General of Petroleum concession (DGPC), Government of Pakistan for the research purpose. The data used for current research includes three seismic lines and one well. Bold lines are assigned to me for the completion of this research work. Information of the well data which has been provided to us for the dissertation.

1.3.2 Base Map

A base map is a map on which primary data and interpretation can be plotted. A base map typically includes location of concession boundaries, wells, seismic survey points, longitude, and latitude of the study area. Following 2-D reflection seismic lines are used to construct the Base map of 2D seismic survey for given study area. Base map of the study area shown in Figure 1.1.

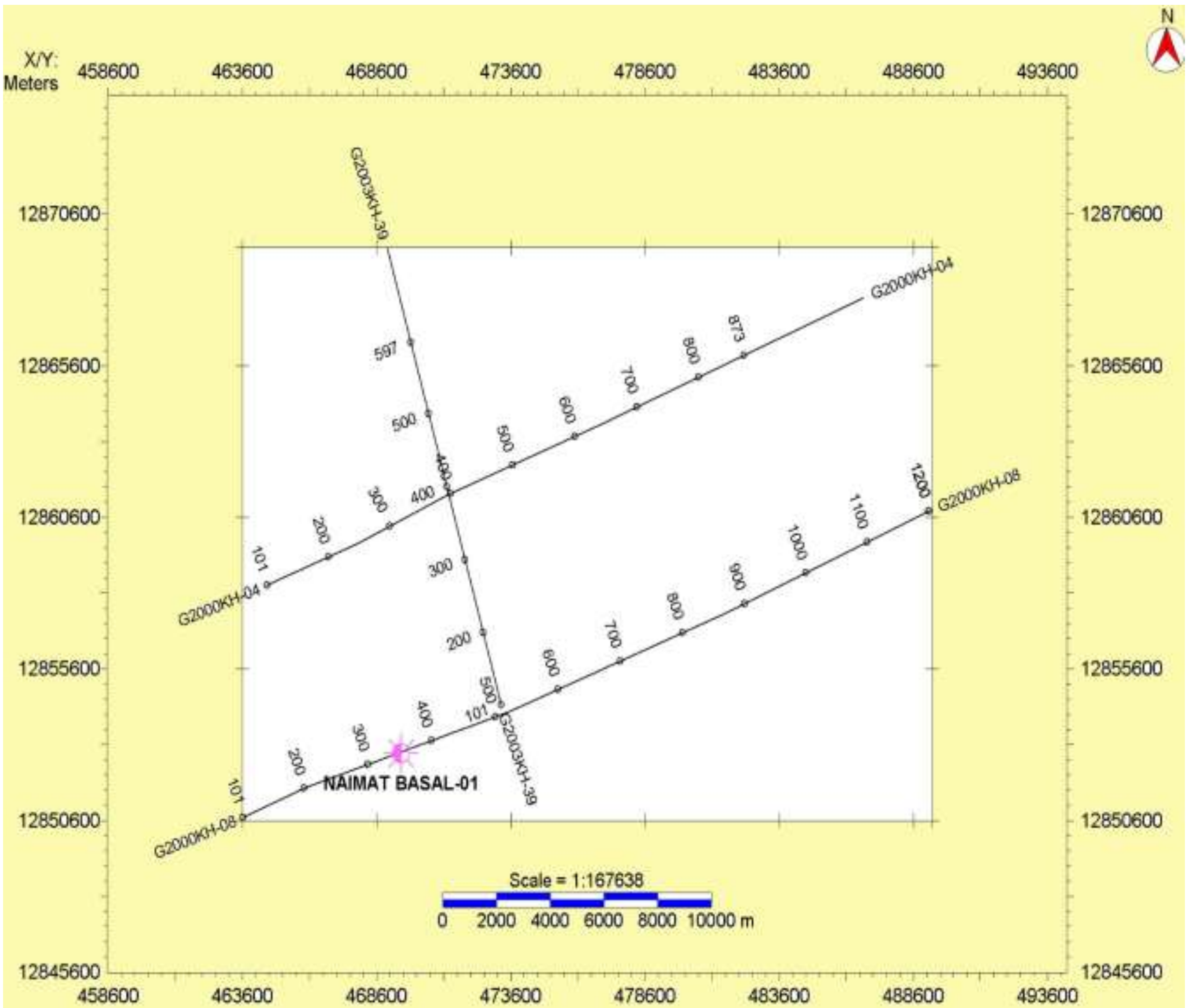

Figure 1.1: Showing the base map of the study area (Khipro).

Information of a well Naimat Basal-01 are listed in Table 1.1.

Well	Naimat Basal-01
Latitude	025.793802
Longitude	068.696482
KB	110 ft.
Total Depth	3621.6300 m
Status	Exploratory
Exploration	Gas/Cond
Source	Dynamite
Company	OPI
Formation Tops	**Depth(m)**
Alluvium	0
Kirthar-Laki	524.8
Ranikot	1010.7
Khadro	1374.6
Upper Goru	1697.7
Upper Shale	2860.4
Middle Sand	2999.1
Lower Shale	3143.9
Sand Above Talhar shale	3389.2
Talhar Shale	3407.5
Sand below talhar Shale	3479.1

Table 1.1: Information of Naimat Basal-01 Well.

1.4 Introduction to Study Area

The area of interest is laying in Southern Indus Basin. Normal faults are more prominent structures of the area (Horst and Graben geometry), which form the structural traps. The identification of these traps is one of the main tasks for the Geoscientists in exploration of hydrocarbons. To observe these structures the seismic line G2000 KH-08 and well Naimat Basal are provided by the department of Earth Sciences Quaid-i-Azam University Islamabad, in order to interpret the seismic section along the seismic lines. Geographical coordinates of the area are in Figure 1.1.

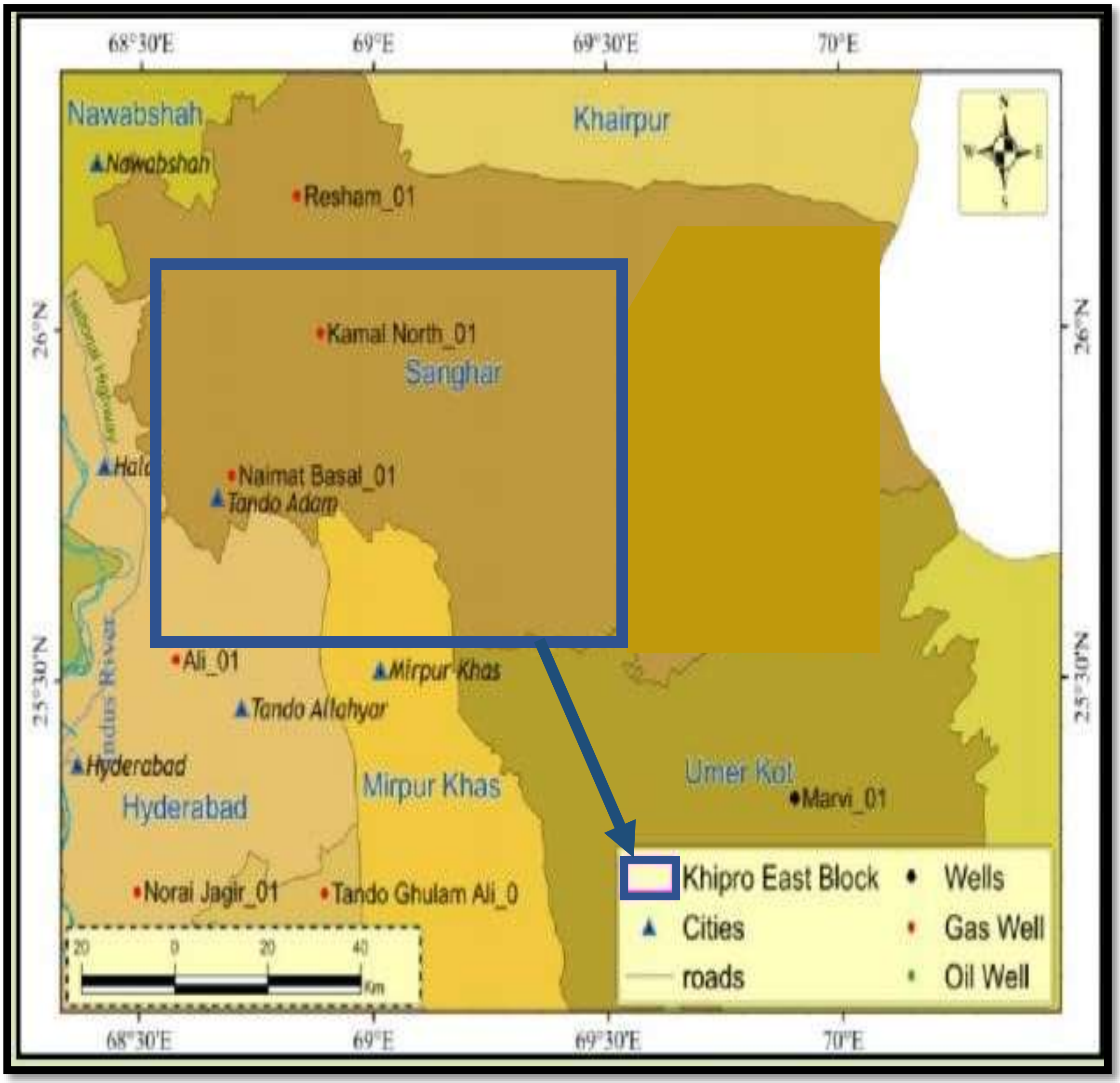

Figure 1.2: Showing the location of the Study Area (Khipro).

1.5 Methodology

Seismic reflection data of the Lower Indus Basin of Khipro area is given to us to interpret the sub surface structures. In this practice, software Kingdom 8.4 was used. After uploading the seismic lines data on kingdom, synthetic seismogram was generated, from one of the given wells then the faults and horizons were marked and faults on seismic section Time and depth contour maps are generated based on the marked horizons. Seismic attribute analysis is carried out on one of the given lines in order to confirm the seismic interpretation. Petrophysical analysis is done in order to differentiate the zone of interest or hydrocarbon potential zone in the reservoir formation. The workflow is given below in figure 1.3

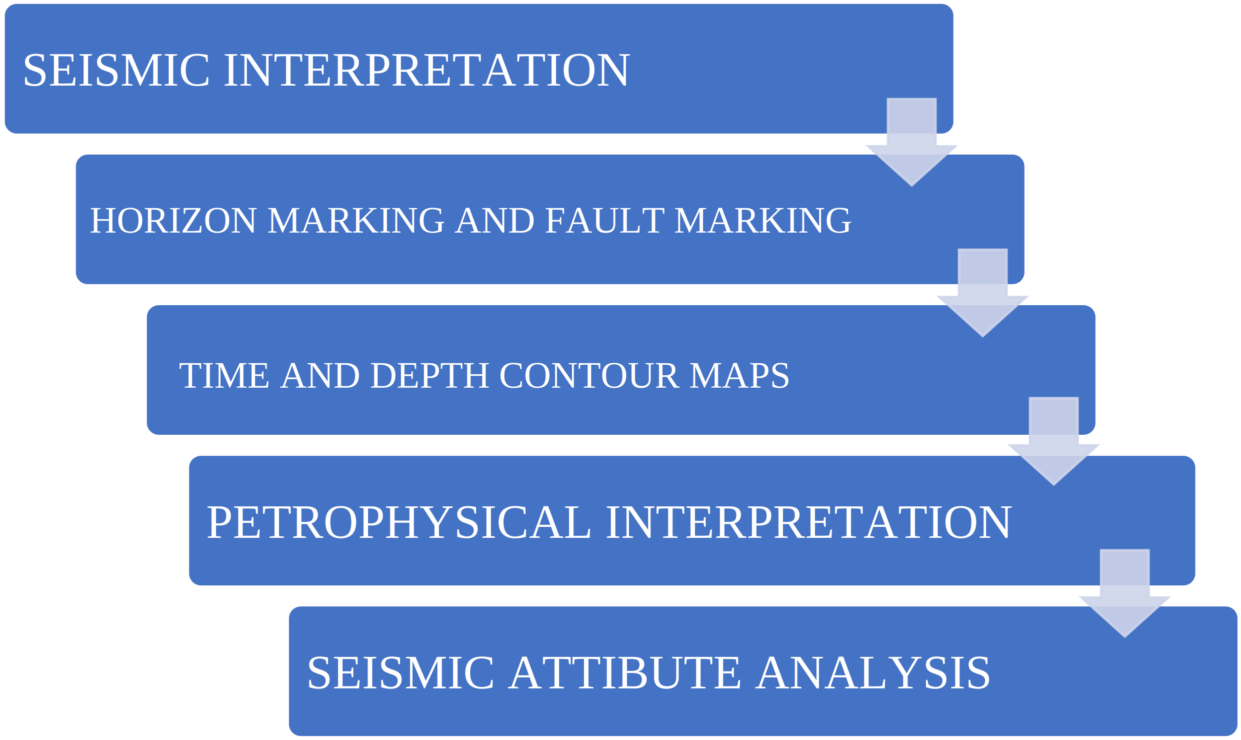

Figure 1.3 Detailed workflow used in this research.

CHAPTER 02

GEOLOGY AND TECTONIC OF THE AREA

2.1 Introduction to Geology

General geology and geological history of an area is very important for exploration of hydrocarbons. A geological history of basin can be compiled by considering basin forming tectonics and depositional sequence (Kazmi and Jan 1997). Geology of the area is quite important for the interpretation of the seismic data, without having precise information about the geology of the area we are unable to pick the different horizons in the seismic data. For structural analysis (faulting and folding) in the area is determined by the tectonic history of the area. The area of study is in lower Indus basin extended approximately between latitude **24˚ to 28˚N** and **66˚ to 68˚E** (eastern boundary of Pakistan).

2.2 Geological Boundaries of Lower Indus Basin

The study area is situated in Southern Indus basin and have following geological boundaries as shown in Figure 2.1.

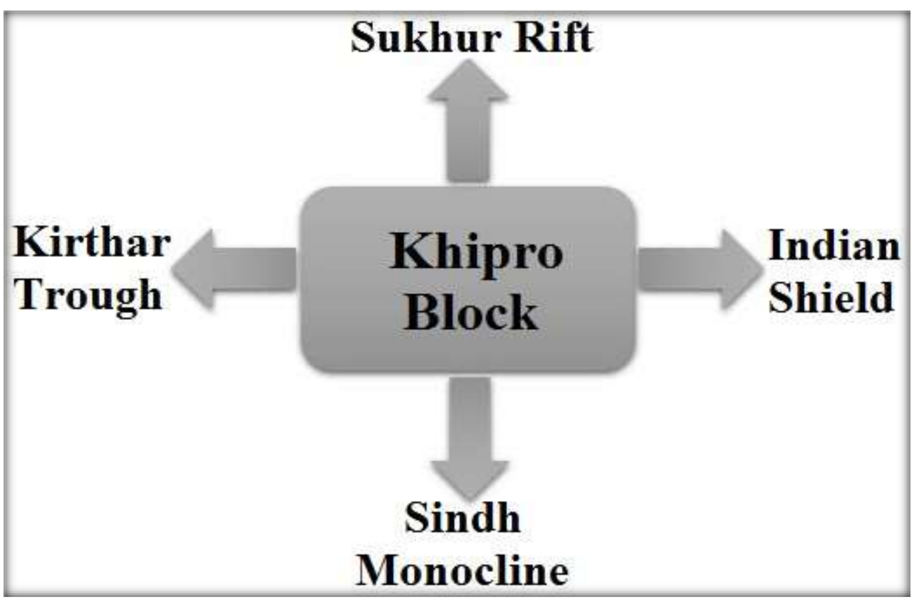

Figure 2.1: Geological boundaries of Khipro block.

2.3 Structural Setting of Lower Indus basin

The geological history of Indus basin goes back to the Precambrian age. The Indus basin is mainly classified as upper Indus basin and lower Indus basin (central Indus basin and southern Indus basin). The central and southern Indus basin are separated by Jacobabad and Mari Khandkot highs together termed as Sukhur rift (Raza et al., 1990).

The study area is situated in southern Indus basin which is located just south of the Sukhur rift. It comprises the following four main units.

- Thar Platform
- Karachi Trough
- Kirthar Foredeep
- Kirthar Fold Belt

The platform and trough extended into offshore Indus. The southern basin is bounded by Indian shield to the east and the marginal zone of Indian plate to the west, its southward extension is confined by offshore Murray ridge-oven fracture plate boundary (Kadri, 1995).

The oldest rocks encountered in the area are of Triassic age, central and southern Indus basin were undivided until lower/middle cretaceous when Khairpur Jacobabad high became a prominent positive feature. This is indicated by homogeneous lithologies of Chilton limestone of Jurassic age and Sembar formation of lower cretaceous age across the high. Sand facies of Goru formation of lower/middle cretaceous are also extended up to Khandkot and Giandari area (Kadri, 1995).

Normal faults are generated as a result extensional tectonics, forming horst and graben structures with former being of great exploratory importance. The extensional tectonics during the Cretaceous time created tilted fault blocks over a wide area of the Eastern lower Indus basin (Kemal et al 1991). Lower Indus basin is characterized by passive roof complex type structure and a passive back thrust along Kirthar fold belt. Passive roof thrust forming a frontal culmination wall along the margin of the fold belt and the Kirthar depression and out of syncline intra-molasses detachment in the Kirthar depression sequence (Zaigham, 2000).

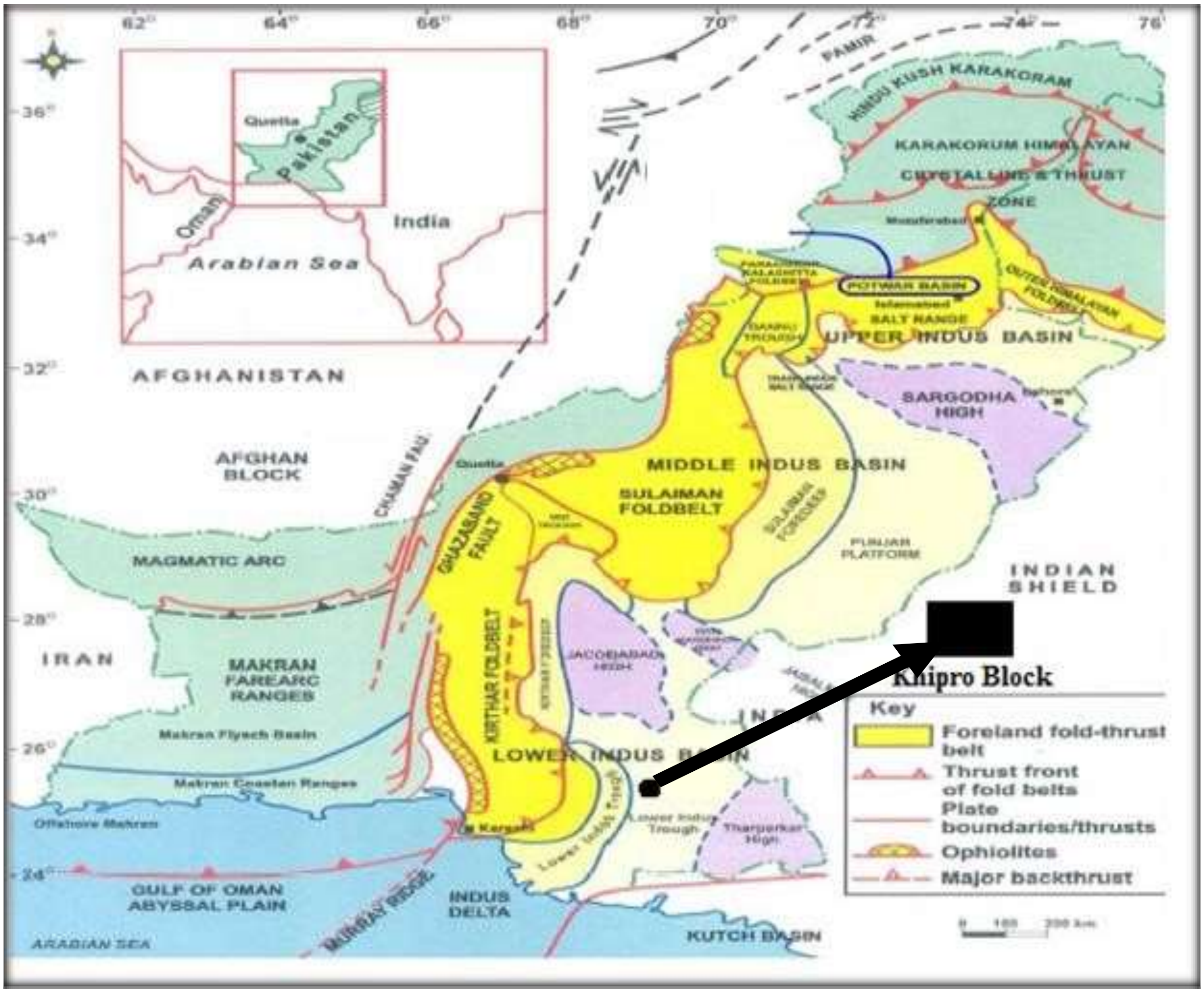

Figure 2.2: Tectonic framework of Pakistan (Banks and Warburton, 1986).

2.4 Stratigraphy in the Study Area

It is very critical to have knowledge about the stratigraphy of the area for the hydrocarbons prospecting, by this knowledge it is determined that what are the source, reservoirs and seals rocks of the area. The lithological setting (Figure 2.4) and stratigraphic sequence of the study area is given below, with the generalized stratigraphic column of the study area as shown in Figure 2.3.

2.4.1 Kirthar Formation

Kirthar formation (Middle Eocene) is mainly fossiliferous limestone interbedded with subordinate shale and marl. The limestone is thick bedded to massive and nodular in places. The environment of deposition is shallow marine (Shah, 1977).

2.4.2 Parh Limestone

This formation consists of hard, thin to medium bedded limestone with subordinate calcareous shale and marl intercalations. Environment of deposition is shallow marine (Shah, 1977).

2.4.3 Goru Formation

Goru formation (Early cretaceous) consists of interbedded limestone, shale, marls, sandstone and siltstone. The environment of deposition is shelf to shallow marine. Different parts of this thick formation have enough reflectivity indexes to produced very clear reflections. Goru formation is divided into two parts (Kadri, 1995).

2.4.4 Upper Goru

It is comprised of marl calcareous clay- stone occasionally with inter-beds of silt and limestone (Kadri, 1995).

2.4.5 Lower Goru

It is consisting of Basal Sand unit, Lower Shale, Middle Sand unit (which is a very good reservoir rock) Upper Shale and Upper Sand (Shah, 1977).

2.5 Petroleum Play of the Study Area

In geology a petroleum play or simply a play is a group of oil field or prospects in the same region that are controlled by the same set of geological circumstances. The Petroleum System consists of a mature source rock, migration pathway, reservoir rock, trap and seal appropriate relative timing of formation of these elements and the processes of generation migration and accumulation are necessary for hydrocarbons to accumulate and be preserved (Stoneley, 1995).Lower Indus basin is main hydrocarbons producing basin of the Pakistan 37% hydrocarbons of the Pakistan are extract from the lower Indus basin (Kadri, 1995).

2.5.1 Source Rock

Sembar Formation of Early Cretaceous age is a proven as major source rock in Lower Indus Basin and Intra Lower Goru Shales of Cretaceous age also has source rock potential. Sembar is mainly composed of clastic rocks, primarily shale followed by sandstone and siltstone with minor limestone. Sembar is considered to have been deposited on a broad shelf, gently sloping westward off the Indian shield. Shale of Goru formation is widespread and thick. They contain abundant organic matter and generally exhibit the good source rock characteristics (Kadri, 1995).

2.5.2 Reservoir Rock

Reservoirs are rocks having hydrocarbon bearing potential. Hydrocarbons are trapped in these rocks after migration. Lower Goru Sands are reservoir rocks in Khipro. The main reservoir rocks are the sand of cretaceous age (Lower Goru formation). The Goru formation is dominantly shale and mudstone frequently calcareous. Sand is rare in upper part with increasing tendency toward the base where it has developed into a producing reservoir. Based on its lithological content it has been divided into lower Goru and upper Goru, petroleum potential of Lower Goru sand is very good as it contains hydrocarbons in Sindh monocline (Kadri, 1995).

2.5.3 Seal Rock

Seals act as a barrier for the flow of hydrocarbons. In the Lower Indus Basin Upper Goru and Intra Lower Goru Shales of Cretaceous age provide seal for the Lower Goru reservoir sands (Kadri, 1995).

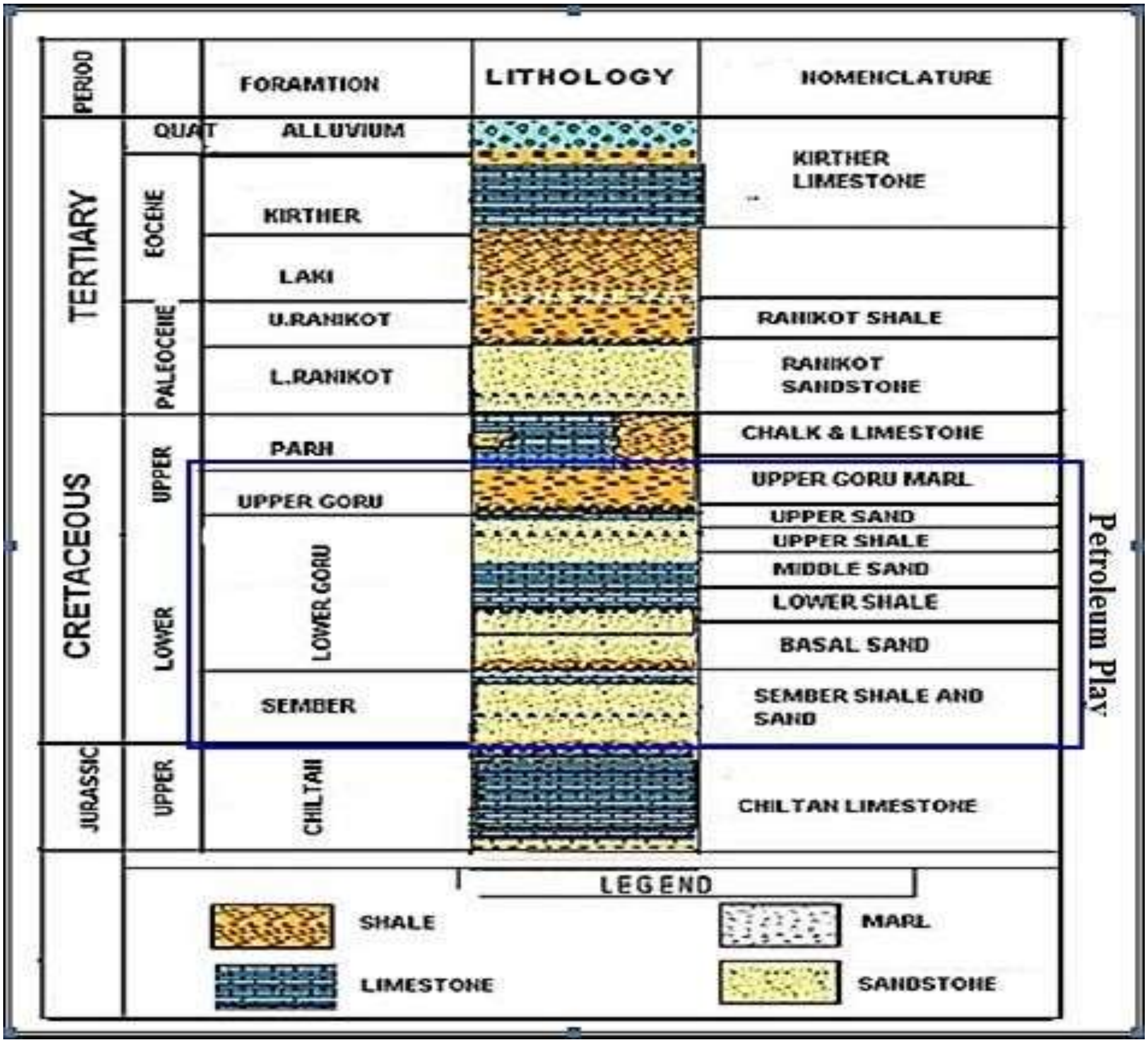

Figure 2.3: Petroleum play of Lower Indus basin. (Stoneley,1995)

CHAPTER 03

SEISMIC INTERPRETATION

3.1 Seismic Surveying

In seismic surveying, seismic waves are created by a controlled source and propagate through the subsurface. Some waves will return to the surface after refraction or reflection at geological boundaries within the subsurface. Instruments distributed along the surface detect the ground motion caused by these returning waves and hence measure the arrival times of the waves at different ranges from the source. These travel times may be converted into depth values and, hence the interfaces of subsurface lithologies can be marked (Kearey et al., 2002).

3.2 Seismic Methods

Seismic Methods deal with the use of artificially generated elastic waves to locate hydrocarbon deposits, geothermal reservoirs, groundwater, archaeological sites, and to obtain geological information for engineering. It provides geophysical, borehole and geological data, and with concepts of physics and geology, can provide information about the structure and distribution of rock types in the subsurface (Kearey et al., 2002).

There are two types of seismic methods:

- Seismic refraction method
- Seismic reflection method

3.2.1 Seismic Reflection Method

In seismic reflection surveys seismic energy pulses are recorded which are reflected from the subsurface interfaces. The travel times are measured and can be converted into estimates of depths to the interfaces (Kearey et al., 2002). Depth of reflecting interfaces can be estimating from the recorded time and velocity information that can be obtain either from reflected signal themselves or from surveys in well (Dobrin & Savit, 1988). Velocity may also vary horizontally, due to lateral lithological changes within the individual layers (Kearey et al., 2002).

3.3 Seismic Interpretation

Seismic interpretation is the technique to get the information about the subsurface using available seismic data. This information may contribute towards the general information of the area, tells the interpreter about the favorable prospects or it is used for further development of already discovered oil and gas field.

Sheriff (1999) describes that it is rare that the correctness or incorrectness of interpretation can be firmed because the actual geology is rarely known in well manner. A good interpretation is consistency with all of the available data. In oil and gas exploration, our focus is on finding an interpretation that is more favorable for hydrocarbon accumulation. As with many scientific investigations, interpretations are almost always non-unique (Sheriff, 1999).

According to Coffeen (1986), most common activity in interpretation is picking a horizon and marking faults. A horizon is a reflection that appears on the seismic section for a considerable geographical extent. The reflections are picked i.e. marked at shot points, along the vertical section over the area. The picks are timed by reading the reflection times. These times can then be plotted on a map and contoured, to show locally high places or other features that may be prospects for drilling.

3.4 Types of Seismic Interpretation

There are two types of seismic interpretation

- Stratigraphical Interpretation
- Structural Interpretation

3.4.1 Structural Interpretation

Seismic data interpretation is mainly done based on available information and stratigraphy of the area. Seismic is correlated with the formation tops penetrated in the wells using well tops if available. In this study, seismic interpretation is done by picking horizons in Kingdom suit and reflector is continued in all other seismic lines. Major faults are picked on the dip lines and their parts are correlated across the strike lines to map the structures throughout the area. Two-way time (TWT) maps are generated using fault polygons in order to describe the structural inclination at different levels. The study area is in extensional regime, horst and graben structures are present in the area. The horizons which are marked on seismic section show normal faults.

3.5 Seismic Interpretation Workflow

Procedure adapted for interpretation is given in Figure 3.1. Base map is prepared by loading navigation data and Seg-Y in software Kingdom 8.8. Horizons of interest are marked manual with help of synthetic seismogram. In this process faults are identified and also marked. Faults polygons are generated, and horizons are contoured to find out structural highs and lows. The different important steps involved in the interpretation workflow (Figure 3.1) are discussed in detail as follow.

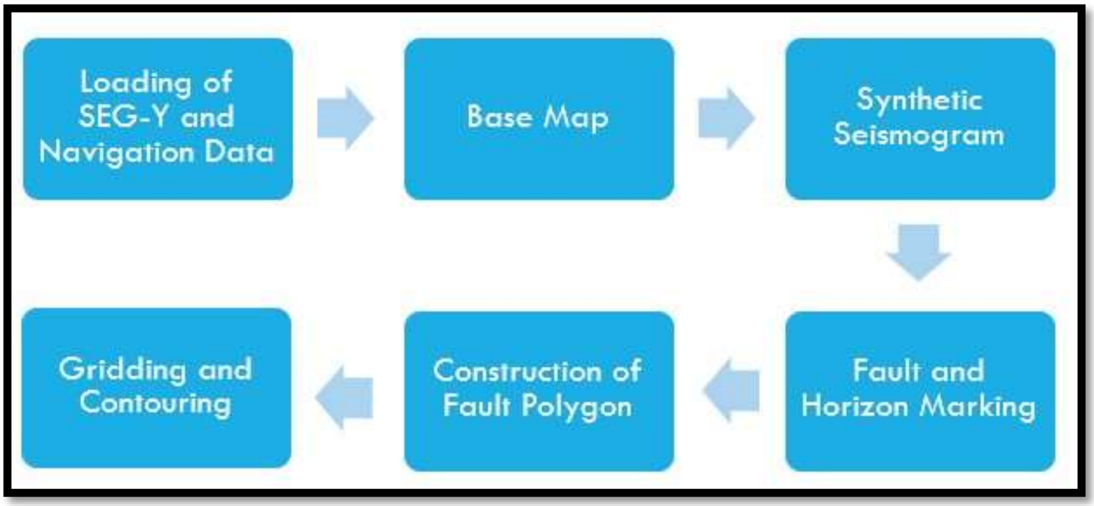

Figure 3.1: Workflow for seismic data interpretation.

3.6 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. With the help of Naimat-Basal-01 well, we construct the synthetic seismogram (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. 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 petrophysics, it is possible to identify the origin of seismic reflectors and trace them laterally along the seismic line (Handwerger et al., 2004).

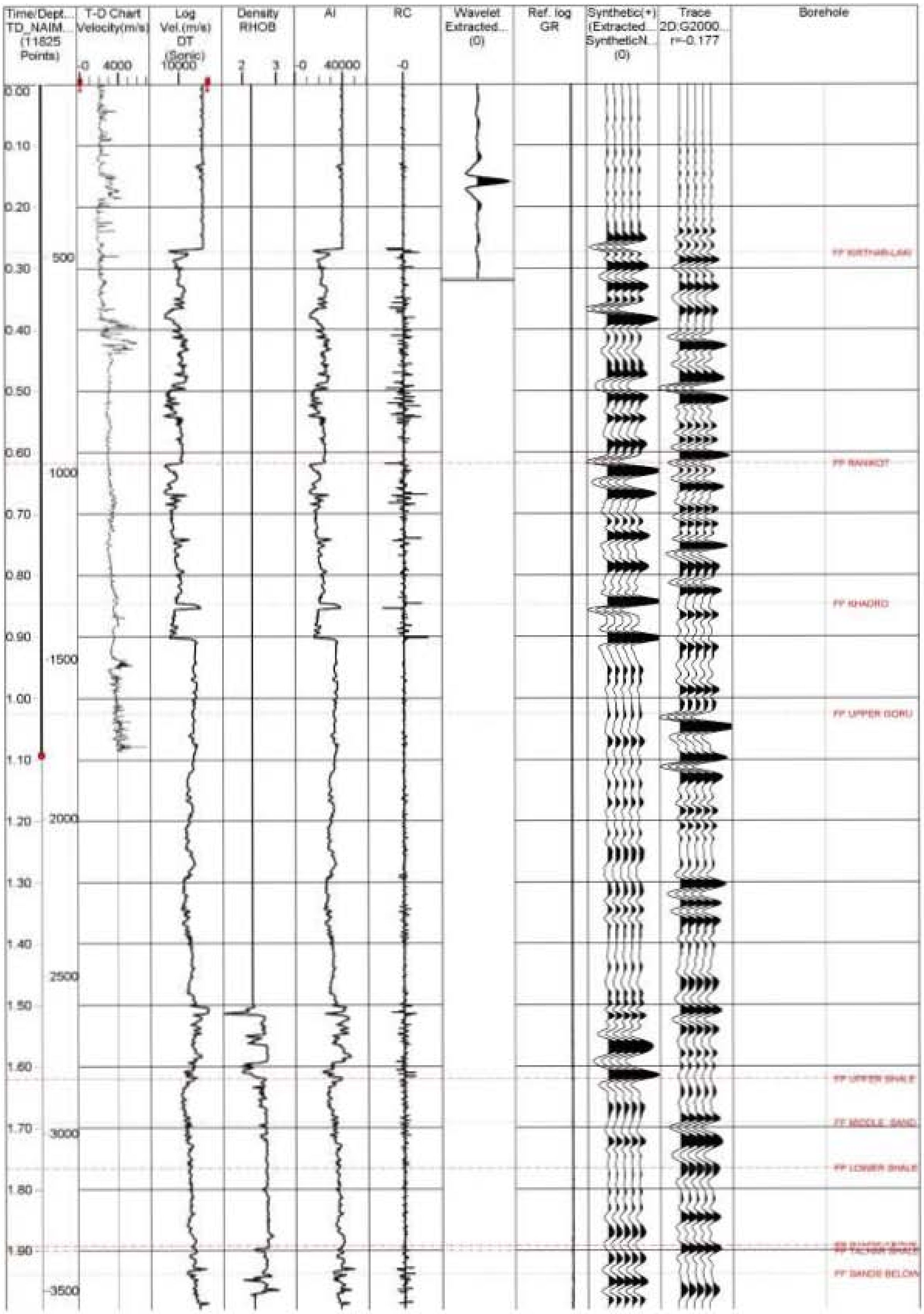

Figure 3.2: Showing Synthetic seismogram of Naimat-Basal-01 well.

3.7 Picking of Horizons and Fault Identification

Primary task of interpretation is the identification of various horizons as an interface between geological formations. For this purpose, good structural as well as stratigraphic knowledge of the area is required. Thus, during interpretation process, I mark both, the horizons, and faults on the seismic section (McQuillan, et al., 1984). Naimat-Basal-01 is drilled on line 2000-KH-08 and ties all available dip lines and horizons are continued on all lines. Finally, marked horizons are named as Sand below Talhar Shale and top of Talhar Shale formation with the help of synthetic seismogram of Naimat-Basal-01 well data on the strike line 2000-KH-04(Figure 3.3).

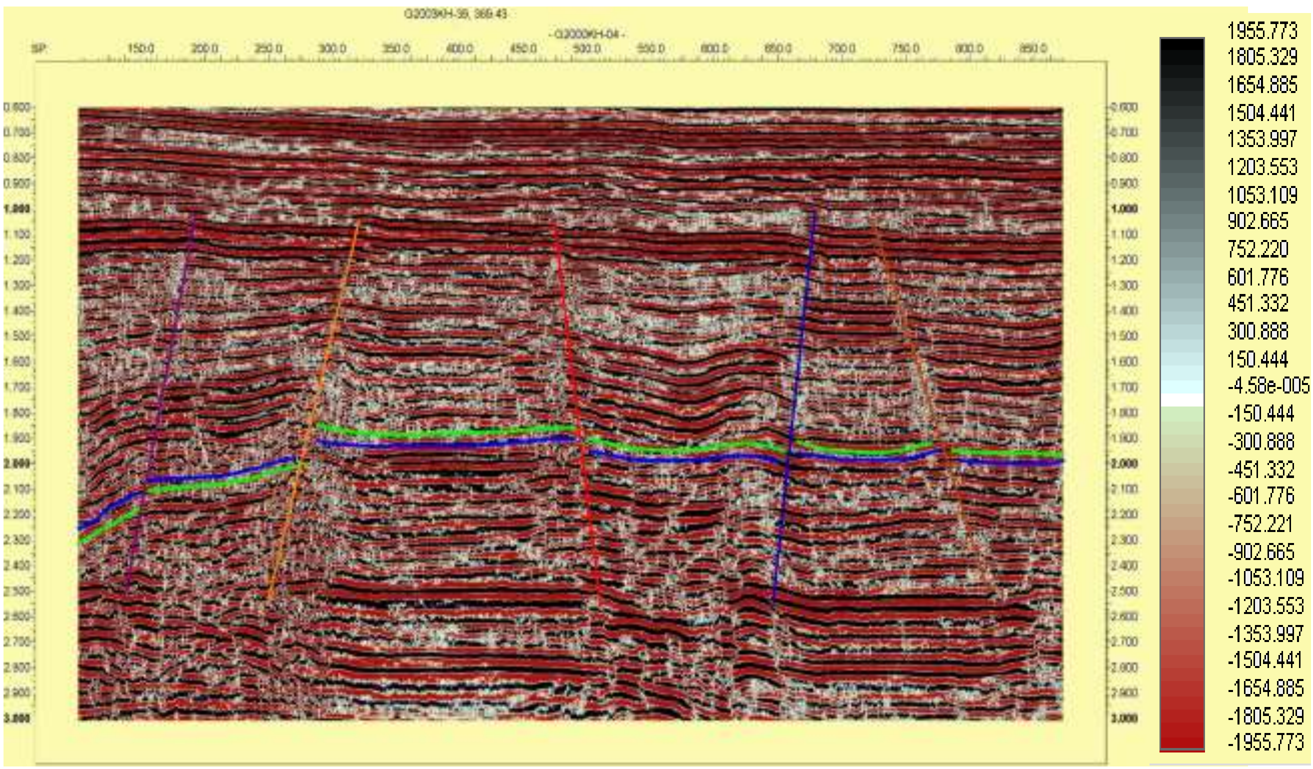

Figure 3.3: Showing Synthetic Seismogram on Seismic section of line 2000-KH-04

Study area lies in extensional regime dominated by normal faults and associated horst and graben structures. The identification of faults was difficult to some extent due to data quality. The average throw of the faults is observed to be about 15 – 20 m. Showing Synthetic Seismogram on Seismic section of line 2000-KH-08 in following figure. Here is the Seismic line shown on which seven faults are marked based on continuity of reflectors and two formation Basal sand is marked with the help of synthetic seismogram. After marking Horizons and faults, we got different structures, which with matches our previous geological information. Seismic Section of strike line 2003-KH-39.

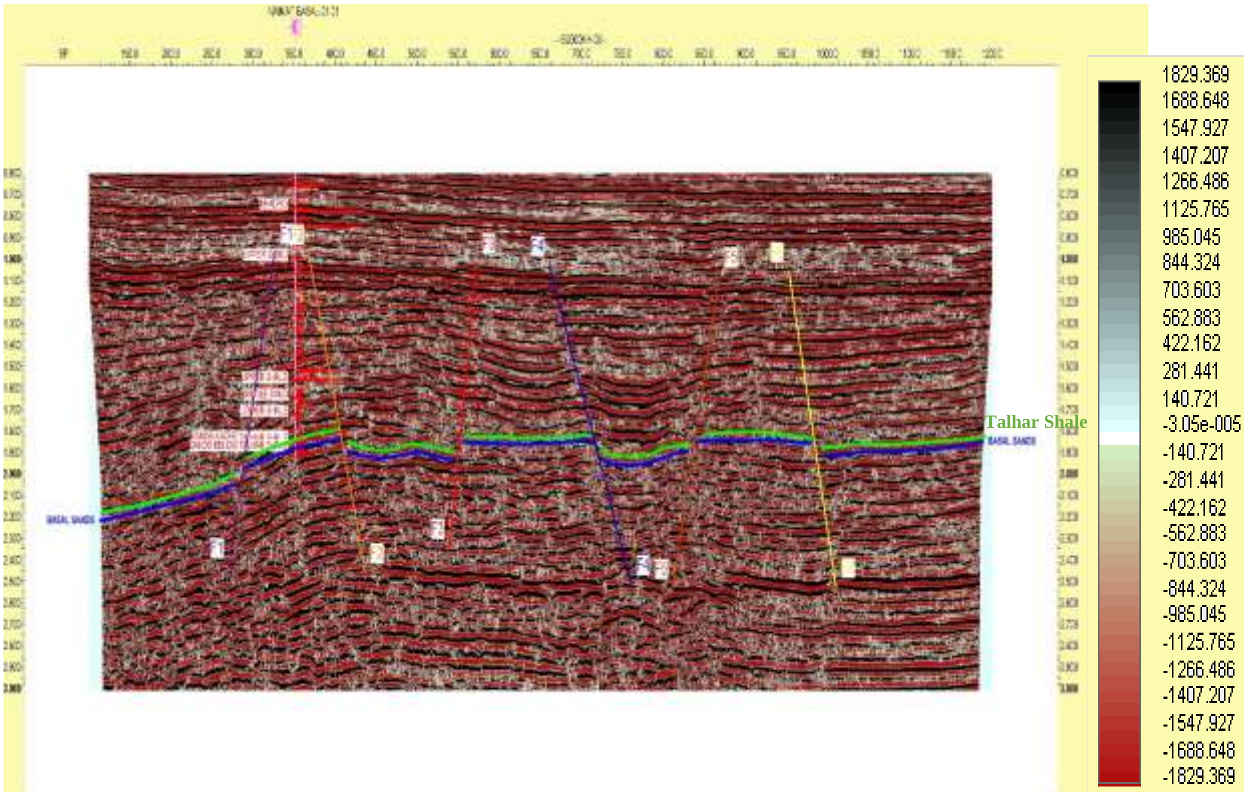

Figure 3.4: Showing normal faulting on Interpreted seismic dip line 2000-KH-08

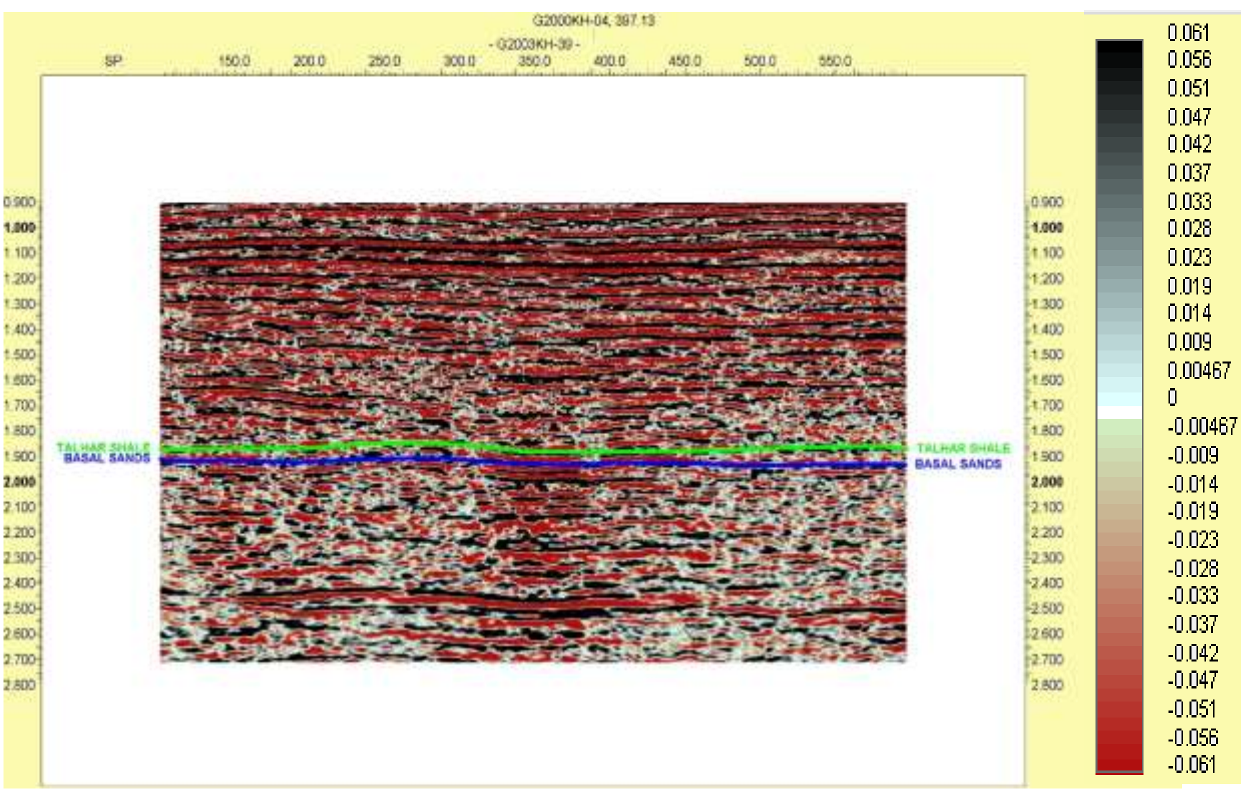

Figure 3.5: Showing Synthetic Seismogram on Seismic section of line 2003-KH-39

3.8 Construction of Fault Polygons

Construction of fault polygons are very important as far as time contouring of a horizon is concerned. Any mapping software needs all faults to be converted into polygons prior to contouring. The reason is that if a fault is not converted into a polygon, software doesn't recognize it as a barrier or discontinuity, thus making any possible closures against faults represents a false picture of the subsurface structures.

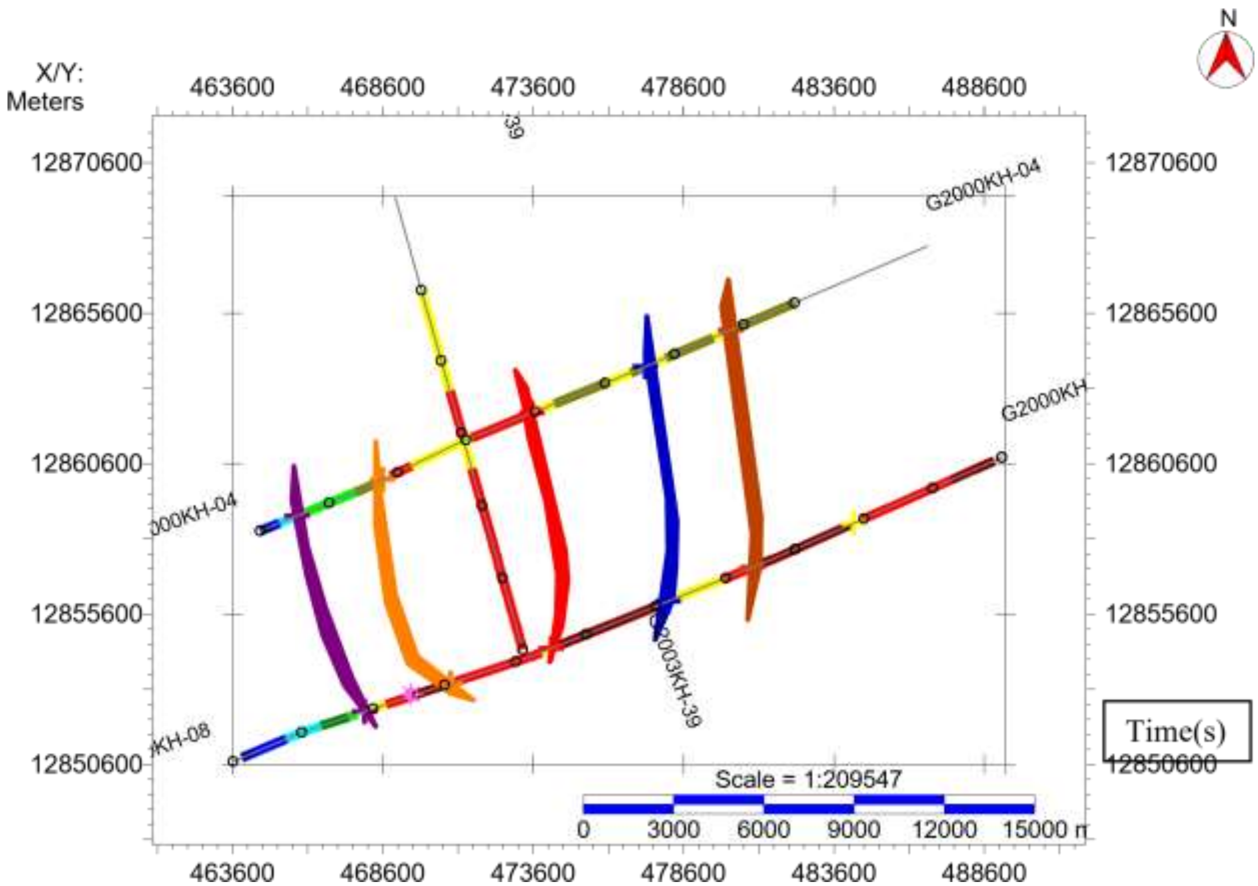

Figure 3.6: Fault polygon of Basal Sand formation.

Figure 3.6 and 3.7 shows fault polygons of the marked faults that have been generated in order to construct grids and contour maps. There are five polygons on the base map oriented in NE to SW direction. The high and low areas on the horizon become obvious. Moreover, the associated color bar helps in giving information about the dip directions on a fault polygon if dip symbols are not drawn.

Fault polygon of Talhar Shale is given below;

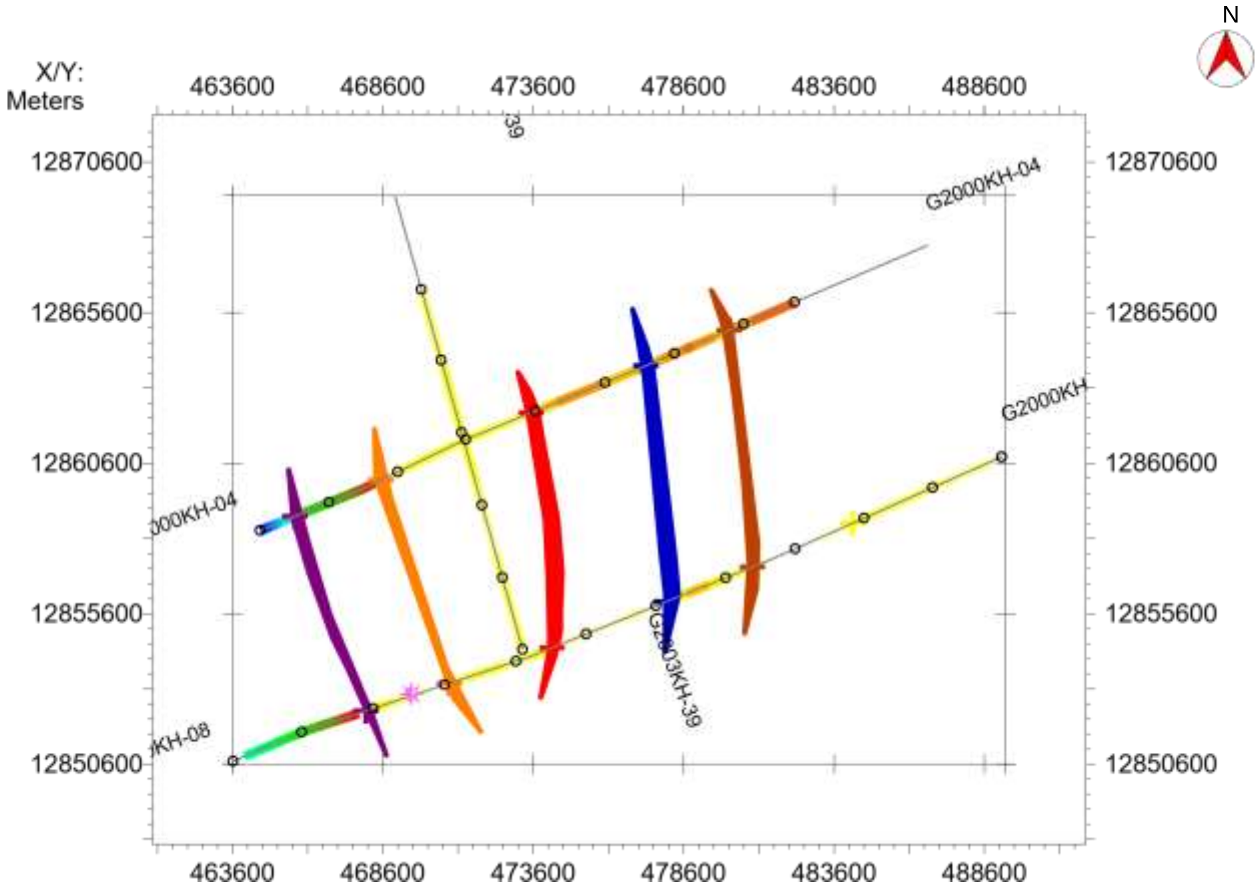

Figure3.7: Fault polygon at Talhar Shale.

3.9 Contour Maps

Contouring is the essential constituent of the interpretation of the seismic data. Seismic interpretation displays the most essential information extracted during interpretation in the form of time and depth contour maps. The contours are the lines of the same time or depth roving about the map as dictated by the data (Coffeen, 1986).

3.9.1 Time Contour

After completing horizons and fault interpretation time contour maps are constructed. There are some reasons for making time maps. The times are read directly from the sections and are immediately available for mapping. The pattern of Time Contour map confirms the shape of the subsurface structure. Time contour maps of these formations show 2D-variations with respect to time and the hydrocarbons probably accumulate at those places where contour values are low.

Figure 3.8 and 3.9 shows the time contour map of the marked horizons.

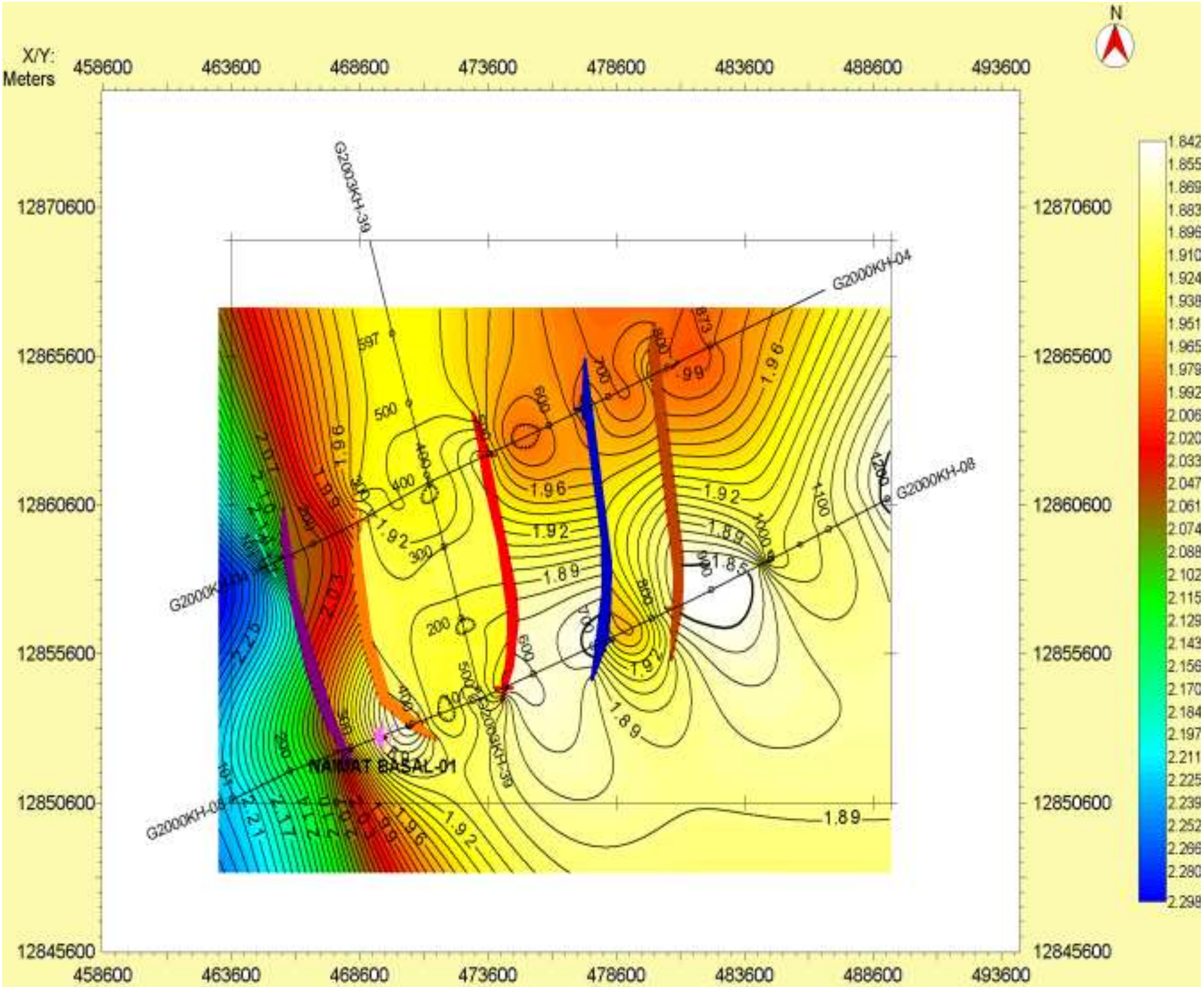

Figure 3.8: Time contour at Basal Sand level showing color variation in time along polygons.

Above Figure 3.8 shows the variation in color along both sides of the polygon. Variation in the contour map shows the horst and graben geometry and time variation proves that it is normal faulting due to extension in the area. Contouring also confirms the bookshelf symmetry. In between faults F2 and F3 time values are higher which shows the deeper area or the confirmation of graben structure in the area. Also, west of fault F1 has low time value delineates the shallower region which confirms the horst structure.

3.9.2 Depth Contour

When we read the time of a horizon from the section it tends to show the structure of the horizon in the subsurface, it does not show us the structure directly. Depth conversion and depth contour maps are constructed to see the horizons in the subsurface at their true positions. Depth must be calculated from time to make a map that is more truly related to the subsurface shapes, because structure is a matter of depth. The idea of converting the times into depths is very reasonable in case of showing the subsurface structures. Figure 3.10 and 3,11 shows depth contour maps of the marked horizons. Time contour maps of Talhar Shale is given below,

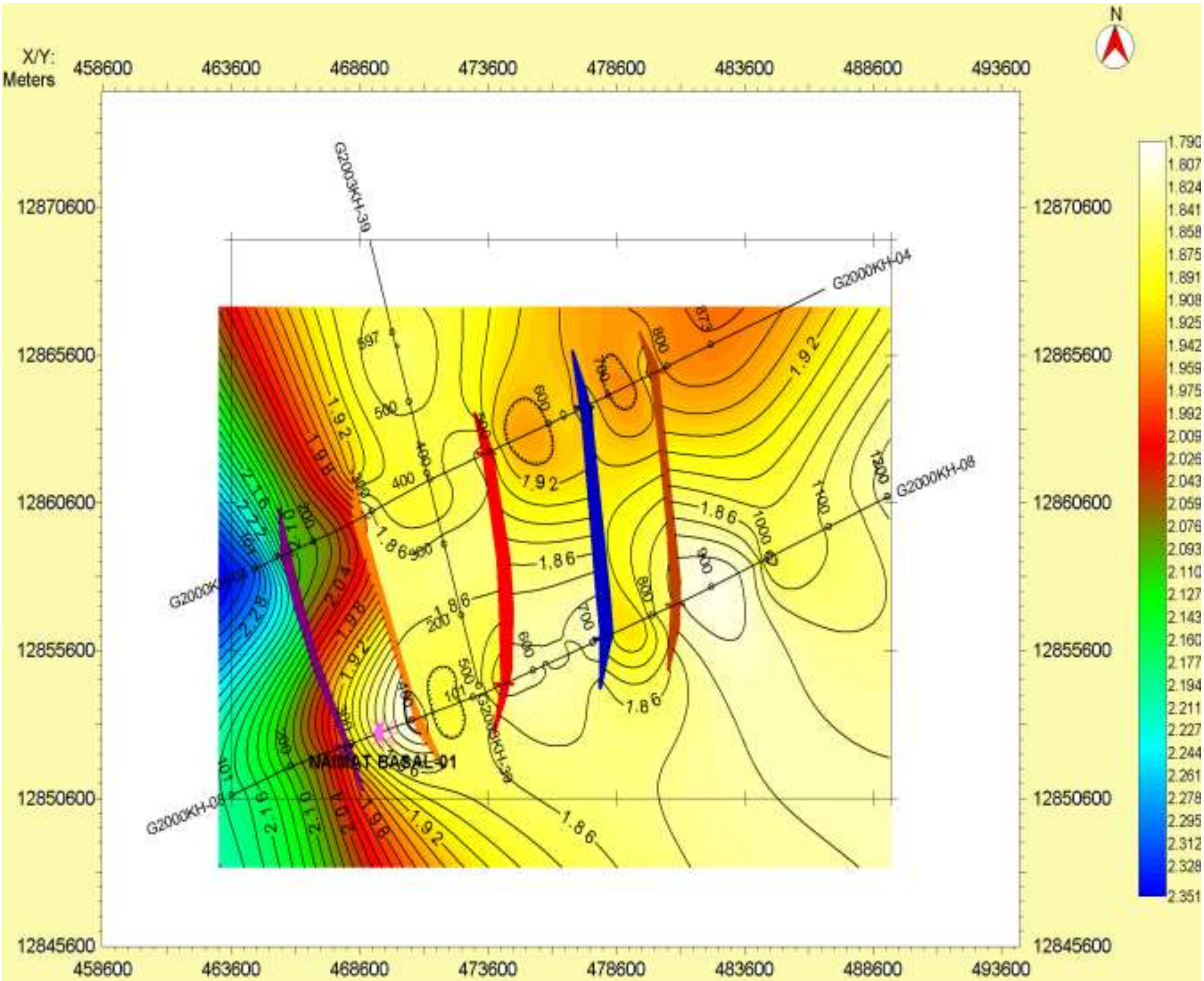

Figure 3.9: Time contour at Talhar Shale showing color variation in time along polygons.

As Basal sand is recognizing as a good reservoir rock of the Lower Indus Basin, depth contour map of this formation is constructed shown in Figure 3.8. Contour map confirms the horst and graben geometry in the area. The area with low depth values might be the good zone for the accumulation of hydrocarbons.

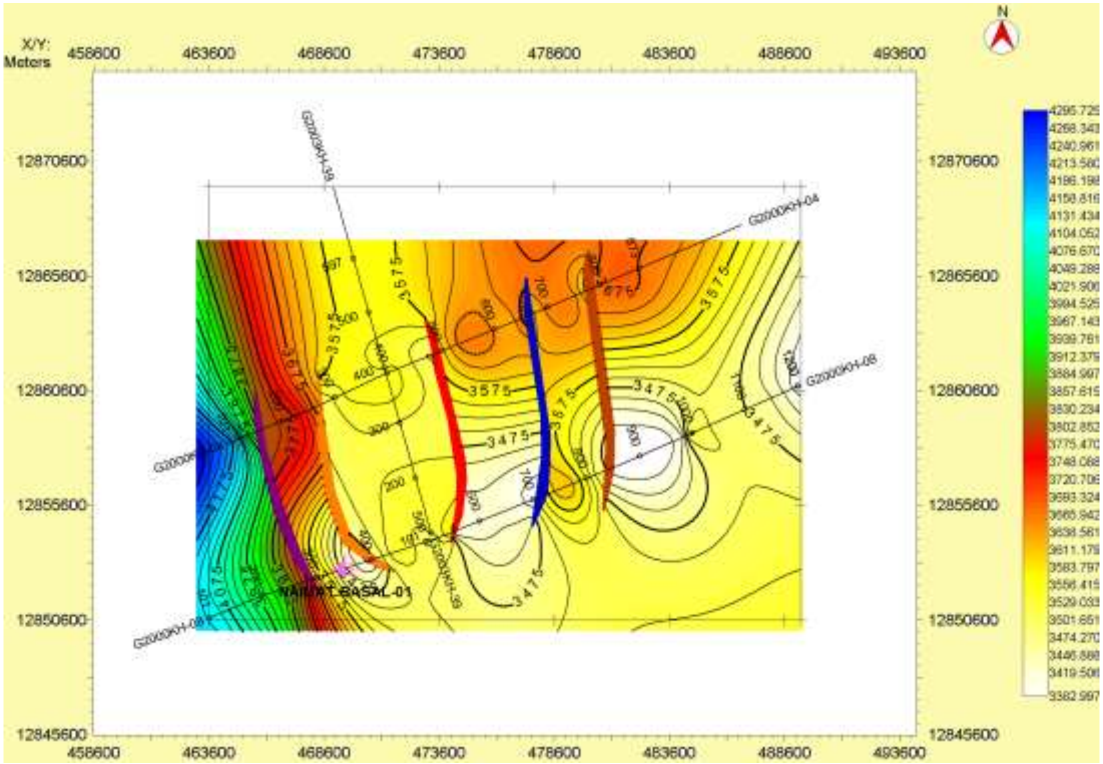

Figure 3.10: Showing Variation in depth of the Basal Sand in the study area.

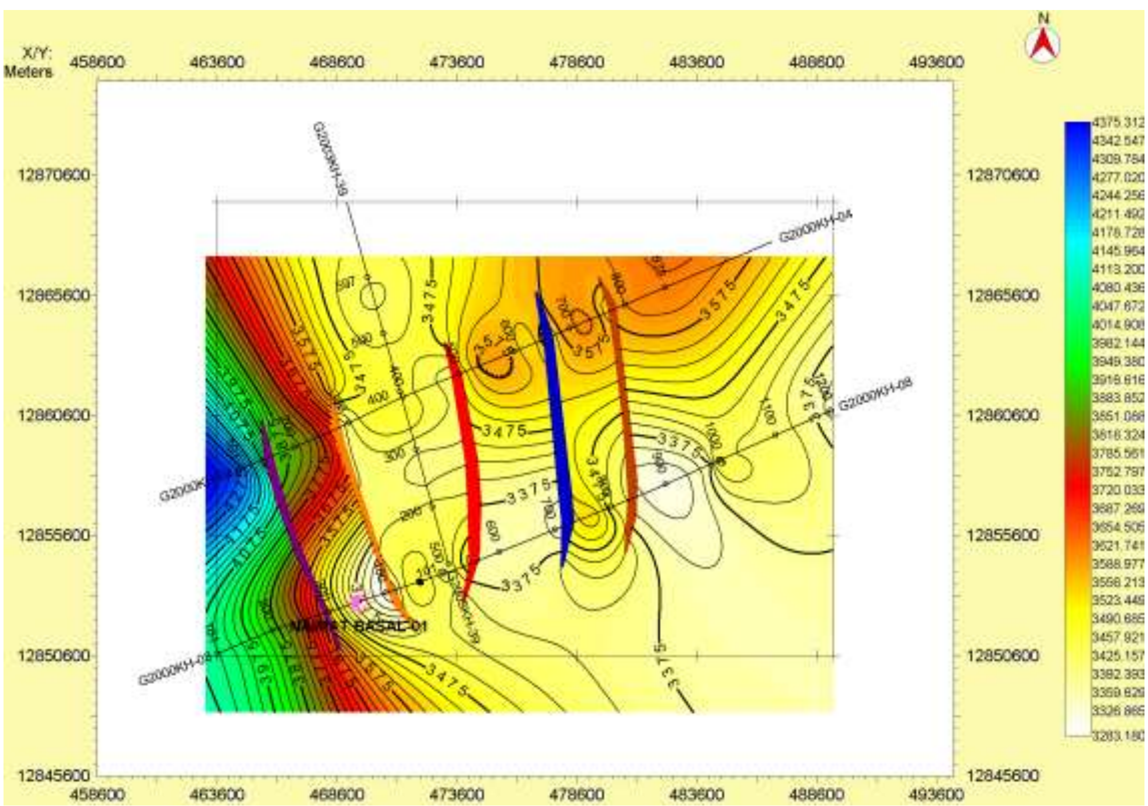

Figure 3.11: Showing Variation in depth of the Talhar Shale in the study area.

Chapter 04

SEISMIC ATTRIBUTE ANALYSIS

4.1 Introduction

The quantities that are measured computed or implied from the seismic data. From the time of their introduction in early 1970’s seismic attributes gone a long way and they became an aid for geoscientists for reservoir characterization and as a tool for quality control. Development of a wide variety of seismic attributes warrants a systematic classification. Also, a systematic approach is needed to understand the use of each of these attributes and their limitations under different circumstances (Subrahmanyam & Rao, 2008).

4.2 Classification of Seismic Attributes

Attributes can be classified in many ways. Seismic attributes can be classified on the following basis.

Seismic data domain-based classification,

- Pre-Stack Attributes
- Post-Stack Attributes

4.2.1 Pre-Stack Attributes

Input data are CDP or image gathers traces. They will have directional (azimuth) and offset related information. These computations generate huge amounts of data; hence they are not practical for initial studies. However, they contain considerable amounts of information that can be directly related to fluid content and fracture orientation. AVO, velocities and azimuthal variation of all attributes are included in this class (Taner et al, 1994).

4.2.2 Post-Stack Attributes

Post stack attributes are derived from the stacked data. The Attribute is a result of the properties derived from the complex seismic signal. Input data could be CDP stacked or migrated. One should note that time migrated data will maintain their time relationships, hence temporal variables, such as frequency, will also retain their physical dimensions. For depth migrated sections, frequency is replaced by wave number, which is a function of propagation velocity and frequency. Post-stack attributes are a more manageable approach for observing large amounts of data in initial reconnaissance investigations (Taner et al, 1994). Seismic data attributes provide the seismic interpreter with new images that enhance the physical and geometric descriptions of the subsurface. Geometric attributes facilitate the definition of both the structural and stratigraphic framework of the seismic interpretation, while physical attributes may be used as direct hydrocarbon or lithology indicators. When the seismic response is more complex, attributes may be used to drive advanced interpretation and analysis processes (Subrahmanyam & Rao, 2008).

4.3 Instantaneous Phase Attribute

Such type of the attribute is measured in degrees known to be the Instantaneous phase attribute. This attribute gives information about the continuity and discontinuity, relates to the phase component of the wave propagation, and can be used to compute the phase velocity, (Subrahmanyam and Rao, 2008). The Instantaneous phase attribute that is applied on G2000KH04 is shown in Figure 4.1.

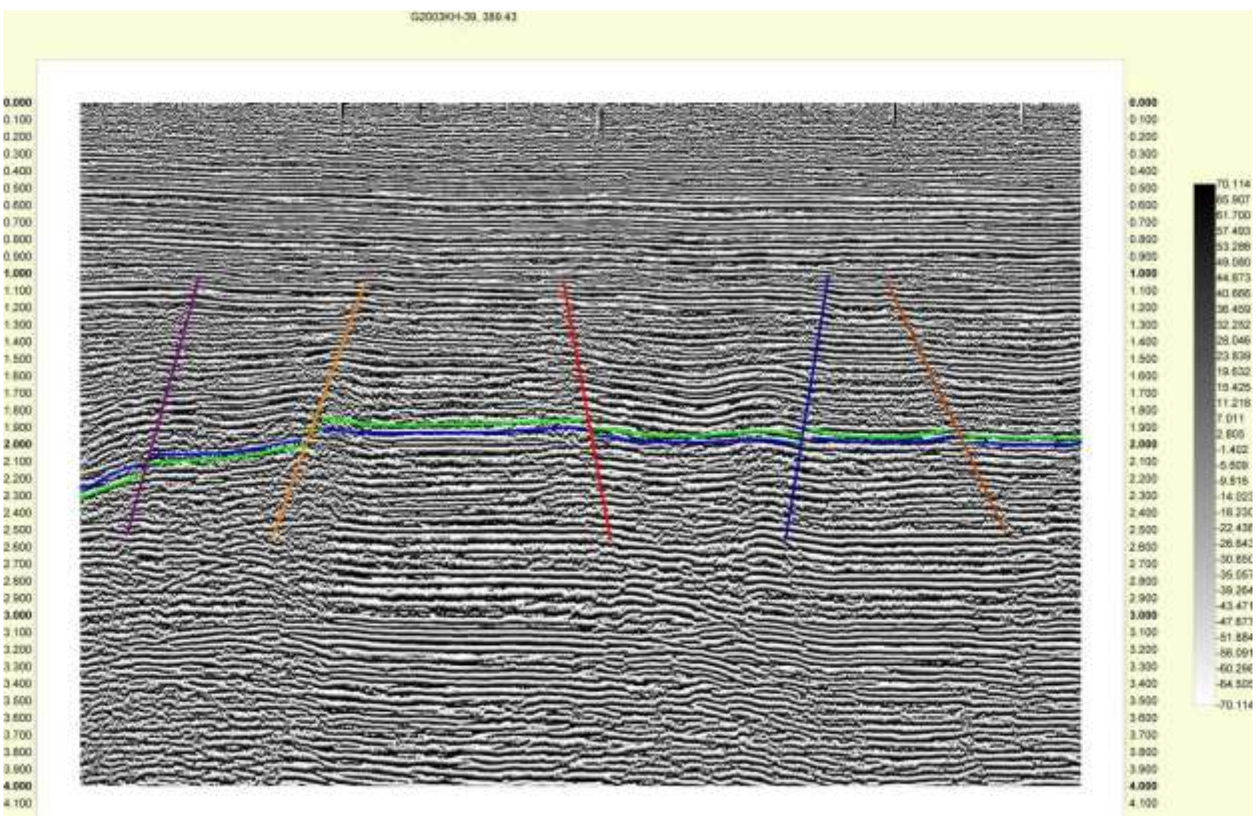

Figure 4.1: Shows the Phase attribute applied on seismic line G2000KH-04.

4.4 Average Energy Attribute

Energy and the seismic attribute have the direct relation. Average energy attribute shows the lateral continuity and the reflection strength. This attribute is applied on the 2D seismic line G2000KH-04. Discontinuity represent that there is a fault that is present. This attribute indicates spatial variation of the wavelets and therefore relate to the response of the composite group of individual interfaces below the seismic resolution. Figure 4.2 shows the discontinuity in the average energy which confirms the presence of faults, it clearly shows the faults displacement and discontinuity.

Figure 4.2: Shows the Average Energy attribute applied on seismic line G2000KH-04.

4.5 Envelop attribute

Trace Envelope can be used as an effectively describe the acoustic impedance contrast, hence reflectivity, Gas accumulation, Bright spots, Major variations in depositional environment, Sequence boundaries, spatial relationship to porosity and other lithological variations. It is helpful in reflector marking. It justified the major part of interpretation, tops of horizons and the fault surfaces. At some places like edges of the line we are unable to see prominent reflectivity that is due to the limitation of the data. Attribute is applied on seismic line G2000KH-04 that clearly shows the reflectivity and local and the major change in the lithology. Trace Envelop Attribute of G2000KH-04is shown below in figure 4.3.

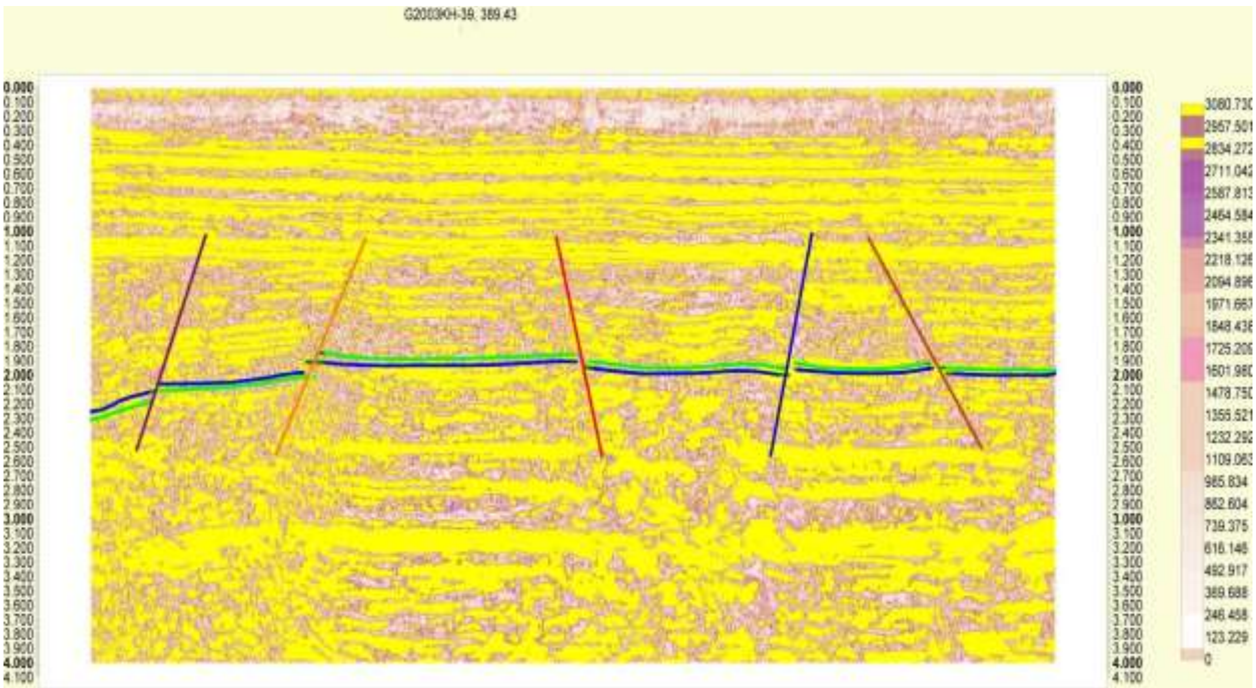

Figure 4.3: Shows the Envelop attribute applied on seismic line G2000KH-04.

CHAPTER 05

PETROPHYSICAL INTERPRETATION

5.1 Introduction

Petrophysics is the study of physical and chemical properties which defines the occurrence and behavior of rocks and the containing hydrocarbons (oil and gas). Petrophysical interpretation is the process which leads to combining the knowledge of tool response with geology, to provide a complete picture of the changes of important petrophysical properties with depth (Ellis & Singer, 2007)

Caliper log, gamma-ray (GR), neutron log (NPHI), density (RHOB), resistivity logs (LLS, LLD, and MSFL), core data and production data lead to petrophysical properties estimation. Each log has its own importance and contributes to quantifying the important reservoir parameter. Gamma-ray is particularly used for defining shale beds. When the SP is distorted or when the SP is featureless. The gamma-ray log reflects the proportion of shale and in many regions and it can be used quantitatively as a shale indicator. It is also used for the detection and evaluation of radioactive minerals such as potash or uranium ore. During the log analysis of wells, the gamma ray log is used for the interpretation of shale volume (Rider, 2002). All the measurements and borehole signatures have their own significance, but the traditional role of well logs has been limited to participation in the evaluation of formation which is summarized as:

- Identification of reservoir and their nature (oil and gas)
- Delineation of pay zone in reservoir strata
- Quantification of hydrocarbon contained in the formation
- Estimation of recoverable hydrocarbons

5.2 Workflow for petrophysical analysis

For petrophysics analysis a step by step workflow is followed to achieve the target for calculating petrophysical properties is described in fig 5.1, the log signature i.e. caliper log, gamma-ray (GR), neutron (NPHI), density (RHOB), laterolog deep (LLD), laterolog shallow
(LLS) and micro- spherically focused log (MSFL). the steps are;

- Marking the zone of interest
- Review input log curves

- The volume of shale calculation
- Calculation of formation of water resistivity

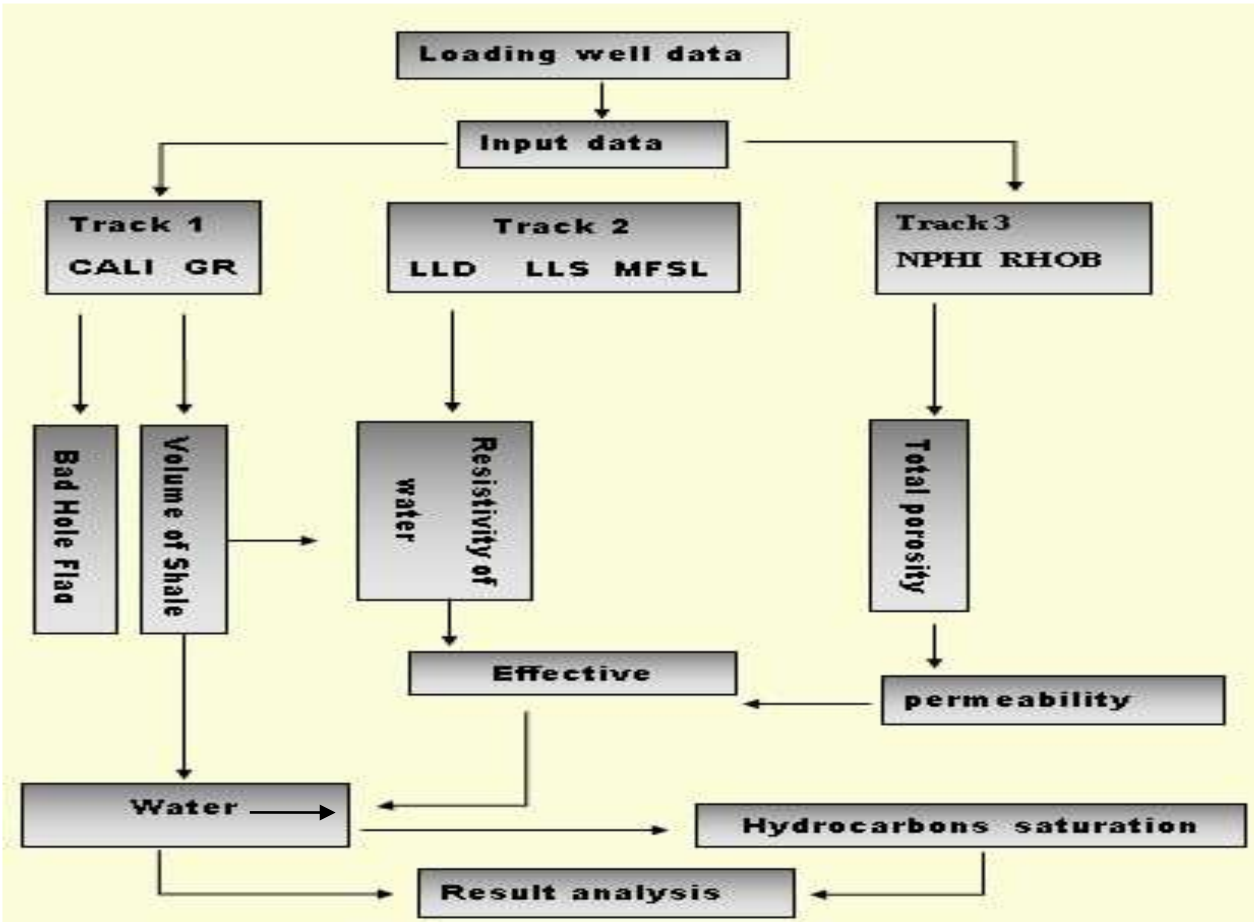

Fig 5.1 Workflow for petrophysical analysis

5.3 Petrophysical Analysis of Naimat Basal -01

In the project, three wells have been provided but Naimat Basal -01 has been selected due to its complete data. Secondly, that was the key well that was used for well to seismic tie.

In the Petrophysical analysis, we have used Archie's Interpretation to calculate the following.

- Effective Porosity.
- The volume of Shale.
- True Resistivity.
- Water Saturation.

- Bulk Volume of Rock
- Hydrocarbon Saturation.

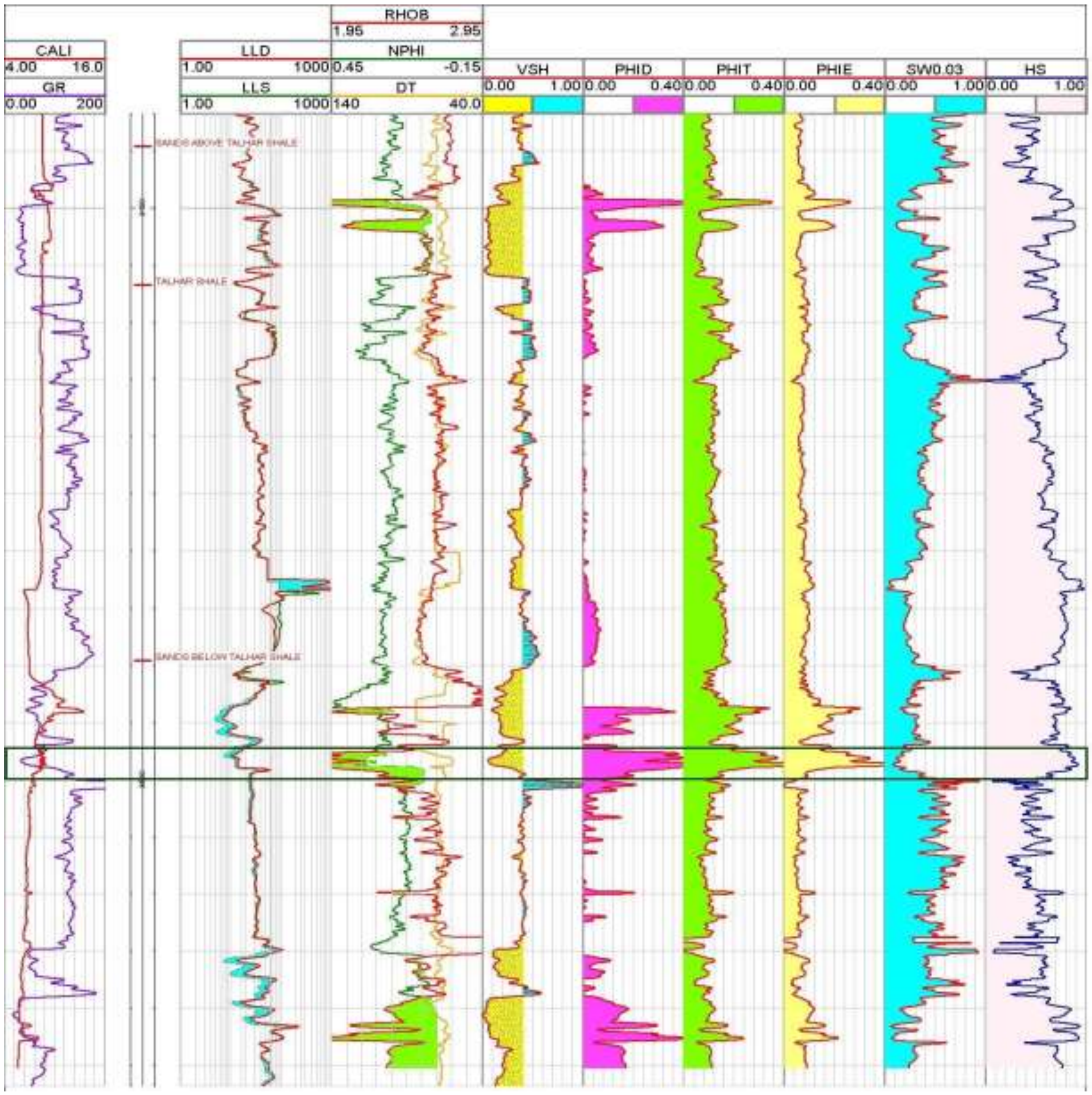

Fig 5.2 Petrophysics analysis for Naimat-Basal 01, with zone of interests marked.

5.3.2 The volume of shale (V_{sh})

GR log is the most widely used for volume of shale determination. In the quantitative evaluation of shale content, it is assumed that radioactive minerals are absent in clean rocks as compare to shaly rocks. The volume of shale can be determined at any point with the following formula (Sclumberger, 1989).

$V_{sh} = (GR_{log} - GR_{matrix}) / (GR_{shale} - GR_{matrix})$

GR log= gamma-ray log

Vsh= volume of shale

GR matrix= minimum value of gamma-ray

GR shale= maximum value of gamma-ray

5.3.3 Effective porosity

Effective porosity calculation is made from the log signature of the neutron, density, and volume of shale. Pore space contributes to effective porosity in producing such pore spaces exclude capillary-bound water as well as isolated and clay bound water. Disaggregation of core sample gives total non-solid spaces from which the total porosity can estimate (Bhuyan & Passy, 1994).

It is the number of interconnected pore spaces. Effective porosity is calculated with the help of the following formula.

$$\varphi_e = \varphi_t * (1 - vsh)$$

Where, φ_e= effective

porosity φ_t = total

porosity

5.3.4 Density porosity(ρ_d)

The porosity can be calculated at any point by using the neutron, density, and sonic logs. The porosity values as computed from various sources showed reasonable agreement with each other. Using the neutron, sonic and density logs,

porosity values of interesting zones are calculated. then total porosity and effective porosity can be calculated using the porosity values of density and neutron logs.

The following formula has been used to calculate the density porosity of the formation.

$$\emptyset_d = \frac{\rho_m - \rho_b}{\rho_m - \rho_f}$$

Where,

- $\varnothing_d$ is the porosity derived from the density log
- ρ_b is the bulk density of formation
- ρ_m is the matrix density and for sandstone it is 2.65
- ρ_f is the density of fluid (0.3 for Gas).

5.3.5 Neutron porosity

Neutron logs determine the hydrogen atom concentration in a formation. Hence the neutron log measures the fluid-fluid porosity. The values of neutron porosity can be read directly from the neutron log curve (NPHI).

5.3.6 Total porosity

Total porosity or average porosity is calculated with the help of the following formula.

$$\varphi_t = (\varnothing_d + NPHI)/2$$

Where,

- φ_e = total porosity
- $\varnothing_d$=density porosity
- NPHI= neutron porosity

5.3.7 Calculation of water saturation

During the log analysis of Naimat-Basal-01 well. Water saturation (SW) is calculated with the help of Archie equation.

$$S_w = \sqrt[n]{\frac{F * R_w}{R_t}}$$

Where,

- F is formation factor which is

$$F = \frac{a}{\varnothing^m}$$

- R_w is the resistivity of water calculated from above formulation (0.03).
- R_t is the true formation resistivity
- n is the saturation exponent (2)
- a is the constant and its value is 0.62 in case of sand
- $\emptyset$ represents effective porosity
- m is the cementation factor and it value is taken 2.15 for the sandstone.

By putting values of these parameters and simplifying the above equation it becomes as follows. Archie equation is used because it gives the direct relationship between the resistivity of water (RW) and true resistivity (RT) with water saturation. It is more realistic than any other equations. Finally, this water saturation is subtracted from 100% to give the hydrocarbon saturation.

5.3.8 Hydrocarbon Saturation

The values of hydrocarbon saturation are calculated with the help of formula as under

$$S_h=1-S_w$$

Where,

Sh = hydrocarbon saturation percentage

Sw = water saturation percentage

5.4 Petrophysical Interpretation

The petrophysical results are shown graphically for further interpretation. The crossover on the density-neutron log sometimes may be the indicator of the presence of gas. Resistivity logs are very helpful to identify the hydrocarbon in reservoir rocks. Higher resistivity values usually caused by shale.

The reservoir encountered in the Naimat Basal -01 well was Lower Goru formation which was of lower cretaceous age. In Naimat Basal -01 the Lower Goru formation is divided into two zones of interest. The available input log curves including Caliper log, Spontaneous Potential (SP) log, Resistivity logs, Gamma-ray log, Density log, Sonic log, and Neutron log. All these logs are represented in proper tracks.

The caliper log shows the diameter of the hole in inches in ranged from 4 to 14 inches. The gamma-ray log measures the natural radiations and expressed in API. The SP log shows the natural spontaneous potential of the formation in millivolts against the depth. The resistivity track includes LLD, LLS plotted on the logarithmic scale due to more variation (0.2-3000ohm) in resistivity against depth. The porosity track includes the Sonic log, Density log and Neutron log and these are normally used to calculate the porosity of the formation.

The average effective porosity of the zone A that is found from the petrophysical analysis is 15.16%. The saturation of water ranges for zone A is 42.14%, and hydrocarbon saturation for the zone A is 57.86%.

Interpretation of porosity log the large crossover shows the presence of a gas reservoir in lower Goru formation of Naimat Basal-01.

Zones	Top(m)	PHIE %	Vsh %	Sw %	Hs %
Zone A	3490-3500	7.98	29.43	35.24	64.76

Table 5.1 Petrophysical parameters for Basal Sands.

The calculations of petrophysical parameters indicate that the porosity values are high in two zones, the hydrocarbon saturation is also very good in these zones.

CONCLUSIONS

Seismic reflection surveying is the most widely used and well-known geophysical technique specially used for hydrocarbon exploration. By this technique we can extract the information of geological structures on scales from the top tens of meters of drift to the whole lithosphere. Part of the spectacular success of the method lies in the fact that the raw data are processed to produce a seismic section which is an image of the subsurface structure.

Reflectors of formation Basal Sand is marked on seismic section, with the help of synthetic seismogram of Naimat-Basal-01 well. Time and depth contour maps show the presence of horst and graben structures in study area. These Uplifted horst structures may act as structural traps in the area and are favorable places for hydrocarbon accumulation.

Seismic interpretation also identifies the bookshelf geometry form due to parallel faulting in the Khipro block.

Seismic attributes applied on geological section G2000KH-04, such as Trace envelop confirm the major lithological changes and the instantaneous phase confirm the continuity of marked horizons on seismic section and the average energy attribute increases the reflection strength of the horizons on the seismic sections. Petrophysical analysis not only showed that the reservoir lithology was Basal Sands, but also, we were able to mark zone of interest which is highly hydrocarbon saturated. (With 35% water saturation and 64% hydrocarbon Saturation).

REFERENCES

- Batzle, M. L., and Wang, Z., 1992, Seismic properties of pore fluids: Geophysics, 64, 13961408.
- Bhuyan, k and Passy, Q.R., "clay estimation from GR and neutron density porosity log "SPWLA logging symposium, Tulsa, Okla., June 19-22,1994.
- Chopra, Satinder, and Kurt J. Marfurt. "Seismic attributes, A historical perspective." Geophysics 70.5 (2005): 3SO-28SO.
- Coffeen, J.A., 1986, Seismic Exploration Fundamentals, PennWell Publishing Co.
- Dobrin and Savit., 1988, Geophysical Exploration, Hafner Publishing Co.
- Ellis, D. V., & Singer, J. M. (2007) Well logging for earth scientists. Springer.
- Handwerger, D. A., et al. "Synthetic seismograms linking ODP sites to seismic profiles, continental rise and shelf of Prydz Bay, Antarctica. Proc. Ocean Drill. Prog., Sci. Res. Vol. 188. 2004.
- Kadri I.B., (1995), "Petroleum Geology of Pakistan'', PPL, Karachi, Pakistan.p143-154.
- Kazmi, A.H., & Jan, M.Q., (1997). "Geology & Tectonics of Pakistan", Graphic Publishers, Karachi, Pakistan.
- Kearey, Philip, Michael Brooks, and Ian Hill. "An introduction to geophysical exploration". John Wiley & Sons, 2002.
- Kemal, A., 1992. Geology and New Trends for Hydrocarbon exploration in Pakistan. International Petroleum Seminar, Islamabad, 56, 16-57.
- Kemal. A. (1991). Geology and new trends for petroleum exploration in Pakistan
- Kingston, D. R., Dishroon, C. P., & Williams, P. A. (1983). Global basin classification system. AAPG bulletin
- McQuillan, R., Bacon, M., and Barcaly, W., 1984 An introduction to seismic interpretation, Graham & Trotman Limited Sterling House, 66 Wilton Road London SW1V 1DE
- Powell, C. (1979). A speculative Tectonic history of Pakistan and surroundings: some constrains from Indian ocean: In A Farah and K.A Dejong (Editors), Geodynamics of Pakistan, Geol. Survey of Pakistan, Quetta.p 5-24.
- Rider, D. L., 2002 Horizontal Well System Application No.60/172,536.
- D.Subrahmanyam, P.H. Rao, (2008), Seismic attributes – a Review, 7^{th} International conference and exposition of Geo physics, Hyderabad, India.

- Sheriff, R. E. (1991). Encyclopedic dictionary of exploration geophysics (Vol. 1). Tulsa: Society of exploration geophysicists.
- Stoneley, R., & Stoneley, R. (1995). Introduction to petroleum exploration for non-geologists (p. 199). Oxford, UK: Oxford University Press.
- Telford, William Murray, and Robert E. Sheriff. "Applied geophysics". Vol. 1. Cambridge university press, 1990.
- Taner, M.T., 2001. Seismic attributes, rock solid images, CSEG Recorder, Hoston, USA, pp.48-56.
- Zaigham, N.A., and K.A. Mallick, 2000, Bela ophiolite zone of southern Pakistan: Tectonic setting and associated mineral deposits: GSA Bulletin, v.112, no. 3, p.478-489.