2D-Integrated Seismic And Well Log Interpretation, Seismic Attributes And Rock Physics Of Khipro Area, Lower Indus Basin, PAKISTAN

By

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CERTIFICATE

This dissertation submitted by Abdullah Nawaz Abbasi S/O Shaukat Nawaz is accepted in its present form by the Department of Earth Sciences, Quaid-i-Azam University Islamabad as satisfying the requirement for the award of BS degree in Geophysics.

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بسم الله الرحمن الرحيم

To start with the greatest name of Almighty Allah. Most gracious and merciful, with Him is the knowledge of the Hour, He sends down the rain, and knows that which is in the wombs. No person knows what he will earn tomorrow, and no person knows in what land he will die. The knower of the unseen is Allah these are the keys of the unseen, whose knowledge Allah alone has kept for himself and no one else knows them unless Allah tells him about them.

DEDICATION

I specially dedicate this to my mother who motivated, supported and encouraged me in every field of life and all those who helped me in this work

ACKNOWLEGMENT

First and foremost, all praises to Allah Almighty the most Beneficent and the most Merciful, The One, The Everlasting ,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.

I am especially thankful to my dissertation supervisor **Dr Tahir Azeem** that he always gave me his loving guidance whenever I asked and spared His precious time for me during my work. Besides this work I'm thankful to him for their guidance in my degree.

I am thankful to my respectable friend Jamal for his cooperation and guidance in this work.

And I'm thankful to all my **Fauji Boys** for their endless love, care and moral support during my study. Thanks for the friendship and memories.

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Abdullah Nawaz Abbasi

ABSTRACT

Khipro area is prominent in the Lower Indus Basin for its hydrocarbon (oil and gas) structural traps.. The data used for this study consists of six seismic lines along with their navigation, velocity data and well logs data of one well. Three horizons; Lower Shale , Middle Sand and Sand Below Talhar Shale have been interpreted along with normal faults. Time and Depth contour maps of the three horizons have been generated and the resulting interpretation indicates Horst and Graben structures.

The interpretation is further confirmed through seismic attributes analysis. Seismic attributes analysis of seismic section helps in identifying the different lithological boundaries and also confirmed the structural disturbance.

Petrophysics is the one of the most reliable tools for the confirmation of the types of the hydrocarbon and for marking the proper zone of the interest for the presence of the hydrocarbon by combination of the different logs results. Petrophysics is performed on the Naimat Basal-01 and 3 zones of interest are identified where there is chance of the presence of the hydrocarbon. Both quantitative and qualitative interpretation is calculated in interest zones. Zone 1 and Zone 3 shows good hydrocarbon saturation, high effective porosity , and low volume of Shale while zone 3 would be effective reservoir. Further hydrocarbon zones are confirmed through rock physics and it also confirmed the lithology.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Hydrocarbon plays vital role in the growth of any country and have wide uses at smaller scales in everyday life as well. Geophysicists have been trying for hydrocarbon exploration since a long time ago and developed many techniques in this regard. Seismic method is direct result evaluating and accurate geophysical method used for litho-structural analysis especially; Seismic Reflection Method has greater precision than refraction method for deep hydrocarbon exploration in petroleum geology. Petroleum geology refers to the specific set of geological disciplines that are applied to the search for hydrocarbons.

The seismic method is rather simple in concept. In which an energy source is used to produce seismic waves (similar to sound) that travel through the earth and the motion or pressure variations to electricity which is recorded by electronic instruments (Gadallah and Fisher, 2009).

Pakistan has a high potential of hydrocarbons and consists of three major sedimentary basins (covering more than 2/3rd of its area) namely, Indus Basin in the east, Baluchistan Basin in the west and Pishin basin in the northwest. Indus and Baluchistan basin are separated by Ornach Bela transform fault zone and the Pishin basin lies between Indus and Chamman transform fault. A variety of sub-basins, fold belts and monoclines with variable structural styles resulting from diverse geodynamic conditions have been identified in Baluchistan Basin and Indus Basin (Kadri, 1995). Indus is the only producing basin of Pakistan where 83 oil and gas fields have been discovered. The Indus Basin covers an area of about 533,500 Km^2 and contains more than 15,000m thick sediments ranging in age from the Precambrain to recent. This giant basin has been divided into three compartments based on structural highs namely, The Jacobabad Khairpur High, Mari Khandkot High (Sukkur Rift) and the Sargodha High (Kazmi and Jan 1997). Indus basin is divided into Upper Indus Basin, Middle Indus or Central Indus Basin and Lower Indus or Southern Indus Basin.

1.2 Introduction to Study Area

The study area, Khipro Block (as shown in Figure 1), is tectonically situated in thar platform of Lower Indus Basin and geographically in Sanghar, Sindh province of Pakistan. It covers an area of 2376km. Lower Indus Basin is very important for hydrocarbon exploration because it is the main producing oil and gas basin of Pakistan.

The geographic coordinate of the area are:

- **Latitude of the area: 25° to 26°N.**
- **Longitude of the area: 68° to 69°E.**

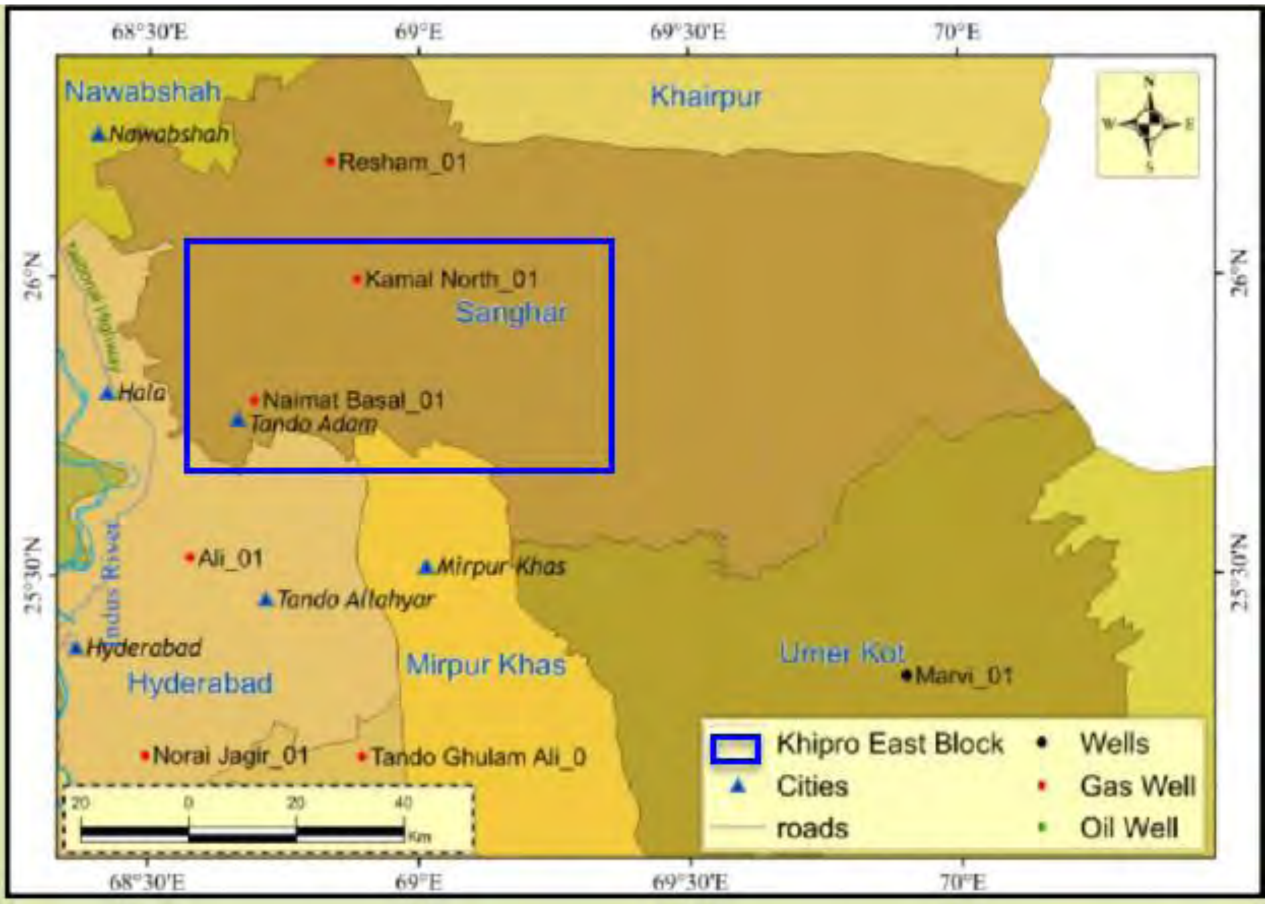

Figure 1.1: Location map of Khipro Block, Sindh, Pakistan(www.Googlemaps.com).

1.3 Objectives

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

- 2-D Structural interpretation to find out the structural traps and horizons of the formation
- Preparation of the depth contour map, time contour map on the basis of seismic data. To develop an understanding of tectonic and structural framework of the area
- Attribute analysis to improve understanding and mapping reservoir and to resolve structural and stratigraphic complexities.
- Petrophysical analysis for the identification of the hydrocarbon bearing zones.
- Rock physics is done to confirm lithologies in reservoir.

1.4 Data used

The data used for current research includes 6 seismic lines and a well i.e. Naimat-basal-01. Seismic data is of three different vintages 2000, 2001 and 2003 acquired by orient petroleum Inc in which 4 are dip lines and 2 are strike lines. The orientation of seismic lines with the location of wells is shown in the base map Fig 1.2. lines assigned to me for this work are G2000KH-04, G2001KH-30 and G2003KH-35(Strike line)

All wells are gas condensate and have been drilled up to the Sand Below Talhar shale unit of Lower Goru.

The data set used extensively in preparing this dissertation contained data regarding.

- SEG-Y
- LAS
- Navigation
- Velocity Data.

1.4.1 Base Map

A map on which primary data and interpretation can be plotted. The base map is important for interpretation point of view because it depicts the spatial location of seismic section and also shows how seismic section is interconnected. It includes location of lease and concession boundaries, wells, and seismic survey points with geographic reference such as latitude and longitude or Universal Transverse Mercator (UTM). Geophysicists typically use shot point maps, which show the orientations of seismic lines and the specific points at which seismic data were acquired, to display interpretations of seismic data .Figure 1.2.

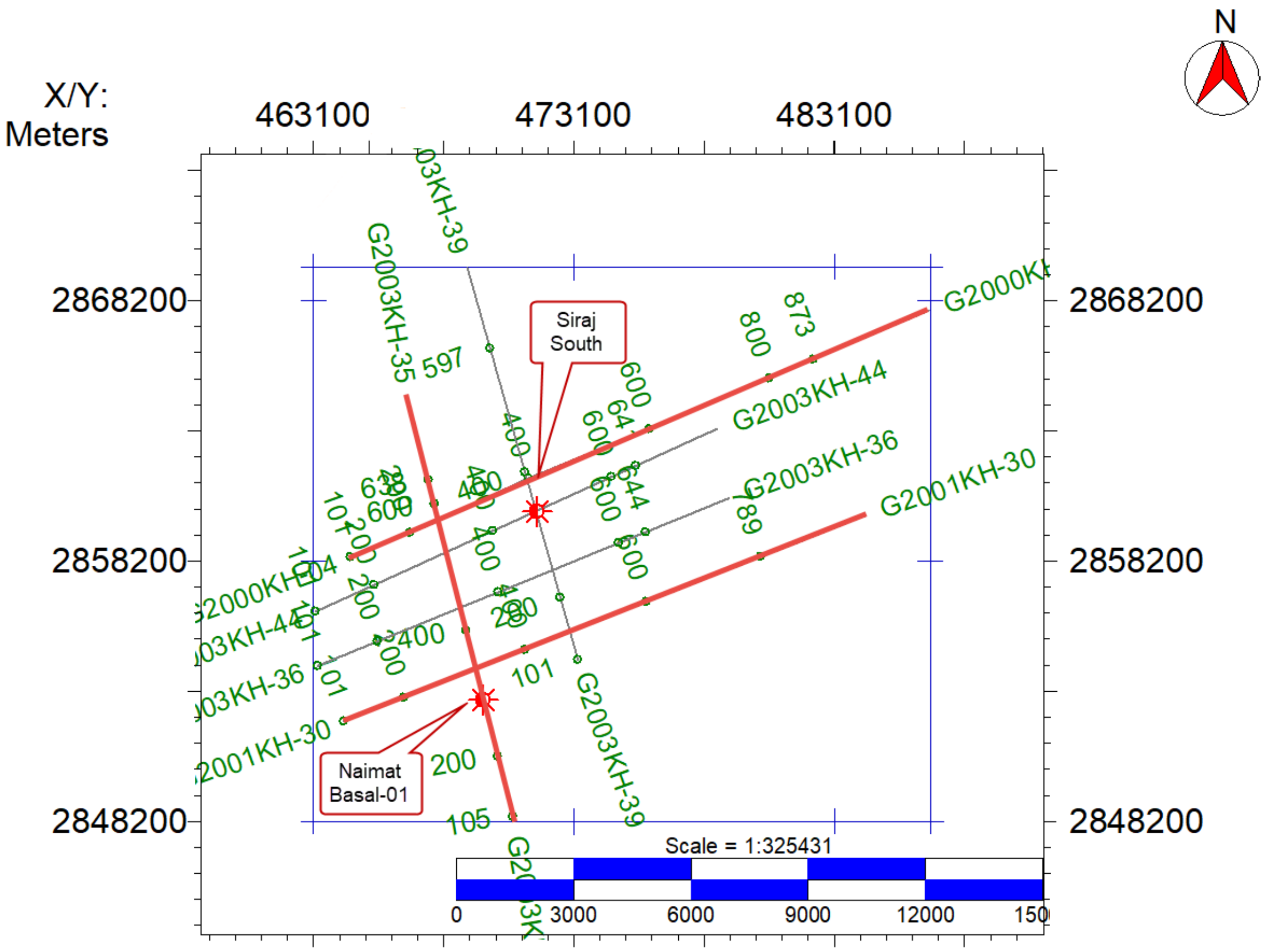

Figure 1.2: Showing the base map of the study area (Khipro)

1.5 Information of Naimat-Basal-01 Well

Information of the well data which has been provided to us for the dissertation. Information of well Naimat Basal-01 is listed in table 1.1 and information of formation tops in table1.2.

Well	Naimat Basal-01
Latitude	025.793802
Longitude	068.696482
KB	33.5 meters
Total Depth	3621.6300 m
Status	Exploratory
Exploration	Gas/Cond
Source	Dynamite
Company	OPI

Table 1.1: Information of Naimat Basal-01 Well.

1.5.1 Formation Tops

Formation Tops	Depth(m)
Alluvium	0
Kirthar-Laki	524.8
Ranikot	1010.7
Khadro	1374.6
Upper Goru	1697.7
Lower Goru (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 1.2:Information of formation top of Naimat Basal-01 Well.

1.6 Methodology

Seismic reflection data of the Lower Indus Basin of Khipro area is given in order to interpret the subsurface structures and other properties. In this practice, software **Kingdom 8.8** was used for structural interpretation. For this purpose, seismic lines data were uploaded on Kingdom, synthetic seismogram was generated, from well. After that faults and horizons were marked on seismic section, polygons were developed, and time and depth contours were made. Attribute analysis were performed to conform interpretation. Petrophysical analysis have been done for the identification of hydrocarbon bearing zones. The brief methodology Workflow is shown in figure 1.3

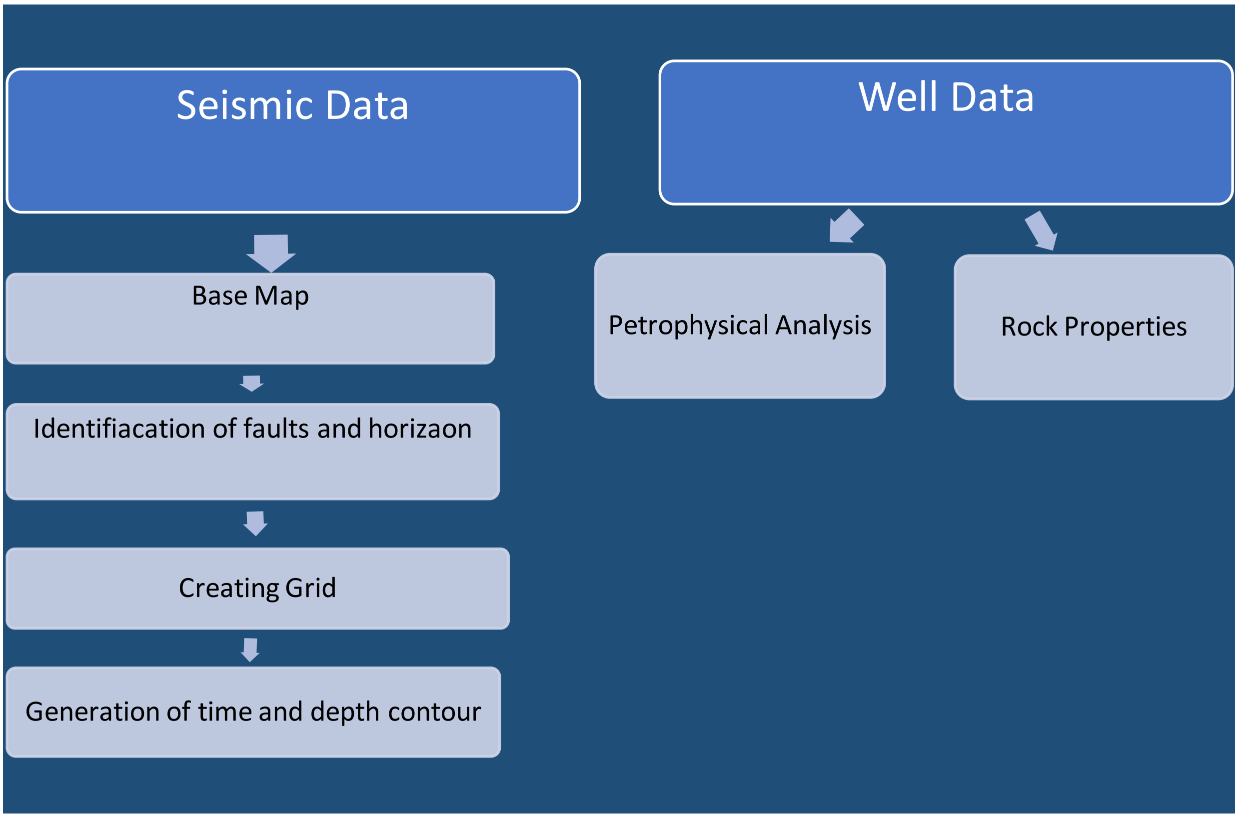

Figure 1.3:Workflow adopted to perform this study.

CHAPTER 2

GEOLOGY AND STRATIGRAPHY OF THE AREA

2.1 Importance of Geology of Area

Information about the geology of an area is very important in seismic survey. As the same velocity effect can be produce from the formations of different lithology and vice versa. The position and penetration of local fault and the presence of the unconformities between the rocks is very necessary for interpretation point of view. So as if we don't know geological information in area we don't recognize the different reflections appearing in the seismic section. A geological history of basin can be compiled by considering basin forming tectonics and depositional sequence (Kingston et al., 1983).

2.2 General Geology of Study Area

Rifting and breaks up Gondwana land in Jurassic period is responsible for the formation of Khipro block. The East Gondwana plate (India, Antarctica and Australia) separated from the West Gondwana plate (Africa and South America) in the Cretaceous period.

In Aptian time (120 Ma), the Indian plate separated from east Gondwana. Powell (1979) defines in article "A Speculative Tectonic history of Pakistan and Surroundings" that at the end of Cretaceous, Seychelles and Madagascar separated from India with associated faulting resulting in basaltic flows(Deccan Volcanism) in the southern part of Lower Indus basin. After Paleocene there was continuous oblique convergence of Asian plate and Indian plate throughout Tertiary time and the collision results in tilting of the entire region.

Deposition during the rifting is shown by the presence of Jurassic rocks in the area. Due to rifting normal faulting and horst and graben structures are formed. The famous among these structures include "Sukkur Rift". However, this localized rifting phase was unable to continue after the Paleocene-Eocene time (Powell, 1979; Smith et al., 1994).

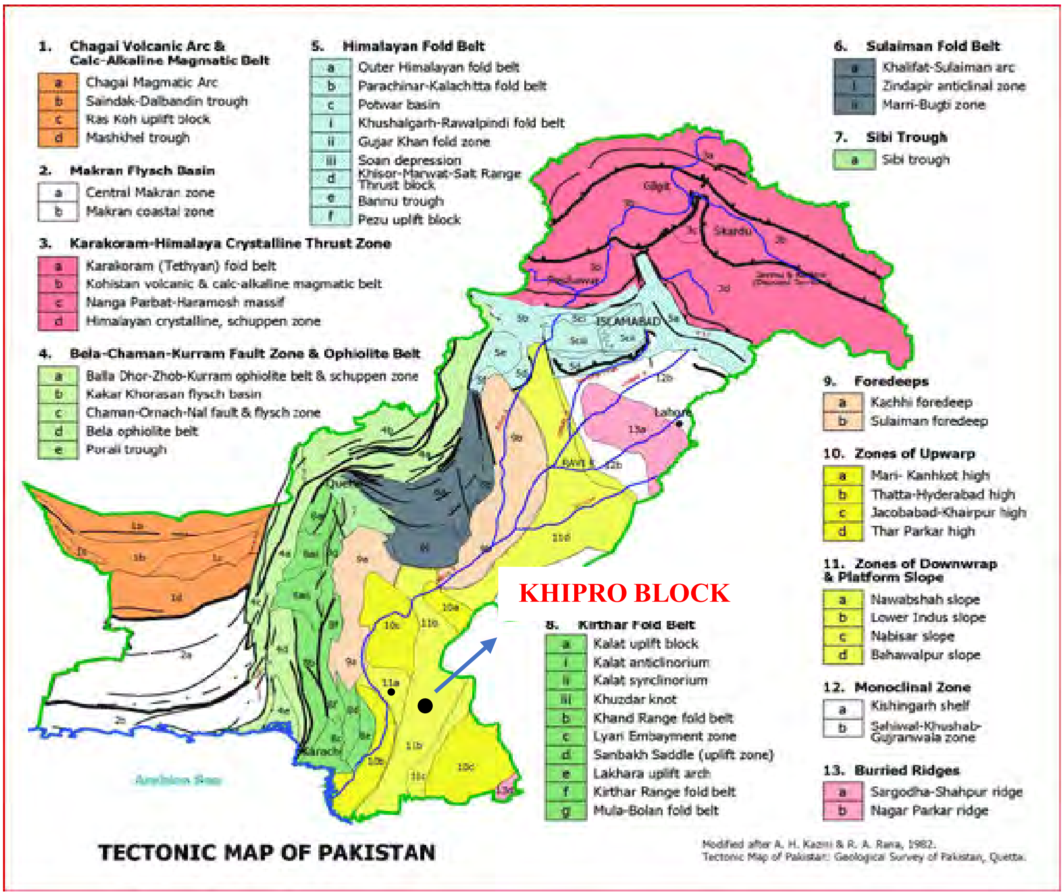

Figure 2.1: Tectonic map of Pakistan with the location of the project area. (Kazmi and Rana, 1982.)

2.3 Structural Setting of Study Area

The structural setting in the area is due to result of a normal block faulting on west dipping Indus Plain. The fault planes act as migrating paths for hydrocarbons from underlying shaly source sequence. Trends of faults and contours are mapped utilizing wells and seismic control for the field. Seismic interpretation creates basis for structural interpretation as no surface outcrops are found over the field. Study area characterized by a series of horst and graben structures present almost below the base Paleocene within the cretaceous age producing reservoir Basal Sand is bounded on east and west by regional extension faults dipping to west and east and trending NW-SE (Kadri, 1995).

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. Kirthar and Karachi depression contain several large anticlines and dome sand some of these contain small gas fields e.g. Sari, Hundi, Mazarani, but in eastern part of it, there are several faults and tilted blocks which form structural traps containing small oil and gas fields e.g. Sinjhoro, Khipro, Sanghar. On the northern side, there is Sukkur Rift zone bearing large anticlimax structures and contains Khandkot and Mari gas fields (Zaigham, 2000).

2.4 Stratigraphy in the Study Area.

The main reservoir rock is sand of Lower Goru of cretaceous age. Shale of Sembar is source rock and Shale of Upper Goru acts as cap rock also having Cretaceous age (Ahmad et al., 2009). The lithological setting and stratigraphic sequence of the study area is given below.

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 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's consisted of Basal sand unit, Massive sand unit, Lower shale, Middle sand unit, upper shale, lower shale and upper sand (Shah 1977).

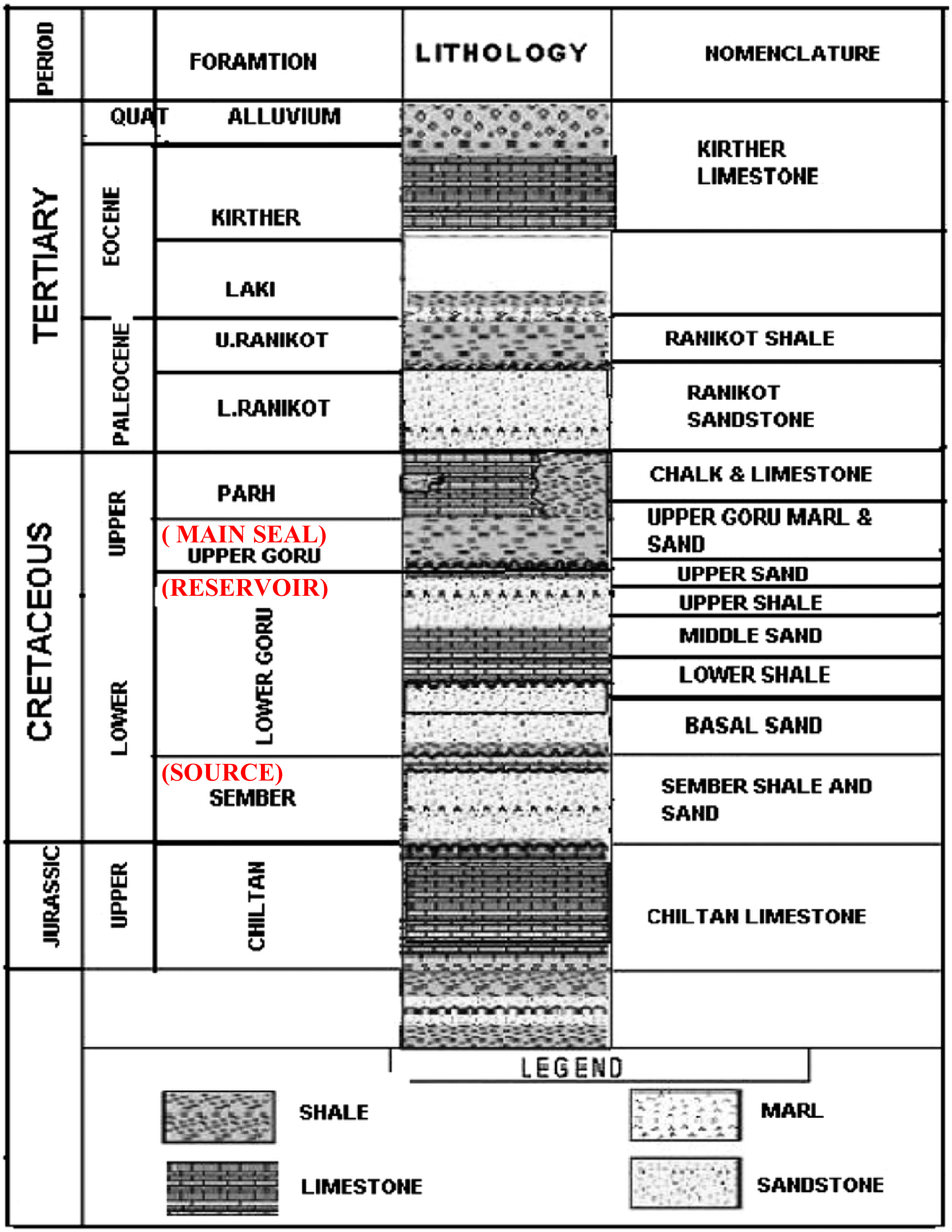

Figure 2. 2: General stratigraphy and petroleum play of the study area.

2.5 Petroleum Play of the Study Area

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. 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 and Mughal kot formations both are 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. Ranikot sandstone is also a good reservoir rock. The Pab sandstone within Mughal Kot formation is the potential reservoir rock for the entire study area. 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. On the basis of 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 all the 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).

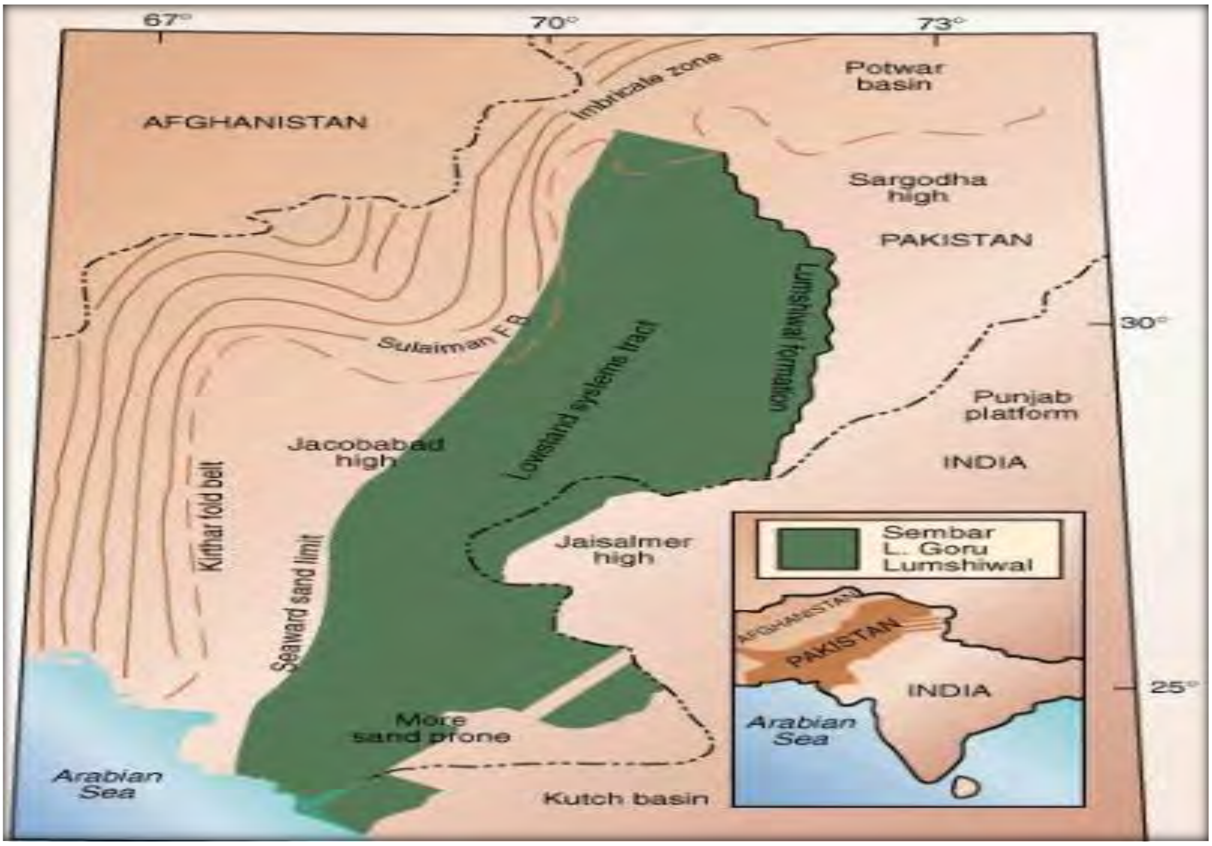

Figure 2.3: Petroleum play of Lower Indus basin.

CHAPTER 3

SEISMIC INTERPRETATION

3.1 Seismic Interpretation

Interpretation is a technique or tool by which an attempt is made to transform the whole seismic information into structural or stratigraphic model of the earth. Since the seismic section is the representative of the geological model of the earth, by interpretation, one tries to locate the zone of final anomaly (Sheriff, 1999).

Interpretation is the transformation of the seismic reflection data in to a structural picture by the application of correction, migration and time depth conversion (Dobrin and Savit, 1988). The computer based working (Processing & Interpretation) is more accurate, precise, efficient and satisfactory which provides more time for further analysis of data. This whole work is carried out using a combination of computer software products and SMT Kingdom suit.

3.2 Structural Interpretation

In structural analysis main emphases is on the structural traps in which tectonic play an important role. Tectonic setting usually governs which types of the structure are present and how the structural features are correlated with each other, so tectonic of the area is helpful in determining the structural style of the area and to locate the traps. Structural traps include the faults, folds anticline, pop up, duplex, etc. (Sheriff, 1999)

Seismic section can predict the structure that scale up to few tens of kilometers. For large scale interpretation, we have to use the grids of seismic lines.

The main application of the structural analysis of seismic section is in the search for structural traps containing hydrocarbon. Most structural interpretation uses two way reflection time rather than depth. Time structural maps are constructed to display the geometry of selected reflected events. Discontinuous reflectors clearly indicate faults and undulating reflectors reveal folded beds (Telford et al., 1990).

3.3 Interpretation Workflow

The Interpretation was carried out using different techniques and steps with each step involve different processes which were performed using the software tools as mentioned above. Simplified workflow used in the dissertation is given in Figure 3.1, which provides the complete picture depicting how the dissertation has been carried out by loading navigation data of seismic lines and SEG-Y in IHS kingdom Software, base map was generated. Faults and Horizons of interest were then marked manually. Identification of marked horizons was done with help of synthetic seismogram, generated with help of well data and faults were marked by keen observation on seismic section and knowing geologic history of study area.

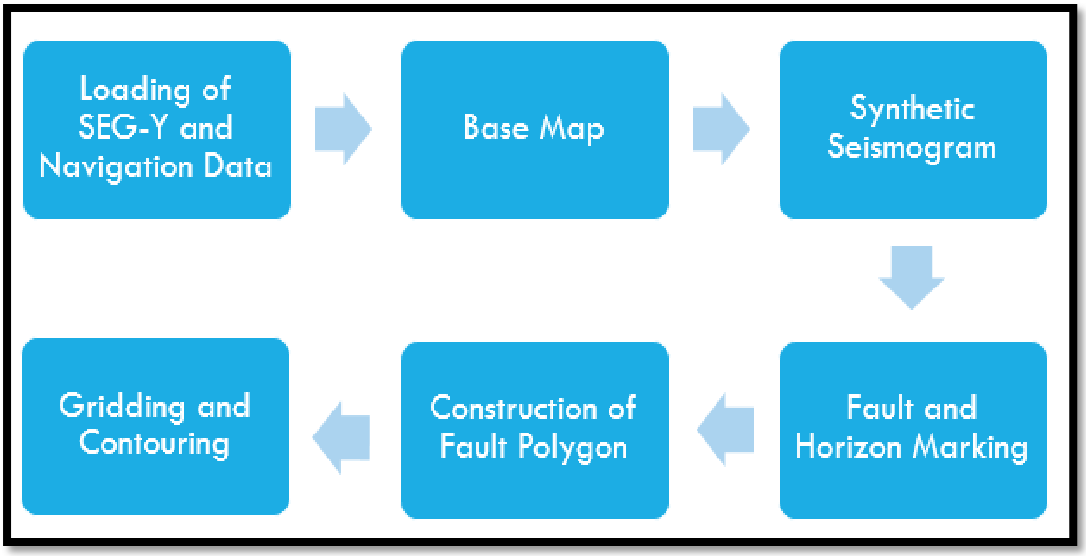

Figure 3.1: Workflow for seismic data interpretation.

3.4 Seismic to well tie

Well to seismic tie involves comparing the seismic data which is in time domain with well data which is in depth domain. An accurate synthetic seismogram is the key for performing well to seismic tie. Synthetic seismogram confirms our hypothesis and identifies horizons of interest Polarity either positive or negative, so seismic to well tie are important for the accurate picking of horizons.

3.5 Generation of Synthetic Seismogram

Synthetic seismograms provide a crucial link between lithological variations within a drill hole and reflectors on seismic profiles crossing the site. In essence, they provide a ground truth for the interpretation of seismic data. Synthetic seismograms are useful tools for linking drill hole geology to seismic sections, because they can provide a direct link between observed lithology's and seismic reflection patterns (Handwerger et al., 2004).

The following process of synthetic seismogram is done by Software automatically, so we explain it manually that how it works.

- Integrate the DT log to rescale from depth in meter to two-way travel time in Sec
- Compute Acoustic impedance log using velocity and density log.
- Compute the reflection coefficients from the time-scaled velocity log.
- Then extract wavelet along borehole.
- Two-way travel time; using a frequency in Hertz.
- Convolve the reflection coefficient log with the wavelet to generate the amplitudes of the synthetic seismogram.

The generated synthetic confirm the sand above and below talhar shale and middle sand. Top of the lower shale, Sand below Talhar Shale and Middle sand are marked. The display of the synthetic seismogram is shown in the Figure 3.2.

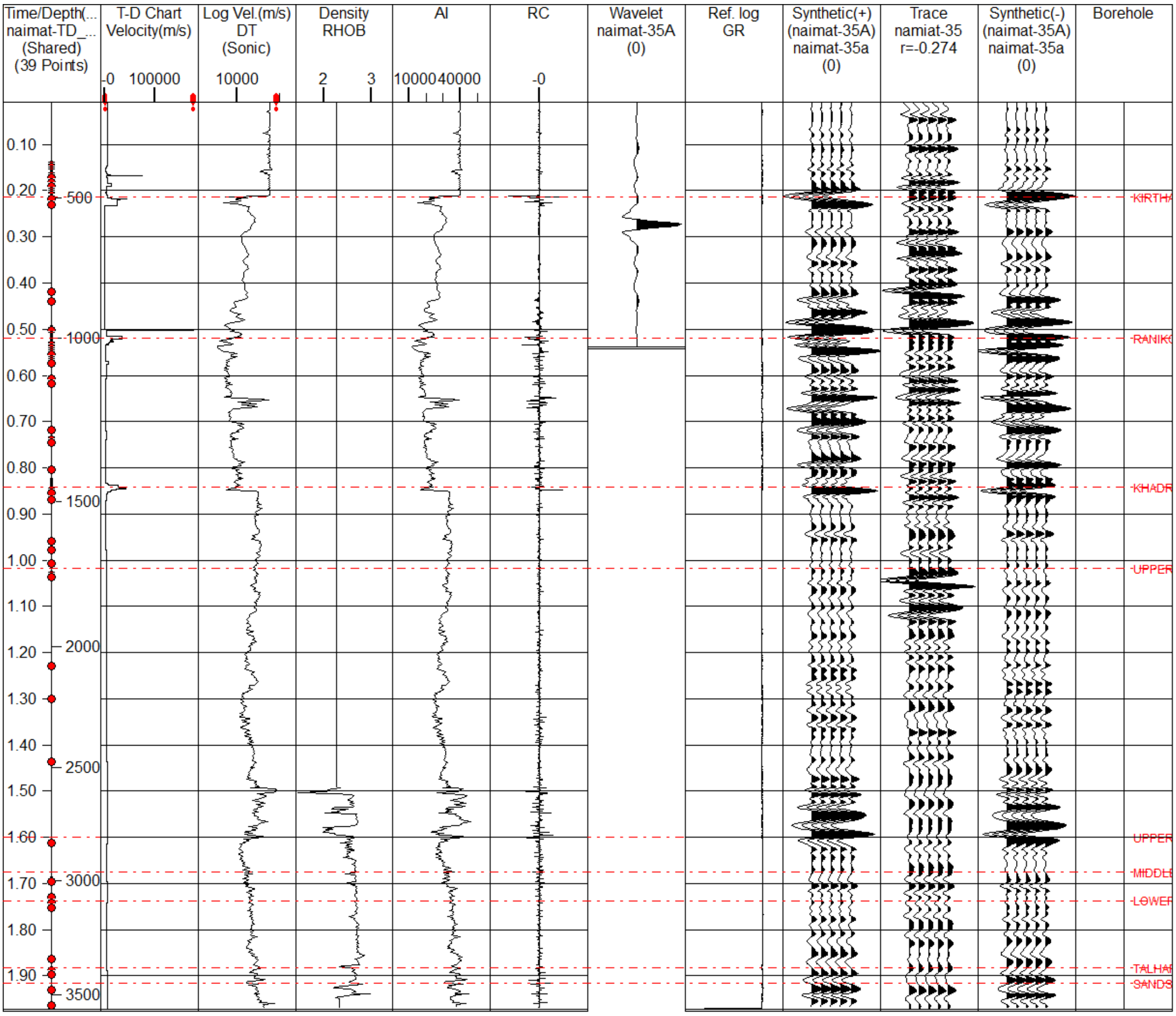

Figure 3.2: Synthetic Seismogram of well Naimat Basal-01.

3.6 Fault Marking

Conventional seismic interpretations are the arts that require skills and thorough experience in Geology and Geophysics to be precise (Mc. Quillin et al., 1984). Fault marking on real time domain seismic section is quite a hard work to do without knowing tectonic history of Area (Sroor, 2010). Faults are marked on the basis of breaks in the continuity of reflection. This Discontinuity of the reflector shows that the data is disturbed here due to the passing of the faults. The Naimat Basal-01 is lying in extensional regime hence we have conjugate normal faulting due to which the clear cut horst and Graben are formed.

3.7 Picking of Horizons

Interpreting seismic sections, marking horizons, producing time and depth maps is a task which depends on interpreter's ability to pick and follow reflecting horizons (reflectors) across the area of study (Mc. Quillin et al., 1984). Reflectors usually correspond to horizon marking the boundary between rocks of markedly different lithology, but it does not always occur exactly at geological boundary of horizon which is sometimes important problem in seismic interpretations (Kemal et al., 1991). However basic aim in seismic section interpretation is picking a horizon, and mostly, reflections on the section represent a certain geological formation where change in acoustic impedance occurred and this is the seismic way to interpret subsurface stratigraphic features.

3.8 Interpreted Seismic Sections

Using well data of well **NAIMAT BASAL-01**, horizons are marked on dip lines 2000KH-04, 2001-KH-30 and strike line 2003-KH-35.The marked horizons are Middle sand, Lower shale and Sand Below Talhar Shale on the basis of the change in the acoustic impedance also confirmed by the synthetic seismogram. All faults and horizons are marked with their names.

3.8.1 Interpreted Seismic Line G2000KH-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. Based on the discontinuity of the marked horizon I have marked faults on the given seismic line

Seismic section of G2000KH-04 line is interpreted, three horizons are marked including middle sand in pink color, lower shale in cyan color and sand below Talhar shale in yellow color , also seven normal faults are marked showing horst and graben structures also showing parallel faulting. The orientation of line is from NE-SW

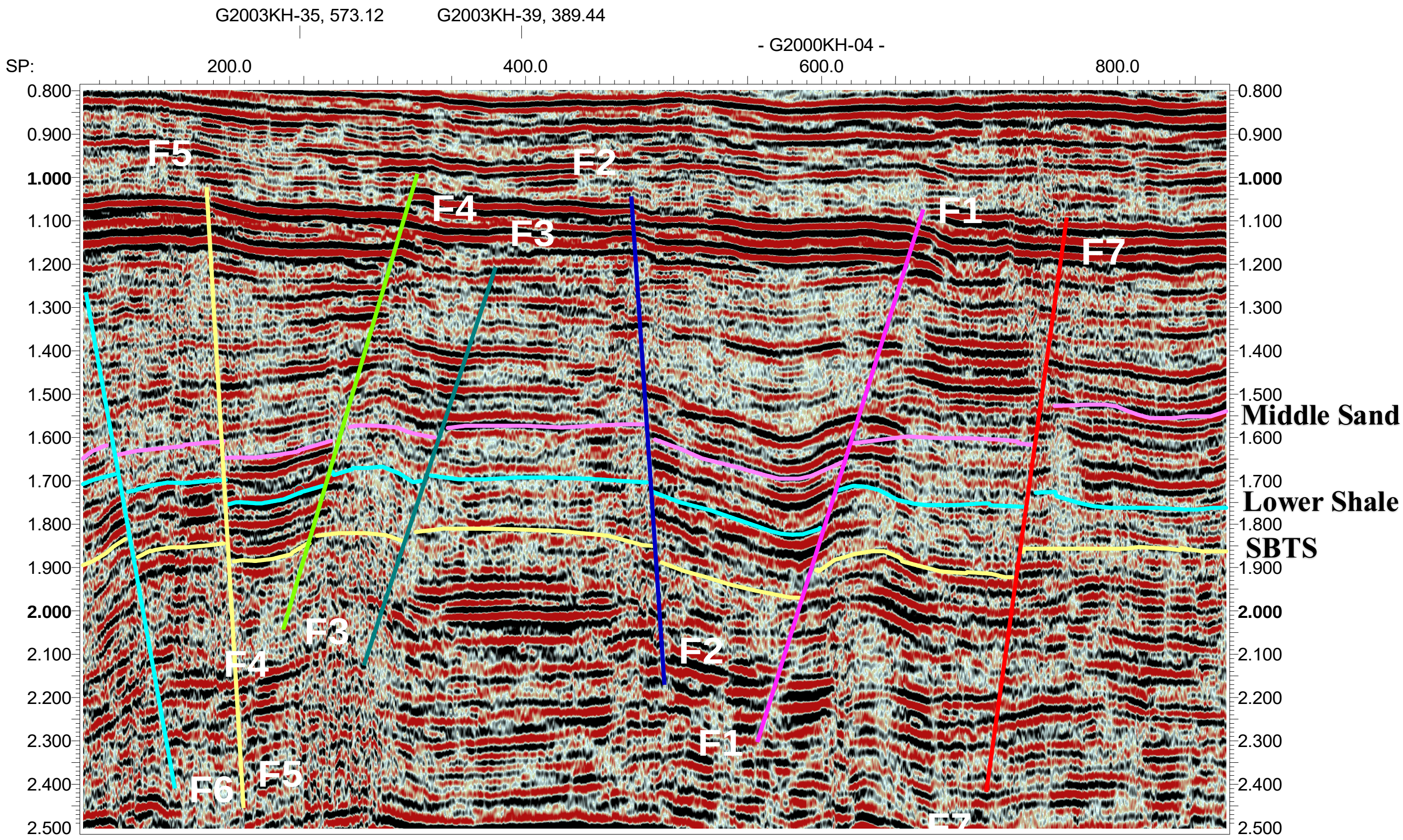

Figure 3.3: Interpreted Time section of line G2000KH-04

The dip of F1 , F3,F4 and F7 are on Western side while dip of F2, F5,F6 are towards Eastern side. Horst and graben structures are formed because of conjugate faulting.

3.8.2 Interpreted Seismic Line G2001KH-30

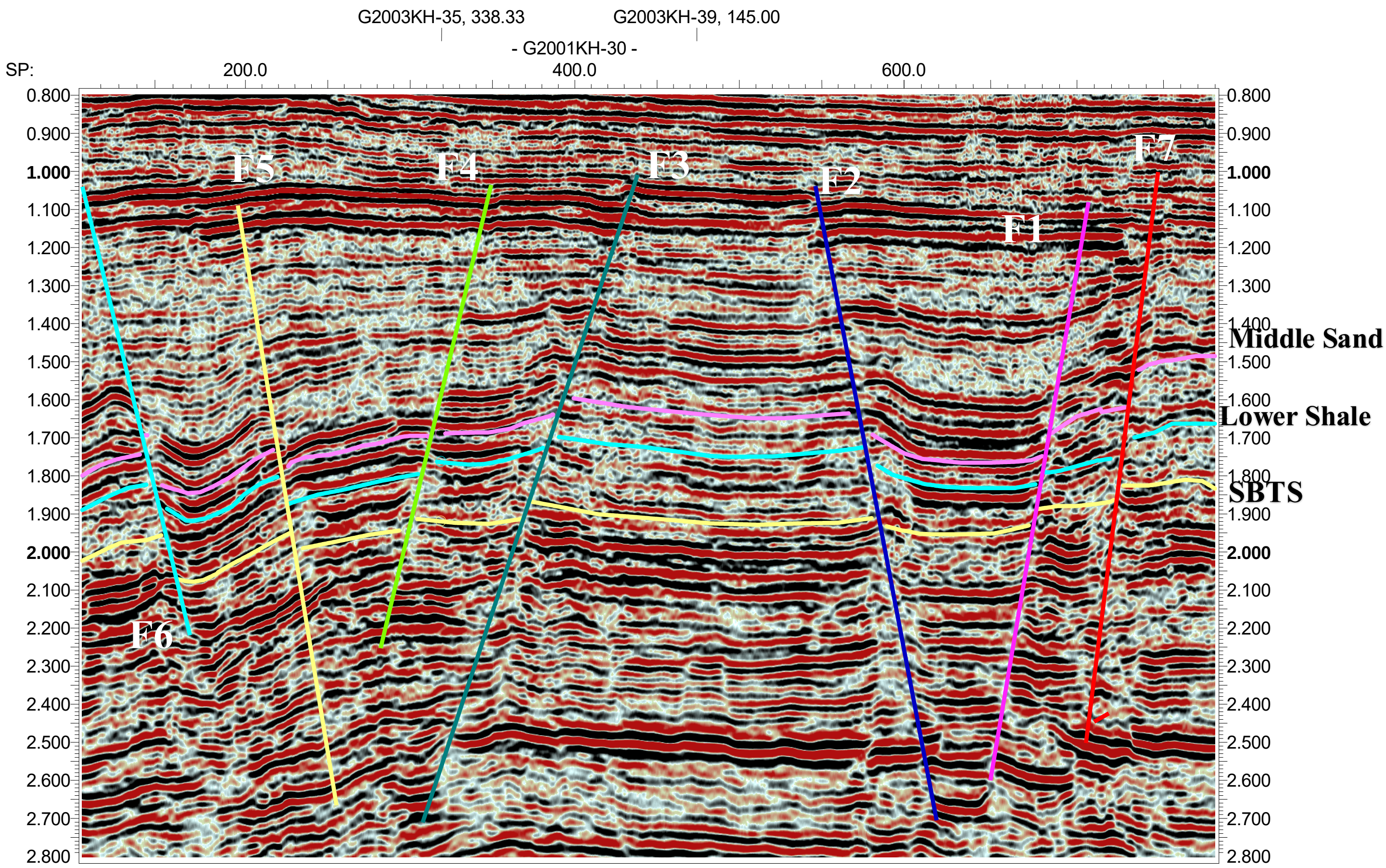

Figure 3.4: Interpreted Time section of line G2001 KH-30 .

Seismic section of line G2000-KH-04 and G2001-KH-30 in the Fig 3.3 and Fig 3.4. After marking horizons and faults, we got good horst and graben geometry structures, which matches with previous geological information.

On the basis of discontinuity in time, seven normal faults have been marked on the seismic sections of the line 2001-KH-30 (Figure 3.4) forming the horst and graben features. Clues of normal faulting exist on all of interpreted seismic lines and the line is oriented from NE-SW.

3.8.3 Interpreted Seismic Line G2003KH-35

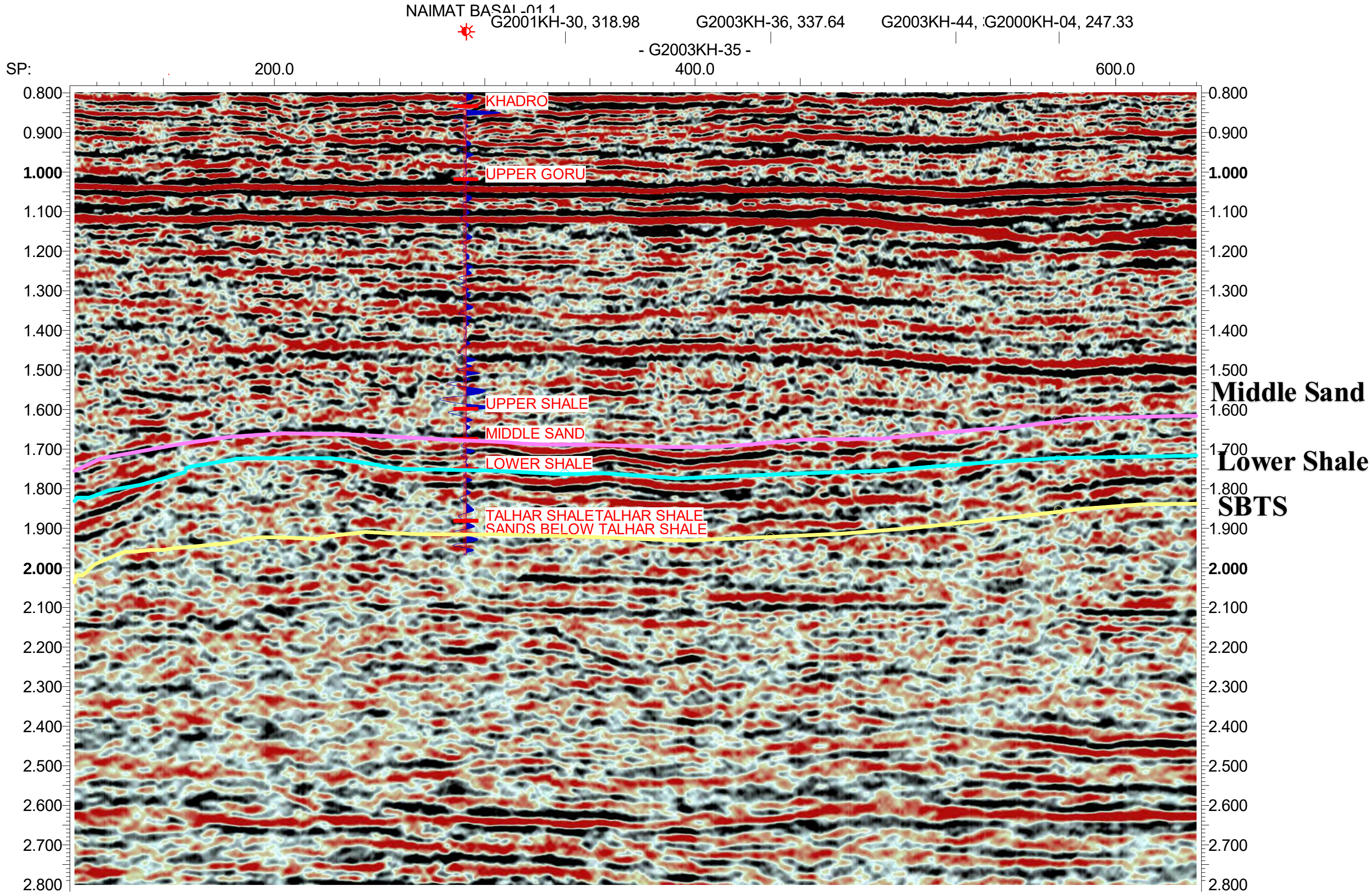

Figure 3.5: Interpreted Time section of line G2003KH-35

Three Horizons Middle Sand marked with blue color , Lower Shale marked with cyan color and Sands Below Talhar Shale marked with yellow color. The line is extended from North to South so no faults can be observed on strike line. The orientation of line is from NW-SE

3.9 Fault Polygons Generation

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

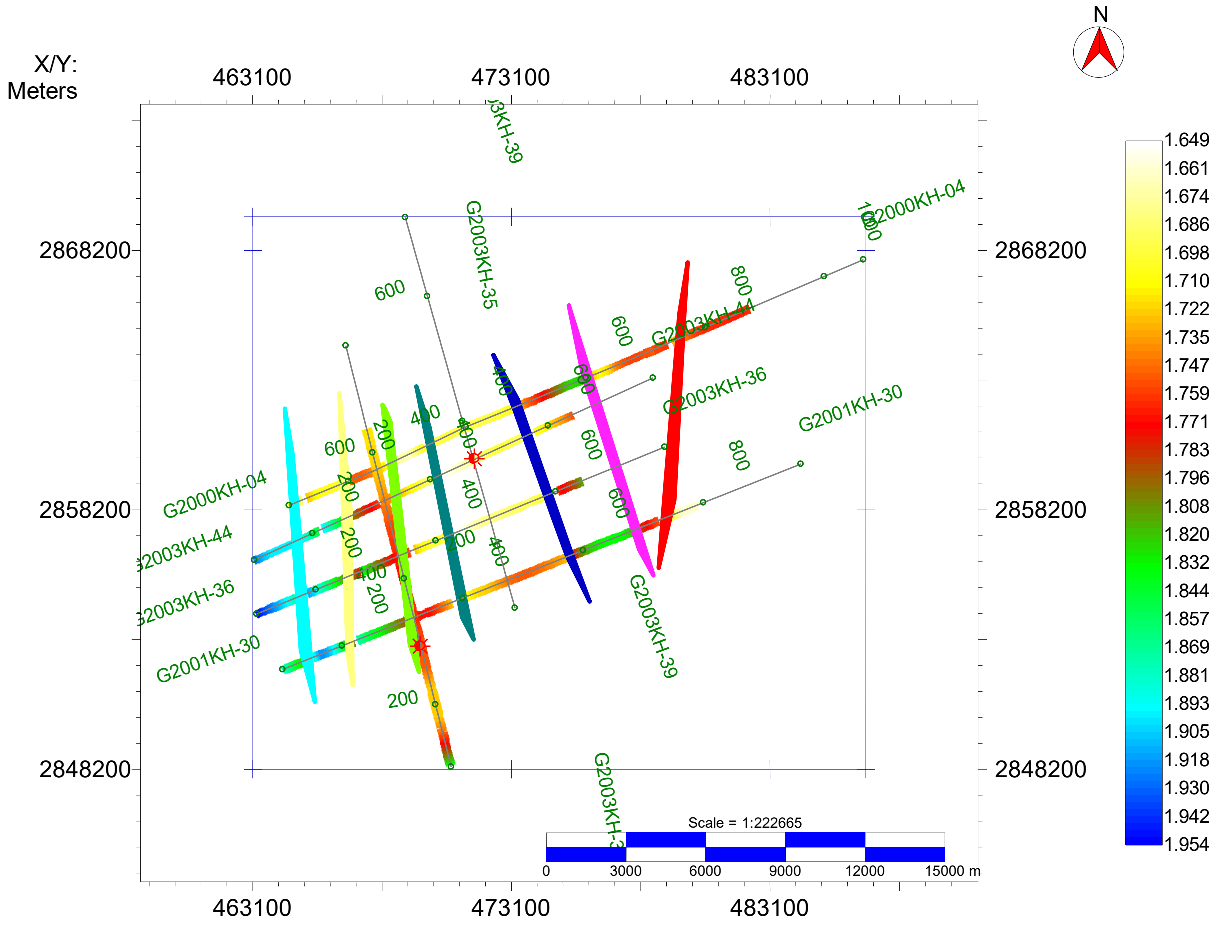

Figure 3.6: Fault Polygon of Lower Shale Formation.

Fig 3.6 shows polygons of Lower Shale formation. At lower shale seven fault polygons are generated which shows alternate different color due to time change along both sides of polygon representing in color bar, showing normal faulting. As we move from right to left time increases.

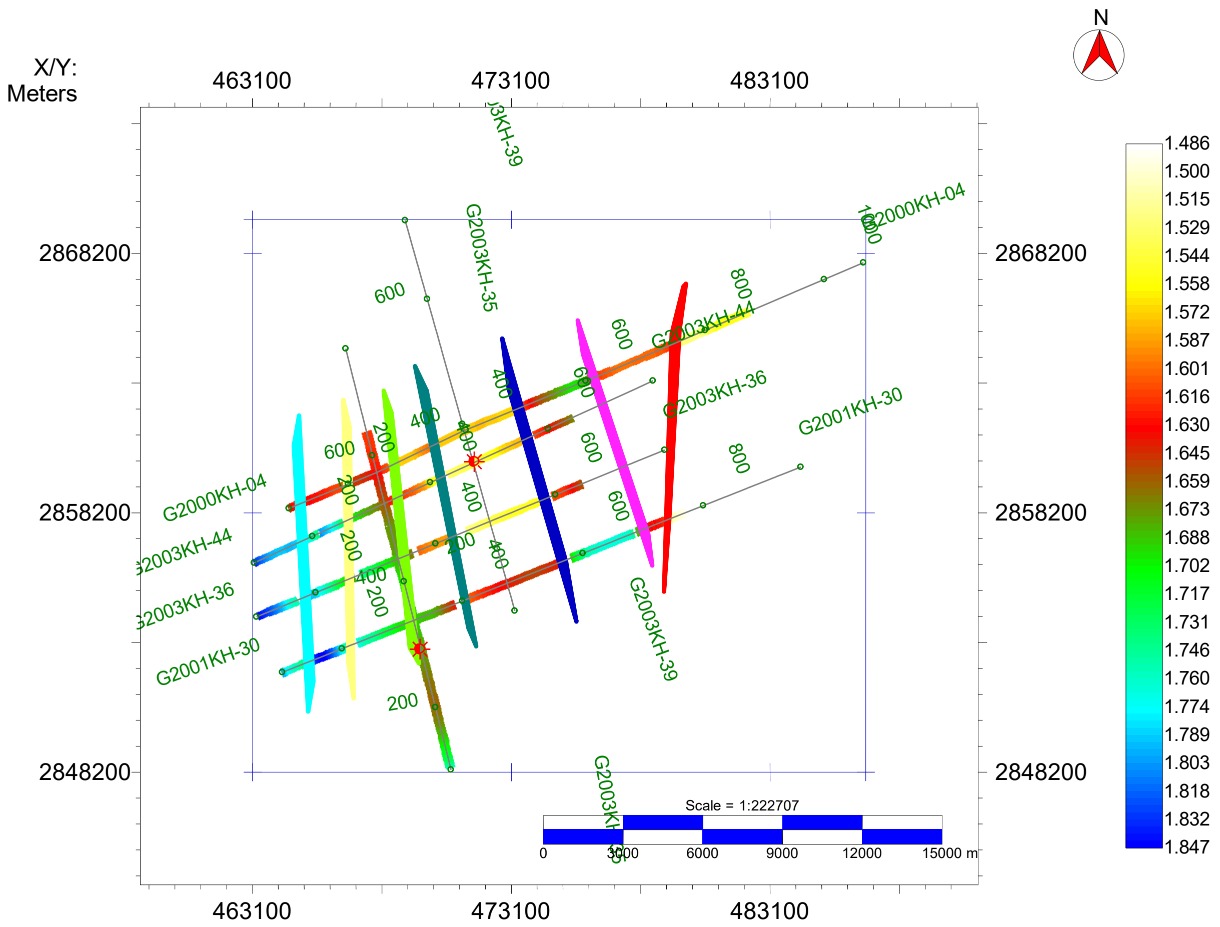

Figure 3.7: Fault Polygon of Middle sand formation**.**

Fig 3.7 shows color variation along both sides of polygon depicts the change in time of seismic reflected waves due to presence of faults. Shape in nature of fault polygons almost similar with polygons formed at lower Shale formation. At Eastern side its shows low values while , as we move from East to West , we move towards deeper area.

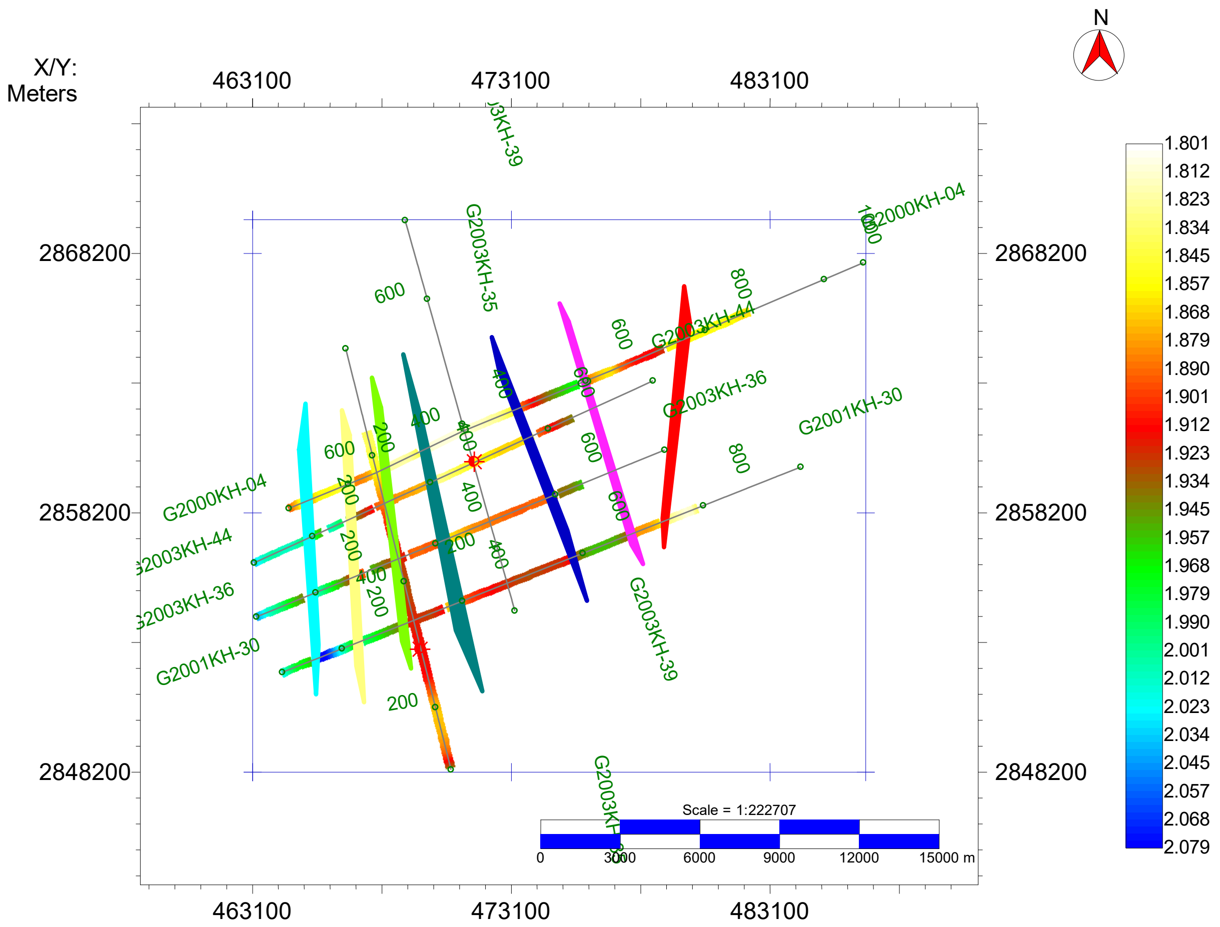

Figure 3.8: Fault Polygon of Sand Below Talhar Shale formation.

3.10 Contour Maps

The contours are the lines of equal elevation (time or depth). Mapping is usually final product of exploration, the one on which whole operations depends for its effectiveness (Coffeen, 1986). Contour maps show relief on horizons with contour lines that represent equal two way time (TWT) below a reference datum. These contour maps describe the slope of the formation, its dip, and any faulting or folding. In constructing a subsurface map from seismic data, a reference datum must first be selected. The datum may be sea level or any other depth above or below sea level.

3.10.1 Time Contour Maps

Time contour maps give a reliable picture of the subsurface if drawn properly. Middle sand and sand below Talhar shale are main formations of interest producing oil and gas, and composed of Sand. It is noted from time contour maps the main structure lies at the side of faulted region and shown by minimum time on the scale. Time contour map of this formation show 2D-variations with respect to time and the hydrocarbons probably accumulate at those places where contour values are low. Time counter map of Middle Sand shown in figure 3.9.

3.10.1.1 Time contour map of Middle Sand

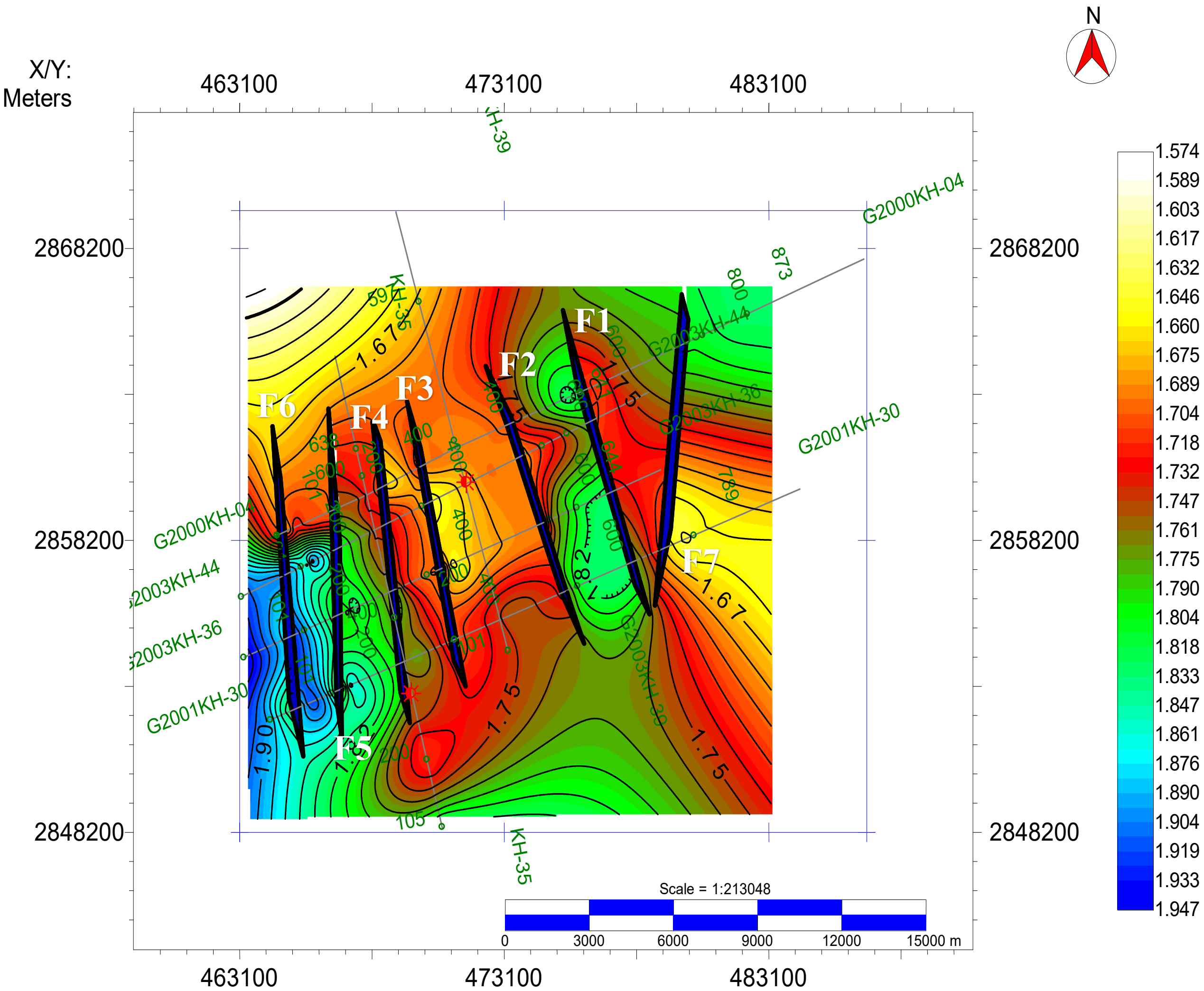

Figure 3.9: Time contour map of Middle sand Formation.

The alternate color variation shows horst and graben geometry and time variation proves that it is normal faulting. N-E region is found to be uplifted area as compared to S-W region. Fault F1 and F2 shows horst and graben structure. As area between them is depressed.

3.10.1.2Time contour map of Lower Shale

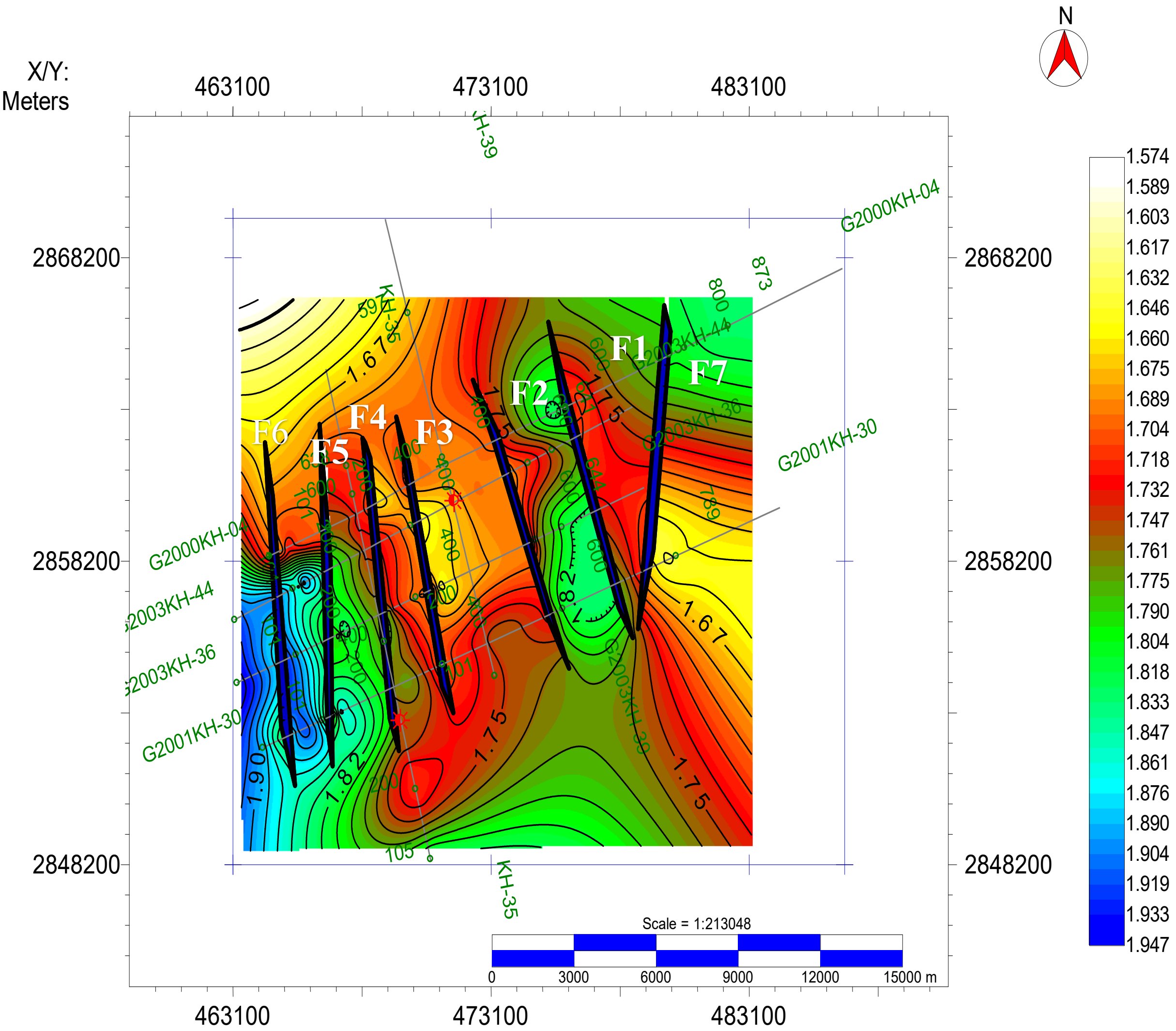

Figure 3.10: Time contour map of Lower Shale Formation.

Time contour map of Lower Shale shown in Fig 3.10 also shows the same pattern of variation in time as the previous ones. Also shows horst and graben structure between F1 and F7. Yellow colored part(Eastern side) of map showing shallowest zone of formation whereas blue colored(Western) part is indicator of deepest zone.

3.10.1.3 Time Contour map of Sand Below Talhar Shale

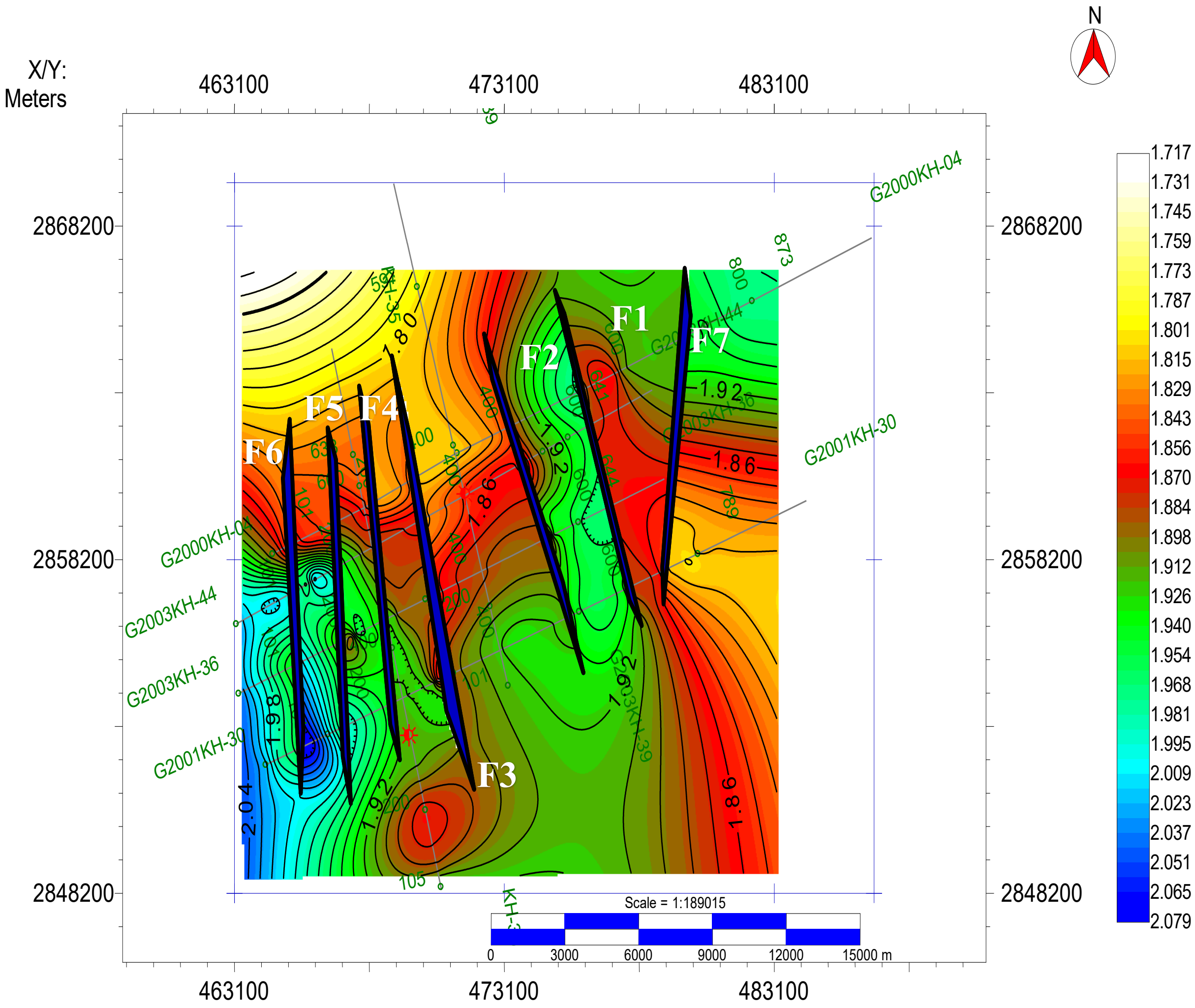

Figure 3.11: Time Contour map of Sand Below Talhar Shale Formation.

SW direction shows higher time which means deeper area. While SE shows lower values. Fault F1 And F2 shows graben structure. While F2 and F3 shows horst structure.

3.10.2 Depth Contour Maps

Depth contour maps are not as common as time contour maps. Mostly, the depth estimates are made with the help of time contour maps in a particular area. However, depth contour maps can give an extra edge when there’s a good velocity control. Contouring can be a challenging job when done over areas of extensive faulting or mapping small features in stratigraphically complex regimes.

Depth contour of Middle Sand and Sand Below Talhar Shale formations shown in figure (3.12 & 3.14) shows contouring pattern N-E region as relatively uplifted area. Structural pattern of the area also confirm by contouring as the horst and graben geometry. Region shown in blue color is the shallowest with low values of depth might be the good zone for the accumulation of hydrocarbons.

3.10.2.1 Depth contour of Middle Sand

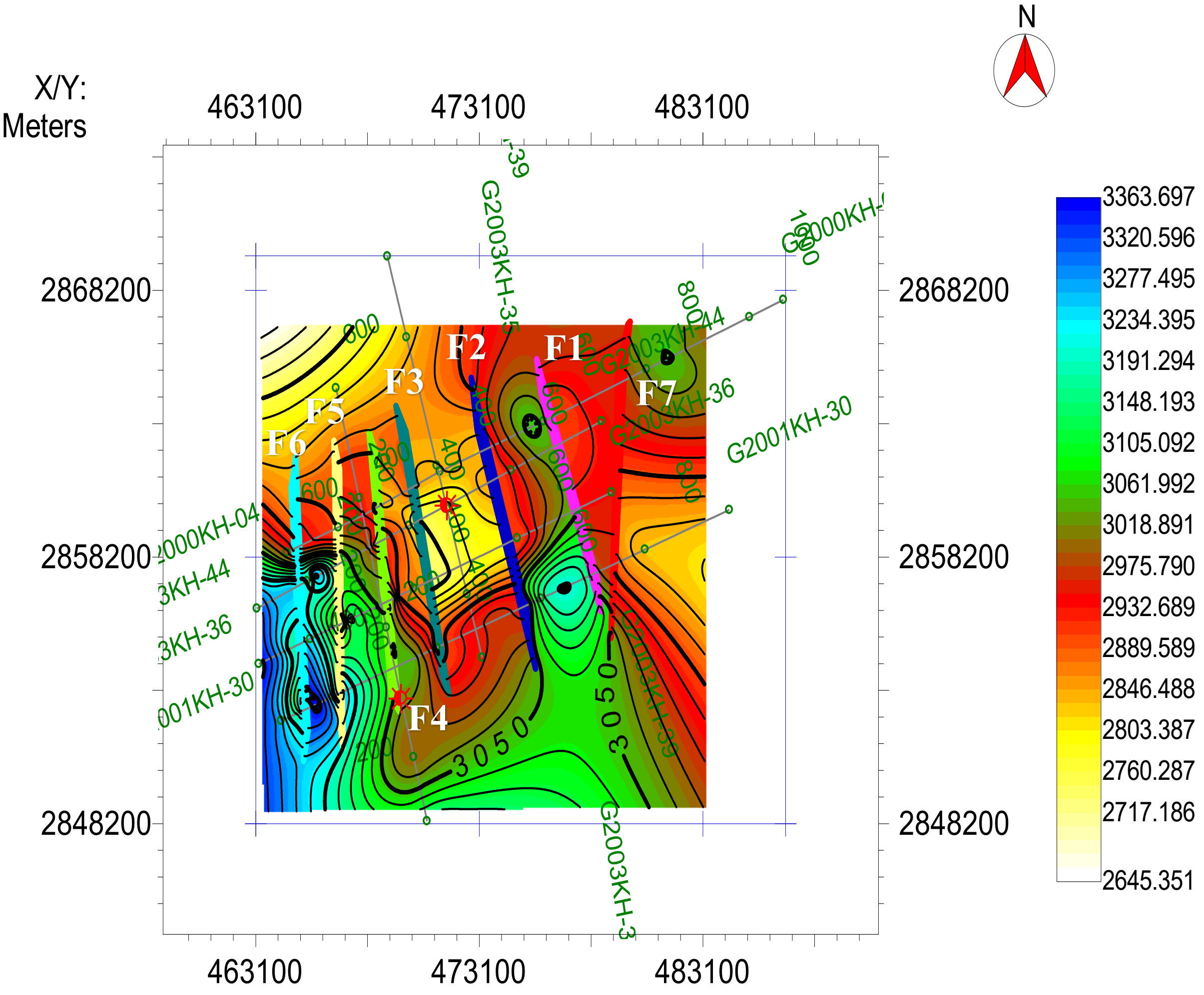

Figure 3.12: Depth contour of Middle sand formation.

3.10.2.2 Depth contour of Lower Shale Formation.

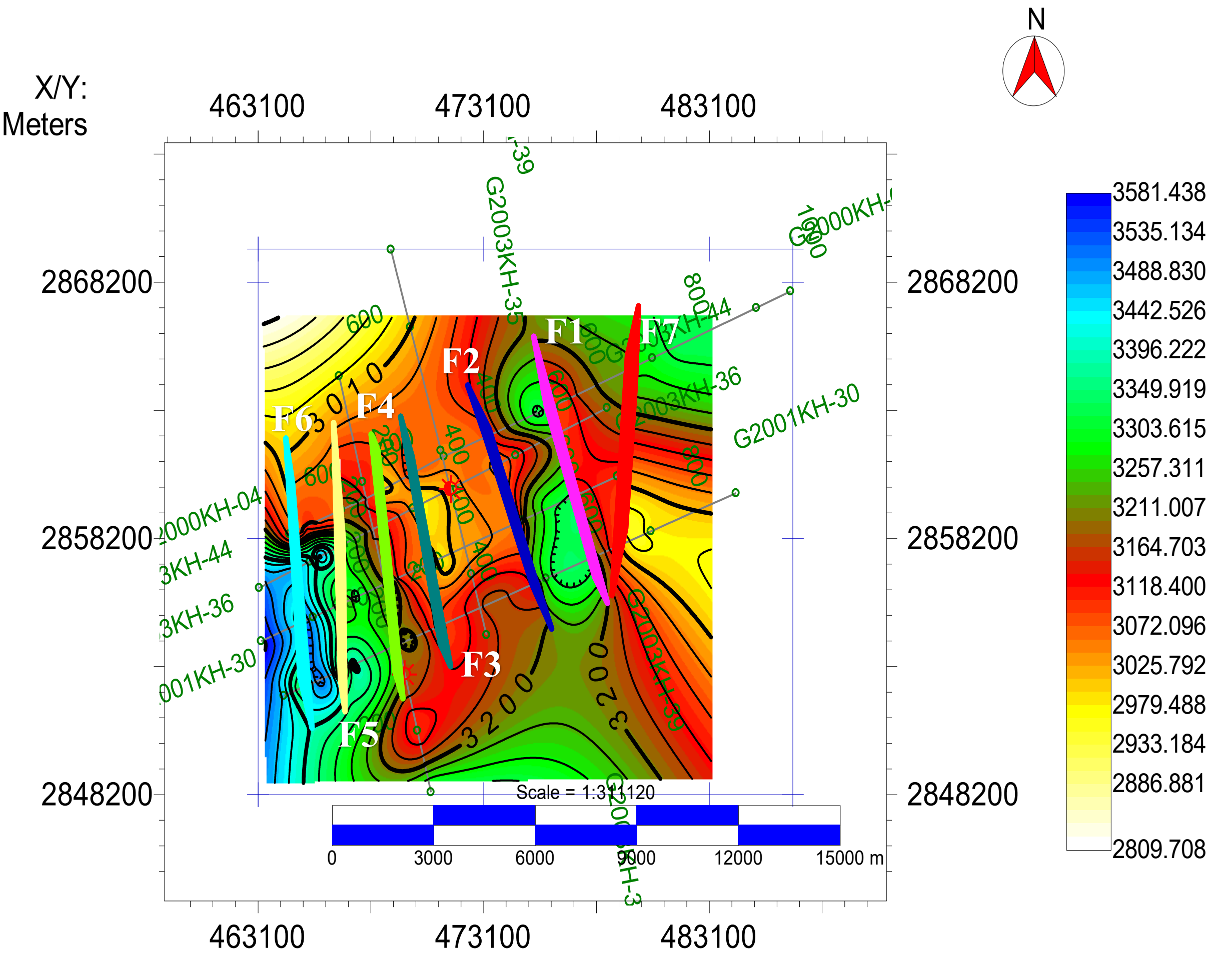

Figure 3.13: Depth contour of Lower Shale Formation.

Time contour map of Lower shale shown in Fig 3.13 also shows the same pattern of variation in time through the base map as the Middle sand and Sand below Talhar shale formations. Blue colored part of map showing shallowest zone of formation whereas yellow colored part is indicator of deepest zone all wells are drilled on horst blocks. If we notice the time values, we can clearly see the presence of normal faulting with horst and graben geometry. SW direction shows deepest area having more depth and SE shows high values

3.10.2.3 Depth contour of Sand Below Talhar Shale Formation.

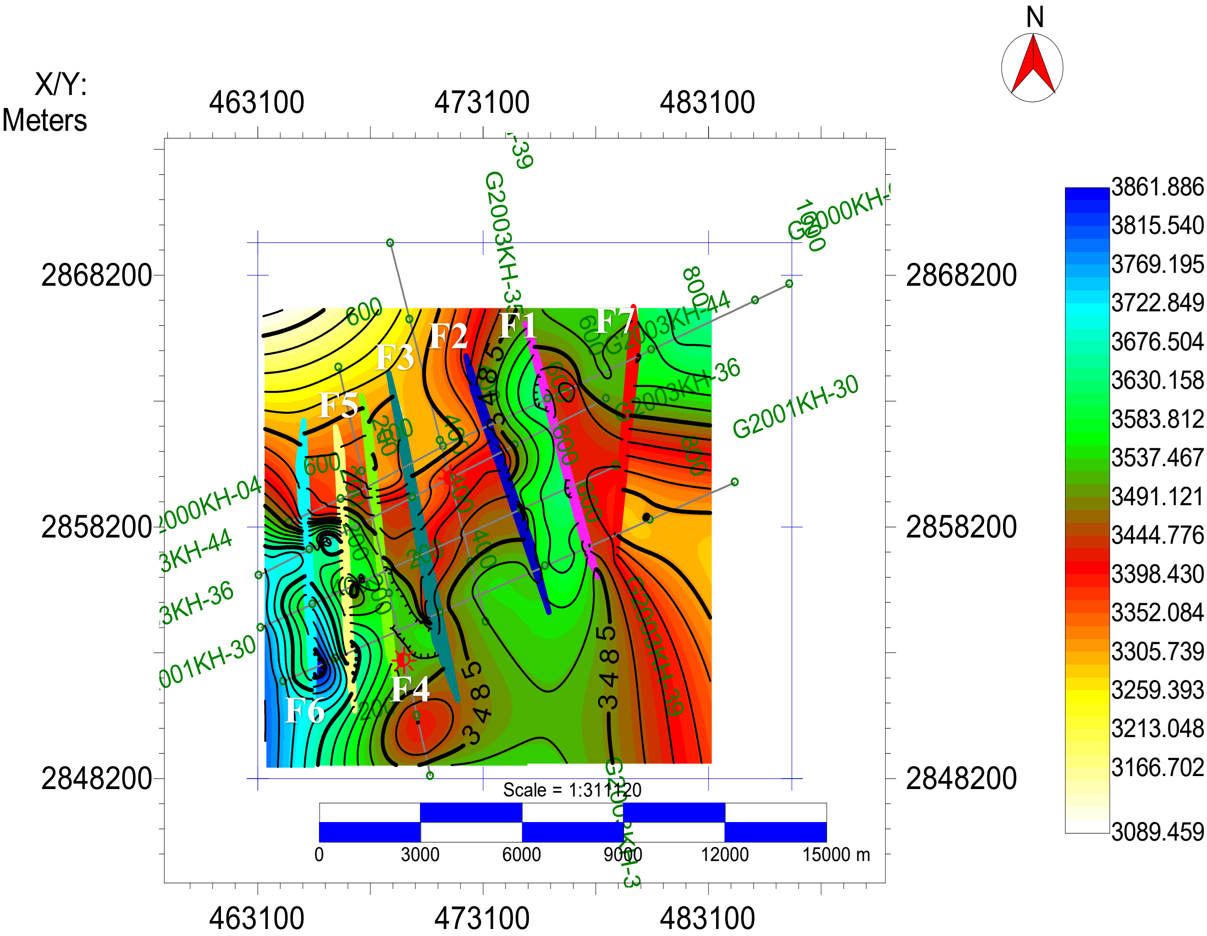

Figure 3.14: Depth contour of Sand Below Talhar Shale Formation.

SE shows lower depth as compared to SW. F1, F2, F3 and shows NW-SE direction. And F4, F5, F6 and F7 shows NE-SW direction.

CHAPTER 4

ATTRIBUTE ANALYSIS

4.1 Introduction

Seismic Attributes are all the information obtained from seismic data, either by direct measurements or by logical or experience-based reasoning. The study and interpretation of seismic attributes provide us with some qualitative information of the geometry and the physical parameters of the subsurface. It has been noted that the amplitude content of seismic data is the principal factor for the determination of physical parameters, such as the acoustic impedance, reflection coefficients, velocities, absorption etc. The phase component is the principal factor in determining the shapes of the reflectors, their geometrical configurations etc. The principal objectives of the attributes are to provide accurate and detailed information to the interpreter on structural, stratigraphic and lithological parameters of the seismic prospect (Taner 1994).

4.2 Seismic Attributes

Attributes can be computed from pre- stack or from post- stack data, before or after time migration. The procedure is the same in all of these cases. Attributes can be classified in many different ways. Several authors have given their own classification. Here we give a classification based on the domain characteristics of the attributes (Taner 1994).

4.2.1 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. Azimuth related information. 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 1994)

These attributes may be sub-classified on the basis of the relationship to the geology.

4.2.2 Physical Attribute

Physical attributes relate to physical qualities and quantities. The magnitude of the trace envelope is proportional to the acoustic impedance contrast; frequencies relate to bed thickness, wave scattering and absorption. Instantaneous and average velocities directly relate to rock properties. Consequently, these attributes are mostly used for lithological classification and reservoir characterization (Taner 1994).

4.2.3 Geometric Attribute

Geometrical attributes describe the spatial and temporal relationship of all other attributes. Lateral continuity measured by semblance is a good indicator of bedding similarity as well as discontinuity. Bedding dips and curvatures give depositional information. Geometrical attributes are also of use for stratigraphic interpretation since they define event characteristics and their spatial relationships, and may be used to quantify features that directly assist in the recognition of depositional patterns, and related lithology (D.Subrahmanyam 2008).

4.3 Attribute Analysis of Line G2001KH-30

4.3.1 Envelope of Trace (Reflection Strength/ Instantaneous Amplitude)

The Trace Envelope is a physical attribute and it can be used as an effective discriminator for the following characteristics.

- Mainly represents the acoustic impedance contrast, hence reflectivity
- Bright spots, possible gas accumulation
- Sequence boundaries
- Thin-bed tuning effects
- Major changes in depositional environment
- Unconformities
- Major changes of lithology
- Spatial correlation to porosity and other lithological variations
- Indicates the group, rather than phase component of the seismic wave propagation (D.Subrahmanyam 2008).

Figure 4.1 shows envelope attribute of line 2000KH-30. Since this attribute is the square of the real and imaginary components of seismic trace, it always has a positive value. Thus, the vertical resolution of this attribute decreases and it is not able to highlight sand shale intervals. However, it is useful in highlighting the major lithological changes. It gives low reflection where fault is present, and it also gives high reflection at marked horizons.

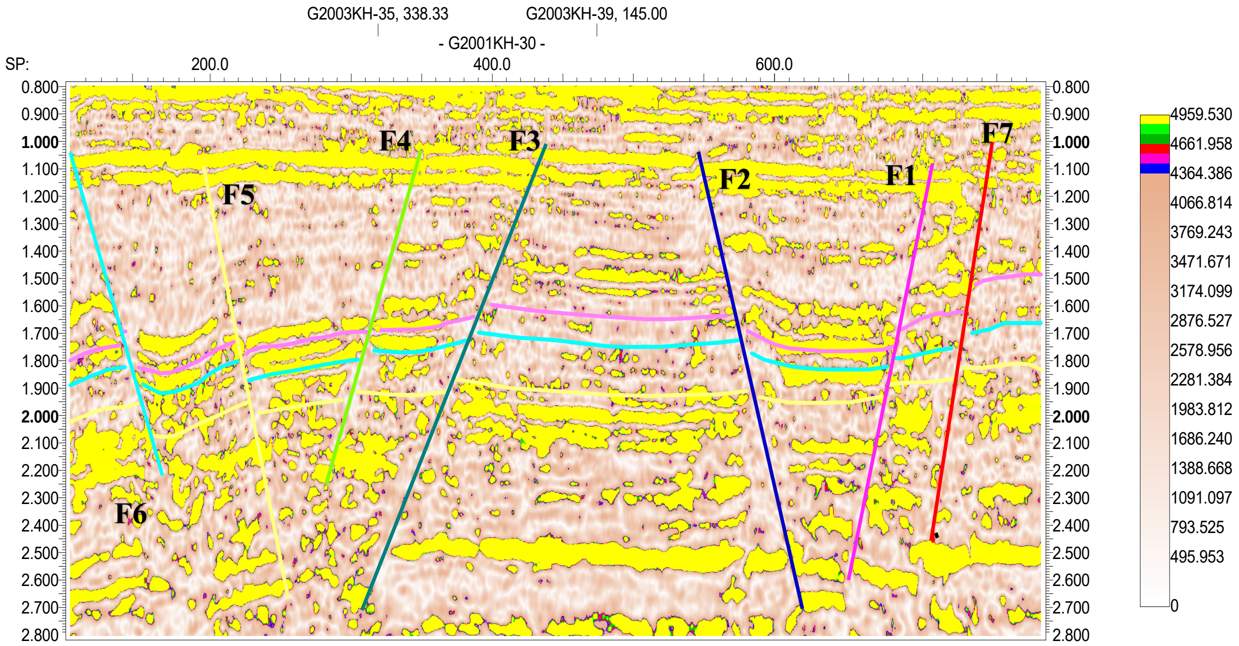

Figure 4.1:Envelope Attribute Map of Line G2001KH-30

4.3.2 Instantaneous Phase

Phase attribute is also a physical attribute and can be effectively used as a discriminator for geometrical shape classifications. The phase information is independent of trace amplitudes and relates to the propagation of phase of the seismic wave front.

- Instantaneous phase is the best indicator of lateral continuity
- It can be used to highlight interface in sections with high decay of amplitudes and even highlight deeper horizons which are not visible in the normal amplitude sections Shows discontinuities
- Detailed visualization of bedding configuration(Subrahmanyam 2008).

Instantaneous phase highlights the continuity of reflectors. Since it is independent of amplitude, therefore it is capable of highlighting subsurface imagery in case of low amplitudes. Figure 4.2 shows phase attribute of line G2001KH-30. It confirm the continuity of marked reflectors. This gives lateral continuity of the reflector As shown in Figure 4.2 .

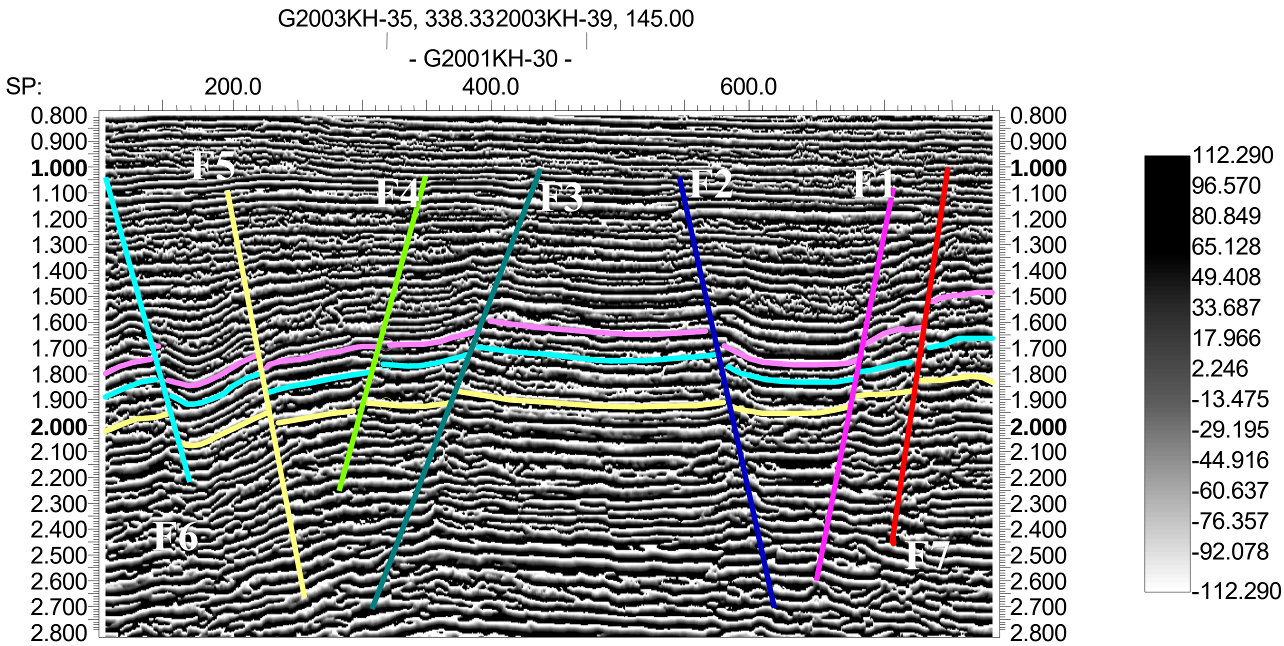

Figure 4.2: Phase Attribute Calculated for Seismic Line G2001KH-30

4.3.3 Instantaneous Frequency

Instantaneous Frequency (Hz) is the rate of change of phase over time. Instantaneous frequency attribute responds to both wave propagation effects and depositional characteristics, hence it is a physical attribute and can be used as an effective discriminator (Subrahmanyam 2008).
Its uses include:

- Hydrocarbon indicator by low frequency anomaly. This effect is sometimes accentuated by unconsolidated sands due to the oil content of the pores
- Fracture zone indicator, since fractures may appear as lower frequency zones
- Bed thickness indicator. Higher frequencies indicate sharp interfaces such as exhibited by thinly laminated shale, lower frequencies are indicative of more massive bedding geometries, e.g. sand-prone lithology.

Frequency attribute is used as a geologic indicator in a number of scenarios. It is most commonly used to highlight the hydrocarbon reservoir with low frequency as the reservoir tends to absorb the higher frequencies. Figure 4.3 shows the frequency attribute of line G2001KH-30 where the identified reservoirs are highlighted by low frequency. Low frequencies between F1 and F2 shows there might be a reservoir.

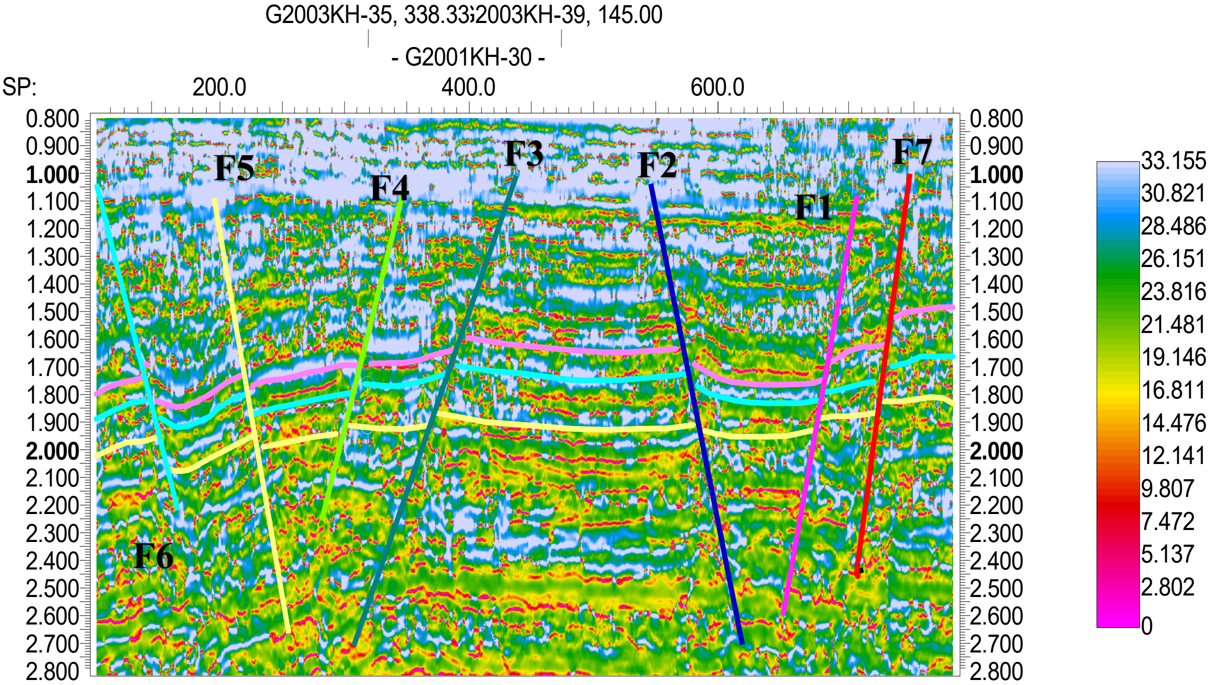

Figure 4.3: Frequency Attribute Calculated for Seismic Line G2001KH-30.

4.3.4 AVERAGE ENERGY

Average energy is a post-stack wavelet attribute, in which, within a specified window the square root of the sum of squared amplitudes is calculated and divided by their number of samples. The wavelet attributes are computed at the peak of the envelope, which represent the attributes of the wavelets within a zone defined by the trace envelope minima. These attributes indicate spatial variation of the wavelets and therefore relate to the response of the composite group of individual interfaces below the seismic resolution. The attribute has a blocky response and individually highlights the seal, reservoir and source rocks as shown in (figure 4.4)

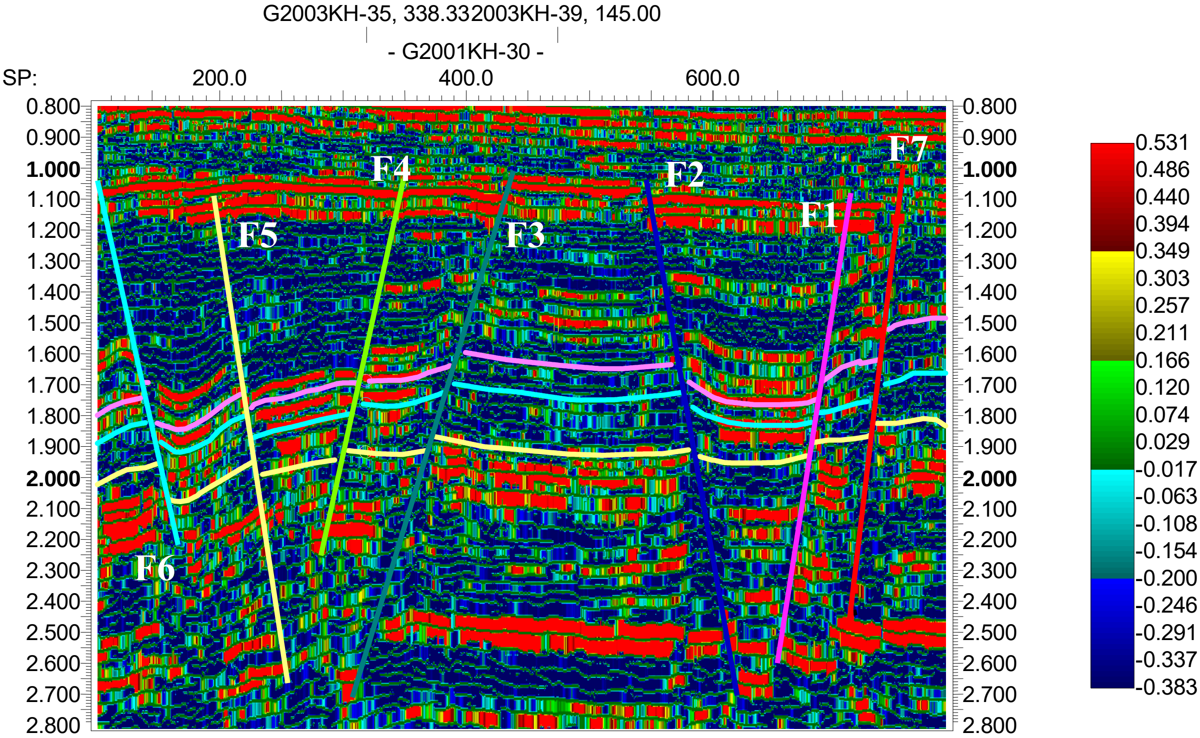

Figure 4.4: Average Energy Attribute Calculated for Seismic Line G2001KH-30

This attribute give clear indication of the faults based on the average energy in that region.

CHAPTER 5

PETROPHYSICAL ANALYSIS

5.1 Introduction

Petrophysics is study of the physical properties relating the incidences, behavior of the rocks and fluids inside the rocks Reservoir characterization is the key step in oil and gas industry as it helps in defining the well and field potential so identify the zones within the reservoir which bears the hydrocarbons and can be recovered (Cosgrove et al., 1998).

Petrophysics is one technique used for the reservoir characterization. This study facilitates in identification and quantification of fluid in a reservoir (Aamir et al., 2014). Knowledge of reservoir physical properties like volume of shale, porosity, and water and hydrocarbon saturation is needed to define accurately probable zones of hydrocarbons. The integration of petrophysics along with the rock physics enables the geologists and geophysicists to understand the risks and opportunities in the area. Petrophysics is apprehensive with using well measurements to subsidize reservoir depiction (Daniel, 2003).

Petrophysics uses different geophysical tools (GR, Caliper Log, SP, LLD, and LLS etc.), core data and production data and integrates the results extracted. These geophysical tools are designed to quantify some specific reservoir property such as porosity, shale volume, net pay, effective porosity, saturation of hydrocarbon etc. Petrophysical analysis is often less related to seismic data but more concerned to well log data for reservoir description.

5.2 Data set

The petrophysics analysis has been carried out in order to measure the reservoir characterization of the Khipro area using the borehole data of Naimat-Basal-01.We used the log curves including Spectral Gamma ray (GR), Sonic log (DT), Latero log deep (LLD), Neutron log, density log. For petrophysics analysis the following parameters are acquired on the basis of the log curves.

- Volume of shale

- Water saturation
- Hydrocarbon Saturation

5.3 Lithology Track

5.3.1 GR log

GR logging tool detect the natural Gamma radiations across the formation. These radiations come from radioactive element like Potassium, Uranium and Thorium etc. GR show maximum deflection for dirty lithologies (Shale) and minimum against clean lithologies. A clean lithology (Sandstone) has smaller quantity of clay minerals while a dirty lithology is enriched in clay minerals (Shale). From GR log we not only interpret lithologies, but we can also find Volume of shale.

5.3.2 Spontaneous potential log

The spontaneous potential log (SP) measures the natural or spontaneous potential difference (sometimes called self-potential) that exists between the borehole and the surface in the absence of any artificially applied current. It is a very simple log that requires only an electrode in the borehole and a reference electrode at the surface. These spontaneous potentials arise from the different access that different formations provide for charge carriers in the borehole and formation fluids, which lead to a spontaneous current flow, and hence to a spontaneous potential difference. The SP log has four main uses: The detection of permeable beds, determination of Rw. The indication of the shaliness of a formation and for Correlation.

5.3.3 Caliper log

Caliper log tell us about borehole diameter. Borehole diameter is actually equal to the bit size. A line is drawn on the Caliper log which shows the size of borehole. A simple mechanical measure a vertical profile of borehole diameters. Any deflection from this line show the variation of borehole diameter and it actually gives us clue of the lithology. It is run in track 1 with Sp and GR log.

Increase of borehole diameter indicates Caving and Washouts and similarly decrease in borehole diameter indicates that Mud Cake has formed on the wall of borehole. Caliper log showing the decrease in bore size indicates that mud cake is formed on the walls of bore hole, which is a good indicator of Permeable lithology because mud Cake only form when rock is permeable. Caving and washouts show loose lithology, i.e. Shale, so increase of bore hole diameter is an indication of shale.

5.4 Resistivity Track

5.4.1 Resistivity logs

A log of the resistivity of the formation is expressed in ohm-meter. The resistivity can take a wide range of values, and, therefore, for convenience is usually presented on a logarithmic scale from, for example, 0.2 to 2000 ohm-m. The resistivity log is fundamental in formation evaluation because hydrocarbons do not conduct electricity while all formation waters do. Therefore, a large difference exists between the resistivity of rocks filled with hydrocarbons and those filled with formation water. Clay minerals and a few other minerals, such as pyrite, also conduct electricity, and reduce the difference. Resistivity logs are of various types these are described below

- **LLD**
  (Deep Laterolog) Laterolog log deep also measures the true formation resistivity beyond the outer boundary of invaded zone.
- **LLS**
  Shallow Laterolog deep measures the resistivity in the invaded zone
- **MSFL**
  Micro spherically focused log measures the resistivity of the flushed zone (Rxo).

5.5 Porosity Track

5.5.1 Density Log

Density porosity log (RHOB) displays the electron density of formation in contact by detecting the scattered gamma rays. It gives an indication of porosity, lithology and can assist to detect gas bearing zone. Cross over of neutron and density log is an indicator of Gas/hydrocarbons called Gas Effect. The overlapping curves indicate the presence of water.

5.5.2 Sonic log

Sonic log is a porosity log that measures interval transit time of compressional sound waves. It displays travel time of P-waves versus depth. Sonic logs are typically recorded by pulling a tool on a Wireline up the wellbore. The tool emits a sound wave that travels from the source to the formation and back to a receiver. (1).the interval transit time is dependent upon both lithology and porosity. For porous rock the travel time increases and hence the larger deflection occurs on the log display and for denser and nonporous material the traveling velocity increases and hence the travel time decreases.

To calculate porosity from sonic log we must know formation matrix velocity. By Wyllie's formula

$$\varphi_{sonic} = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

Where, Δt_{log} is the interval transit time of formation

Δt_{ma} is the interval transit time of the matrix

Δt_f is the interval transit time of the fluid in well bore

5.5.3 Porosity log

Neutron log, density logs and sonic logs are the porosity logs. None of these logs gives direct porosity values. We can find the porosity of the formation by analyzing these logs.

5.5.4 Neutron log

Neutron log is based on effect of the lithology on fast neutrons emitted by a source. Hydrogen has the largest effects on these neutrons in slowing down and absorbing them. Since hydrogen is found in with water and hydrocarbons. This is found mainly in pores, so neutron is direct indicator of porosity.

5.6 Volume of Shale

Volume of shale can be calculated by using Gamma ray log. For finding the volume of shale computation of Gamma ray index is first step. It can be computed as

$$Igr = \frac{GRlog - GRmin(17.4)}{GRmax(305) - GRmin(17.4)},$$

I_{GR}= Gamma Ray Index,

GR_{log} = Gamma Ray log reading of the formation,

GR_{max} = Maximum gamma Ray log reading,

GR_{min} = Minimum gamma Ray log reading

Then by using the following formula volume of shale is computed

V_{sh} =0.0883[2(3.7*I_{GR}) -1],

The average value of shale content in reservoir, zone 1 is 10% , Zone 2 having 18% and in Zone 3 is 13%.

5.7 Porosity

Porosity is defined as the ratio of the volume of void spaces to the total volume of the rock. Velocities have an inverse relation with the porosity, so that for small values of velocities the porosity value is high. The porosity is represented by (Φ).

Porosity is calculated by averaging the sonic and density porosity. Sonic and density porosity is computed by using sonic log and density log with the help of following formulae

$$\mathbf{\Phi S} = \frac{\Delta T - \Delta Tmat}{\Delta Tf - \Delta Tmat},$$

Where

$\mathbf{\Phi_{S}}$ = sonic porosity μs/ft

ΔT= Log response

$\mathbf{\Delta T_{mat}}$= Transit time in matrix

$\mathbf{\Delta T_{f}}$= Transit time in fluids

$$\mathbf{\Phi D} = \frac{\rho m(2.65) - \rho b}{\rho m - \rho f(0.3)},$$

W

ρm = density if matrix (gm/cm^3)

ρf = density of fluid (gm/cm^3) =

ρb = log Response in zone of interest.

Figure 5.1 shows that reservoir has good amount of porosity. The effective porosity of reservoir zone including Sand Below Talhar Shale is 8% and Middle sand is 10%.

5.8 Water and Hydrocarbon Saturation

Archie's Equation can be used to calculate the water saturation:

Sw=$\frac{a}{\Phi m}.\frac{Rw(0.03)}{Rt}$,

Where

Sw = water saturation

Rw = is water resistivity (formation) = 0.03

Φ= is porosity, m is (cementation factor) = 0.81, **a** (constant) = 1

Rt = LLD log response

Rw has been calculated with help of the following formula:

Where
Φ = porosity in clean zone

RT = Observed LLD curve in clean zone.

By using following relation hydrocarbon saturation (**S_{hc}**) can be found **S_{hc} = 1-S_w**,

Water saturation in marked zones goes to lower side. In zone 1 its 29% ,in in zone 3 its 36%. While in zone 3 its bit high but this zone would also effective for hydrocarbon accumulation.

NAIMAT BASAL-01

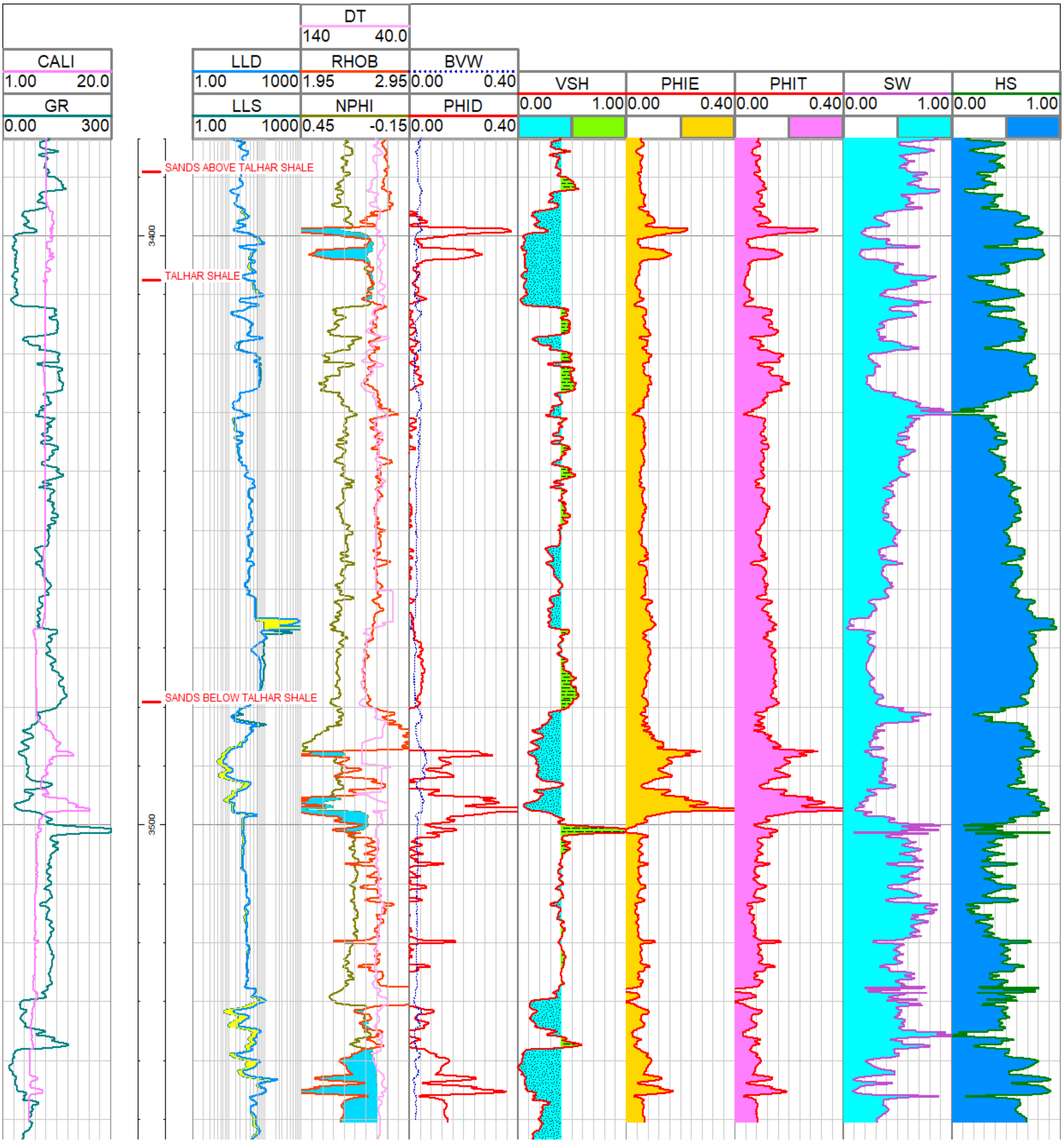

Figure 5.1: Petrophysical analysis of Naimat Basal-01.

NAIMAT BASAL-01

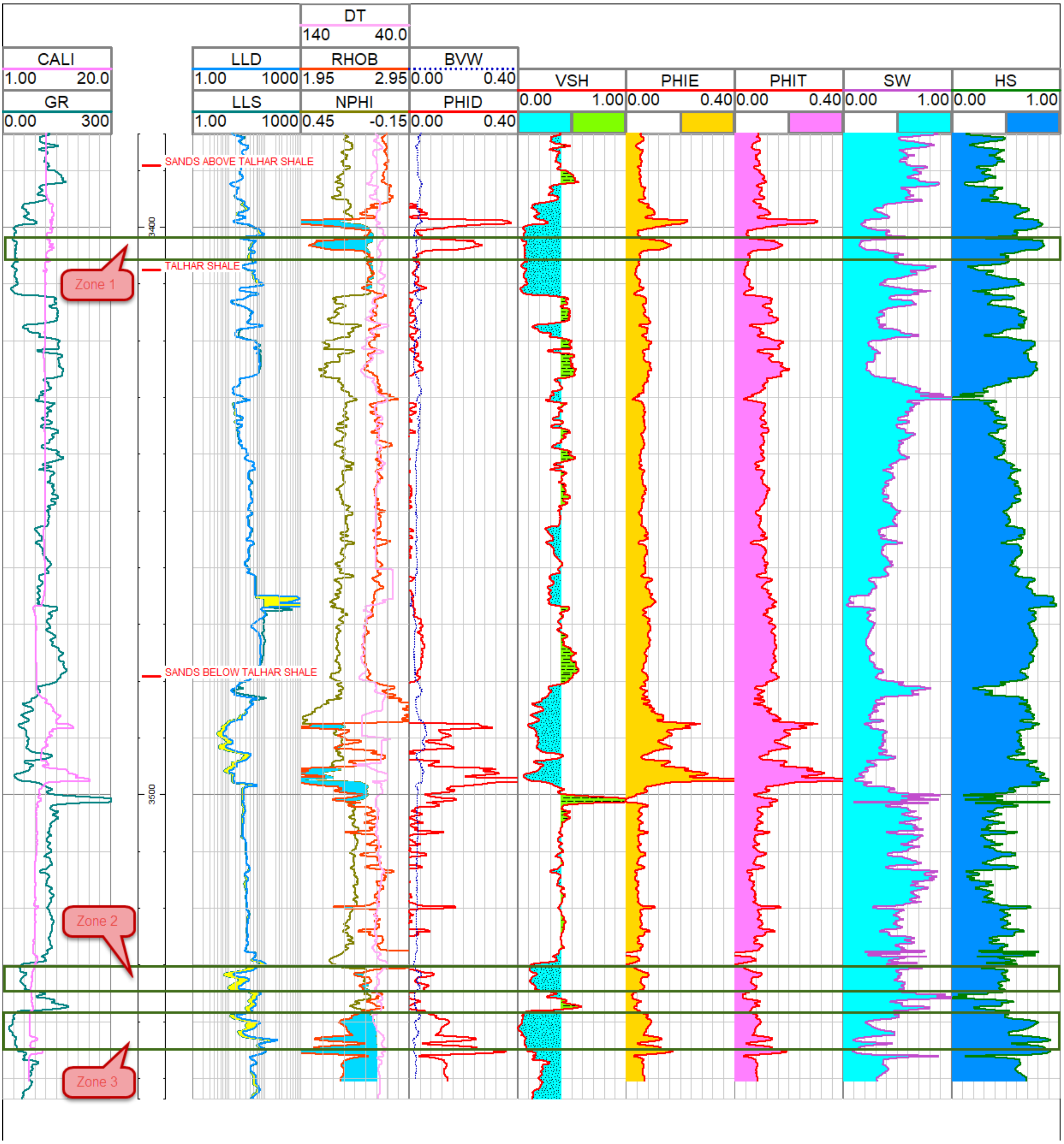

Figure 5.2: Petrophysical analysis of Naimat Basal-01.

3 zones are marked based on high hydrocarbon saturation and other logs. The cross over between bulk volume of water and porosity also gives the clear indication of hydrocarbon accumulation in Basal Sand and Middle Sand as shown in figure 5.1 and 5.2

Interpretation of Sand above talhar shale Formation

- ✦ Volume of Shale = 48-52%.
- ✦ Effective Porosity = 8-10%.
- ✦ Water Saturation = 45-50%.
- ✦ Hydrocarbon Saturation = 20-25%

Interpretation of Sand Below talhar shale Formation

- ✦ Volume of Shale = 30-35%.
- ✦ Effective Porosity = 8-10%.
- ✦ Water Saturation = 45-50%.
- ✦ Hydrocarbon Saturation = 50-55%

5.9 Zone Of Interest:

First of all, we mark the zone on the basis of different logs because we cannot justify our zone on the basis of one single log. After running different logs, we can suggest good zone for hydrocarbon accumulation.

Here we have three main zone of interest in well Naimat Basal- 01. Depth ranges of Zone of interest varies

- **Zone 1 (3402m-3406m)**

In zone 1 caliper log is stable , while GR log is also on lower side which shows there is low presence of shale. In track 2 LLD and LLs shows clear separation and Nphi and Rohb also give separation with lower side and volume of shale is low with high hydrocarbon saturation

- **Zone 2 (3530m-3535m)**

In zone 2 hydrocarbon saturation is low as compare to other zones but it would also be effective reservoir.

- **Zone 3 (3537m-3550m)**

In zone 3 it give huge lower side separation oh Rohb and Nphi , as this separation occurs while presence of hydrocarbon specially in the presence of Gas.

Average Values (%)			
Petrophysical properties	Zone 1	Zone 2	Zone 3
Volume of shale	10	18	13
Effective porosity	11	5	8
Hydrocarbon saturation	71	40	67
Water saturation	29	60	33

Table 5.1:Calculated values for Zones

For reservoir first we see the caliper log and Gamma ray log. For this, caliper log should not be disturbed as compared to Bit size. And Gamma ray should be on the lower side because high Gamma ray normally represent shale. Then we look for the separation of LLD and LLS log. Because when there is presence of hydrocarbon because resistivity of hydrocarbon(in LLD) separates itself from resistivity of brine present in LLS. Then we look for SP log, Sp log should be on the higher side because hydrocarbon zone is porous and transit time will be high. Then we look for separation of RHOB and NPHI, but both on lower side. And porosity of the zone must be high (also effective porosity and total porosity) and volume of shale must be on lower. And finally, hydrocarbon saturation must be on higher side.

CHAPTER 6

ROCK PHYSICS

6.1 Introduction

Quantitative Seismic Interpretation shows how rock physics can be functional to predict different parameters of reservoir, such as pore fluids and lithologies, from seismically resulting attributes. It demonstrates how the multidisciplinary combination of rock physics models with seismic data, sedimentological information and stochastic techniques can lead to more powerful results than can be obtained from a single technique. This provides an integrated methodology and practical tools for quantitative interpretation, characterization of reservoirs in the subsurface and assessment of uncertainty, using seismic and well-log data. The aim, in preparing Quantitative Seismic Interpretation, is to aid illustrate the potent role that rock physics can play in integrating both the data and expertise of geology and geophysics for characterization of reservoir (Avseth et al., 2005).

The objective for this research is to prepare links between seismic and properties of reservoir more quantitatively. The Quantitative Seismic Interpretation includes the use of any seismic attribute for which there are specific models and relates them to different rock properties. This technique introduces primary rock physics relations, which help to quantify the fluid properties and geophysical signatures of rock. Since rock properties are outcome of geologic processes, I begin to quantify the seismic signatures of various geologic trends.

One of the main uses of rock physics is for extrapolation. At a well location having good data quality, we can estimate the porosity, lithology, permeability and fluids from logs, cores and cuttings. But we have no idea what is happening as moving away from the well. But by using rock physics, we can extrapolate to geologically probable conditions that might be present away from the well, by knowing how the seismic signatures might change. This is very useful when we have to understand the facies and seismic signatures of fluids that are not represented in the well.

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. Rock physics or engineering parameters have been computed using velocity data derived from the velocity functions. In the real earth velocity varies laterally as well as vertically. Thus, instead of using a regional averaged velocity function which only shows a vertical mean trend of the velocity with depth, velocity of DT log was used. The RMS and average velocities are not the true representative of a particular subsurface layer as they provide a vertically summed effect of all overlying layers rock properties.

6.2 Elastic Rock Properties

6.2.1 P-Wave and S-Wave Velocity

Sonic travel time of compressional wave is generally used as porosity tool for given lithology. VP-VS relations are keys to the determination of lithology from Seismic and Sonic log data as well as for direct seismic identification of pore fluids using e.g. AVO analysis with passage of time as the waves go deeper, its values are decreasing. Introducing shear wave travel time is very helpful in determining mechanical rock properties. It is found that compressional wave is sensitive to the saturating fluid type. The use of the ratio of compressional wave velocity to shear wave velocity, Vp/Vs, is a good tool in identifying fluid type.

Lower values of P-wave and S-wave velocities show the porous material and higher values consolidated material. Seismic velocity increases with depth due to compaction of rocks, because of overburden pressure of rocks. S-wave velocity is best indicator of fluids, as these waves can't pass through fluids.

From DT log, which has trainset time in µs/ft, we have calculated P-wave velocity in m/s using formula **V=1/DT.**

$$\mathbf{Vp= (10^6)/\ (DT\times 3.28\ (m/s)}$$

6.2.2 S-wave velocity

S- Wave velocity in m/s has been calculated from P-wave velocity using formula. Castagna suggests a different formula for Vs depend upon the lithology but it is not reliable for reservoir characterization.

$$V_s = \frac{(v_p - 1.36)}{1.16}$$

Vs derived by using Castagna formula (1985) written above through which we finally compute any required rock physical parameters.

6.2.3 Density

A very important property of a rock is density. The density of the material directly affects the P wave velocities passing through it. Lower values of density show the shaly material or fluid substitution and higher values consolidated material.

$$\rho = 0.31 \times (VP)^{0.25}$$

6.2.4 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. For a fluid, only the bulk modulus is meaningful.

Bulk Modulus will be low where greater the volume of shale in other words the density would be high.

The value of K is calculated by the following relation.

$$K = P*[Vp^2-4/3*Vs^2]$$

K = Bulk Modulus,

Vp = P-Wave Velocity,

Vs = S-Wave Velocity,

P =Density

In Fig 6.1 The zone where the value of bulk modulus is high it may indicate the presence of less resistive material and high resistive material may be present in the zone where bulk modulus has low value.

6.2.5 Shear Modulus (μ)

Shear modulus or modulus of rigidity (μ), is defined as the ratio of shear stress to the shear strain (angle of deformation). Lower values show the shaly material and higher values stiffer material. Shear Modulus is good indicator of fluid presence, because fluids have zero value of Shear Modulus.

$$\mu = \rho * Vs^2$$

6.2.6 Young's Modulus

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 uniaxial stress over the uniaxial strain in the range of stress in which Hooke's Law holds. It describes the material's response to linear strain. Young Modulus will be high where greater the volume of shale because it is linear strain.

$$\mathbf{E} = \frac{(9 * K * \mu)}{3K + \mu}$$

6.2.6 Acoustic Impedance (AI)

Acoustic impedance is the product of primary wave velocity and density of the rock. Mathematically it can be written and calculated by the formula:

$$\text{AIs} = \rho \times Vp$$

6.2.7 Shear Impedance (Ais)

Shear impedance is the product of the secondary wave velocity and density.
Mathematically it can be written calculated by the formula

$$\text{AIp} = \rho \times Vs$$

Zone 1(3402m-3406m)

Average Vp	Average Vs	Average ROHB
4360.6	3344.1	2.51

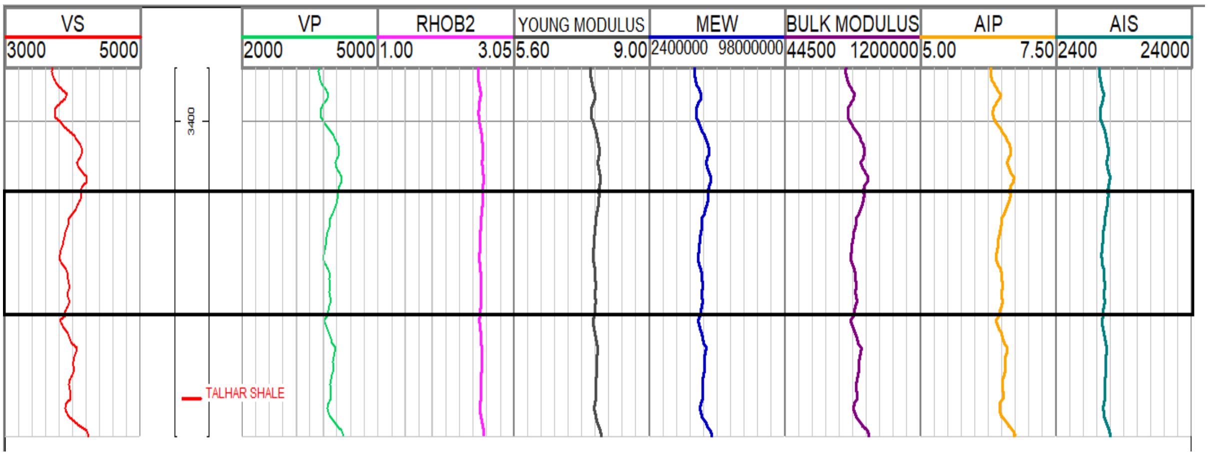

Figure 6.1: Rock physics modeling of zone of interest 1

Results

Rock physics confirms the lithology and confirmed the zone of interest. As shown in the figure 6.1. The average velocity of P wave and S wave decreases in hydrocarbon zone. Which confirms the petrophysical analysis. Also , the average Vp in this zone is nearly 4360 with the effective porosity of 8-10% , which confirms that its gas sandstone. While Vs is 3344 and also decreasing in hydrocarbon zone and density is also near to the density of tight gas sandstone.(Mavko, and Mukeri , 2003)

Zone2: (3530m-3535m)

Average Vp	Average Vs	Average ROHB
4437	3410	2.543

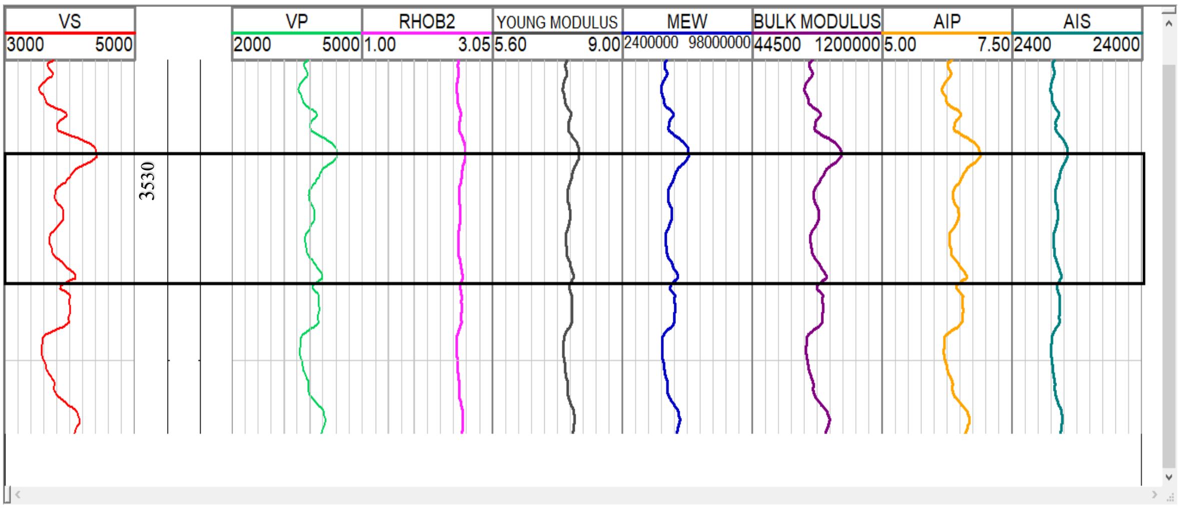

Figure 6.2: Rock physics modeling of zone of interest 2

Results

This figure shows that clear decrease in the Vp and Vs in the marked hydrocarbon zone also density decrease in this zone. Bulk modulus and young modulus give idea about the presence of hydrocarbon ,because they also goes to decreasing side in prospect zone.

If we talk about the lithology then average Vp in this zone is nearly 4430 and Vs is 3410 which lies in the range of gas Sandstone. The average Vp and Vs increases in this zone as compared to Zone 1 is because of the increase in depth. As depth increases the velocity also increases. (Mavko, and Mukeri , 2003)

Zone 3: (3537m-3550m)

Average Vp	Average Vs	Average ROHB
4460	3710	2.53

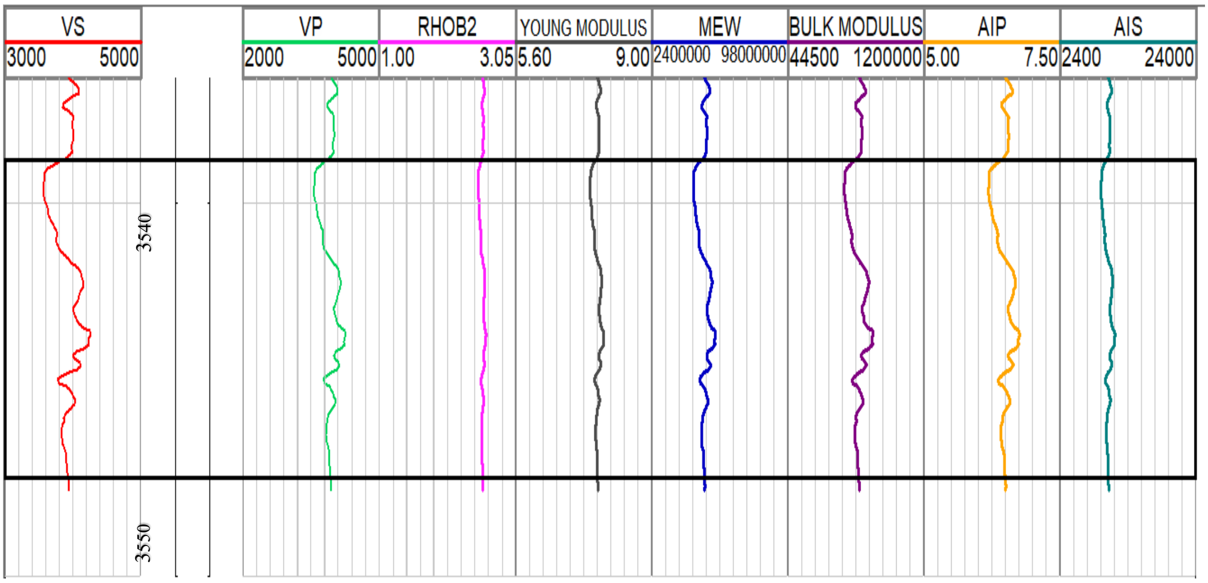

Figure 6.3: Rock physics modeling of zone of interest 3

Results

The increase in the average velocities in this zone is because of the increase of depth of this zone . the Vp and Vs decreases in this zone confirms the presence of hydrocarbon along with the decrease of the bulk modulus and young modulus.

The lithology of zone is also confirmed as tight sandstone as the average Vp in this zone is nearly 4460 and Vs is 3710 which lies in the range of gas Sandstone. The average Vp and Vs increases in this zone as compared to Zone 1 and Zone 2 is because of the increase in depth. (Mavko, and Mukeri , 2003)

Conclusion

Following conclusions can be made from this study:

- Three horizons have been marked on the basis of generalized stratigraphy and from the formation tops of well .
- Horizons marked are Middle Sand, Lower Shale, Sand below Talhar Shale. Horizons are marked with the help of synthetic seismogram of well Naimat Basal-01 which is generated from well log data by using density log and sonic log.
- Depth contour maps are generated by using the well point velocity of seismic section. By keeping in view all these things, it confirmed that all the sections are interpreted correctly.
- Seven major faults were marked on seismic section depend on the geology and tectonics of the study area. Normal faulting results horst and graben structures which shows the area lies in extensional tectonic regime. There is horst and graben geometry in the area, the major horst block present between oppositely dipping faults at all levels. The tilted fault blocks similar to a bookshelf model are formed.
- Seismic Attributes such as Trace envelop confirm the major lithological changes and the instantaneous phase confirm the continuity of marked horizons on seismic section and instantaneous frequency confirm the marked horizons are in reservoir rock by showing the low frequency signal and average energy shows clear discontinuity where there is presence of faults.
- Well bore data was interpreted to describe the physical properties and behavior of rocks, soils and fluids, focusing mainly on the calculation of hydrocarbon potential of the area. With the help of the well data average porosity, volume of shale, hydrocarbon saturation and water saturation were calculated for sands of the potential reservoir Massive sands. The overall trend indicates a good hydrocarbon potential in the area.
- Quantitative results shows the 8-10% porosity of sand which is good for the reservoir rock, 10-15% volume of shale, 30-35% water saturation and 60-70% hydrocarbons saturation. These results show that the reservoir zone is effective for the accumulation of the hydrocarbons. I have marked 3 zones, zone A, zone B, and zone C. Zone A and zone C shows good accumulation of hydrocarbon while zone B has less hydrocarbon saturation because of small zone and slightly low porosity as compared to other zones but this would be also effective for hydrocarbon accumulation.

- Rock physics confirms the zone of interest with the help of average values of the velocities, in all zones Vp and Vs decreases in the prospect zone because of presence of hydrocarbon . Also, rock physics indicates its gas Sandstone as the average values of the zone lies in its range.

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