# INTEGRATED SEISMIC INTERPETATION, PETROPHYSICAL ANALYSIS ALONG WITH COLORED INVERSION OF BADIN BLOCK IV, LOWER INDUS BASIN

**BY**

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# CERTIFICATE OF APPROVAL

This dissertation by **Muhammad Adil** s/o **Muhammad Saeed** 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 degree of B.s Geophysics.

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# Contents

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# ABSTRACT

The aim is to understand the tectonics and geology of the Badin block along with the interpretation procedure of migrated seismic sections to check out the subsurface structures, that maybe possible lead for hydrocarbons. Using control line, horizons were marked, namely Parh Limestone, Khadro, Lower Goru Formation . As the area is in the extensional regime so the faults marked in the area were normal faults making horst and graben structure, dipping in East and West directions and forming half negative flower structure. Petro physical analysis of subsurface was done with well DOTI-01. No hydrocarbon bearing zone was found in the given logs. These low values of resistivities were due to presence of saline fluid, which are highly conductive and produce low resistivity zone

**Chapter 1**

# INTRODUCTION

## 1 Introduction

Hydrocarbons are among the earth's most important natural resources and hydrocarbons are the main constituents of petroleum (literally, "rock oil"), also called "oil," and natural oil.They are commonly found in and extracted from the Earth´s subsurface. Petroleum is a mixture of liquid hydrocarbons, while natural gas is mainly constituted of methane gas.

Badin district lies in Lower Indus Basin of Pakistan. The total area of district is 6726 square kilometer. Badin has been a major producer of hydrocarbons for more than 30 years. 90% of oil production of Lower Indus Basin comes from Badin. The Badin block is a part of Lower Indus Basin which is located in Southern-Eastern part of Pakistan (Mozaffer et al., 2002).

Badin district lies between Thar Desert and coastal stretches of Arabian Sea. It stretches North-South along the Indus River and South of Khairpur-Jacobabad high towards Arabian Sea. The area is under extensional regime so the area comprises structures like tilted fault blocks, normal faults especially horst and graben and truncations. The area majorly is gas producing with minor oil prospect (Hashmi et al., 2012). Badin is located to the South-East part of Pakistan. The Nagar Parkar granite in the extreme south east corner of Pakistan is the exposed part of Indian craton. The area located to the west and northwest of Nagar Parkar is the Tharparkar slope that dips to Westward and Northward-Westward and where Indus basin most prolific hydrocarbons bearing territory is located (Mozaffer et al., 2002).


**Figure 1.1 Location map of Badin Block, Lower Indus Basin Pakistan (Khan et al, 2008).**

## 1.1 Location and Accessibility

Badin region is located between 24˚ 50ˈ - 25˚ 25ˈ N and 68˚ 21ˈ - 69˚ 20ˈ E and is surrounded on the Northern side by Hyderabad district, on Eastern side by Mirpur Khas and Tharparkar districts, on the Southern side by Rann of Kutch area and on the Western side it is surrounded by Thatta and some parts of Hyderabad district. Badin was classified as district on 1st January there are 46 union councils, 109 tapas and 511 dehs. Badin supports a proper road and rail networks which enables it to connect to all nearby major districts (Hashmi et al., 2012).

## 1.2 Climate

The climate of Badin district is moderate and is moderated by sea 1976. District Badin comprises of 5 taluks out of which 2 taluks are coastal; these taluks include Matli, Talhar, Tando Bago, Badin and Golarchi. More than 86% of population lives in rural area and breeze which blows for 8 months of the year from March to October, making the hot weather comparatively cool. The average rainfall is 125mm normally; during the monsoon period the sky remains cloudy with little precipitation. The climate is generally moist and humid. The cold season in Badin starts from the beginning of November when a sudden change from the moist see breeze to dry and cold North East wind brings about, as a natural consequence and immediate fall in temperature. The maximum temperature in the hot weather does not generally exceed 40˚C, while the minimum in winter does not fall below 8˚C. The autumn sets in September and lasts for almost 6 weeks (Hashmi et al., 2012).

## 1.3 Prospectivity

An analysis of discoveries shows that 53% of the in place volume of the total discovered hydrocarbon volume is oil and the remaining 47% in place is gas (Wasimuddin et al., 2005). In Badin block, since oil recovery is at best 61% (including secondary recovery) and Gas 84% (including compression). The actual recoverable reserves is 45% oil and 55% gas. Oil of Badin is of very high quality, it is sweet and paraffinic with API gravity range from 32-55 and is easy to flow (Hashmi et al., 2012).

## 1.4 Base Map

A base map typically includes locations of concession boundaries, wells, seismic survey points and other cultural data such as buildings and roads, with a geographic reference such as latitude and longitude or Universal Transverse Mercator (UTM) grid information. Geologists use topographic maps as base maps for construction of surface geologic maps. 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. Base Map of interest is given in Figure 1.2:

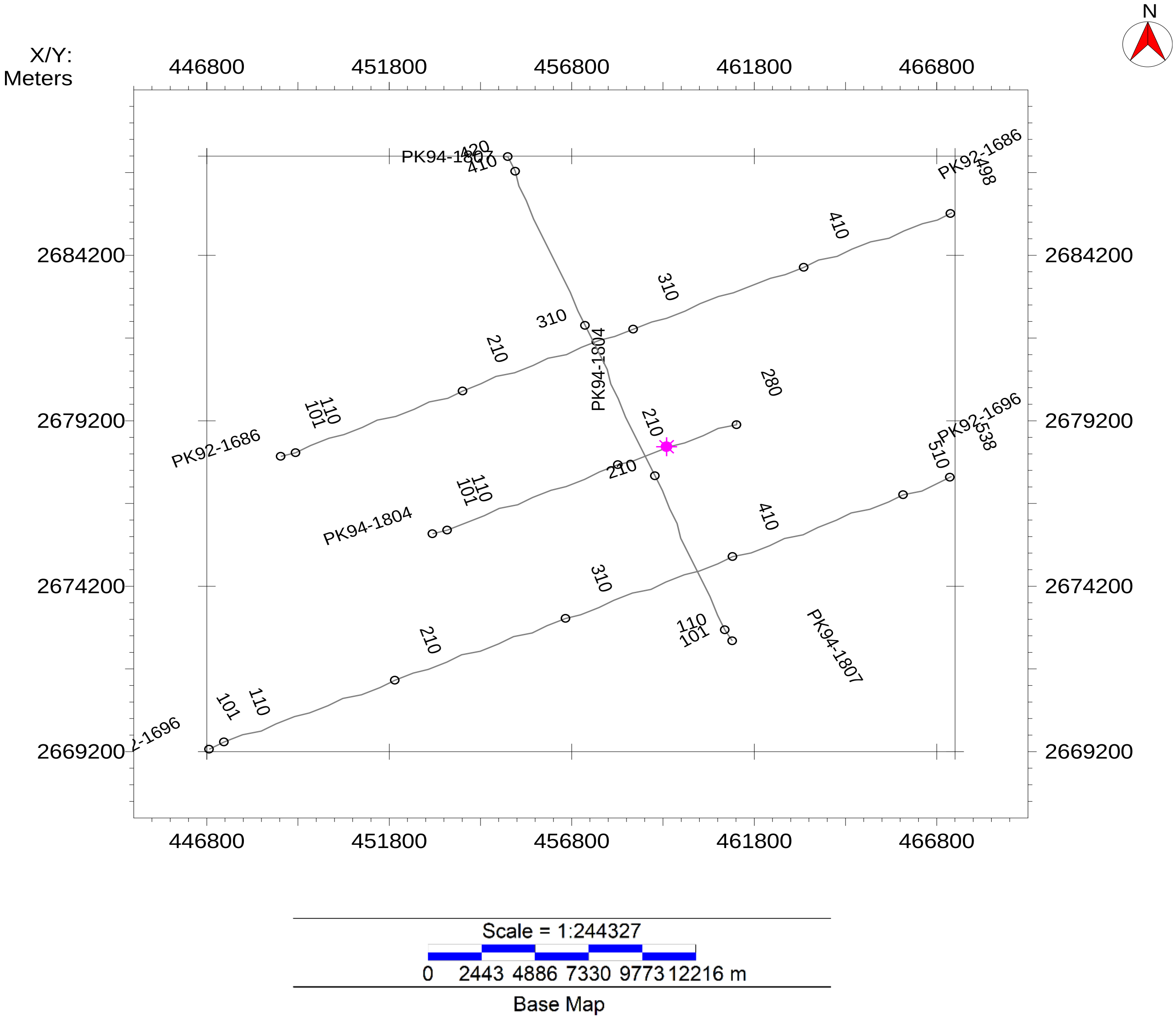


**Figure 1.2 Seismic Lines and Location of Wells on Base map of Badin Area**

## 1.5 Seismic Data

2D seismic reflection & well data is obtained from Landmark Resources (LMKR) by permission of Directorate General Petroleum Concessions (DGPC) of Pakistan. The orientation and direction of seismic lines are shown in Table 1.1

**Table 1.1 The line number and orientation**

| **Sr #** | **Line Name** | **Line Orientation** | **Well** |
|---|---|---|---|
| **1** | Pk92-1686 | NE-SW(DIP) | |
| **2** | Pk92-1696 | NE-SW(DIP) | |
| **3** | Pk94-1804 | NE-SW(DIP) | DOTI-01 |
| **4** | Pk94-1807 | NW-ES(STRIKE) | |

## 1.6 Data Formats

Seismic reflection data which consist of following formats

- SEG-Y (Seismic Data format)
- LAS (Well Log Data format)
- Navigation

## 1.7 Software Tools and Applications

### SMT Kingdom 8.8

- Structural Interpretation
- Stratigraphic Interpretation
- Well correlation
- Seismic attribute analysis.
- Rockphysics and Petrophysics

### 1.8 Analysis of Workflow

The Interpretation was carried forward 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 1.3, which provides the complete picture depicting how the dissertation has been carried.

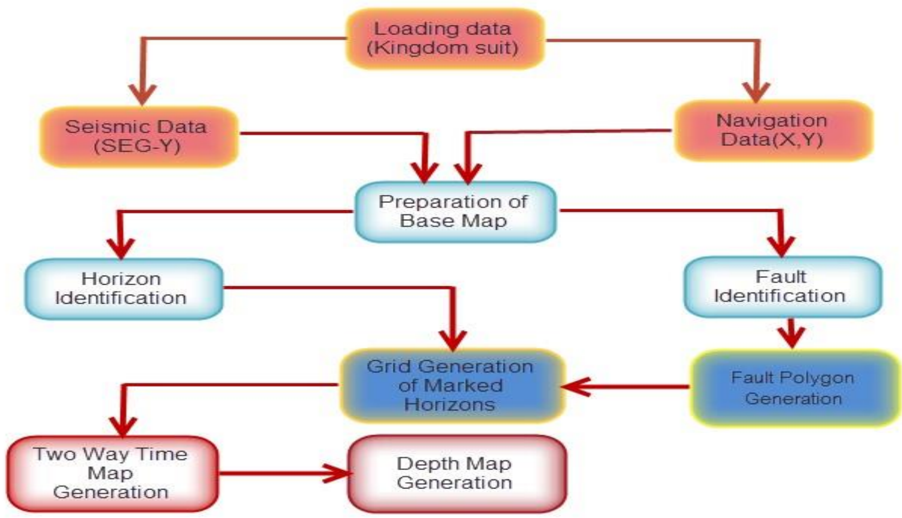


**Figure 1.3 Work flow analysis of Seismic Interpretation**

### 1.9 Previous Work

Badin concession has been a prolific producer of hydrocarbons for more than 30 years. Various Petroleum Exploration companies in the Badin area have had an exploration success rate of about 43%, resulting in approximately 1.65 Tcf (trillion cubic feet) of gas and 225 MM bbls (Million Barrels) of oil found in almost 60 fields. The vast majority of the production is from the middle sand and basal sand unit of the Lower Goru Formation (Ahmed, 2000).

Petroleum Exploration activities were started by Union Texas Pakistan in the Badin Block in 1977. The first major oil discovery took place in early 1980's at Khaskheli, near Badin where several large and small oil and gas fields have been discovered since then. Till the end of June 1999 a total of 52 discoveries were made of which 21 are classified as oil fields with gas caps in 5 of these fields and 31 are considered gas fields with significant oil rims in 10 of these fields (Kazmi et al., 1979). The exploration activities in the block continue with a good success rate of 43%. Khaskeli, Golarchi, Bhatti, Turk, Tando Alam, Jabo and Pasakhi are the large oil and gas fields of this area. Khaskheli is the largest oilfield in the Badin Area. The operating petroleum companies in this region are UEPL, MPCL, PEL, PPL, and NHEPL (Ahmed, 2000).

### 1.10 Aims and Objectives

The following are the objectives of this study:

- This dissertation is primarily focused on seismic interpretation of the study area, which includes marking of horizons, fault picking and construction of time and depth contour maps.
- Petro-physical analysis of the well using well log data.
- Identification of reservoir lithology
- Generate time and depth contour maps on different levels of strata to analyze structural and stratigraphic trend of the area.
- The identification of seismic horizons by using well tops.
- Petrophysical interpretation of the area to understand the subsurface rock properties and its contribution to the hudrocarbon generation.

**Chapter 2**

# Geological setting of the Area

## 2.1 Introduction

The Indus Basin, which covers an area of 535,580 $km^2$, is located on the northwest slope of the Indus Shield and includes the fold belt (Mozaffar et al., 2002). It is divided into Lower, Middle and Upper Indus Basins based on structural highs (Kadri, 1995).

Badin is the part of Lower Indus Basin, located on the south eastern part of Pakistan. The Lower Indus Basin stretches north-south along the Indus River and south of Khairpur-Jacobabad High towards Arabian Sea. The Nagar Parker Granite in the extreme south-eastern corner of Pakistan is exposed part of the Indian Craton. The areas located to the west and north-west of Nagar Parker are the Tharparker slope that dips westward and north-westward and where Indus Basin most fertile hydrocarbon bearing territory is located (Mozaffar et al., 2002).

The Badin Rift is characterized by a series of horst and graben structures present below the base Paleocene unconformity within the Cretaceous formations. These horst and graben structures were formed because of rifting between India and Seychelles during the Late Cretaceous (Khan et al., 2013).

**Table 2.1 shows the boundaries of Badin Block-IV**

| **Direction** | **Boundaries** |
|---|---|
| East | Indian shield |
| West | Kirthar and Sulaiman Ranges |
| North | Sargodha High |
| S0uth | Offshore |

Study area lies in the East of district Badin (Latitude $24^{o}$ 5′ N to $25^{o}$ 25′ N: longitude $68^{o}$ 21′ E to $69^{o}$ 20′ E) in Sindh province of Pakistan. To the North of Badin is Hyderabad, Arabian Sea and Run of Kutch are in the South, Mirpurkhas and Tharparker are in the East and districts Thatta and Hyderabad are in the West (Munir et al, 2014).

## 2.2 Structural Setting of Badin Area:

A series of horst and graben structures are present in study area almost below the base of Paleocene 5 within the Crateceous in lower indus basin (Shuaib, 1982).

0n west indus plain as a result of normal faulting, these faults performed as a major migrating paths for hydrocarbon from fundamental shaly source sequence (kadri, 1995). The complex type structure and a passive back thrust along kirthar foldbelt (Figure 2.1)

Tectonic instability occurred in Cretaceous time when rifting rate was high about 20-30 cm/a in 80-53 Million years (Farah et al, 1984; Mohoney, 1988; Gnos et al, 1997). Badin Rift exists in Thar Platform vicinity which is in fact Sargodha High that divides Indus Basin into Upper and lower Indus Basins (Kadri I.B, 1995). Mostly horst and graben structures can be seen in Badin Rift (Alam etal, 2002).

Most prominent structure are rifting and doming in study area. The area was away from the main tectonic zone therefore degree of deformation was relatively low. The rate of deformation increases from East to West. Over a large area of Eastern Lower Indus Sub-Basin tilted faults are produced due to extensional tectonic in the time of Cretaceous. Cretaceous and older strata are broken by system of faults with normal dip separation that can be seen on seismic reflectors. Strike of Cretace ous faults is between N $30^{o}$ W & N $50^{o}$W.

When hydrocarbons generated then block of tilted faults traps were in existence. In Badin block the faults related traps are responsible for trapping hydrocarbons in Lower Goru Sandston (Kemal, 1991). Fig 2.1 shows the tectonic framework of the Pakistan in which Badin area is highlighted using coordinates.

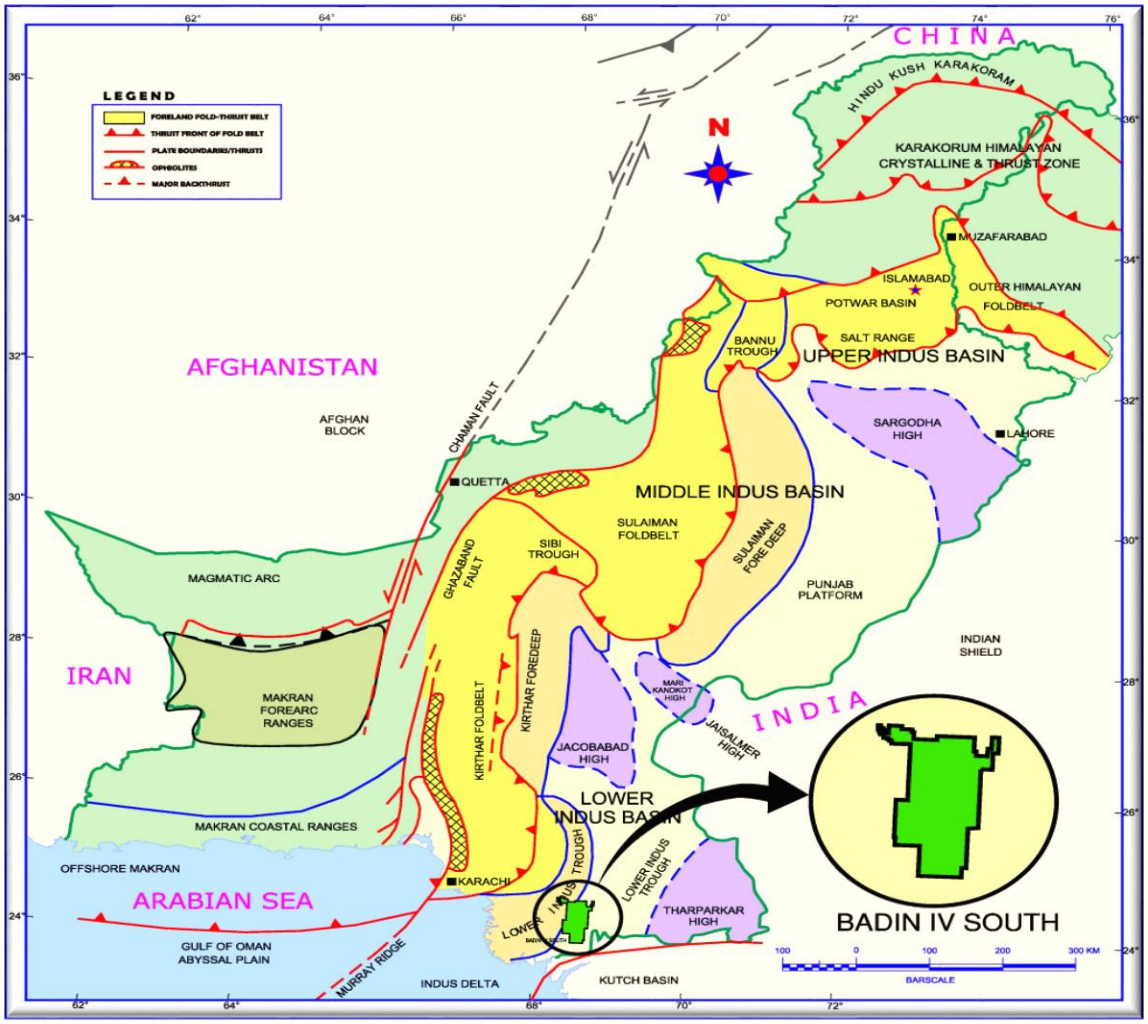


**Figure 2.1 Tectonic Setting of Indus Basin, Pakistan (modified after Saleem et al., 2011; Alam et al., 2002; courtesy MPCL).**

## 2.3 Stratigraphy of the Area:

Generalized stratigraphy chart of the area is shown in the Fig 2.2. In Badin block Chiltan limestone of Jurassic age overlies Triassic sequence. About 610 m thick shale of Sembar formation overlies the Chiltan limestone. On the top of Sembar formation is Lower Goru which is consider as major reservoir rock in the area. Lower Goru is further divided into five units such as Basal sand overlies Sembar formation, Lower shale overlies Basal sand, Middle sand overlies Lower shale, Upper shale lies between Middle and Upper sand which is $5^{th}$ unit of the Lower Goru . Depositional environment of the Upper sand is shallow marine to deltaic and consider as good reservoir in the Lower Indus Basin (Alam et al, 2002).

Stratigraphically, the shale series of the Early Cretaceous Sember formation and interbedded shale layer of Lower Goru formation are the main document petroleum source rock units in the southern Indus basin. Upper Paleocene marine transgressive shale acts as secondary source rock, deeply buried in the western half of the southern Indus Basin (Zaigham and Mallick, 2000).

The basal sand of Lower Goru Formation is target formation in the area. Massive Sand is another interesting producing reservoir from its various sand sheets of multiple thickness. The possibility of reservoir in lower Goru overlain on Basal sand could not be ruled out,however thet have not yet proved to be such up till now ( Kadri I.B, 1995).

In general, the transgressive shales of the Cretaceous (Sember formation) and Tertiary (Bara-lakhlra, Laki-Gazij and Kirthar formation) acts as a seal in Southern Indus Basin (Zaigham and Mallick, 2000). Intra-formation shale of Lower Goru formation provides effective vertical and lateral seal. The shale units also provides cross fault seal. Fault may also acts a seal. Upper Goru shale, Lower Goru and Talhar shale are the primary seal for Lower Goru reservoir sands (Kadri etal, 1995).

## 2.4 Formations Encountered in the Well

Formations that are encountered in the well is shown in the table given below:

**Table 2.2 shows Formation encountered in well**

| Formation Tops | Age | Formation Top value (m) | Lithalogy |
|---|---|---|---|
| **Kirthar Laki** | Eocene | 222 | Limestone |
| **Upper Ranikot** | Paleocene | 277 | Sandstone, Shale, Limestone |
| **Lower Ranikot** | Paleocene | 461 | Sandstone, Shale, Limestone |
| **Khadro** | Paleocene | 629 | Sandstone, Shale |
| **Parh Limestone** | Cretaceous | 739 | Limestone |
| **Upper Goru** | Cretaceous | 771 | Shale, Sandstone |
| **Lower Goru** | Cretaceous | 1537 | Sandstone |

### 2.4.1 Laki Formation

The age of Laki Formation is Eocene and major lithology is limestone. The environment of deposition is shallow marine. The lower contact of Laki Formation is with Lakhra Formation and upper contact is with Kirthar Formation (Kadri, I.B, 1995).

### 2.4.2 Ranikot Formation

The age of Ranikot Formation is Paleocene and major lithologies include sandstone, shale and limestone. The environment of deposition is estuarine. The lower contact of Ranikot Formation is with Khadro Formation and upper contact is with Lakhra Formation (Kadri, I.B, 1995).

### 2.4.3 Khadro Formation

The age of Khadro Formation is Paleocene and major lithologies include sandstone, shale with subordinate limestone and basalt. The environment of deposition is shallow marine. The lower contact of Ranikot Formation is unconformable (with Pab Formation) and upper contact is with Bara Formation (Kadri, I.B, 1995).

### 2.4.4 Parh Limestone

The age of Parh Formation is Early Cretaceous and major lithology is argillaceous limestone. The environment of deposition is shallow marine. The lower contact of Ranikot Formation is with Goru Formation and upper contact is with Mughal Kot Formation (Kadri, I.B, 1995).

### 2.4.5 Goru Formation

The age of Goru Formation is Early Cretaceous and major lithologies include sandstone and shale. The environment of deposition is shallow marine (Kadri, I.B, 1995).

## 2.5 Petroleum Play In the Study Area

- Source Rock : Sember shale
- Reservoir Rock : Basal sand
- Cap Rock : Upper Goru marl

### 2.5.1 Reservoir Rock

The Basal Sand of Lower Goru formation is target formation in the area. Massive Sand is another interesting producing reservoir from its various sand sheets of multiple thicknesses. The possibility of reservoir in Lower Goru overlain on Basal Sand could not be ignored although they have not proved as reservoirs still now (Kadri, 1995). Hydrocarbon targets may also exist in the Jurassic Chiltan Limestone, Paleocene and Eocene formations (Zaigham and Mallick, 2000).

### 2.5.2 Source Rock

Sembar is considered as source rock in the lower and middle Indus basins that has high vertical and lateral extension throughout the basins. Source rock in the study area is of early cretaceous. The lower Goru Sand provide the accumulation of hydrocarbon while the upper Goru shaly formation provide a trap. Normal fault provide as excellent seal to hydrocarbon.

### 2.5.3 Seal Rocks

Sember Formation, Bara-Lakhra, Laki-Ghazij and Kirthar Formations act as seal in Southern Indus basin (Zaigham & Mallick, 2000). Inter-bedded Shales (Upper, Lower and Talhar) of Lower Goru formation provides effective vertical and lateral seal and act as a primary seals. The Upper Goru forms the top and lateral seals for the Upper Sand units of Lower Goru formation. (Kadri, 1995).

### 2.5.4 Traps

All production in the study area is from structural traps. The tilted fault traps in the Lower Indus Basin are a product of extension related to rifting and the formation of horst and graben structures. The temporal relationships among trap formation and hydrocarbon generation, expulsion, migration, and entrapment are variable- throughout the Indus Basin. These provide the significant trapping system along tilted fault blocks and negative flower structures.

**Chapter 3**

# SEISMIC ACQUISITION AND PROCESSING

## 3.1 Introduction

Seismic data acquisition consists of gathering and recording of continuous seismic signals from seismic stations. Acquisition of seismic data, it is the very first step in the seismic exploration. It is the procedure through which seismic reflection data is acquired. With the help of modern electronics and computer industry, acquisition becomes very easy. Acquisition starts from shot and ends at recording the seismic events through various steps. Different energy sources are used to produce seismic waves and array of geophones are used to detect the resulting motion of earth. The data is recorded in digital as well as analogue form (Keary et al, 2002).Seismic surveys use low frequency acoustical energy generated by explosives or mechanical means.

Purpose of seismic data acquisition is to record the ground motion caused by a known source in a known location.

- First step in seismic data acquisition is to generate a seismic pulse with a suitable source.
- Second is to detect and record the seismic waves propagating through ground with a suitable receiver in digital or analogue form.
- Third is the registration of data on a tape recorder.

## 3.2 Energy Sources

### 3.2.1 Energy sources are categorized into two groups

- Impulsive energy sources
- Non impulsive energy sources

### 3.2.2 Impulsive Energy Sources

The mechanism for generation of energy in this type is by exploding dynamite in a shot hole. Because of the impulsive nature of the seismic signal it creates and the convenient storage and mobility it provides for energy that can be converted into ground motion.

An important example of impulsive energy source is dynamite (Yilmaz, 2001).

#### 3.2.2.1 Dynamite

It is commonly used to generate sources, used in seismic prospecting. Generally it is exploded inside a drilled hole at a depth ranging from few meters to several tens of meters. The deeper the charge the less intensive the generated surface waves are. It is advisable to place this charge below the weathering layer as it absorbs the high frequency components. Charge is usually sealed with water or mud to increase coupling with surrounding. Amounts of charge per shot point depend upon pattern of shooting (Telford, 2004).

### 3.2.3 Non Impulsive Energy Source

These sources involve mechanical impact upon the earth's surfaces or shaking of the surfaces with a mechanical vibrator. All sources of this type are so disposed in the field that signals received from impacts are applied to the earth over a linear distance comparable to what would be used for a line of shot holes at a shot point or over an area that would be used for two dimensional arrays of shot holes (Robinson & Corch, 1988).

#### 3.2.3.1 Vibroseis

It is based on the use of a mechanical vibrator which is hydraulically or electrically driven to exert a force, on ground surface, of an oscillating magnitude Its energy is called as sweep (Al-Sadi, 1980). Note the flat pad suspended under the middle of the truck. Once the truck reaches the specified point, this pad is used to raise the 20,000 kg truck entirely off the ground. The hydraulics then shakes the truck up and down on this central piston for a specified time and over a precisely controlled frequency band (e.g., eight 14 second sweeps from 10 to 56 Hz).

## 3.3 Acquisition Setup

The seismic acquisition setup involves the following;

- **The spread configuration**
- **Shooting types**
- **Shooting parameters**
- **Recording parameters**

### 3.3.1 The Spread Configuration

For acquisition of data and as well as to have quality of data high certain field operations are adopted. So the first step in this practice is the choice of spread type. The spread is defined as the lay out on the surface of, of the detectors which give recorded output for each source. Spread is made up of equal inter receiver distance and a defined offset. There is certain number of spreads called as basic spreads, which are used in seismic acquisition. These spreads are;

- **End on spread**
- **Inline offset spread**
- **Split Spread/Centre shooting**
- **Fan shooting**

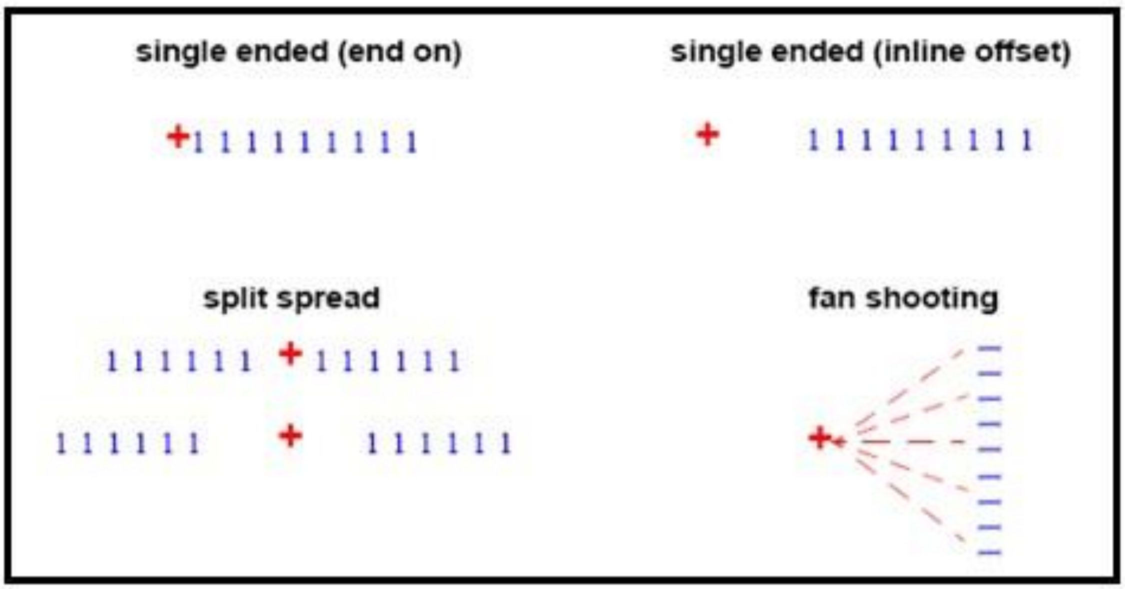


**Figure 3.1 The basic spreads used in Seismic Acquisition.**

### 3.3.2 Shooting Types

There are different types of shootings used in the field. These types are:

- Symmetric shooting (In this type the number of channels on sides of source is same.)
- Asymmetric shooting (In this the number of channels on sides of source is not same)
- End shooting (The source is at one end of the spread)
- Roll along/Roll out shooting (In roll along method receivers are added in the spread while shooting in the source along the spread. Roll-out shooting is one in which the receivers are removed from the spread while shooting out along the spread.

### 3.3.3 Shooting Parameters

- Shooting parameters include:
- Source size
- Number of holes
- Hole depth.
- Shot at or between the pickets.
- The shooting parameters are set by determining the following parameters:
- Maximum offset ~depth deepest zone of interest
- Minimum offset ~ not greater than shallowest section of interest
- Maximum array length is determined by the minimum apparent velocity of reflections
- Charge size determined by ambient noise late on the record
- Line orientation (up-dip, down-dip)

### 3.3.4 Recording Parameters

- The recording parameters include:
- Group Interval
- Group Base
- Number of Channels
- Number of Geophones in a Group
- Geophone Array(Linear or Weighted)
- Sample Rate
- Record Length
- Coverage (Folds)
- Zero Offset and Common Offsets

### 3.4 Introduction to Seismic Data Processing

It can be said “as an approach by which the raw data recorded in the field is enhanced to the extent that it can be used for the geological interpretation”.

Data processing is to convert the information recorded in the field into a form that mostly facilitates geological interpretation (Al. Sadi , 1980).Seismic data processing strategies and results are strongly affected by field acquisition parameters. Additionally, surface conditions have a significant impact on the quality of data collected in the field. Lack of seismic reflected events on seismic section is not the result of a subsurface void of reflectors. Rather it is caused by low signal-to-noise ratio (S/N) resulting from energy scattering and absorption in the medium of propagation.

### 3.5 Aim and Purpose

The basic aim and purpose of data processing is to produce a perfect seismic section by applying a sequence of correction. Actually the seismic reflections from the depth are generally week and need to be strengthened by digital processing of field data (Robenson & Coruh, 1988).This approach involves the sequence of operation for improving signal to noise ratio(Dobrin &Sovit, 1988).The seismic field recorder generally records the data on magnetic tape. These tapes are then transferred to the data processing centre. Where the seismic data is processed. Processing seismic data consists of applying a sequence of computer program.

### 3.6 Seismic Data processing Flow

The basic seismic data processing flow is given below

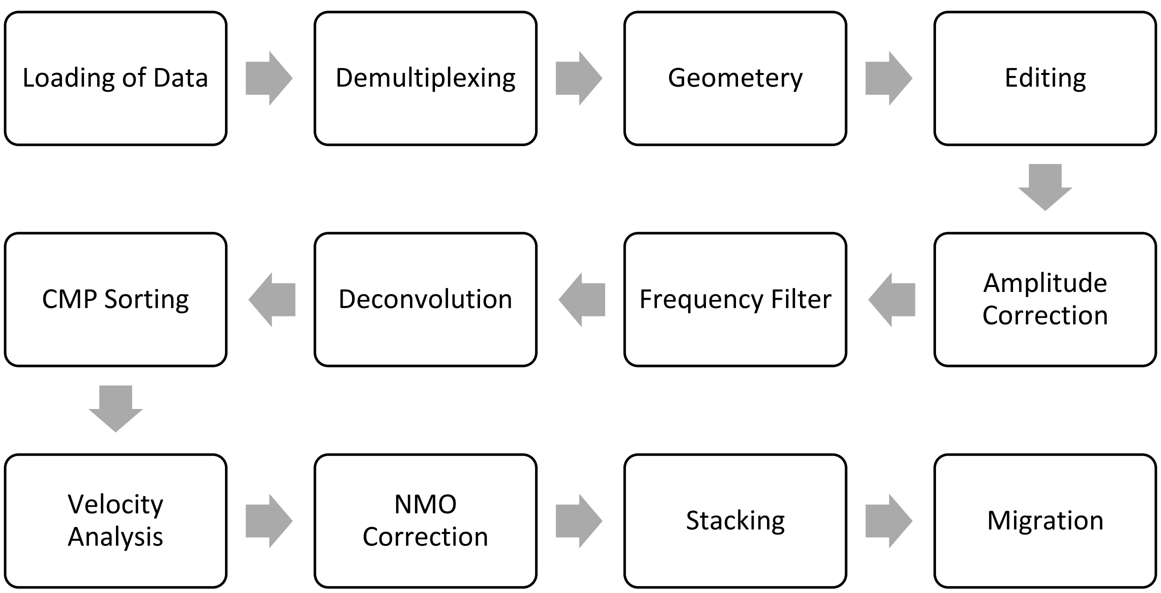


**Figure 3.2 Showing flow of seismic data processing**

### 3.6.1 Editing and Muting

Raw seismic data contains unwanted noise and sometime dead traces due to instrumental reasons. Thus the quality of data recorded is first observed by visual examination of raw field traces. Data may be affected by following reasons

- Polarity reversals in data
- Poor traces as well as poor bits

To remove polarity reversal, trace with reverse polarity is multiplied with it that becomes a trace with the polarity. Therefore editing is a process of removing or correcting traces, which in their original recorded taken, may cause stack deterioration (Rehman,1989).

After doing this all the contributing traces per each CDP are gathered together. Each trace in one CDP is identified by its shot point and receiver numbers .The CDP-gathers may be displayed as such for direct inspection and checking of edited data.

### 3.6.2 Geometric Correction

In order to compensate for the geometric effects, we have to apply certain corrections on the recorded data .These corrections are called as geometric corrections (Dobrin, 1988). These corrections are applied on the traces gathered during trace editing and muting .The geometric corrections are

1. **Static correction**
2. **Dynamic correction**

#### 3.6.2.1 Static Correction

Static correction compensates the effect of weathered layer and elevation effect due to unleveled surface .So static correction is of two types

- Elevation correction
- Weathering correction

For land data, elevation corrections are applied at the stage of development of field geometry to reduce the travel times to a common datum level (Yilmaz, 2001).This level may be flat or floating along the line.

#### 3.6.2.2 Dynamic Correction

Dynamic correction compensates the effect of offset of receiver from the source .It is also related to the shape of the subsurface interfaces .It is also of two types.

- Normal move out correction (NMO).
- Dip move out correction.

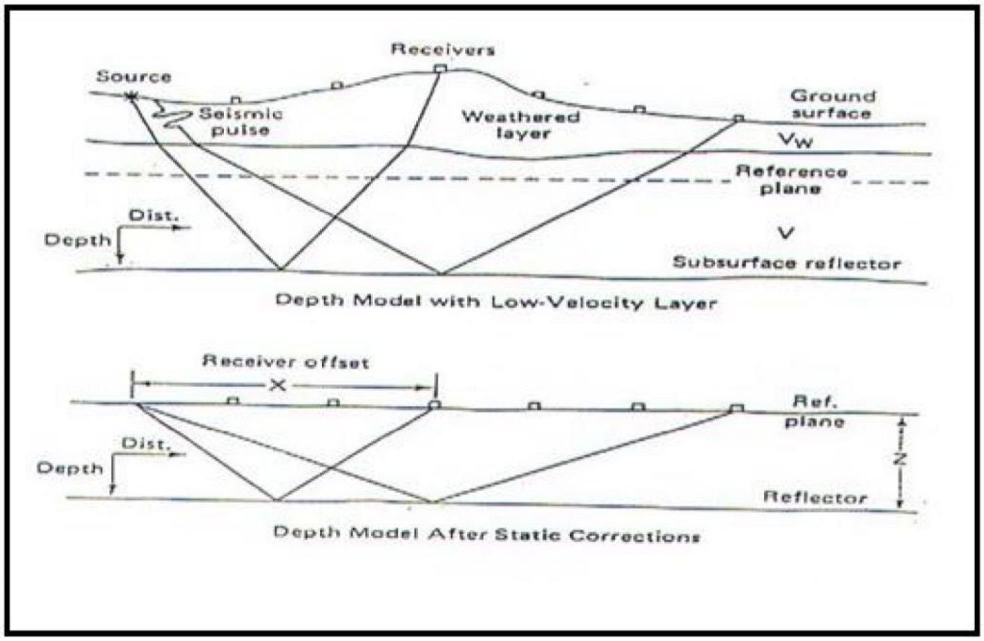


**Figure 3.3 Diagrammatic representation of static and dynamic corrections.**

### 3.6.3 Data Analysing and Parameter Optimization

There are three steps involved in the Data Analysis and Parameter optimization filtering.

- Deconvolution.
- Velocity Analysis.

#### 3.6.3.1 Filtering

A filter is a system, which discriminates against some of its input. Seismic data always contain some signal information, which we want to preserve. Everything else is called noise, and we want to remove it. These systems, which are generally called filters work either by convolution in the time domain or by spectral shaping in the frequency domain. The common types of filters are the following:

- Low pass frequency filter.
- High pass frequency filter.
- Band Pass frequency filter.
- Notch filter.
- Inverse filter.

#### 3.6.3.2 Deconvolution

Deconvolution is the inverse of convolution in such a way that reflectivity function is reconstructed. It is a filtering process designed to improve resolution and suppress multiple reflections. Deconvolution can be considered either in the time domain or in the frequency domain. When

dynamite is blasted, spike is produced that is visible in the seismogram. Spike has very high frequency and short wavelength. When it travels through earth its amplitude decreases and it becomes a waveform, with lower frequency and greater wavelength. Thus earth is absorbing higher frequencies with time and depth. This behavior of earth is termed as hi-cut filter. Thus Deconvolution with a reverse process by which these higher frequencies are reproduced, called reverse filtering. Sometime- there are fake reflectors produced due to multiples which can cut by Deconvolution and deeper reflections become identifiable (Yilmaz,2001) .

#### 3.6.3.3 Velocity Analysis

Velocity in seismic processing is an important parameter, which controls the stacking quality. Thus the proper velocity value gives the optimum dynamic correction which leads to efficient stacking process. The seismic traces of a common depth point gather are basis for each velocity analysis. Before velocity Analysis suitable static correction and data enhancement procedures are applied to the data (Yilmaz, 2001).

### 3.6.4 Data Refinement

Processes described thus far are used to reformat, correct and diagnose data characteristics. In this step for data refinement the following procedures are carried out:

- **Stacking**
- **Migration**

#### 3.6.4.1 Stacking

Once the necessary corrections have been applied, the data may be stacked. In the "corrected gather" the traces have been gathered into the depth order, both static and dynamics applied and the traces muted. All that remains to stack the data is to sum all the traces in each depth point, resulting in a single stacked traces being output for each depth point. Stacking is a data compression of one to two orders of magnitude. The signal-to-random noise ratio is increased through an N fold stack by N. after stack; the data are displayed at the surface location of the midpoint between source and receiver. When all adjustments to the data have transformed the offset data into time and phase coincidence with the zero offset traces, the common midpoint CMP and CDP are both widely often interchangeably. With dipping reflectors, the CMP after conventional processing is not the CDP. The correct positioning of reflection point will be by migration (Dobrin & Savit, 1988). Stacking chart is shown in Fig 3.4

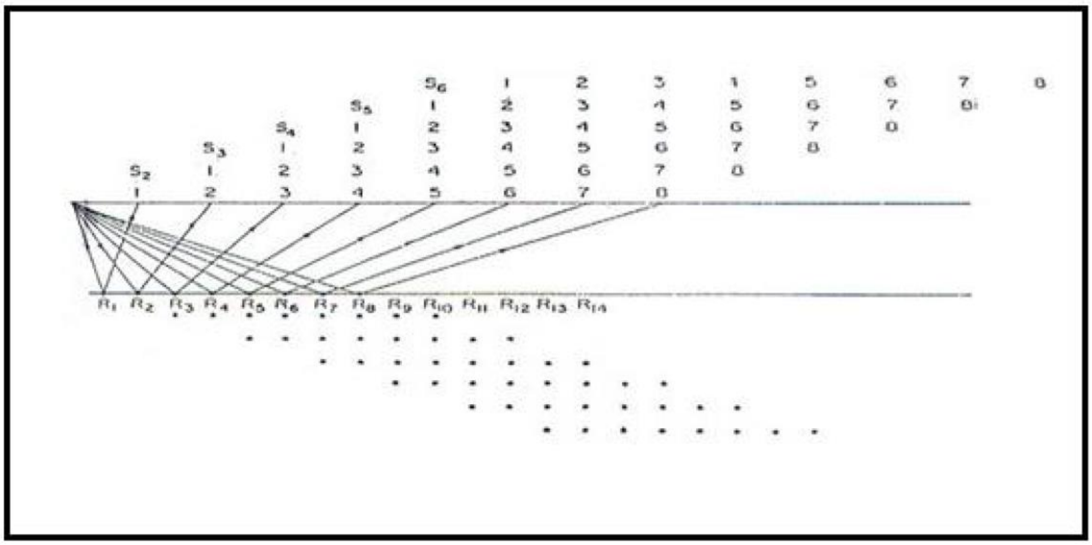


**Figure 3.4 shows Stacking Chart**

### 3.6.4.2 MIGRATION

Migration moves dipping reflectors into their true subsurface position and collapses diffractions, thereby delineating detailed subsurface features such as fault planes. So in this respect migration can be viewed as a form of spatial Deconvolution that increases the spatial resolution. Migration does not displace the horizontal events; rather, it moves dipping events in the up direction and collapses diffractions, thus enabling us to delineate faults.

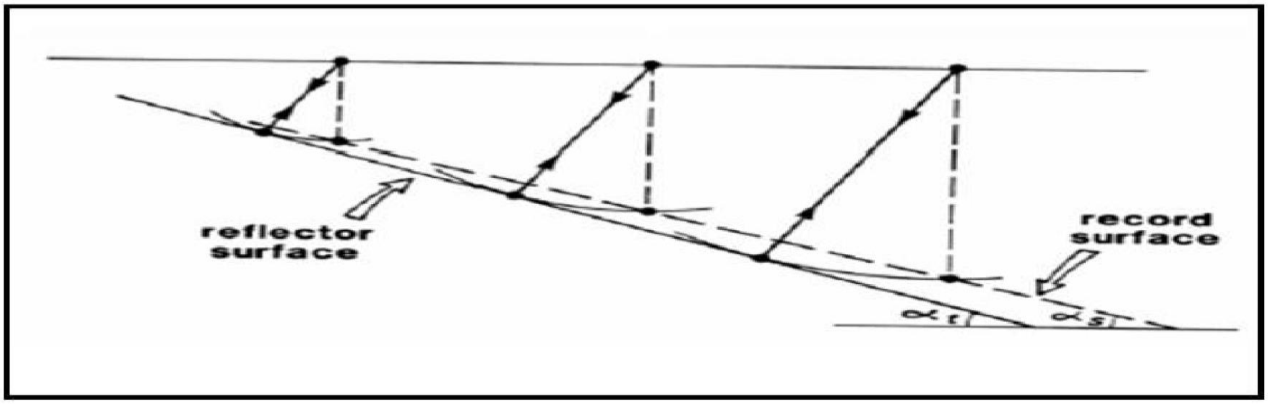


**Figure 3.5 Seismic response form a dipping reflector, the recorded surface gives the apparent dip of the reflector surface.**

Therefore, migration is a tool used in seismic processing to get an accurate picture of the subsurface layer. It involves geometric repositioning of recorded signals to show a boundary or other structure,where it is being hit by the seismic wave rather than where it is picked up Now, not only the position but the dip angle can incorrectly imaged by vertically plotting (Rehman, 1989).

### 3.6.4.4 Types of Migration

With respect to the stage when migration is applied on the seismic data during processing, there are two important types of migration

- Pre-Stack Migration.
- Post-Stack Migration

**Chapter 4**

# SEISMIC DATA INTERPETATION

## 4.1 Introduction

Interpretation is a technique or tool by which we try to transform the whole seismic information into structural or Stratigraphical model of the earth. Since the seismic section is the representative of the geological model of the earth, by interpretation, we try to locate the zone of final anomaly. It is rare that correctness or incorrectness of an interpretation is ascertained, because the actual geology is rarely known in well manner. The test of good interpretation is consistency rather than correctness. Not only a good interpretation be consistent with all the seismic data, it also important to know all about the area, including gravity and magnetic data, well information, surface geology as well as geologic and physical concept (Sheriff, 1999).

Seismic interpretation is the process of determining information about the subsurface of the earth from seismic data. Seismic interpretation implies picking and tracking laterally consistent seismic reflector for the purpose of mapping geologic structures, stratigraphic and reservoir detection. 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 data that, when used in conjunction with other geophysical, borehole and geological data, and with concepts of physics and geology, can provide information about the structure and distribution of rock types.

Exploration seismic methods involve measuring seismic waves traveling through the Earth. Explosives and other energy sources are used to generate the seismic waves, and arrays of seismometers or geophones are used to detect the resulting motion of the Earth. The data are usually recorded in digital form on magnetic tape so that computer processing can be used to enhance the signals with respect to the noise, extract the significant information, and display the data in such a form that a geological interpretation can be carried out readily (Kearey et al, 2002).

The importance of the seismic methods over other geophysical methods as mentioned by Robinson & Coruth (1988) and Kearey & Brooks (1996) is due to its accuracy, resolution and presentation. In addition to oil and gas prospecting, the seismic methods are also employed for the:

- Measurement of the bedrock depth
- Ground water investigation
- Geotechnical purpose

Followings are the main seismic methods:

- **Seismic Reflection Method**
- **Seismic Refraction Method**

### 4.2 Approaches of Seismic Interpretation

There are two main approaches for the interpretation of seismic section

- Stratigraphic Analysis
- Structure Analysis

#### 4.2.1 Structure Analysis

Structural analysis is the study of reflector geometry on the basis of reflection time. The main objective of structural analysis is to search out structural traps containing hydrocarbons. The most common structural features associated with hydrocarbons, are anticlines and faults associated traps. Structural interpretation of seismic sections involve identification of reflective horizons and picking of seismic travel time for each trace on each horizon. From these data, time, and subsequently depth, maps are made for each horizon (Yilmaz, 1987).

Seismic section can predict the structure that scale up to few tens of kilometers. A fault with throw less than ¼ of the wavelength of seismic wave will difficult to pick in the seismic section (Badley, 1985). The study area lies in intense extensional regime, so general structure are normal related i-e horst and graben structure.

#### 4.2.2 Stratigraphic Analysis

Seismic stratigraphy techniques help us for stratigraphic interpretation of seismic reflectors. It is important because geological concepts of stratigraphy can be applied on seismic data and hence, seismic stratigraphy can be used as a predictive tool for petroleum system elements like reservoir, seal and source rock. The basic assumption behind seismic stratigraphy is that individual reflector can be considered as timelines i.e. it is representing a very short time interval of similar sedimentation conditions. This assumption signifies that seismic reflector can have the different depositional environment and therefore it has information of various lithofacies units.

In the stratigraphic interpretation, areas favorable for hydrocarbon accumulation are located which are not formed by the deformation, but in this case the traps are formed by the variations in the deposition of sediments. These traps are marked by pinch outs and unconformities. Stratigraphic analysis involves the sub-division of seismic section in to sequence of reflections that are interpreted as the seismic expression of genetically related sedimentary sequences. Unconformities can be mapped from the divergence pattern of reflections on a seismic section. The presence of unconformable contacts on seismic section provide important information about the depositional and erosional history of the area and on the environment existing during the time, when the movement took place. The success of seismic reflection method in finding stratigraphic traps varies with the type of traps involved (Dobrin and Savit, 1976).

Some of the parameters used in seismic stratigraphic interpretation are:

- Reflection Configuration
- Reflection Continuity
- Reflection Amplitude
- Reflection Frequency
- Interval velocity
- External form

## 4.3 Working Procedure

The following steps were followed for interpretation purpose.

- preparation of base map
- Generation of synthetic seismogram.
- Fault identification and marking
- Horizon marking

All digital maps along with geo-referenced imagery were produced by using Kingdom Suite. The interpretation was done on Kingdom which provides an interactive interface for marking horizons and faults, exporting horizon's time, velocity and depth data for contouring and for further analysis.

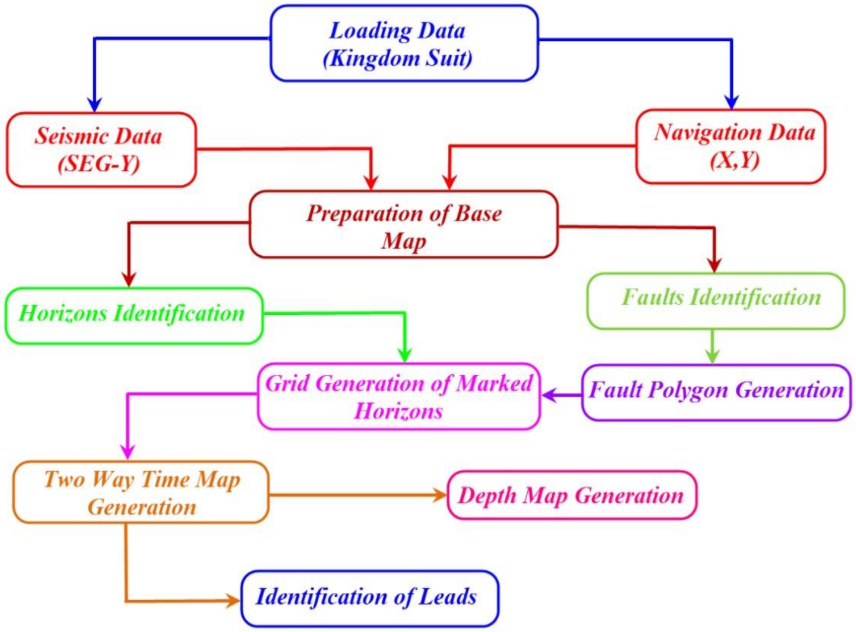


**Fig 4.1 Interpretation work flow.**

### 4.3.1 Generation of Synthetic Seismogram

For the generation of synthetic seismogram two way time for each well top is required. Two way time for each well top or reflector is calculated by using depth, sonic log data of well and replacement velocity of the area. , the purpose of generation of synthetic is to find two way travel time against each depth for marking of horizons.

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

1. Load the Las file of the well in the software.
2. Open 1D forward modeling Project and select the well logs.
3. Integrate the sonic log to rescale from depth in meters to two-way travel time in seconds.
4. Compute velocity from sonic log for P and S waves.
5. Create a TD chart for the well from the velocity logs.
6. Compute Acoustic impedance log using velocity and density log.
7. Compute the reflection coefficients from the time-scaled velocity log.

8. Compute a first-order Ricker wavelet as a digital filter with two millisecond increments of

9. Two-way travel time; using a frequency in Hertz (35 Hz frequency is used in this study)

10- Convolve the reflection coefficient log with the Ricker wavelet to generate the amplitudes of the synthetic seismogram

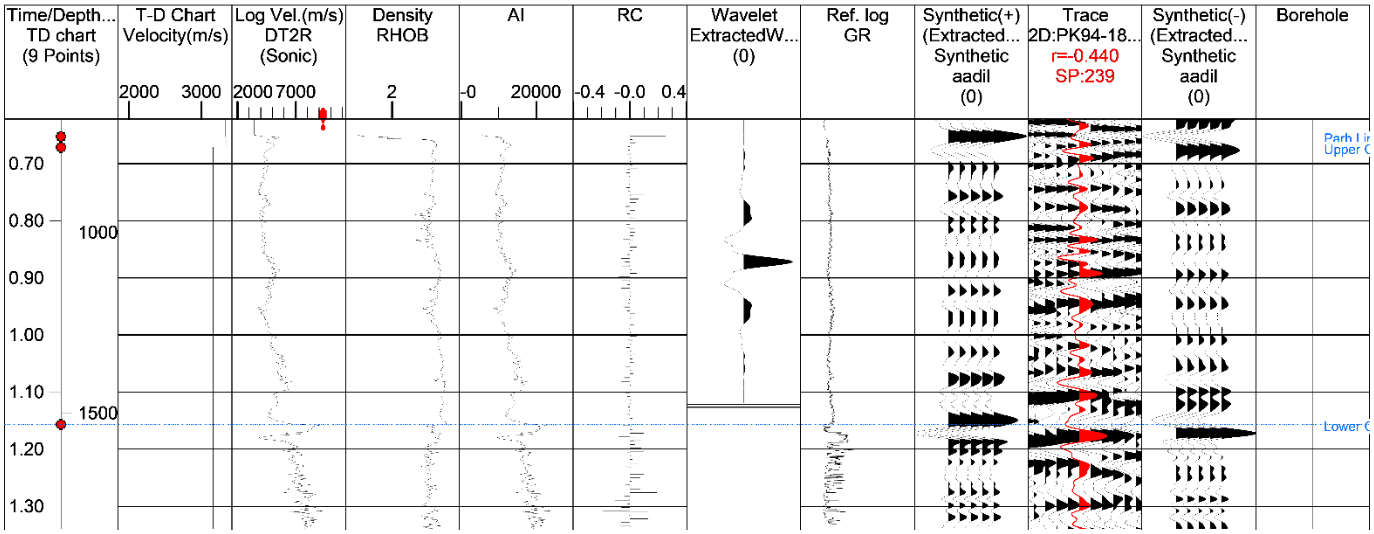


**Figure 4.2 showing Generation of Synthetic Seismogram**

### 4.3.2 Marking the Horizons

In seismic section the time was given in milliseconds, as it is the travel time of the wavelet. To pick up horizon, well tops are required. Well tops give the information about the depth of each formation in subsurface. So to mark horizon time depth chart was prepared.

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.Three horizons are picked on the basis of available information. The horizons are named on basis of well tops of the well Doti-01 . The Kadro, Parh Limestone and Lower Goru formations, Fig 4.3 which are showing high reflections on a seismic section making it easier to be picked.

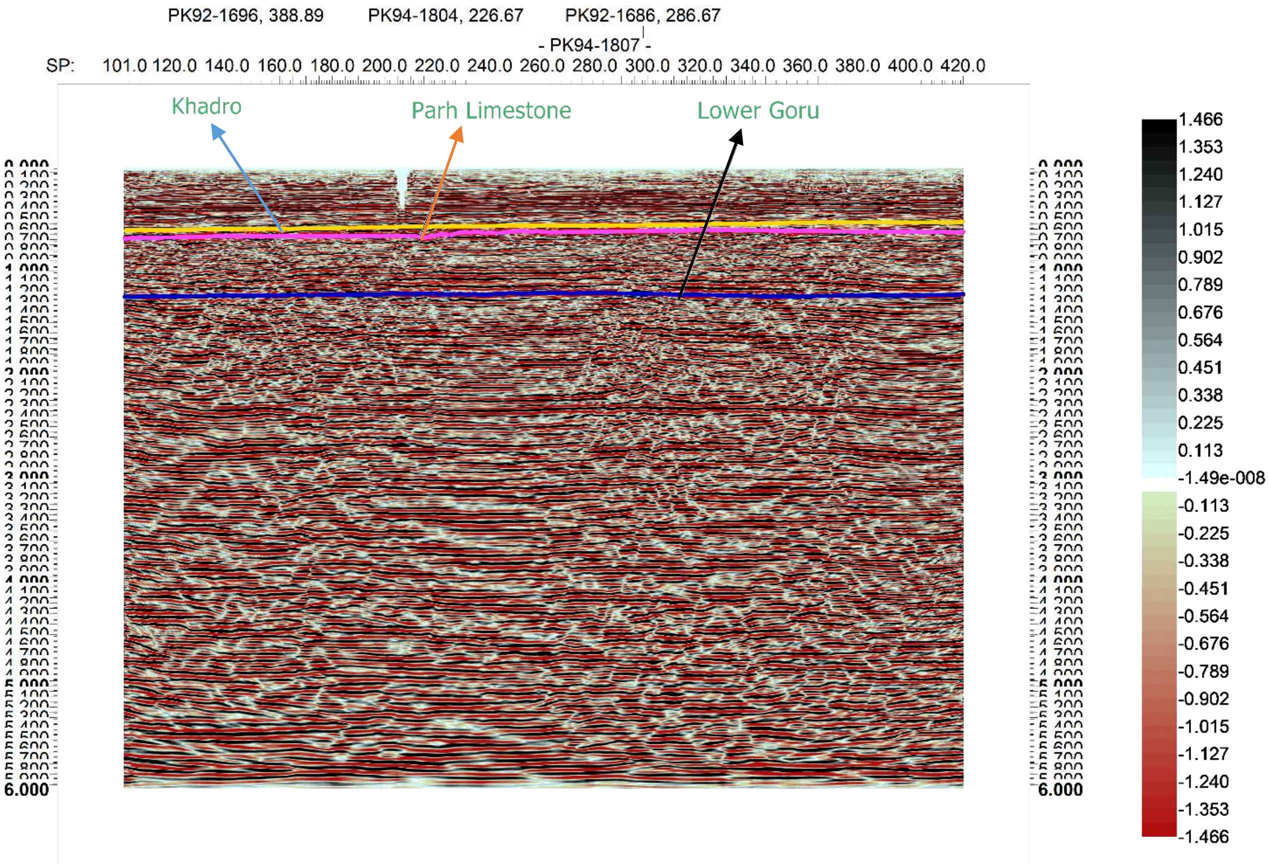


**Fig 4.3 Interpretation of line PK94-1807 (strike)**

### 4.3.3 Fault Identification

Following steps should be followed to interpret the faults on the seismic data.

- Geology of the area
- Marking faults on seismic sections
- Correlation of the faults

### 4.3.4 Interpreted Seismic Sections

The interpreted seismic section of the line PK92-1686, PK94-1804 and PK92-1696 is shown in Figure 4.4, Figure 4.5 and Figure 4.6. Total Three seismic horizons namely Khadro, Parh Limestone and Lower Goru are marked. Along these seismic horizons, faults are also picked shown in figures given below:

**1 PK92-1686**

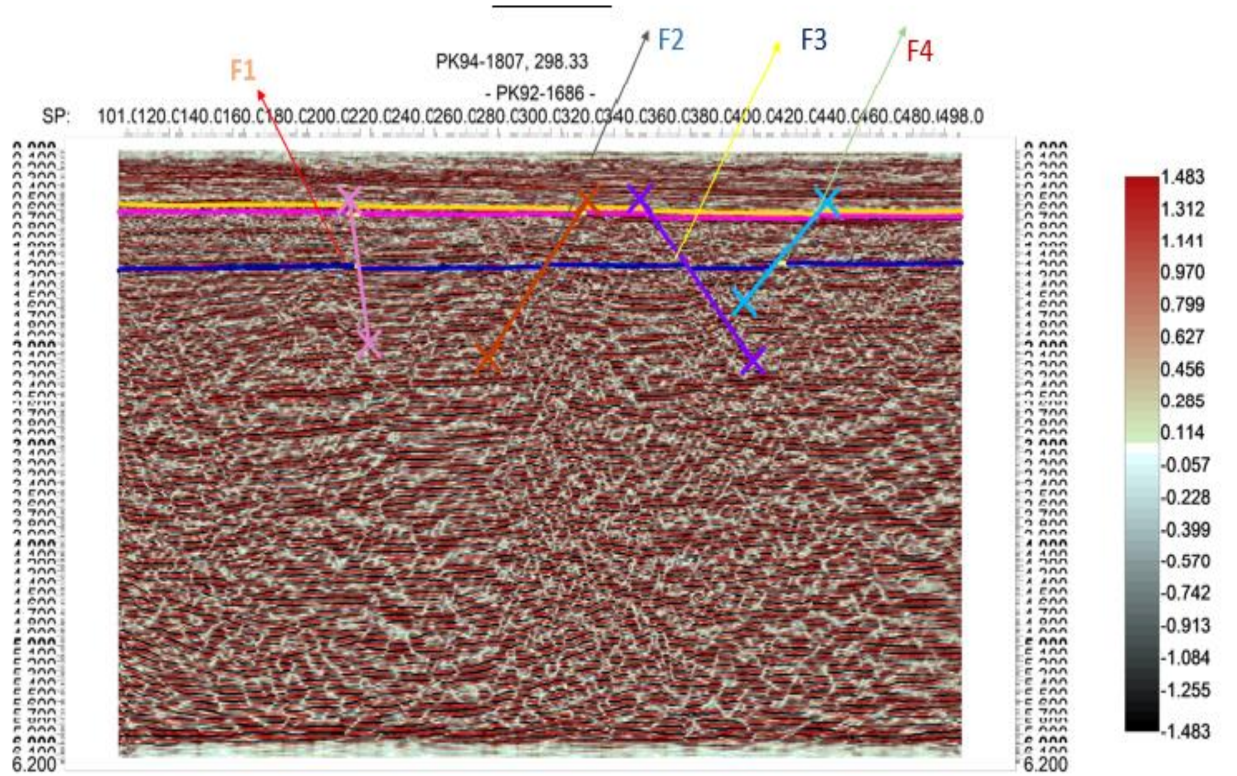


**Figure 4.3 Interpretation of line PK92-1686 (DIP)**

**2 PK94-1804**

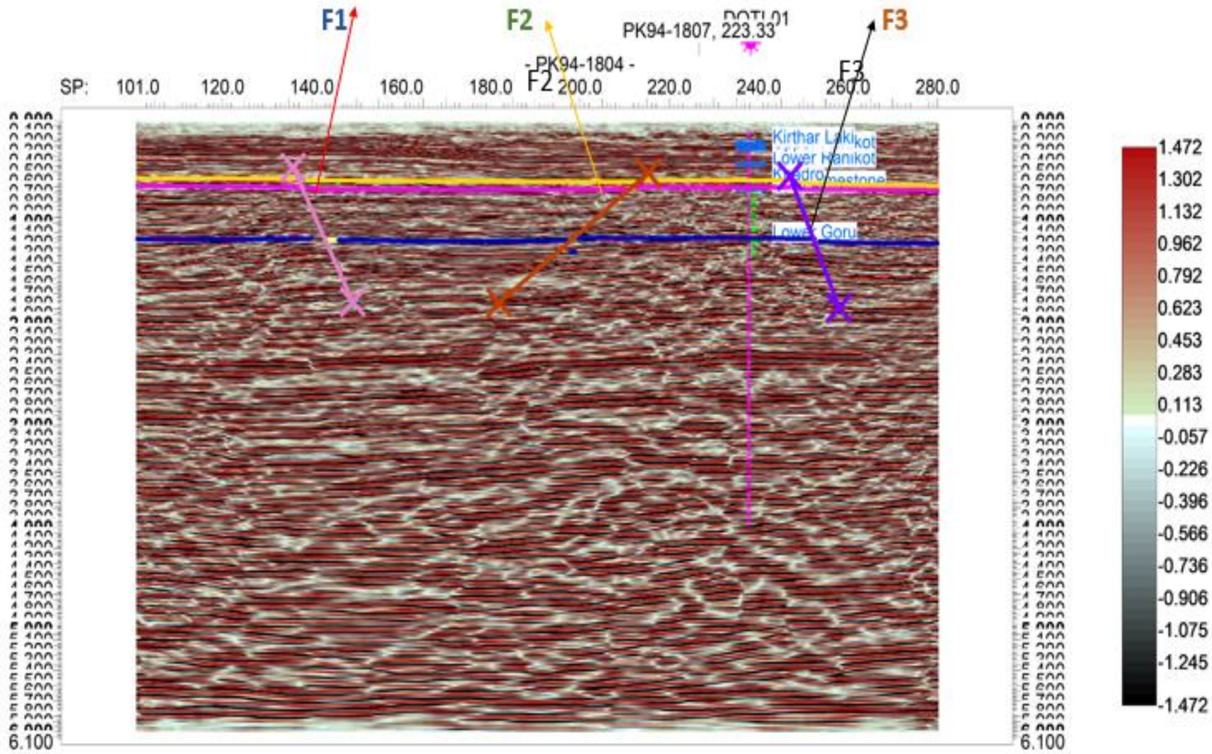


**Figure 4.4 Interpretation of line PK94-1804 (DIP)**

3 PK92-1696

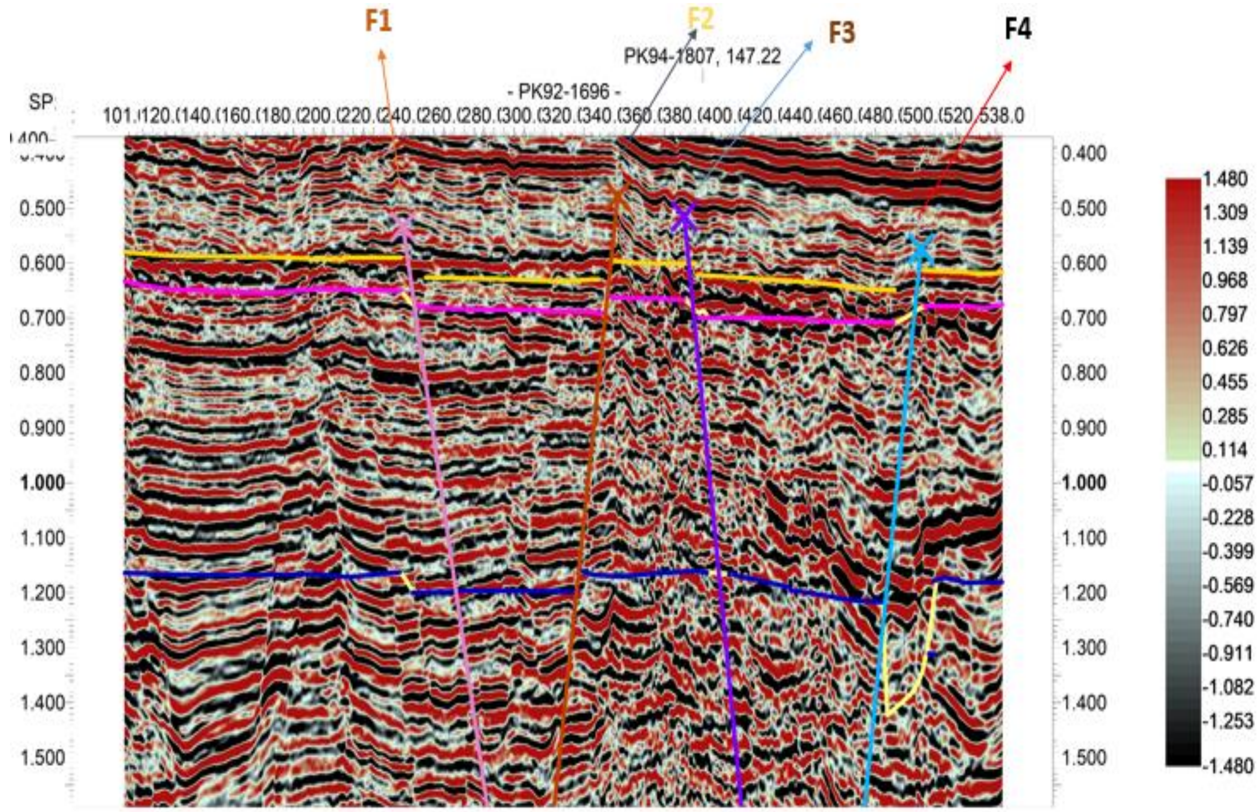


**Figure 4.5 Interpretation of line PK92-1696 (DIP)**

## 4.4 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 polygons it is necessary to identify the faults and their lateral extent by looking at the available seismic data. Construction of fault polygons are very important as far as time and depth contouring of a particular horizon is concerned.

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 directions on a fault polygon if dip symbols are not drawn. Fault polygons are constructed for all marked horizons. Figure 4.6 shows polygon of Lower Goru and figure 4.7 shows polygon of Parh Limestone.

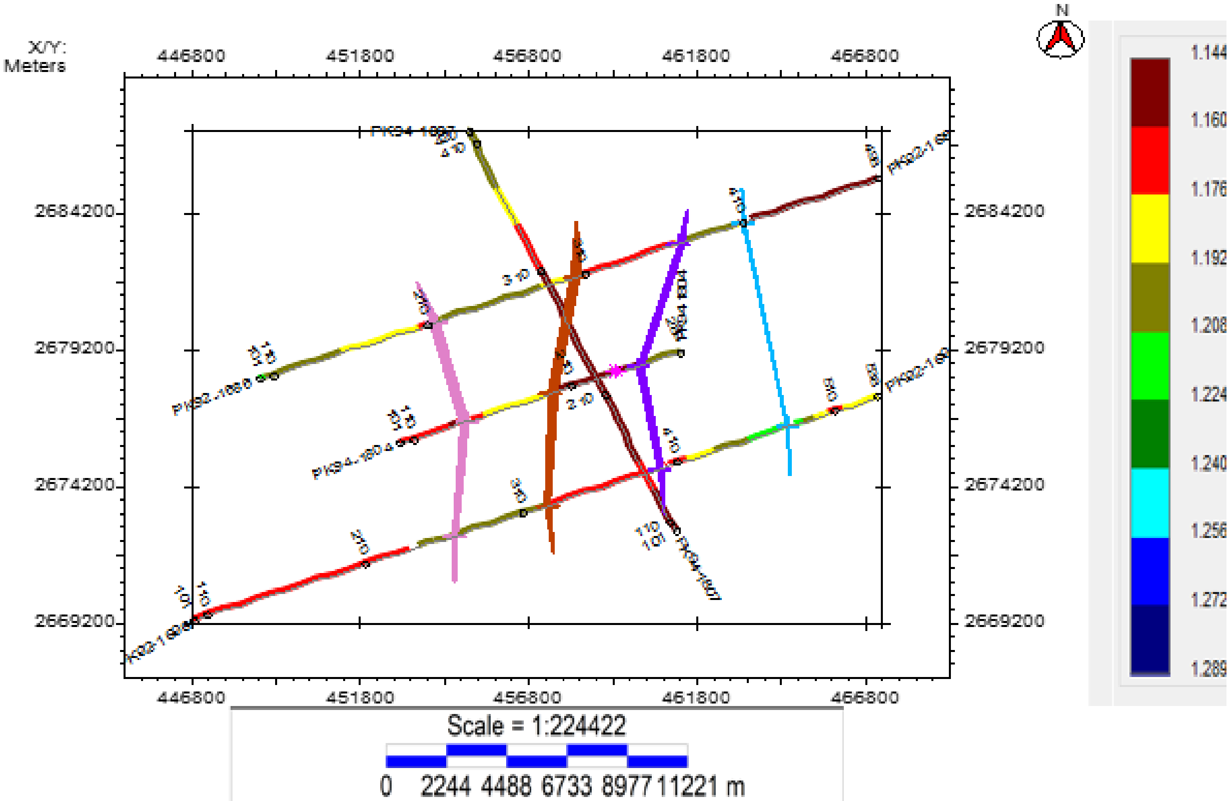


**Figure 4.6 Fault Polygon constructed at Lower Goru.**

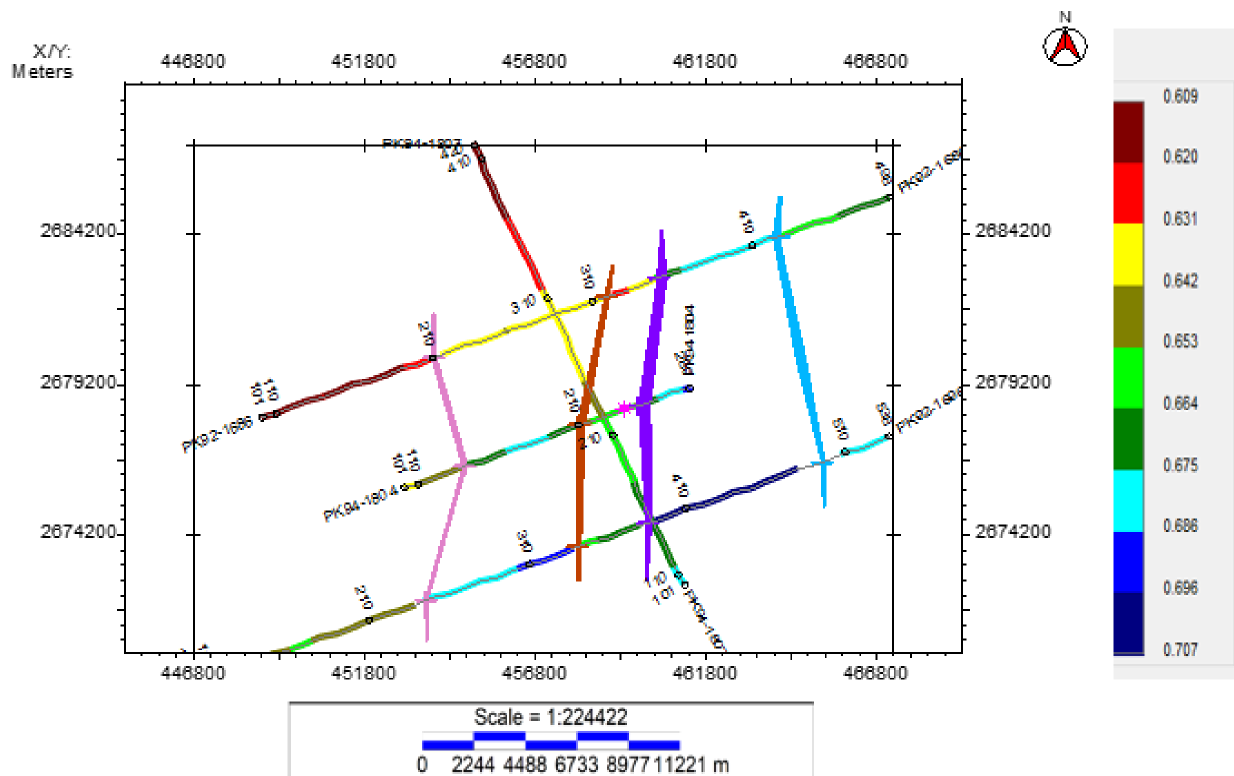


**Figure 4.7 Fault Polygon constructed at Parh Limestone.**

## 4.5 Contour Maps

Contouring is the main tool used in the seismic interpretation. After contouring it becomes obvious that what sort of structure is forming a particular horizon.

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

### 4.5.1 Time Contour Map of Lower Goru

The two way time contour maps have been generated using the Kingdom Software. Time contour map of Lower Goru is shown in the figure 4.8

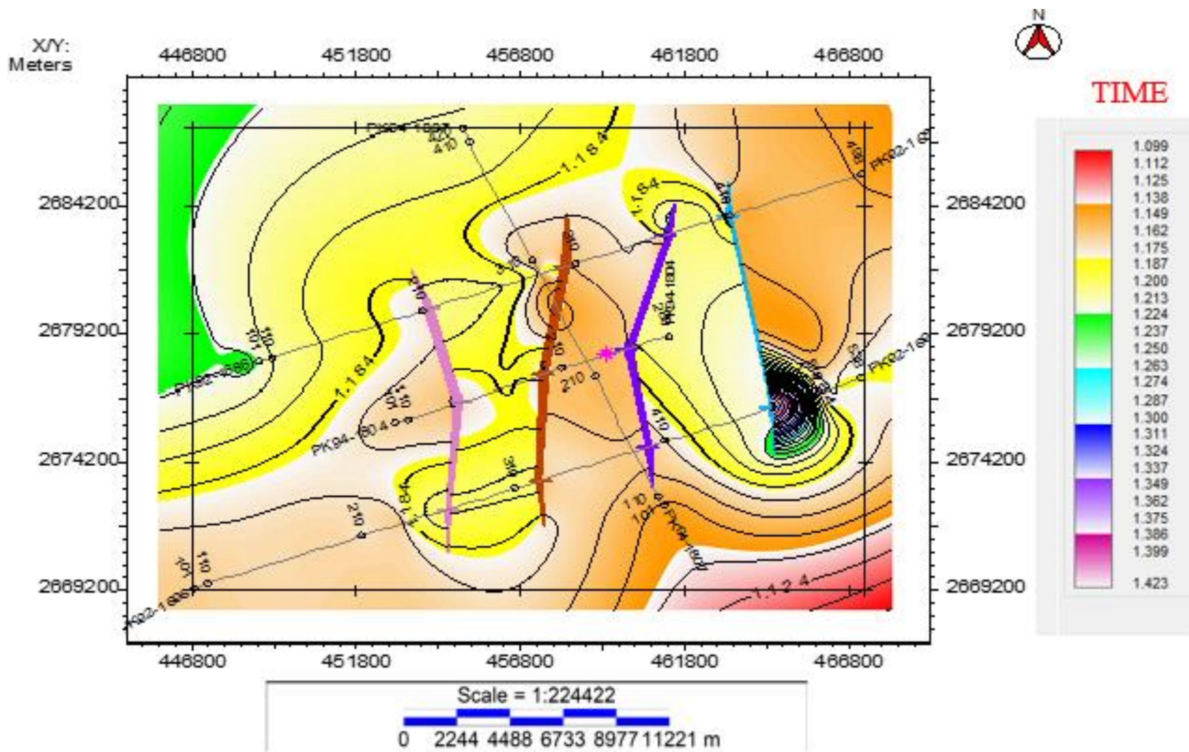


**Figure 4.8 Time Contour of Lower Goru**

### 4.5.2 Depth Contour Map of Lower Goru

The depth contour maps have been generated using the Kingdom Software. Depth contour map of Lower Goru, is shown in the figure 4.9.

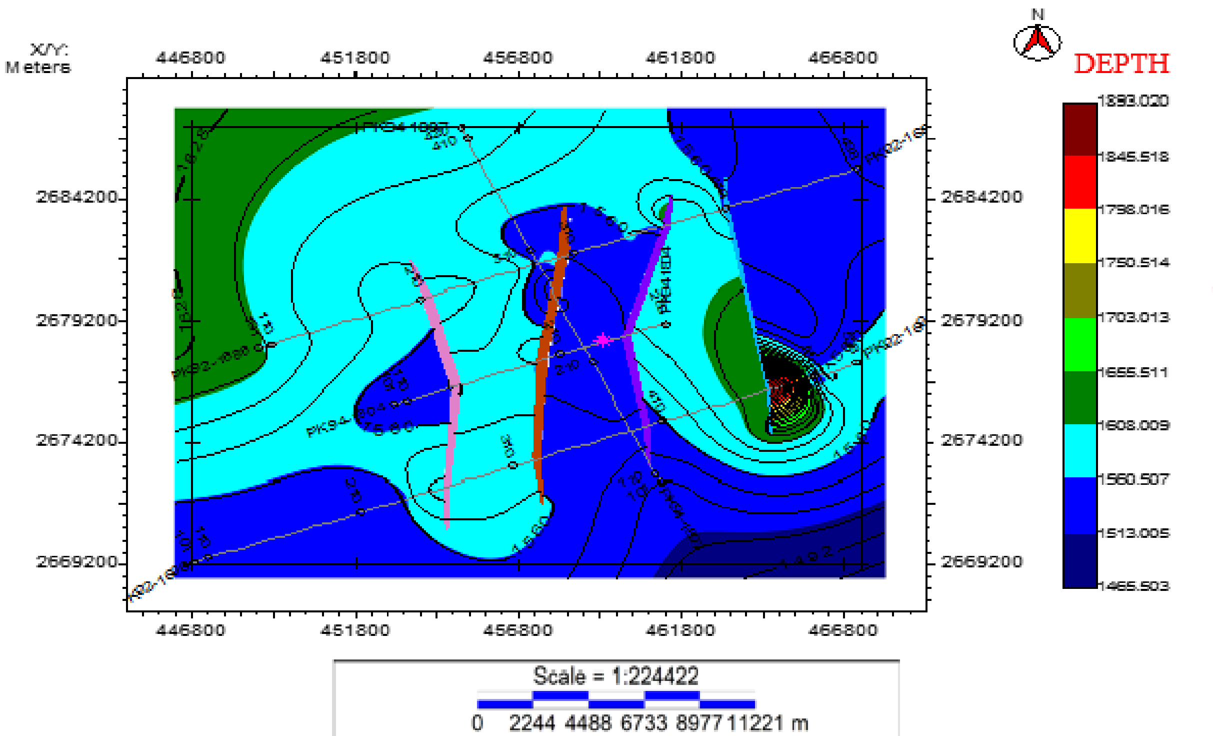


**Figure 4.9 Depth Contour of Lower Goru**

Chapter 5

# PETROPHYSICAL ANALYSIS

## 5.1 General Information

Well DOTI-01 lies upon the seismic line PK94-1804. Badin block consists of a total of 380 exploratory wells and 59 oil and gas condensate discoveries. In Lower Indus, so far more than 12 TCF (Trillion Cubic Feet) gas reserves and more than 100 trillion barrels Oil have been discovered in Lower Indus Basin whereas more than 90% oil production is from Badin area (Mozaffer et al., 2002). Well log interpretation is done on Lower Goru Formation. The purpose of study is to be able to identify the permeable zones, their fluid content and hydrocarbon saturation.

## 5.2 Petrophysics

- Petrophysics uses all kind of logs, core data and production data and integrates all pertinent information.
- Petrophysics is generally less concerned with seismic, and more concerned with well bore.
- Petrophysics can provide things like porosity, saturation, permeability, net pay, fluid contacts, shale volume, and reservoir zonation .

## 5.3 Types of Logs

- Gamma ray
- Spontaneous Potential
- Caliper log
- Gr log
- Resistivity
- Sonic
- Density
- Neutron

### 5.3.1 Spontaneous Potential log:

The SP log records the electric potential between an electrode pulled up a hole and a reference electrode at the surface. This potential exists because of the electrochemical differences between the waters within the formation and the drilling mud. The potential is measured in milli volts on a relative scale only since the absolute value depends on the properties of the drilling mud.

In shaly sections, the maximum SP response to the right can be used to define a “shale line”. Deflections of the SP log from this line indicate zones of permeable lithologies with interstitial fluids containing salinities differing from the drilling fluid. SP logs are good indicators of lithology where sandstones are permeable and water saturated. However, if the lithologies are filled with fresh water, the SP can become suppressed or even reversed. Also, they are poor in areas where the permeabilities are very low, sandstones are tightly cemented or the interval is completely bitumen saturated (i.e. oil sands).

### 5.3.2 Caliper log:

Caliper Logs record the diameter of the hole. It is very useful in relaying information about the quality of the hole and hence reliability of the other logs. An example includes a large hole where dissolution, caving or falling of the rock wall occurred, leading to errors in other log responses. Most caliper logs are run with GR logs and typically will remain constant throughout.

### 5.3.3 Resistivity log:

Resistivity logs record the resistance of interstitial fluids to the flow of an electric current, either transmitted directly to the rock through an electrode, or magnetically induced deeper into the formation from the hole.

### 5.3.4 Sonic log:

Sonic logs (or acoustic) measure the porosity of the rock. Hence, they measure the travel time of an elastic wave through a formation (measured in $\Delta T$ - microseconds per meter). Intervals containing greater pore space will result in greater travel time and vice versa for non-porous sections. They must be used in combination with other logs. Particularly gamma rays and resistivity, thereby allowing one to better understand the reservoir petrophysics.

### 5.3.5 Density log:

Density logs measure the bulk electron density of the formation, and are measured in kilograms per cubic meter (gm/cm3 or kg/m3). Thus, the density tool emits gamma radiation which is scattered back to a detector in amounts proportional to the electron density of the formation. The higher the gamma ray reflected, the greater the porosity of the rock. Electron density is directly related to the density of the formation (except in evaporates) and amount of density of interstitial fluids. Helpful in distinguishing lithologies, especially between dolomite (2.85 g/cc) and limestone (2.71 g/cc), sandstone (2.65 g/cc).

### 5.3.6 Neutron log:

Neutron Logs measure the amounts of hydrogen present in the water atoms of a rock, and can be used to measure porosity. This is done by bombarding the formation with neutrons, and determining how many become "captured" by the hydrogen nuclei. Because shales have high amounts of water, the neutron log will read quite high porosities. Thus it must be used in conjunction with GR logs. However, porosities recorded in shale-free sections are a reasonable estimate of the pore spaces that could produce water.

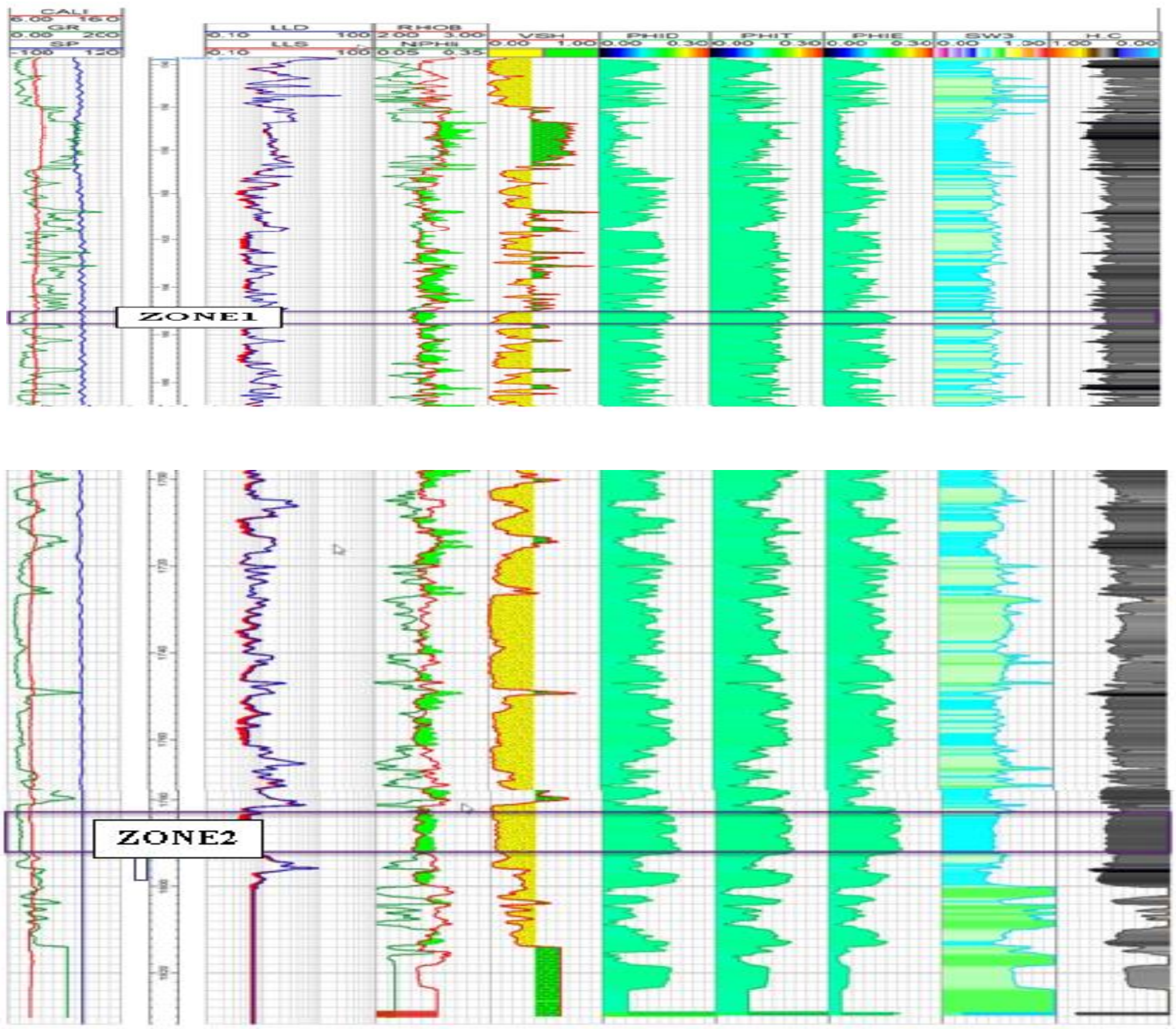


**Figure 5.1 Sand Intervals In Lower Goru Formation**

## 5.4 Petro physical Analysis

Electrical well logging was introduced to the oil and gas industry over half a century ago and since then, many improved and additional logging tools and devices have been developed and have been put in general use. The art of interpretation of the data advanced along with the advancements in well logging science. Today, the detailed analysis of a carefully chosen suite of wire-line services provides a method of inferring or deriving accurate values for the following:

- Hydrocarbons and water saturations
- Permeability indexdcs
- Porosity
- Lithology of the reservoir rock.

## 5.5 Log Curves

The log data of Doti-01 was available in Logging ASCII Standard (LAS) format. The log curves along with some parameters given in the LAS file header are used to calculate all basic and advance parameters. The methodology adopted for this work is given in Figure 5.2 and each analysis step is discussed in the proceeding sub-sections.

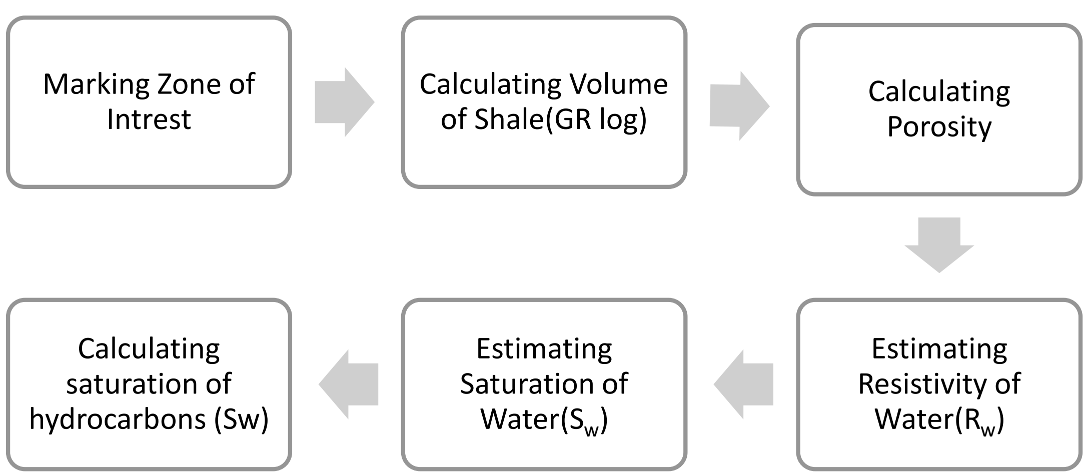


**Figure 5.2 Workflow for petro physical analysis**

### 5.5.1 Zone of Interest

The zones of interest are defined on the basis of source, reservoir and seal rock formations given in well tops of Doti-01 well. The zones of interest which are marked are listed in the Table 5.1:

**Table 5.1 Showing Zone of Interest**

| Zones | Starting Depth (m) | Ending Depth(m) | Thickness(m) |
|---|---|---|---|
| Lower Goru | 1530 | 1830 | 300 |

### 5.5.2 Shale Volume Calculation

The volume of shale is calculated using GR log by given formula:

$$I_{GR}=\frac{GRlog - GRmin}{GRmax - GRmin} \qquad (Rider,\ 2002)$$

Following terminologies have been used in the above formula:

$I_{GR}$: Gamma Ray Index

GR log: Gamma Ray reading at interested depth.

GR max: Maximum Gamma ray reading.

GR min: Minimum Gamma ray reading.

The source formations are commonly shale with higher radioactive content and are therefore indicated by a higher Gamma Ray value. On the other hand, it is also assumed that the radioactive material is not present in other formations which are termed as clean formations. This creates a contrast between shale and other formations.

### 5.5.3 Determination of Lithology

Shales always have high GR values as compared to sandstones that has low GR value and low density –neutron value. Sandstone is permeable by all means so in order to differentiate between any of the sandstone we use Neutron-Density cross plot (*Rider, 2002)*. The root mean square formula provides the best calculation:

For Oil and Water bearing Formation

$$\phi = \frac{\phi N + \phi D}{2}$$

For gas bearing Zone

$$\phi = \sqrt{\frac{\phi N^2 - \phi D^2}{2}}$$

(*Rider, 2002)*

ϕN: Neutron porosity

ϕD: Density porosity

### 5.5.4 Identifying the Fluids Present

While studying the porosity pattern in any formation if we encounter large variation in resistivity in permeable formation of similar porosity, either there is water bearing formation or hydrocarbon bearing formation.

1. High resistivity likely hydrocarbons.
2. Low resistivity likely water.

### 5.5.5 Porosity Determination

It determines the ultimate volume of rock type that can contain hydrocarbons. The value and distribution of porosity, along with permeability and saturation are the parameters that dictates reservoir production and development plans. The porosity of the formation can be obtained from the bulk density if the mean density of the rock matrix and that of the fluid it contains known.

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \qquad \text{(Rider, 2002)}$$

Following terminologies have been used in the above formula:

$\rho_b$: Bulk density of the Formation.

$\rho_{ma}$: Density of the rock matrix.

$\rho_f$: Density of the fluid occupying the pores.

ϕ: Density porosity of the rock.

**(Rider, 2002) Table 5.2 Density Values of Formations/Water Types**

| **Formations/Water Type** | **Values** |
|---|---|
| Saline Water | 1.1 g/cm$^3$ |
| Fresh water | 1.0 g/cm$^3$ |
| Sandstone | 2.65 g/cm$^3$ |
| Limestone | 2.71 g/cm$^3$ |

Porosities are added into neutron porosities, divided by 2 and a total porosity is found then volume of shale is subtracted by 1 and multiplied with total porosity to get effective porosity.

### 5.5.6 Calculation of Resestivity of Water($R_w$)

By using the Archie Method value of Rw was calculated. The value was found to be equal to the Resistivity of Mud Filtrate at Zone of Interest (Reservoir Formation) is calculated by the equation given below:

$$R_{mf2} = R_{mf1} * (T_1 + 6.77/ T_2 - 6.77)$$ (*Rider*, *2002)*

Where

$R_{mf1}$: Resistivity of mud filtrate at surface temperature,

$T_1$: Surface temperature,

$T_2$: Formation temperature.

$R_{mf2}$: Resistivity of mud filtrate at formation temperature (zone of interest).

### 5.5.7 Water Saturation (Sw)

Determination Water saturation has been calculated with help of the Archie's Equation:

$$Sw = (a/\Phi^m) \times (Rw/Rt) \qquad (\textit{Rider, 2002})$$

where,

Sw = water saturation

Rw =water resistivity (formation)

Φ=effective porosity

m (cementation

factor) = 2

a (constant)= 1

Rt = log response (LLD)

Rw has been calculated with help of the following formula:

$$Rw = \Phi 2 \times Rt \qquad (\textit{Rider, 2002})$$

Where, $\Phi$ = porosity in clean zone

Rt =Observed LLD curve in clean zone

5.5.8 Saturation of Hydrocarbon

It is denoted as Shc.

Saturation of hydrocarbon is calculated by given formula below;

$$Shc = 1 - Sw$$

Sw = Saturation of water

Shc= Saturation of hydrocarbon .

### 5.6 Petrophysical Result

The result obtained from the petrophysical analysis is shown in table given below:

**Table 5.3 Show the petrophysical properties**

| **Petrophysical property** | **Lower Goru** |
|---|---|
| Volume of shale | 25-30% |
| Effective Prosity | 10-15% |
| Water saturation | 75% |
| Hydrocarbon saturation | 20-25% |

### 5.7 Results of Lower Goru Zones

**Zone 1 (1650m – 1656m)**

| **Volume of Shale (Vsh)** | **19%** |
|---|---|
| Effective Porosity (PHIE) | 15% |
| Water Saturation (SW) | 72% |
| Hydrocarbon Saturation (Shc) | 28% |

**Zone 2 (1783m – 1793m)**

| **Volume of Shale (Vsh)** | **26%** |
|---|---|
| Effective Porosity (PHIE) | 16% |
| Water Saturation (SW) | 65-75% |
| Hydrocarbon Saturation (Shc) | 30-35% |

**Chapter 6**

# COLORED INVERSION

## 6.1 Introduction

Colored Inversion is a very fast tool which gives a precise interface for marking seismic horizons, improves the resolution and help for both stratigraphic and structural interpretation. It can also help in quantitative interpretation, reservoir characterization, field development and increase signal to noise ratio.

The method is a convolution process: an operator is designed that performs a -90 degree phase rotation and spectral shaping to the seismic trace in order to generate relative impedance profiles. The spectral shaping matches the amplitude spectrum of the seismic to the earth impedance spectrum over the bandwidth of the inversion. The method does not require the generation of a background model, so is particularly appropriate in exploration settings. Depending on the attribute that has been inverted, the use of layer properties versus reflectivity can greatly assist the interpreter. Coloured inversion is a quick and robust way of generating layer properties from seismic.

## 6.2 Procedure For Inversion

The well data and information of logs is required for the performing the colored inversion in Kingdom Software.

- The velocity is obtained from sonic log and density is obtained from density log and values of densities are obtained from density log by convolving these values.
- We get acoustic impedance by cross-matching these impedance data with the input reflection data.
- We derive a single optimal matching filter. Convolving this filter with the input data we see in figure that the result is very much similar, everywhere.
- This Empirical observation indicates that inversion can be approximated with a simple filter and that it may be valid over a sizeable region.

The wavelet is shown in figure 6.1 is extracted on the basis of the well log data that provides the true reflectivity series.

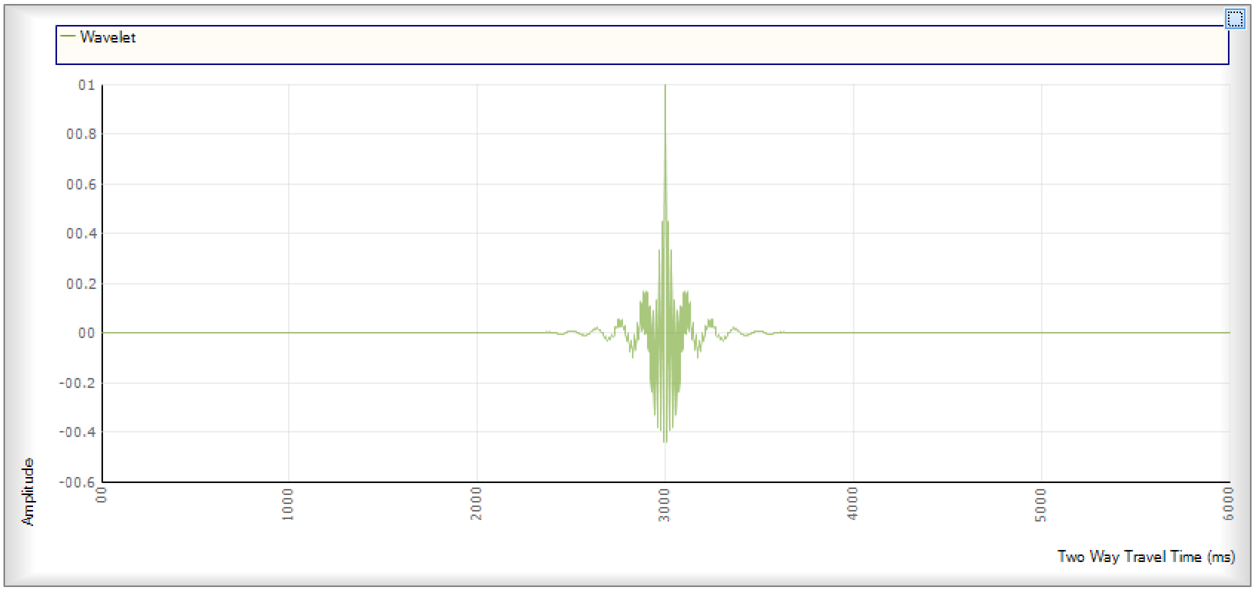


**Figure 6.1: Extracted wavelet**

## 6.3 Impedance Log Spectral Analysis

Usually amplitude spectrum rises gently with frequency in reflectivity logs which is called “blueness” of spectrum. The amplitude spectrum of velocity * density = impedance logs can be calculated and presented on a log-log graph, from which a linear spectral slope can be projected.

In a figure 6.2 impedance and frequency are plotted using BADIN ,DOTI-01 data to measure the variations in physical parameters. Green line shows the impedance spectrum in log scale and blue line is fitted line through the spectrum. The impedance spectrum is shown in figure is estimated after removing source wavelet; noise must be absent; all multiple reflections must be removed; spherical spreading including all plane reflections (Ghosh 2000).

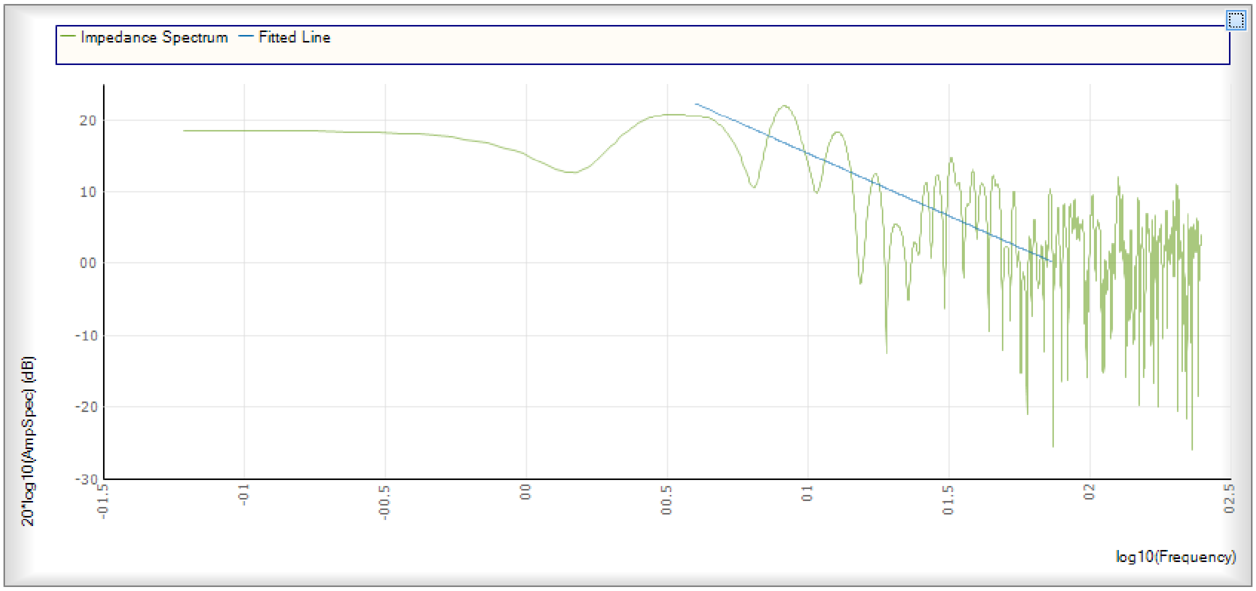


**Figure 6.2 Impedance Spectrum with Fitted Line**

In figure 6.3, I have plotted a butter worth filter which is signal processing filter designed to gain a frequency response as flat as possible in the passband. It is also stated to as outstandingly flat magnitude filter. Amplitude is plotted on y-axis and on x-axis we have frequency, green line is a butter worth filter.

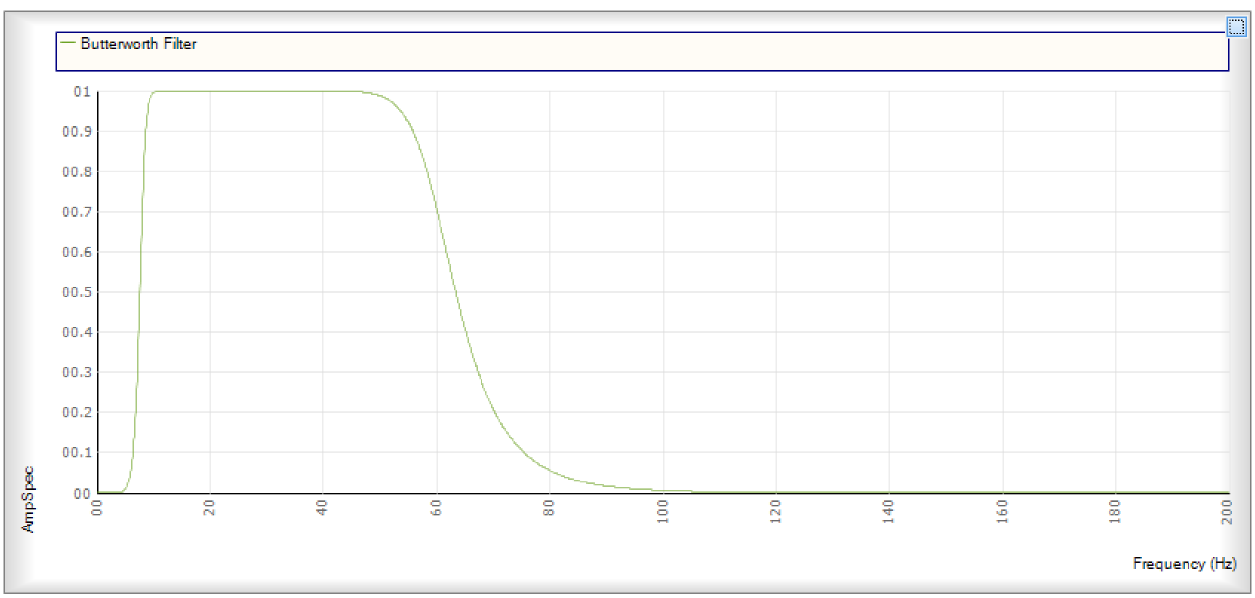


**Figure 6.3 shows Butter worth Filter**

In figure 6.4 we can see a modelled and desired spectrum and we can see that modelled spectrum is very near to desired spectrum. We try to model our amplitude spectrum as close as the amplitude spectrum of our seismic data.so this can be done through a shaping function.

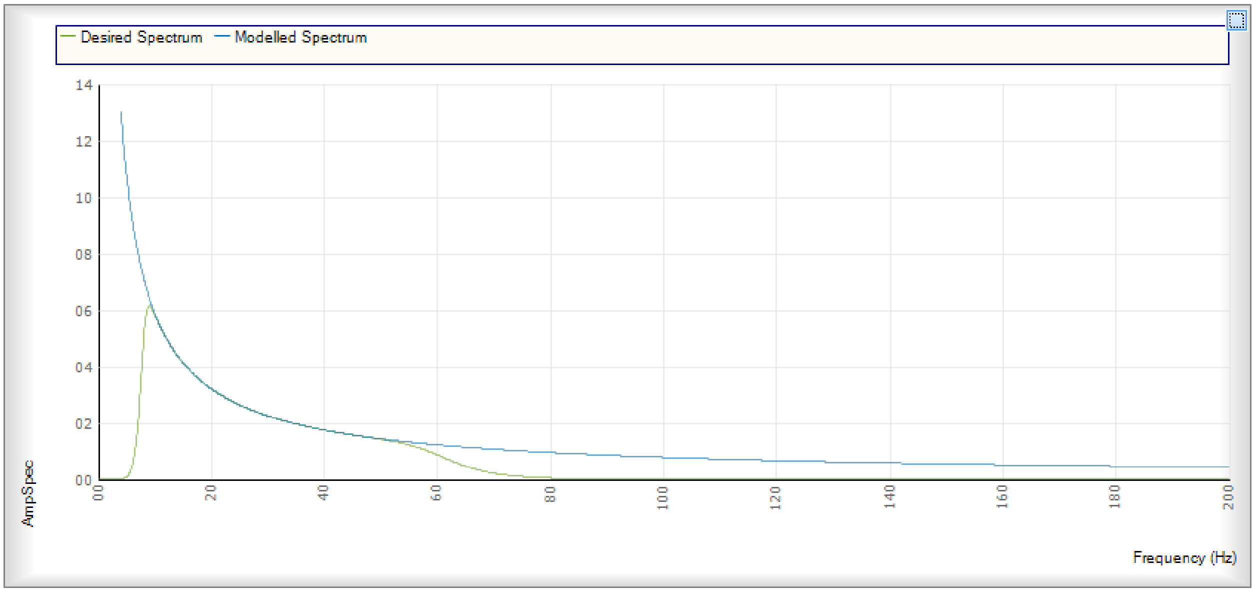


**Figure 6.4 Shows Desired and Modelled Spectrum**

## 6.4 Spectral Shaping of Seismic Data

Figure 6.5 shows a shaping function; it may be called as pre-whitening which helps to acquire desired amplitude spectrum In figure 6.6 we have a shaped seismic spectrum which is a result of convolution of pre whiting filter, wavelet and a desired seismic spectrum. We can see now shaped seismic spectrum is very closed to our desired seismic spectrum.

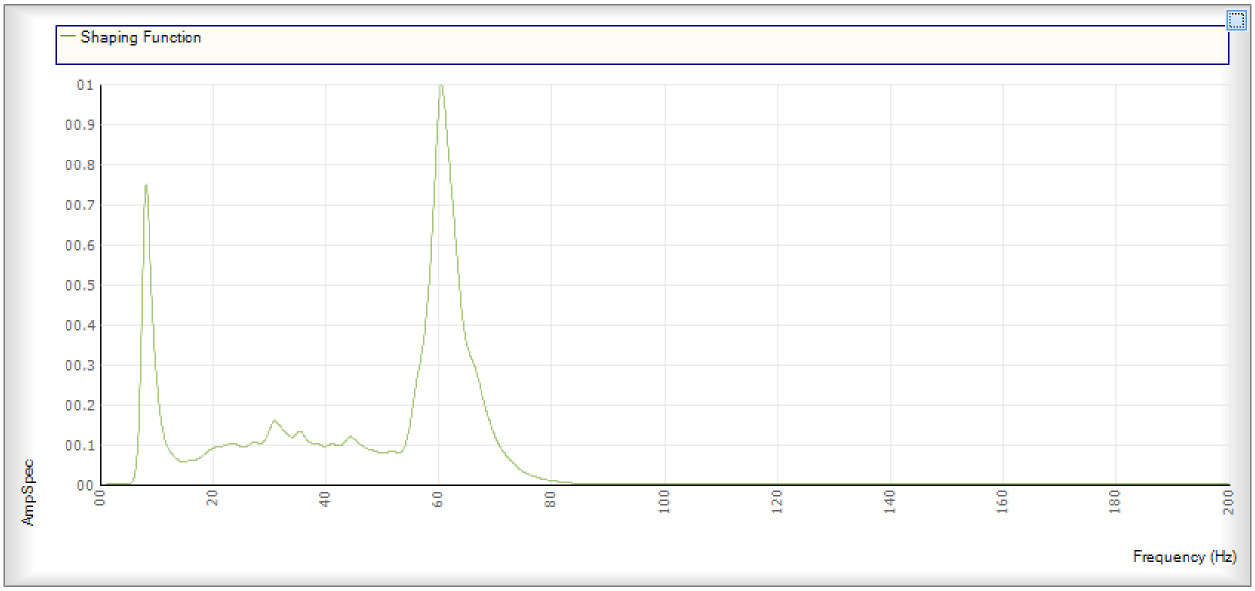


**Figure 6.5 Shows shapping Function**

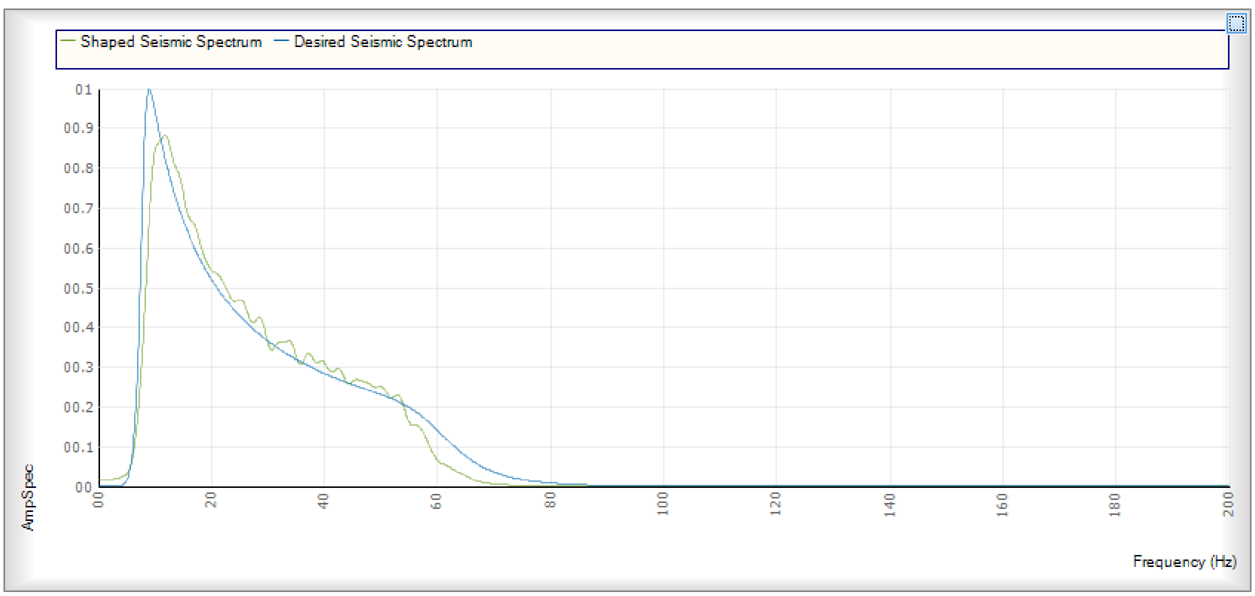


**Figure 6.6: Convolution of shaped seismic spectrum and desired spectrum**

### 6.5 Seismic Color Inversion Display:

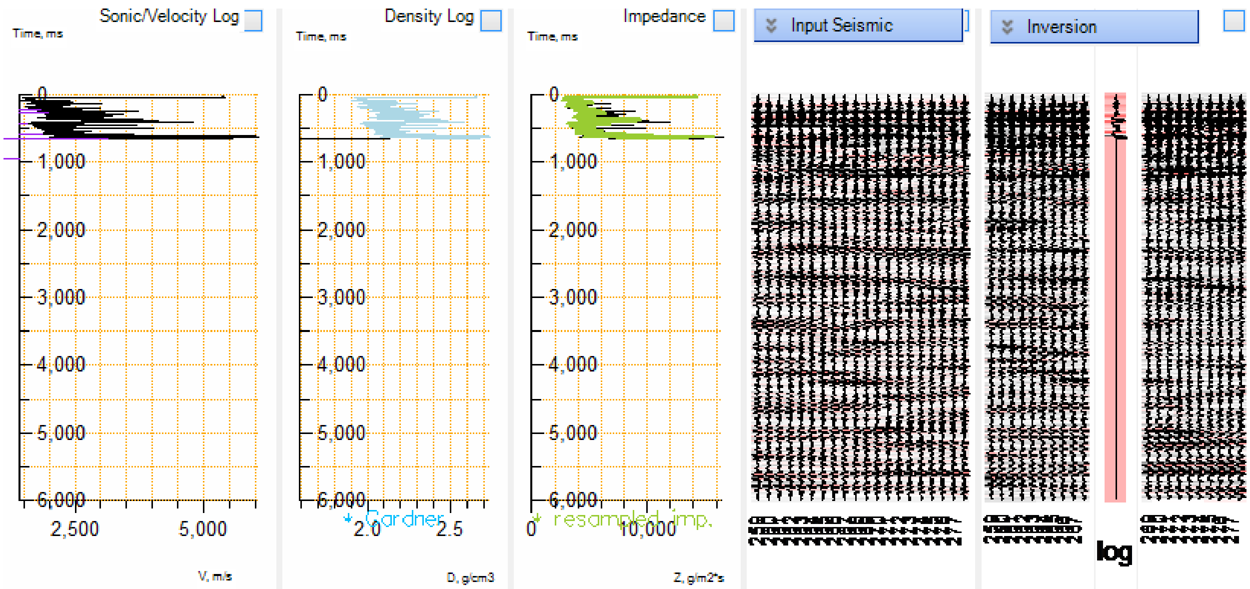


**Figure 6.7 shows Input seismic section and inverted section along with logs**

In figure 6.7 we have a sonic log and density log which is impedance log, on impedance log we see a calibrated impedance log. First we have extracted a single trace from our seismic, a single trace from impedance log and then we have incorporated it to do a color inversion. We see a resemblance in input seismic and inverted seismic data. The above window display the density and sonic log which are used to generate impedence log.In case ,if value of density logs are missing then gardner equation is used to estimate missing densities values. Gardner, is an empirically derived equation that relates seismic P-wave velocity to the bulk density of the lithology in which the wave travels. The equation reads:

$$\rho = \alpha V_P^{\beta}$$

where $\rho$ is bulk density given in g/cc,  is P-wave velocity given in ft/s.

#### 6.5.1 Interpetation of Inverted Seismic Section.

Figure 6.8 shows the zoomed view of inverted seismic section.

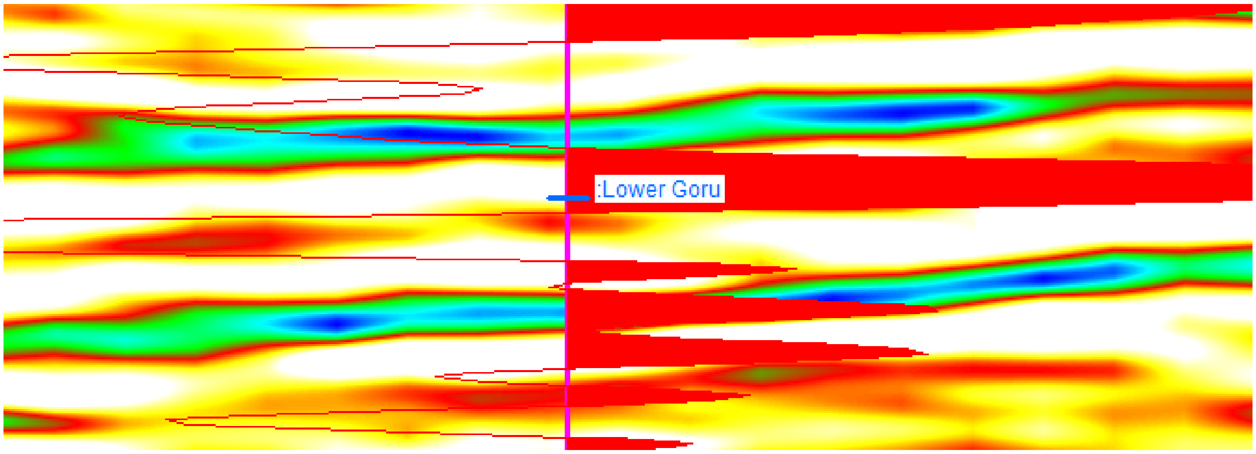


**Figure 6.8 Shows The Zoomed View of Inverted Section of Lower Goru**

# Chapter 7

## Conclusion

After applying seismic and well data on the study area and using different software tools it is conclude that:

- Seismic data interpretation of study area reveals the involvement of extensional and shear tectonics in the study area.
- Mapping of the study area revealed the East and West dipping of fault boundaries and trending in North-West direction
- On the basis of seismic as well as well data two reflector of geological importance is identified among which Lower Goru which is acting as reservoir.
- The seismic interpretation revealed Horst and Graben structure in Badin area.
- Time and Depth Contour Maps help me to confirm the presence of Horst and Graben structure in area.
- Synthetic Seismogram was matched with the marked horizons and it has confirmed the structural interpretation.
- Petrophysical analysis shows Lower Goru formations are good reservoirs.
- Petrophysical modeling indicates that interval Lower Goru Member are the hydrocarbon bearing zone and contains about 24% saturation of hydrocarbons in well Doti-01
- Results of seismic interpretation and well log interpretation justified the dryness of well Doti-01

## References


- Dobrin, M.B. & Savit C.H., 1976, "Introduction to Geo-Physical Prospecting":2nd Edition, McGraw Hill Company.210-300, 450-510p.
- Coffeen, J.A., 1986, Seismic Exploration Fundamentals, PennWell Publishing Co.
- Chopra, S., and Marfurt, K., 2006. Seismic Attributes – a promising aid for geologic prediction. Arcis Corporation, Calgary, Alberta, Canada and Allied Geophysical.
- Ahmed, S., 1999. Study on Oil and Gas Distribution in the Badin Block: Union Texas Pakistan, Inc., SPE-PAPG, Annual Technical Conference, 137-147.
- Alam S.M., Wasimuddin,M. and Ahmad, S.M 2002., Zaur Structure ,A complex Trap in a poor seismic data Area, BP Pakistan Exploration & petroleum Inc.
- Besse, J. and Courtillot, V., 1988. Paleographic Maps of the Continents Boardeing the Indian Ocean since the Early Jurassic. Laboratoire de Paleomagnetism et Geodynamique Institu De Physique du globe de Paris, France, no, 1-2.
- Hashmi, I.h., Ghalib, S.a., Shahid, U., Ghufran, A. and Bhatti, T., 2012. Environmental Impact Assessment for Exploration Activities in Badin Concession – Protected Area.
- Kadri, I.B, 1995, Pakistan Geology of Pakistan, PPL Pakistan.640.
- Kemal, A., 1992. Geology and New trends for Petroleum exploration in Pakistan. Khan. M.A., Ahmad Raza, H.A, Kemal, Arif 1986, Geology of Pakistan in Kohat-Potowar Depression, Pakistan: American Association of Petroleum Geologist Bulletins. 70,396-414.
- Khan, M.R., Iqbal, M., Ahmed, A., Murtaza, G., and Khan, W.A., 2013. An Integrated Approach for Assessment of Lower Goru Reservoir Quality in Western Part of Badin Area, Lower Indus Basin, Pakistan. PAPG/SPE Annual Technical Conference 2013, Islamabad, Pakistan.
- Mozzaffar, S.M., Wasimuddin, M. and Sayeed, S.M., 2002. ‘‘Zaur Structure, A Complex Trap In A Poor Seismic Data Area". British Petroleum Pakistan, SPE. 2004, no. 2-8.
- Robinson ES, & Coruh, c, 1988, "Basic Exploration Geophysics", John Wiley & Sons, New York, 25-70p
- Yilmaz.2001, Seismic Data Analysis and Processing, Inversion and Analysis of Seismic.
- Data, Society of Exploration Geophysics, Tulsa