2D SEISMIC INTERPRETATION, SEISMIC ATTRIBUTE ANALYSIS, PETROPHYSICAL ANALYSIS, FACIES ANALYSIS, AND COLOURED INVERSION OF SABZAL FIELD, DHANDI AREA, CENTRAL INDUS BASIN, PAKISTAN.

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ABSTRACT

Two dimensional seismic interpretation has been carried out in Dhandi area (study area) located near Rahim Yaar Khan in the district of Punjab province, Pakistan to reveal the subsurface geology. The data used for this study was provided by DGPC. Seismic data given for well Sabzal-01 includes navigation of well and segy data whereas well data include well tops and well headers. The horizons are identified and named on the basis of well and generalized stratigraphic data. Sabzal-01 lies in Central Indus Basin. The objective of research is to delineate structures on seismic lines, making time-depth maps and to determine the hydrocarbon potential of Sabzal-01 with the help of petrophyiscal techniques using wireline logs, attributes analysis and coloured inversion. In attribute analysis, relative Acoustic Impedence attribute, Average Energy attribute and wavelet Dominant Frequency attribute confirms that the reflectors are nearly horizontal, and also show high acoustic impedence and frequency in reservoir formation. Different petrophysical parameter, like volume of shale, water saturation, porosity and hydrocarbon saturation are taken into consideration for reservoir characterization. The value of volume of Shale in Habib Rahi is 55%, effective porosity is 6%, Water Saturation is 81% and Hydrocarbon Saturation is 19% in Sabzal well which is dry well. Facies analysis indicate two facies in Habib Rahi Formation, limestone facie and shaly limestone facie. Coloured inversion is performed on a control line, indicates that reflectors are nearly horizontal and justifies that Sabzal-01 is dry well, as the reservoir formation is marked on the high acoustic impedence values.

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CHAPTER 1

INTRODUCTION TO STUDY AREA

The study area is Dhandi, located in Rahim yar khan district of Punjab province, Central Indus Basin. Geologically Pakistan has two main basins these are Indus basin and Baluchistan basin. Indus basins is further divided into sub-basins, these are Upper Indus Sub-Basin, Central Indus Sub-Basin and Lower Indus Sub-Basin. Research is focused on Central Indus Basin which is sub-part of Indus Basin. Central Indus Basin is divided into three parts these are Sulaiman fold belt, Sulaiman depression, Punjab platform. These divisions are based on depositional pattern and sedimentology of Central Indus Basin. The study area Dhandi is based on Central Indus Basin in Platform area which is a stable area. While Baluchistan basin is divided into Baluchistan Sub-Basin and Pishin Sub-Basin (Kazmi & Jan, 1997).

1.1 Data availability

Data is provided by LMKR (Land Mark Resources Pvt,Ltd.), with approval of Directorate General of Petroleum Concessions (DGPC). One well is given for research that is Sabzal-01. This well lies near the line G846-DAN-205 in Dhandi area. Sabzal-01 is dry well. Geological and geophysical studies in Central Indus Basin provides extensive information about reservoir formations (Kazmi & Jan, 1997). The location of Sabzal-01 is 28° 5′ 30″ N and 69° 57′ 39″ E.

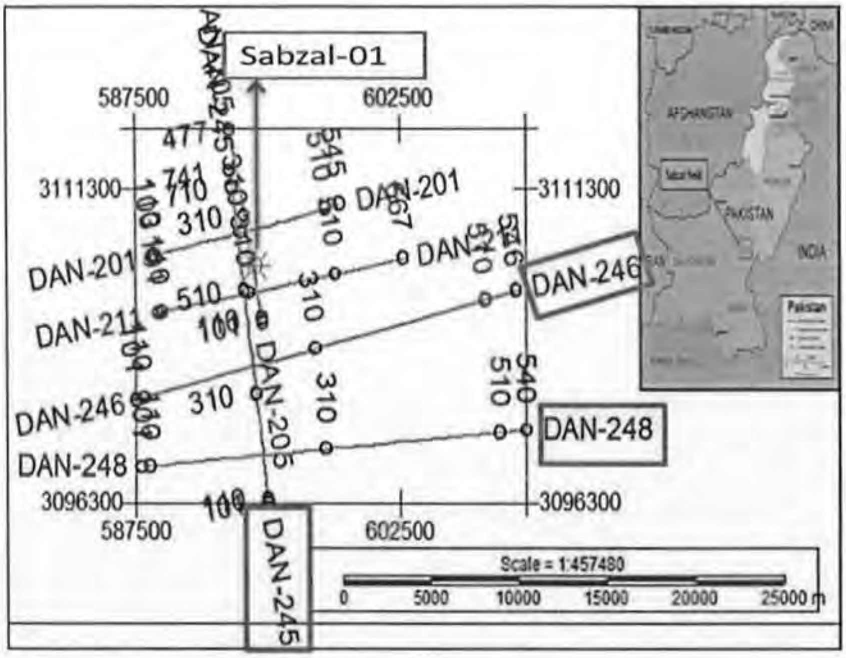

Figure 1.1 Base map of seismic lines and well Sabzal-01.

This area can be approached by N-5 highway that connects to Ghotki district which leads to Rahim-Yar-Khan then to Sabzal field area. The field area is 53kms away from Rahim-Yar-Khan in the direction of SE.

Table 1.1 shows seismic lines used for construction of base map of study area. The red coloured lines are lines of interest.

Table 1.1 Seismic lines with direction and type

S.No.	LINE NO.	ORIENTATION	TYPE
1	G846-DAN-201	NE-SW	dip
2	G846-DAN-205	NW-SE	strike
3	G846-DAN-211	NE-SW	dip
4	G846-DAN-245	NW-SE	strike
5	G846-DAN-246	NE-SW	dip
6	G846-DAN-248	NE-SW	dip

The logs provided in Sabzal-01 are Caliper log (CALI), Gamma ray log (GR), Spontaneous potential (SP), Neutron porosity log (NPHI), Sonic log (DT), Density log (RHOB), Photoelectric log (PEF), Latero log shallow (LLS), Latero log deep (LLD) and Micro spherically focused log (MSFL).

1.2 Objective of research

The objective of research is to determine the hydrocarbon potential of Sabzal-01 with the help of petrophyiscal analysis using wireline logs.

The main proposed objective of this studies are:

- To interpret the structures and stratigraphy on sesimic lines.
- To create Time and depth maps of the formations.
- Seismic Attributres analysis to aid the interpretation of seismic data.
- Perform petrophysical analysis to find Hydrocarbon Saturation in Reservoir Formation.
- Perform Facies analysis to indicate the lithology details of the reservoir formation.
- Coloured inversion to investigate the variation in relative acoustic impedence at reservoir level.

1.3 Work Flow

To achieve the objectives of this research, proposed methodology covers following steps;

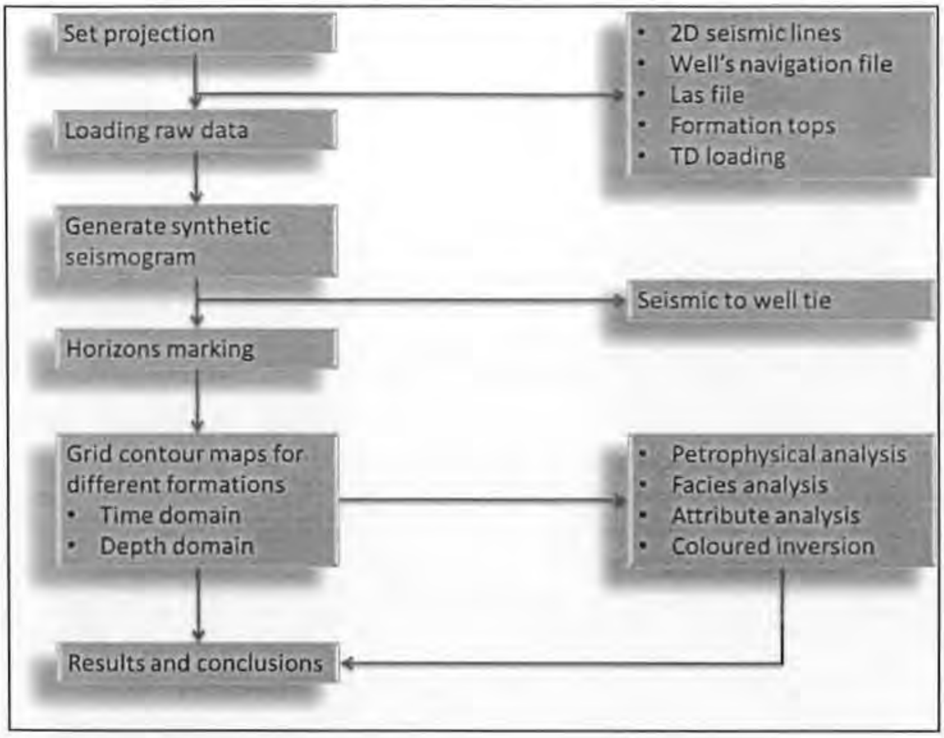

Figure 1.2 Basic steps followed for Research project.

1.3.1 Methodology

- Load SEG-Y of 2D seismic lines with line navigation and well data which includes navigation of well, formation tops and well logs.
- Generate synthetic seismogram and correlate well and seismic data.
- Mark horizons named as Pirkoh, Sirki, Habib Rahi and Ghazij.
- Prepare contour maps for various Formation in Time and Depth Domain.
- Attribute analysis to aid interpretation of seismic data.
- Petrophysical analysis to calculate volume of shale, porosity, hydrocarbon saturation on the basis of given well logs.
- Facies analysis to indicate the lithology details of the reservoir formation.
- Coloured inversion to investigate the variation in relative acoustic impedence at reservoir level.
- Results and conclusions.

CHAPTER 2

GEOLOGY AND TECTONICS OF THE AREA

2.1 Introduction

Pakistan has been geologically well-known for its great mountains, Extensive glaciers etc.These geologic features had been largely revealed by the surveys of the early pioneers who explored vast areas despite the lack of proper topographic base maps (Kadri, 1995). Tectonicaly, Indian plate is bounded by 4 major tectonic plates. North of the Indian plate is the Eurasian plate, to the south east, the Australian plate, to the south west, the African plate and to the west the Arabian plate. About 65 million years ago, Indian plate was separated from Madagasar plate in late Cretaceous-early Paleocene age (70-65 Ma). Then swiftly moves towards Eurasian plate in Oligocene age (33.9-23.03 Ma) due to rise of mantle plume, it created twists. Then in Miocene age (33.03-5.333 Ma) collision between Eurasian and Indian plate was completed and Himalayan mountain chain (which contains the highest peaks on the Earth today) were formed along with Indus fan and small plates in the eastern boundary of the Indian plate. Central Indus Basin and Chaman faults were also formed as a result of this collision.

Reseasrch work is focused on Central Indus Basin as mentioned in chapter 1. Geologically, Habib Rahi formation is a reservoir formation.

2.2 Tectonics Of Central Indus Basin

Central Indus Basin is very important in petroleum prospective. The basin is separated from Upper Indus Basin by the Sargodha High & Pezu uplift in north as shown in figure 2.1. It is bounded by Indian shield in the east, marginal zone of Indian Plate in the west, and Sukkur Rift in south (Kadri,1995).

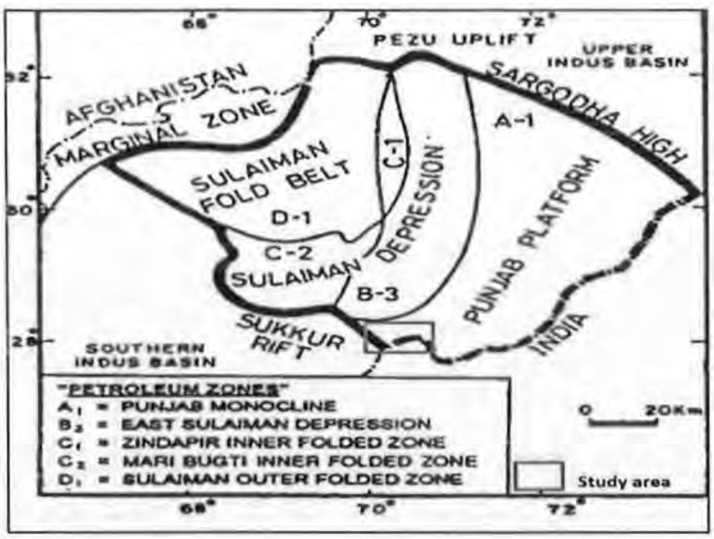

Figure 2.1. Tectonic division of Central Indus Basin (Kazmi & Jan, 1997).

The structural style of the Central Indus Basin is obscured at surface by thick alluvial cover. The oldest rocks exposed in this basin are of Triassic age(252-201 Ma) (Wulgai Formation) while the oldest rocks penetrated through drilling are of Precambrian(4600-542.0 Ma) Salt Range Formation. The depth to the basement is about 15000 meters in the trough areas. The geological structures in Central Indus Basin was formed due to basement uplift and collision between Eurasian (Afghan micro plate) plate with Indian plate. Central Indus Basin is divided into following broad tectonic divisions from east to west (Kadri, 1995).

- Sulaiman fold belt
- Sulaiman depression
- Punjab platform.

2.2.1 Sulaiman fold belt

The Sulaiman fold belt is the major tectonic feature in the proximity of collision zone therefore it contain large number of disturbed anticlinal features. In the figure 2.1, D-1 shows Sulaiman fold belt. The decollement zone in this part are possibly provide by shales. In this region oldest rocks of Lower Indus Basin(Triassic-Wulgai Formation) are exposed. The most important lithostratigraphic variations observed in Sulaiman fold belt are in paleocene/eocene. The reason of this varation is believed to be the presence of number of new basins at that time,created due to collision of plates (Kadri, 1995).

2.2.2 Sulaiman depression

Sulaiman depression is also called Sulaiman fore deep. The Sulaiman foredeep is structurally interpreted as a gently dipping, broad syncline. In the figure 2.1, B-3 shows Sulaiman depression. Several salt co-anticlines are present in the foredeep. These salt basement structures may serve as possible hydrocarbon exploration prospects (Kadri, 1995).

2.2.3 Punjab platform

It is tectonically stable area. Regional scale monocline dipping gently towards Suleiman depression. In the figure 2.1, A-1 shows Punjab monocline. Tilted eastward in Paleozoic time due to non-orogenic movements. Tilted westward since Mesozoic due to collision of Indian and Eurasean plate. (Kadri,1995) describes this part as the eastern segment of Central Indus Basin where no surface outcrops of sedimentary rocks are present. Punjab Platform is tectonically the least affected area because of its greater distance from collision zone. A number of wells have been drilled on this platform. The stratigraphic sequence established on the basis of these wells revealed some of the most significant stratigraphic pinch outs in Pakistan.

2.3 Stratigraphy Of Sabzal-01

Stratigraphy of Central Indus Basin includes formations from Cretacious to Pliocene time., mentioned in figure 2.2. Some of the formations which are not encountered in Sabzal-01, those are either Pinched out or terminated before reaching the well. Only one well can not show these factors. Given below are the discription of those formation which are encountered in well.

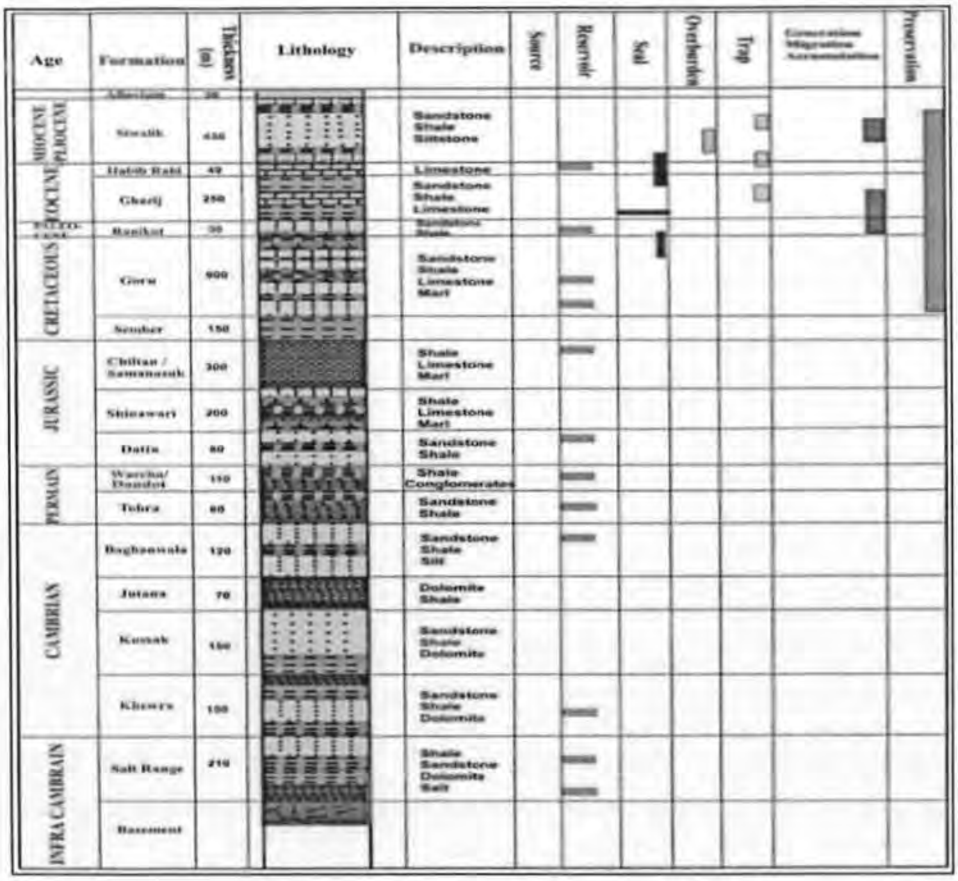

Figure 2.2 Stratigraphy of Central Indus Basin (Khalid et al, 2014).

The oldest stratigraphy unit drilled in the Sabzal-01 is the early Cretaceous Sembar Formation which is followed by Lower and Upper Goru, Parh and Pab formations. Cretaceous sequence is overlained by Paleocene (lower and upper) Ranikot formations. Eocene includes Sui Main Limestone, Ghazij formation, Habib Rahi Formation, Sirki Formation, Pirkoh Formation and Darzinda Formation. Eocene is then followed by Siwalik Formation.

2.3.1 Sembar Formation

The Age of Sember Formation is early Cretaceous. This Formation mainly consists of black shale with interbeded siltstone, argillaceous limestone and sandy shale is present at basal part. Its lower contact is unconformity because the formations of Jurassic and Triasic age are not encountered in our well but they are present as major trend in Central Indus Basin while the upper contact is generally gradational with the Goru formation. Its type locality is 2km south east of Sember pass in the Mari-Bugti area of Sulaiman province (Shah, 2009).

2.3.2 Goru Formation

The Age of Goru Formation is early Cretaceous. Goru Formation is comprises of interbeds of limestone, shale and siltstone. The limestone is fine grained and thin bedded (Shah, 2009). Sand beds is also present is this formation. Limestone is dominant in the lower and upper parts of the formation. The Goru Formation is widely distributed both in the Kirthar and Suleiman provinces. The lower contact with the Sembar Formation is conformable. The upper contact with the Parh Limestone which is transitional (conformable). The type locality is near Goru village on the Nar-river in southern kirthar range. Goru formation is 536m thick at its type locality (Shah, 2009).

2.3.3 Parh Formation

The age of Parh limestone is early cretaceous. The Parh limestone is a lithological very distinct unit. It is a hard, light grey, white, cream, olive green, thin-to-medium-bedded, occasionally platy to slabby limestone, with subordinate calcareous shale and marl intercalations. The type area lies in Parh range in upper reaches of Gaj river. In the type area its thickness is 268m (Shah, 2009). Its lower contact is with Goru formation and upper contact is unconformity because two formations (Fort munro and Mughalkot) of Late Cretaceous are not encountered in our well but they are present in Central Indus Basin in major trend.

2.3.4 Pab Formation

The age of Pab formation is late Cretaceous. Its type locality is along the route samalji trail across the Pab range. Its thickness is 490m in type locality (Shah, 2009). The sandstones of Pab are generally fine to medium grained with significant proportion of coarse grains, sub-angular to sub-rounded, moderately to well sorted, and mostly well cemented with traces of pyrite and Glauconite (Shah, 2009). The fragments of limestone, claystone, and siltstone are present in sandstone. Sandstones of Pab are cross bedded in various intervals with intercalations of mostly shale/claystone, occasionally siltstone, carbonaceous shale, and pebbly sandstone. Its lower contact is unconformity because two formations (Fort Munro and Mughalkot) of late Cretacious are not encountered in our well but they are present in

Central Indus Basin in major trend and upper contact is with Ranikot formation (Mughal et al., 2012).

2.3.5 Ranikot Formation

The age of this formation is Paleocene. The lower part of the group consists of olive, yellowish brown sandstone and shale with interbeds of limstone. The upper part of this group consists of grey limestone and grey to brown sandstone. It contains Lakhra, Bara and Khadro formations as members. Type locality of this group is Kirthar province. The thickness ranges from 540 to 660m. Its upper is unconformity because Dunghan formation of pleocene is not encountered in our well but it is present in Central Indus Basin in major trend and lower contact is with Pab formation.

2.3.6 Laki Formation

Laki formation represents sui main limestone. The age of Laki formation is Eocene. The type locality is Mara Nai southwest of Bara Nai of Laki range. It is 240m thick in type locality.The formation consists mainly of cream colored to grey limestone but marl, calcareous shale, sandstone and lateritic clay may become significant constituents of the formation locally (Shah. 2009). this formaton has two members these are Sohnari member and Chat member.

The Sohnari member consists of clay and shale with locally developed beds of yellow limestone. The member is basal part of Laki formation and directly overlies Ranikot group.

The Chat member consists mainly of creamy white nodular limestone in the lower part and inter-bedded shale and limestone with sandstone in the upper part (Shah, 2009). The upper contact of Laki formation is conformable with Kirthar formation.

2.3.7 Ghazij Formation

The age of Ghazij formation is Eocene. This formation is widely develped in Sulaiman province.It consists of olive,brown and yellow shale shale and green ,grey and brown sandstone with interbeds of limestone and conglomerate. The lower contact of this formation is sui main limestone and upper contact is unconformity because Baska shale of Eocene is not encountered in this well (Shah, 2009).

2.3.8 Habib Rahi Formation

The age of Habib Rahi formation is Eocene. The type locality is along east flank of Suleiman range and as well as north and south of Waziristan. The thickness ranges from 15 to 60m (Shah, 2009). This member consists of pale grey, buff and brown limestone. There are nodules and thin, discontinues beds of chert in the upper part. The upper part of the member is rubbly and massive, the middle is thick bedded and the lower is massive. The lower contact is unconformity because Baska shale of Eocene is not encountered in our well and upper contact is with Sirki formation.

2.3.9 Sirki Formation

The age of Sirki formation is Eocene. This member consists of shale. The upper conformable contact of Sirki formation is Pir koh formation and lower transitional contact is with Habib rahi formation. The type locality is in west of Domanda and fort sandeman. This formation is 130m thick near Domanda.

2.3.10 Pirkoh Formation

The age of this formation is Eocene. The type locality is Pirkoh anticline. The formation is 135m thick in Pirkoh area.This member consists of intergrading limestone and marl that are light grey to chalky white. The upper contact is with Darzinda formation and lower contact is with Sirki formation (Shah, 2009).

2.3.11 Drazinda Formation

The age of this formation is Eocene. The type locality is desighned near Darzinda is by hemphill and kidwai(1973). It is 500m thick in Darzinda area.This member consists of brown, grey and chocolate clay stone and silty shale. Some calcareous shale and marl are present in the lower part (Shah, 2009). The upper contact is unconformity and lower contact is with Pirkoh formation.

2.3.12 Siwalik Formation

The age of Siwalik formation is Pliocene. No type locality has been designed for the group so far. This formation consists of red clay with sandstone at the base which is overlain by thick sandstone and minor clay. This formation is bounded above and below by unconformity because Gaj formation of Miocene and Lei conglomrates of Pleistocene are not encountered in our well but these are present in Central Indus Basin in major trend (Shah, 2009).

2.4 Exploration History Of Sabzal Field

The study area lies in Central Indus Basin,is Sabzal-01. This area (Sabzal-01) is taken to get acuity of hydrocarbons potential of Central Indus Basin. The tectonics, stratigraphy and hydrocarbon potential are based on data obtained from study of outcrops and well drilled in the area. Geological and geophysical investigations were carried out by OGDCL and other oil companies in Central Indus Basin to locate the structural traps for oil and gas. Thirty-five exploratory well were drilled in Central Indus Basin and eleven discoveries were made. So the ratio of discovery well to exploratory well in Central Indus Basin will be:

Ratio= discovered well/exporatory well

Exploration ratio = 11/35

Ratio of discovery is 0.314 or 31% in Central Indus Basin (S.M.Shuaib, S.M.Hasnain 1993).

The petroleum exploration was started in Central Indus Basin in 1983. Later, 420 lines of 2D siesmic survey was carried out in 1990 and 1998 by OGDCL. In Sabzal area, limestone of eocene age are the main gas producing reservoirs. Most of the gas wells have been drilled in Sui Main Limestone, as it is a main producer.

Figure 2.3 Location of Sabzal field (Cole, 2008).

2.4.1 Petroleum play in study area

There are 7 stages of petroleum play. First stage is debris or organisms. They deposited first then in antoxic condition they become decomposed. In decomposition, if pressure and temperature reaches 60-120 degree then dead organism will converted into kerogen this stage is called kitchen (source rock). The time in which organisms get mature enough to be converted in kerogen is known as time period. Then there is migration. It includes primary migration (within source rock) and secondary migration (source rock to reservoir rock). After that there is reservoir rock, where hydrocarbons are deposited. Then there is seal rock, that acts as a barrier to further migration of hydrocarbon liquids. After that there is Trap, is of two types, structural traps are Hydrocarbon traps that form in geologic structures such as folds and faults, stratigraphic traps are Hydrocarbon traps that result from changes in rock type or pinch-outs, unconformities and other sedimentary structures .

2.4.1.1 Source rocks

The Sembar is the most likely source for the largest portion of the produced oil and gas in the Indus foreland. The Lower Cretaceous Sembar Formation consists mainly of shale with subordinate amounts of siltstone and sandstone. The Sembar was deposited over most of the Greater Indus Basin in marine environment. Ghazij and upper Ranikot also act as source in Central Indus Basin. Lower Goru has moderate source rocks.

2.4.1.2 Reservoir rocks

In Sabzal area, limestone of Eocene age are the main gas producing reservoirs. Most of the gas wells has been drilled in Sui Main Limestone, as it is main producer. Pirkoh, Lower Ranikot, Habib rahi Formation, Pab and Lower Goru also act as reservoir rocks.

2.4.1.3 Seal rocks

The thick sequence of shale and marl of Upper Goru Formation serves as cap rock for underlying Lower Goru reservoir. Darzinda, Ghazij, Upper Ranikot and Sembar also act as seal rocks.

CHAPTER 3
DATA ACQUISITION

3.1 Seismic Data Acquisition

Seismic acquisition starts with a clear goal in mind of what the geoscientists want to image in the sub-surface. The objective of seismic data acquisition is to obtain data that can be related to the structural image of the sub-surface geology for the purpose of locating oil and gas traps. Before seismic acquisition is carried out, the area or location where the exploration activities will take place is surveyed by a surveyor and the seismic line is accurately marked out by the surveyor. The lines serve as paths for preparing shot holes and laying of cables for recording. Global Positioning System (GPS) and total stations are used for setting out the lines. The survey lines usually form grids of 500 –500m spacing (Onajite, 2014).

Acquisition parameters related to my study area are not given so for the sequence of the study general acquisition is discussed.

3.2 Seismic Sources

Seismic source is a device that provides acoustic energy for acquisition of seismic data. There are two types of sources these are land source and marine source. Land source is divided into impulsive sources (Dynamite etc) and non-impulsive sources (vibroseis etc). Marine source includes Air gun etc (Suroor, 2010).

Onshore seismic data are acquired using an explosive energy source, such as dynamite. Dynamite is used as the seismic source to generate acoustic waves that are sent into the sub-surface. The detonation of an explosive (dynamite) is referred to as the seismic 'shot'. The seismic shots are normally placed below the weathered (low velocity) layer of the earth. Shot holes are drilled at shot points and dynamite is placed in the holes (Onajite, 2014).

In vibroseis system, energy is produced by the pad pressed firmly to the ground, which vibrates in a controlled way. A typical truck mounted vibrator is pictured in figure

3.1. The pad, which is about one meter square, is attached beneath the truck by hydraulic jacks. Extending these jacks allows part or all of the weight of the truck to be used to press the pad to the ground. Then an oscillatory pressure fluctuation is trasmitted through the jacks to the pad, causing it to vibrate at a fixed amplitude. These fluctuations driving the pad is monitered by an electronic oscillator (Robinson, 1988).

Figure 3.1 Vibroseis (Robinson, 1988).

Air gun is constructed with two air chambers in a cylinder, connected by piston assemly. Pumping compressed air into these chambers causes a pressure difference to develop, which forces the piston to move. At a critical pressure the movement of piston opens parts through which a burst of air is released from the lower chamber. This sudden burst of air produces seismic waves in the water by creating pressure pulse (Robinson, 1988).

3.3 Signal And Noise In Seismic Exploration

The aim of seismic data acquisition is to obtain data that contain only primary, reflected waves. But this is not possible because the generation of unwanted waves is inevitable during seismic data acquisition. Any rays in a seismic record other than primary reflections are called noise (Onajite, 2014).

3.3.1 Types of noise

There are two kinds of noises found in seismic data: random noise and source-generated noise. Random noise is noise generated by the acquisition truck, vehicles, people working in the survey area etc. This noise appears in a seismic record as spikes as shown in figure 3.2. In a marine acquisition, random noise can be created by ship propellors, drilling during acquisition and wind/tidal waves (Onajite, 2014).

Source-generated noises are coherent noise trains and they exist in an organized form from trace to trace and yet they contain no geologic information. This noise is in the form of surface wave. Source generated noises noticed in seismic records are ground roll, direct rays, ghost reflections, and multiple reflections (Onajite, 2014).

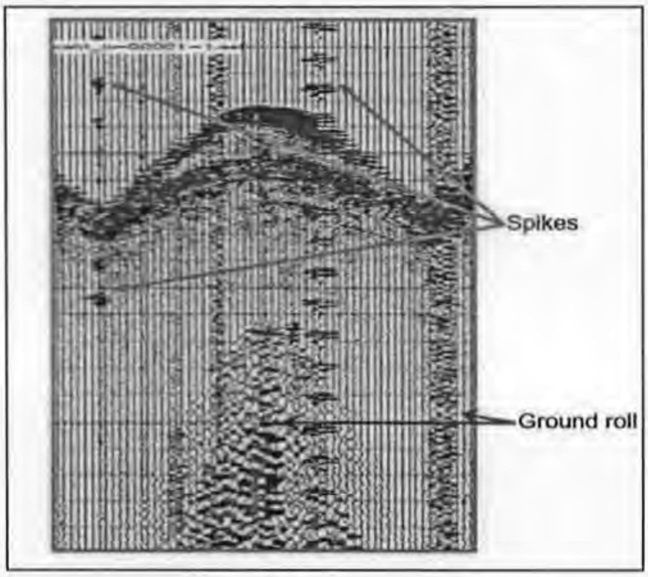

Figure 3.2 Two types of noises can seen on the seismic record (Onajite, 2014).

3.4 Recording Instruments

Seismic recording is done using a device that detects seismic energy in the form of ground motion or a pressure wave in fluid and transforms it to an electrical impulse. There are two types of recording instruments one is onshore recording instrument (geophones) and the other is marine recording system (hydrophones).

3.4.1 Geophones

Onshore seismic data are recorded using a simple electro-magnetic device known as geophone, shown in figure 3.3.

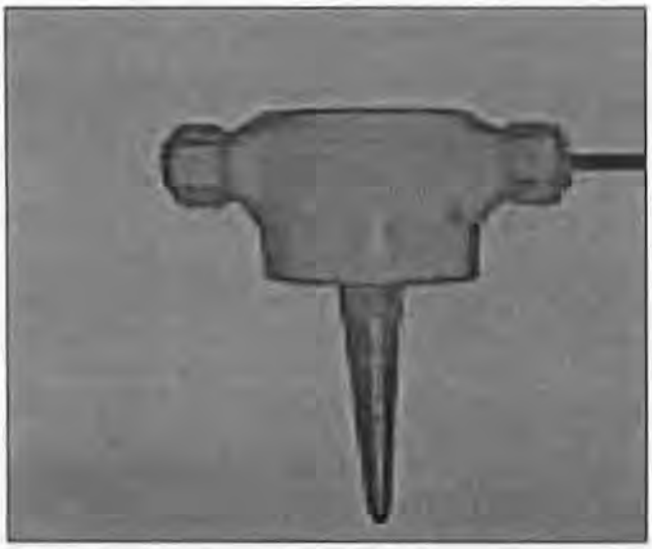

Figure 3.3 A geophone (Onajite, 2014)

Geophone is used, both onshore and on the seabed during marine seismic acquisition, to detect ground velocity produced by acoustic waves and transform the motion into electrical impulses. The geophone generates current that is proportional to the particle velocity of the earth. The electrical current flows out of the wires connected to the geophones and goes to an analogue-to-digital converter to form digital data.

3.4.2 Hydrophones

The hydrophone detects changes in pressure that are created as sound waves from the airguns bounce off geological strata beneath the seafloor. Hydrophones used in marine recording use a pressure-sensitive device to record the incoming energy. Hydrophones are connected together in groups in the streamer and may be placed 6 m apart. Complex electronics within the streamer filters the incoming signal from a whole group of hydrophones and then converts the resultant voltage into a digital format (Onajite, 2014).

3.5 Basic Spread

The arrangement of geophones that is used to record seismic waves is called a spread. Spread is designed with respect to shooting procedure. There are number of configurations used in reflection profiling these are, end spread, In-line offset spread, Split spread, Cross spread and L-spread.

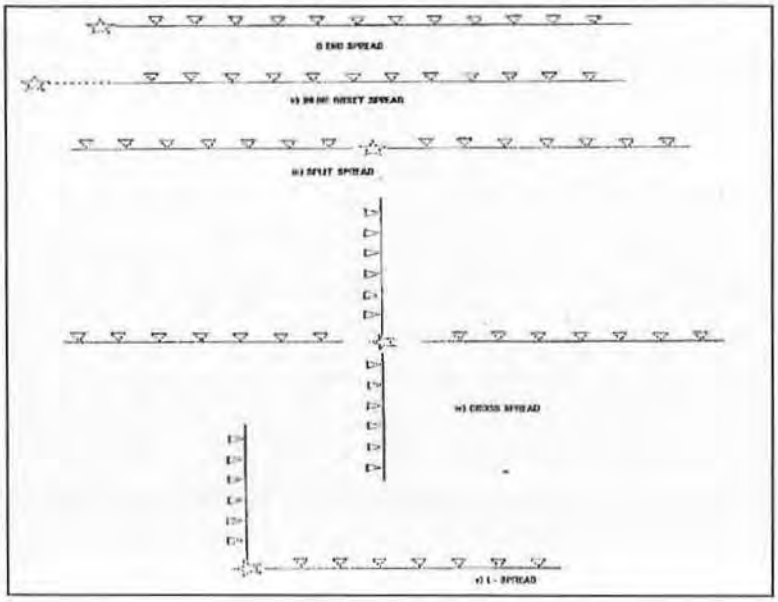

Figure 3.4 Different spreads types commonly used in field (Robinson, 1988).

CHAPTER 4

DATA PROCESSING

4.1 Seismic Data Processing

Seismic processing is the alteration of the acquired data to suppress noise, enhance the recorded seismic trace and migrate the seismic trace to its correct location in space and time. Processing steps include static corrections, deconvolution, normal moveout, velocities analysis, dip move-out, CMP/CDP stacking and migration, which can be performed before or after stacking. The objective of seismic data processing is to remove all noise and distortions introduced during the seismic acquisition method and produce a seismic section as close as possible actual subsurface image of the earth that can be interpreted (Onajite, 2014).

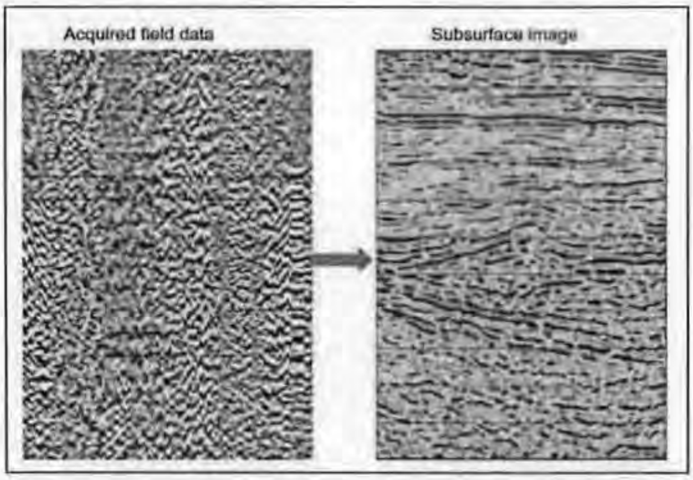

Figure 4.1 Objective of seismic data processing (Onajite, 2014).

The SegY data which is provided by LMKR is lacking with the basic seismic informations such as, Acquisition parameters, Processing parameters, Spread geometries etc. For that reason current dissussion is based on the general standards which are mentioned in various literatures.

4.2 Processing Sequence

Basic processing covers following steps as shown below:

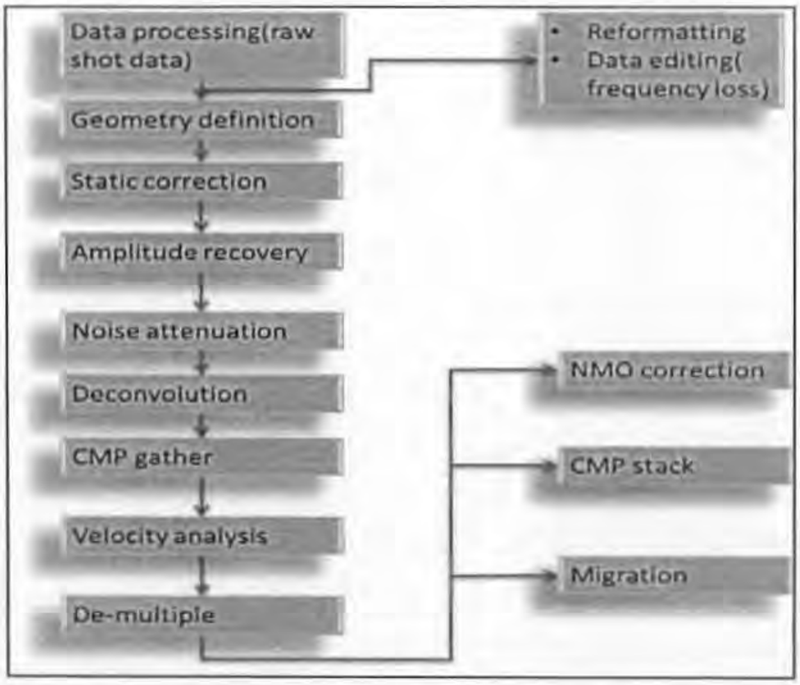

Figure 4.2 Generalized flow chart of processing perameters, which are use to improve signal to noise ratio.

4.2.1 Raw shot data

The acquired seismic data contains lots of noise. Raw data gives us information about type of noise, how much reflection are strong and what will be strategy to remove noise, to preserve frequency and amplitude. This data has different recording sequence, data volume and parameters.

4.2.2 Geometry definition

Geometry means where are the shots and reciever located. It also include lattitude, longitude, elevation, receiver spread etc.

4.2.3 Static correction

Statics correction is a bulk time shift applied to the recorded seismic trace during data processing. Static corrections are applied to remove the effect of variation in the weathered layer and any changes in the near surface that causes trace-to-trace time difference. Static corrections are calculated by picking the first arrivals. It is usually auto-picked by a computer (Onajite,2014).

4.2.4 Seismic Attenuation

This attenuation influence the wave amplitude and reflection coefficient. But the geophysicists want to preserve true seismic amplitude because they contain information about the subsurface geology. So the technique amplitude recovery is used to balance the seismic data and remove these amplitude effects (Onajite, 2014). Normally actual signal data ranges from 8-80 Hz, rest is noise. In processing, that 8-80Hz data is recovered.

4.2.5 Deconvolution

The processes of deconvolution start with the convolutional model of the seismic trace in time domain. Mathematically, convolution is given by St= Rt * Wt + noise. Deconvolution reverses the process used to acquire the seismic trace and begins with the recorded seismic trace. By definition,deconvolution is the separation of the earth reflectivity and the source wavelet or the shortening of the source wavelet to a signal as short as possible. This is done by compressing the source wavelet. Deconvolution is given by St * (Wt)^-1 = Rt (Onajite, 2014).

4.2.6 CMP Gather

Common depth point defines as sum of traces which correspond to the same subsurface reflection point but have different offset distances. At this step, we gather these CDP traces & then integrate all of these traces as one trace (Stacking) (Sroor, 2010).

4.2.7 Velocity Analysis

Velocity analysis is the process whereby the velocity that flattens the reflection hyperbola on a CMP/CDP gather is determined. The velocity is called the stacking velocity. In velocity analysis, velocities are picked at selected locations along the seismic section and the results are linearly interpolated from one analysis location to the other as long as the picks are from the same reflector and the same reflection time (Onajite, 2014).

4.2.8 De multiple technique

In this technique, Before NMO correction, both primary and multiple reflections have hyperbolic move-out curves. After NMO correction was applied with the velocity of the primary reflections, the multiples are all under-corrected while the primary events are flattens. If we apply the multiple velocity function to correct a CMP gather, the primary reflection will be overcorrected. The multiple reflections always have more move-out, that is, curvature than the primary reflections. It is this differential move-out between the primary reflections and multiples that help in removing multiples (Onajite, 2014).

4.2.9 NMO Correction

The NMO correction is defined as the time-shift that is applied to each seismic trace within a CMP gather in order to make all the traces from a particular reflector equal in time. The correction depends on the layer velocities (Onjite, 2014).

4.2.10 CMP Stack

Stacking is the process whereby traces are summed to improve the signal-to-noise ratio, reduce noise and improve seismic data quality. Traces from different shot records with a common reflection point, such as common midpoint(CMP) data, are stacked to form a single trace during seismic processing. Stacking reduces the amount of data by a factor called the fold. In CMP stack, noise is attenuated by adding all the geophones output with the same reflections' point but different random noises (Onajite, 2014).

4.2.11 Migration

A step in seismic processing in which reflections in seismic data are moved to their correct locations in the x-y-time space of seismic data, including two-way travel time and position relative to shot points. Migration improves seismic interpretation and mapping because the locations of geological structures, especially faults, are more accurate in migrated seismic data. Types of migration are time migration and depth migration which includes pre stack depth and post stack depth migration (Sroor, 2010).

CHAPTER 5

2D SEISMIC INTERPRETATION

5.1 Introduction

In this chapter synthetic analysis is performed by loading well data which includes navigation of well, formation tops and logs loading. Interpretation is done to interpret resultant data and to delineate areas in the subsurface which could hold hydrocarbons. This includes structure, stratigraphy, subsurface rock properties etc.

The main application of the structural analysis of seismic section is in the search for structural traps containing hydrocarbons. A structural trap is a type of geologic trap that forms in a subsurface, due to tectonic, diapiric, gravitational and compaction processes. Whereas The main aim of the stratigraphic analysis of seismic section is in the search for stratigraphic traps containing hydrocarbons. Stratigraphic traps are formed when there are changes in lithology, nature of the strata or depositional pattern. They prevent continued migration of hydrocarbons within reservoir beds (Onajite, 2014).

5.2 Data Loading

Segy data is loaded which is post-migrated data. Six seismic lines are given. Well Sabzal-01 is located near line 846-DAN-205.

5.2.1 Seismic Data Loading

Firstly, the projection is adjusted. The Zone 42N and UTM projection is used. Then seismic data is loaded which is 2D seismic lines with line navigation. The short space is 1 and data is loaded in short sequence domain, for navigation. A small window of short point data file will pop-up, skip first 50 lines for required data then select line name, shot point, X and Y. Now import SEG-Y file into single 2D or 3D survey. Then select survey, data type name (amplitude), define trace numbers (trace sequence number by counting), set time bounds (sample interval, no. of traces, start and end time of imported trace and scale(1)). Then set output data format that is 16-Bit, seismic line has been loaded now assign 2D shot points to traces (starting shot points are 103 and trace per shot is 1).

5.2.2 Well Loading

Then well is loaded which includes navigation of well, formation tops and TD loading. The navigation of Sabzal-01 is 28° 5' 30'' N and 69° 57' 39'' E. The well is dry exploratory well. Well data includes well name(Sabzal-01), well number (1), borehole name (main), location unit (decimal deg), UWI (860), well symbol, latitude (28.091), longitude (69), start depth (289.0118), end depth (3640.5925), surface elevation (0) and total depth (3640.5925).

Now select tops option in menu bar, import formation tops. Browse file then import formation top data in line order, use UWI as it exists in import data. Now short window of formation file will pop-up, lines to skip (1), select formation top name and depth.

Then select well and borehole for data and depth type (MD). For loading LAS file, import single LAS file. A short window will pop-up, browse file name, select well name, borehole name, UWI matching criteria, merging operation (add new curve only). Apply all adjustments.

5.2.3 T-D chart

For generating synthetic seismogram, TD values are extracted, and TD chart is created. The seismic refference datum is 0. Formation tops depth are given. From that depth we subtracted KB value which is 78.82m. Then all that depths are located on TD and DT log is used to extract time for given formation at given SRD depth. Table 5.1 shows all Formations with their depths that are used in TD loading.

Table 5.1 Depths of all Formations' tops.

S.no	Formations	Well tops (m)
1	Siwalik	0
2	Drazinda	693
3	Pirkoh	737
4	Sirki	827
5	Habib Rahi	894
6	Ghazij	1003
7	SML	1327
8	Upper Ranikot	1613
9	Lower Ranikot	1680
10	Pab	1723
11	Parh	2045
12	Upper Goru	2548
13	Lower Goru	2955
14	Sembar	3385

For velocity computation formula is given in equation 5.1,

$$V=\frac{1}{DT} \text{ (Rider, 2002)} \qquad (5.1)$$

Units are also converted from micro-seconds per feet to meter per second using [(10^6) / (3.28)] (Rider, 2002).

After that, Time is computed using equation 5.2,

$$\text{Time}= \frac{\text{Depth}}{\text{Velocity}} \text{(Rider, 2002)} \qquad (5.2)$$

From this time, two-way travel time (TWT) is calculated using formula 5.3,

$$\text{TWT}= \text{Time*2 (Rider, 2002)} \qquad (5.3)$$

TD chart covers following steps,

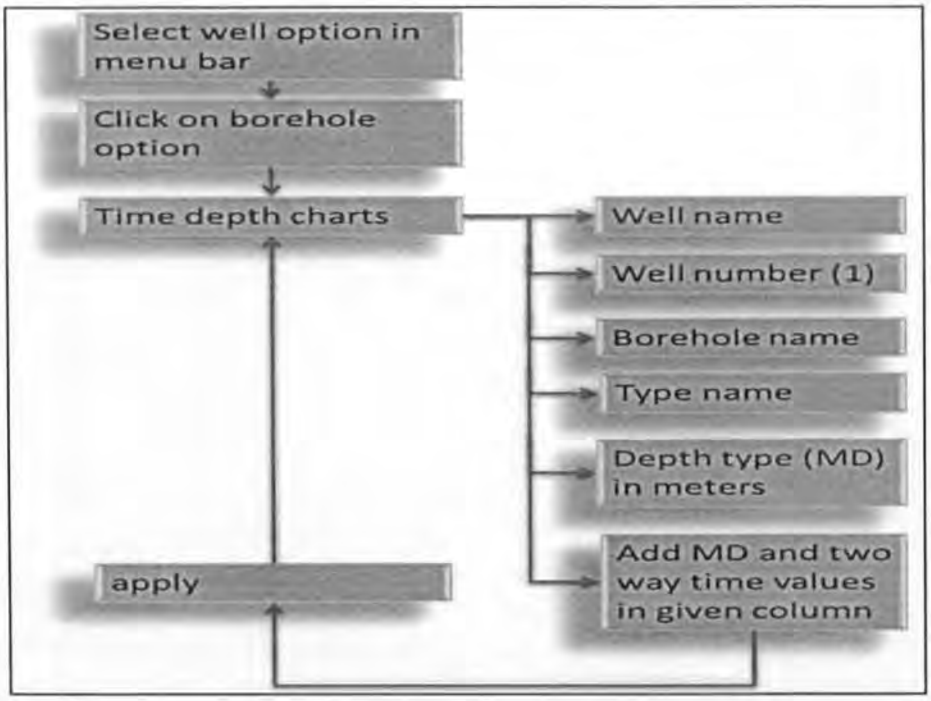

Figure 5.1 Basic flow chart for generating Time Depth chart.

Now all data is been loaded and this to generate synthetic seismogram.

5.2.4 Synthetic seismogram

Once the TD chart is created, synthetic seismogram is generated. Synthetic seismogram is a seismic trace created from sonic log and density log and it is used to compare the original seismic data collected near the well location. The prerequisites of synthetic seismogram are TD chart, Density log RHOB and sonic log DT.

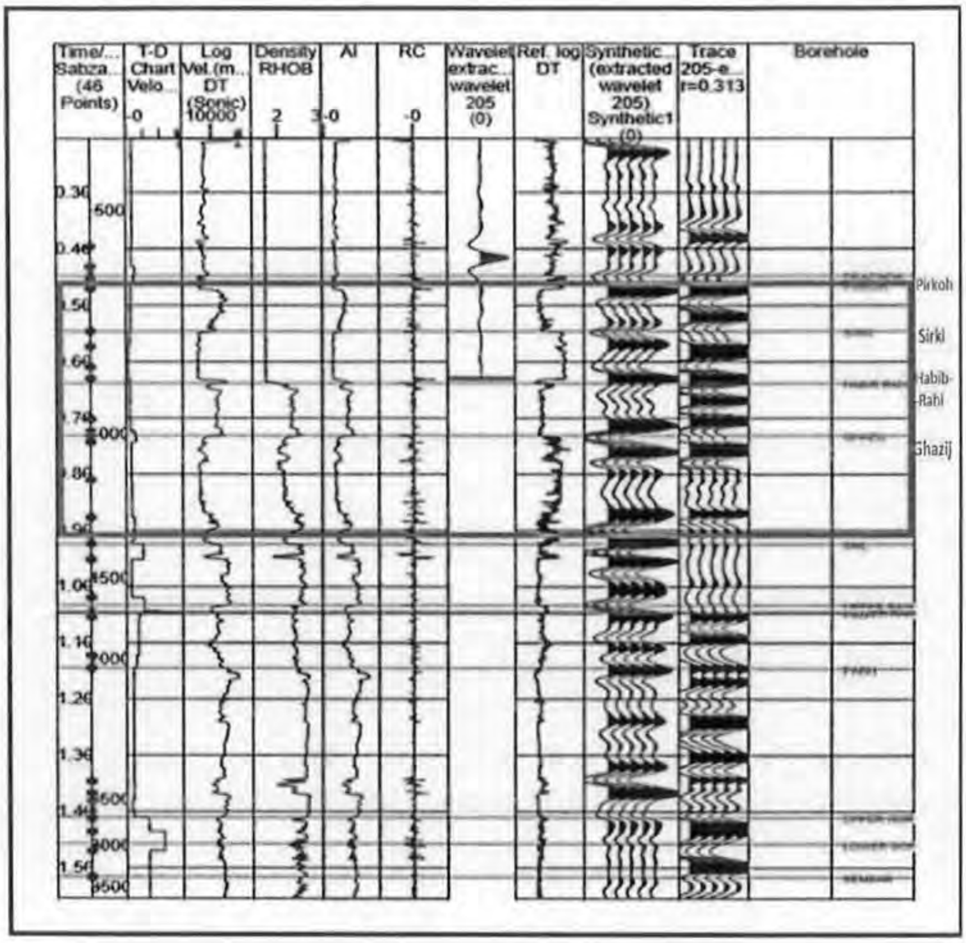

Figure 5.2 The synthetic seismogram.

The red box marked in figure 5.2 shows zone of interest. This zone covers four formations named as, Pirkoh, Sirki, Habib Rahi and Ghazij. Synthetic seismogram covers following steps,

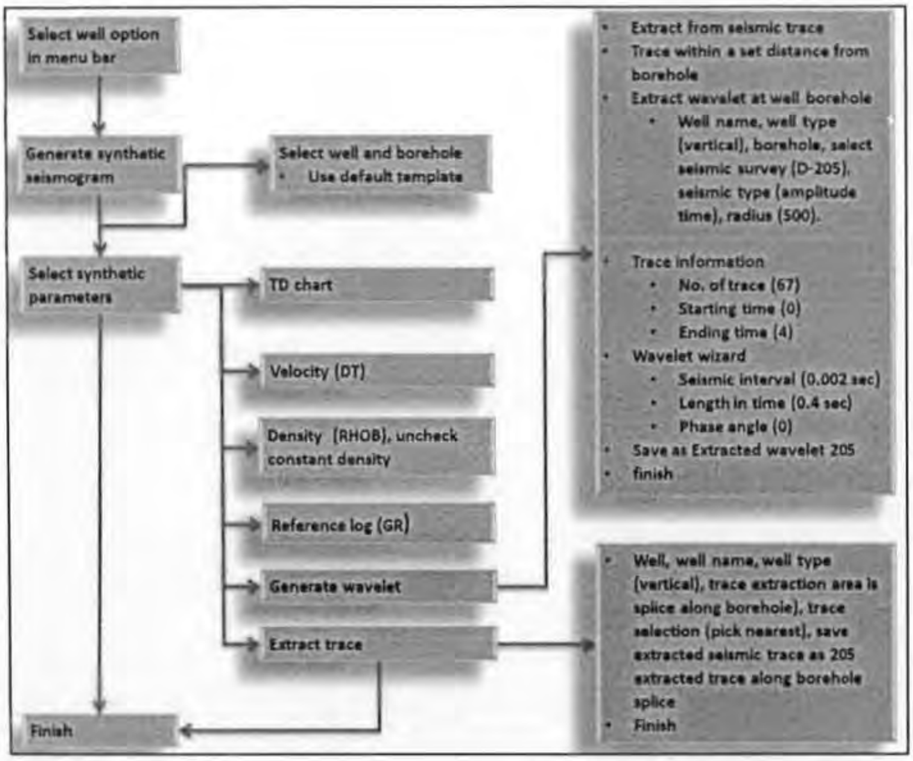

Figure 5.3 Steps for generating synthetic seismogram.

5.2.5 Horizon marking

Seismic horizon interpretation implies picking and tracking laterally consistent seismic reflectors with the aim to detecting hydrocarbon accumulations, delineating their extent, and calculating their volumes (Onajite, 2014). Four horizons are marked and these are Pirkoh, Sirki, Habib Rahi and Ghazij formations.

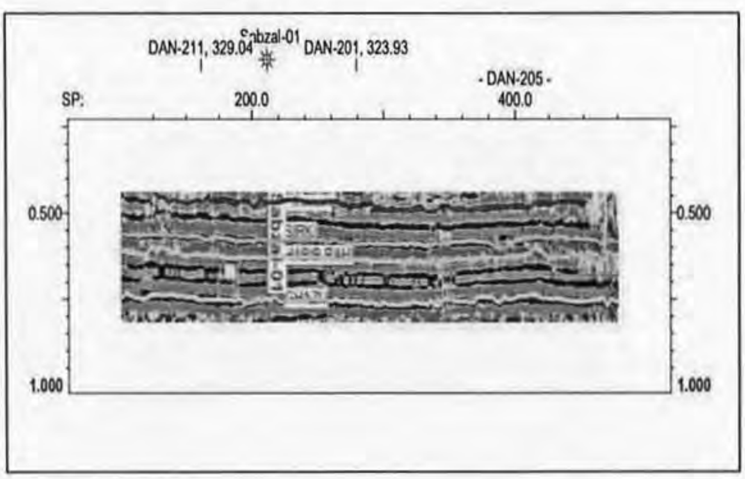

Figure 5.4 Marked horizons on well control line 846-DAN-205.

The zone of interest comprises four horizons as mentioned above, are marked on the control line 846-DAN-205. In above figure, Pirkoh is indicated by violet colour, Sirki by yellow, Habib Rahi by cyan and Ghazij by green colour. The control line is then considered as reference line for marking horizons on line 846-DAN-201 and 846-DAN-211. After that control was shifted to the line 846-DAN-245. Then this line become reference line. With according to this line horizons were then marked on line 846-DAN-246 and 846-DAN-248.

5.2.6 Jump correlation

Jump correlation process is used to overcome any discontinuity of the reflections along seismic gaps. When reflections on both sides of a gap appear on the same level along the seismic section, this may indicate a bad quality survey. On the other hand, when reflectors are either displaced vertically or disappear, this interruption may be due to faulting or pinch-out.

5.6.2.1 Interpreted Seismic Lines

Seismic sections of one strike line 846-DAN-245 and two dip lines 846-DAN-246, 846-DAN-248 are interpreted. Total four horizons mentioned in section 5.2.5 are marked on these lines. The results of interpretation of study lines are as follows,

1. Reflectors are nearly horizontal.
2. Faults are not marked due to low resolution.

Seismic sections of study lines are presented below;

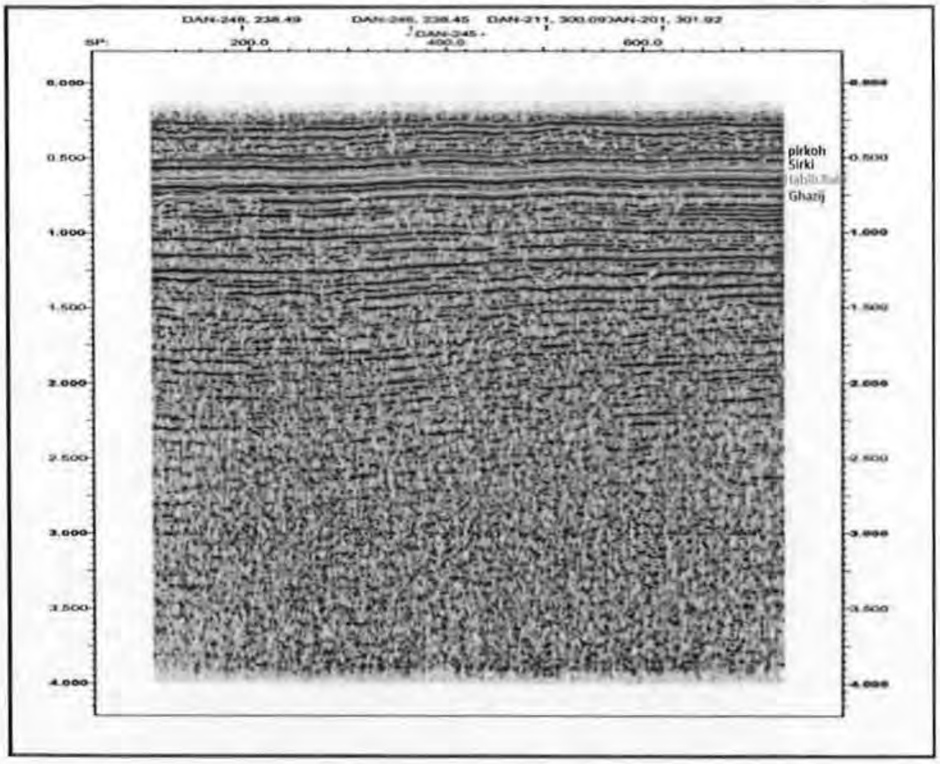

Figure 5.5 Interpretation of strike line 846-DAN-245 (NW-SW).

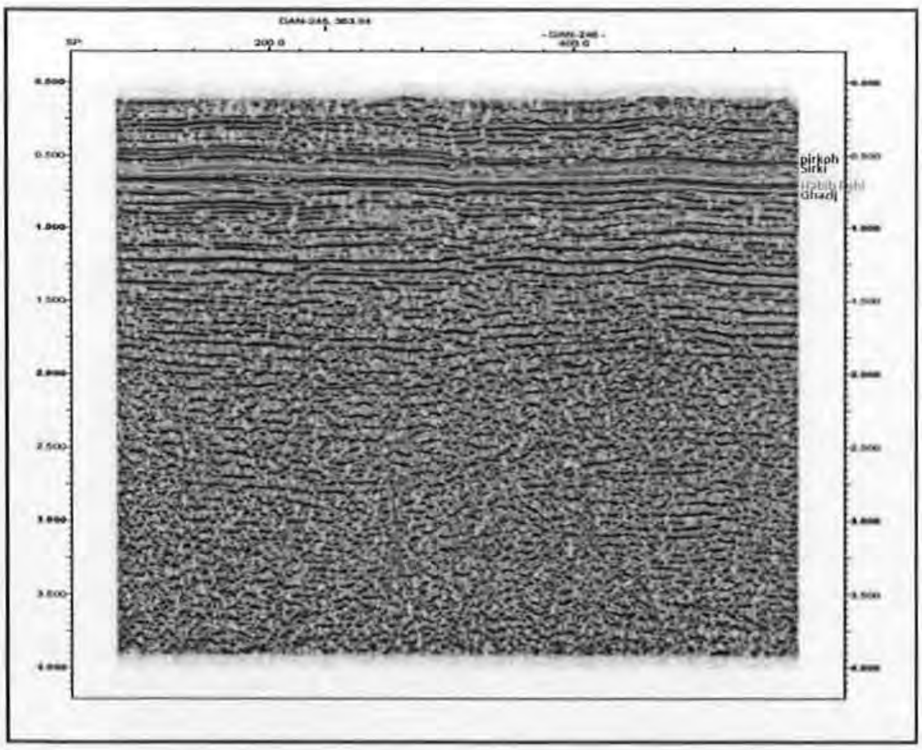

Figure 5.6 Interpretation of dip line 846-DAN-246 (NE-SW).

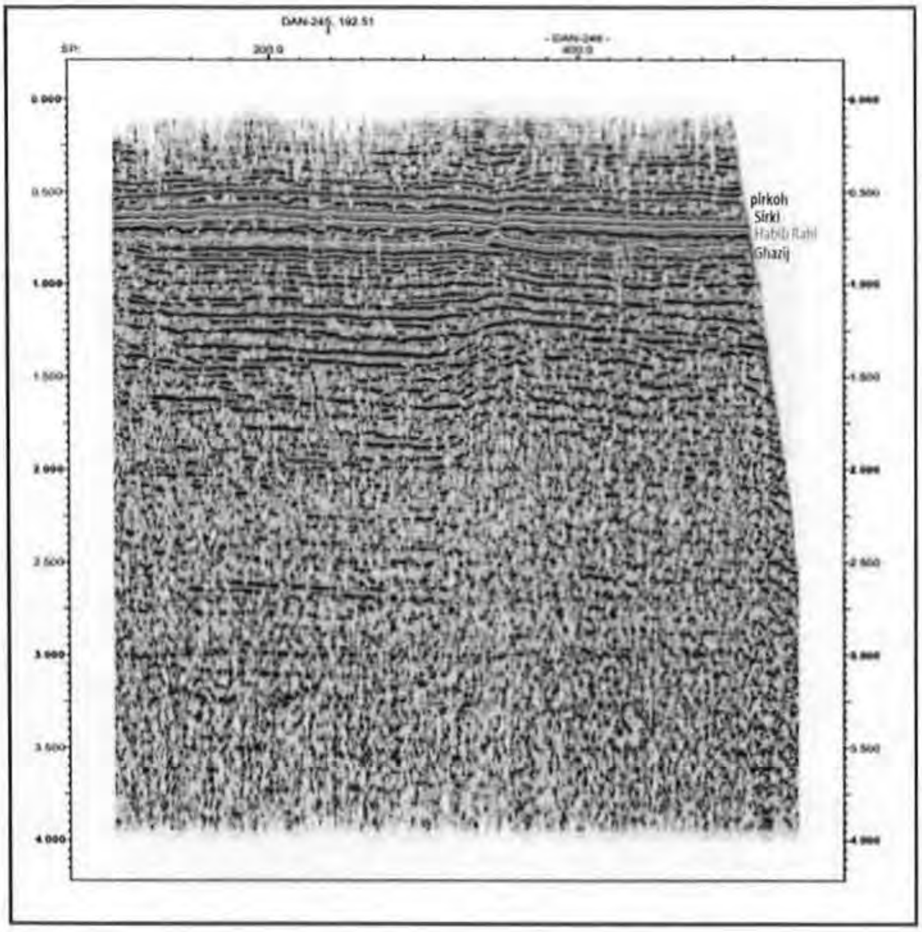

Figure 5.7 Interpretation of dip line 846-DAN-248 (SE-SW).

5.2.7 Grid Contour Maps

Contouring is done for the delineation of any property in map form by constructing lines of equal values of that property from available data points. Grid for contour maps are formed which includes time and depth maps. At the end of interpretation, time and depth contours are made.

5.2.7.1 Time contour map

At first, the time values of each horizon at shot points are taken for all seismic lines. Then, these values are posted at the seismic lines on base map. After that, contour these values to get TWT map with suitable contour interval (Sroor, 2010). Following are the time contour maps of Pirkoh, Sirki, Habib rahi and Ghazij formations in (fig 5.8 – 5.11).

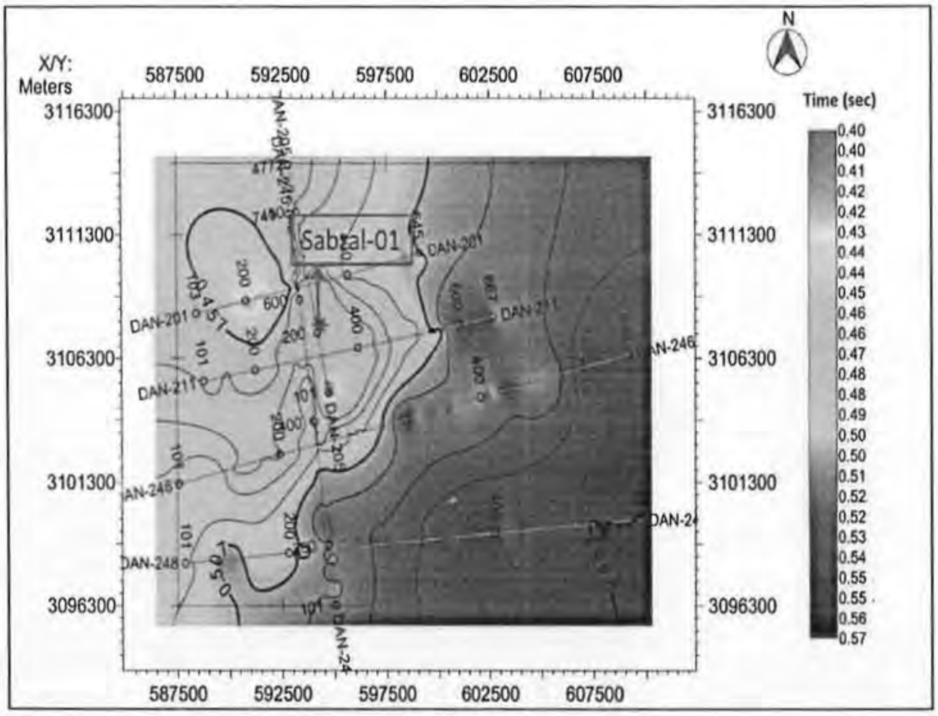

Figure 5.8 Time contour map of Pirkoh Formation.

Time contour map of Pirkoh Formation shows horizons are dipping towards East. Contour interval is 0.010 sec. Red and green colours show shallow region while dark blue part shows deepest region. The minimum limit of this map is (red) 0.40 sec and maximum limit is 0.57 sec (dark blue).

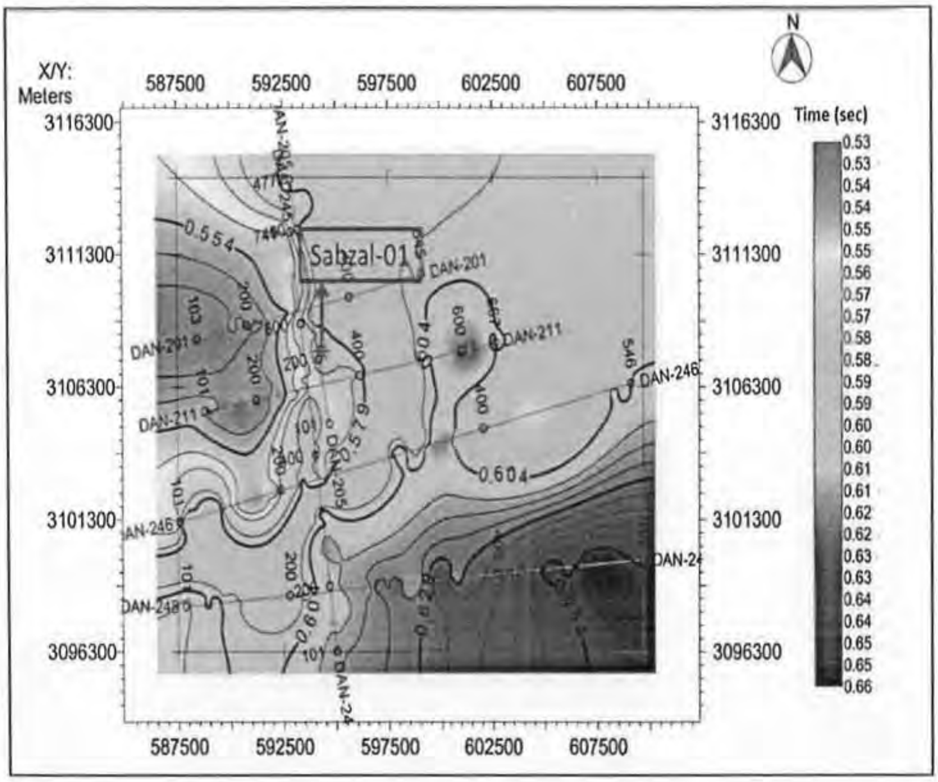

Figure 5.9 Time contour map of Sirki Formation.

Time contour map of Sirki formation shows horizons are dipping towards South-East direction. Contour interval is 0.025. Red part shows shallow region while dark blue part shows deepest region. The minimum limit of this map is (red) 0.53 sec and maximum limit is 0.66 sec (dark blue).

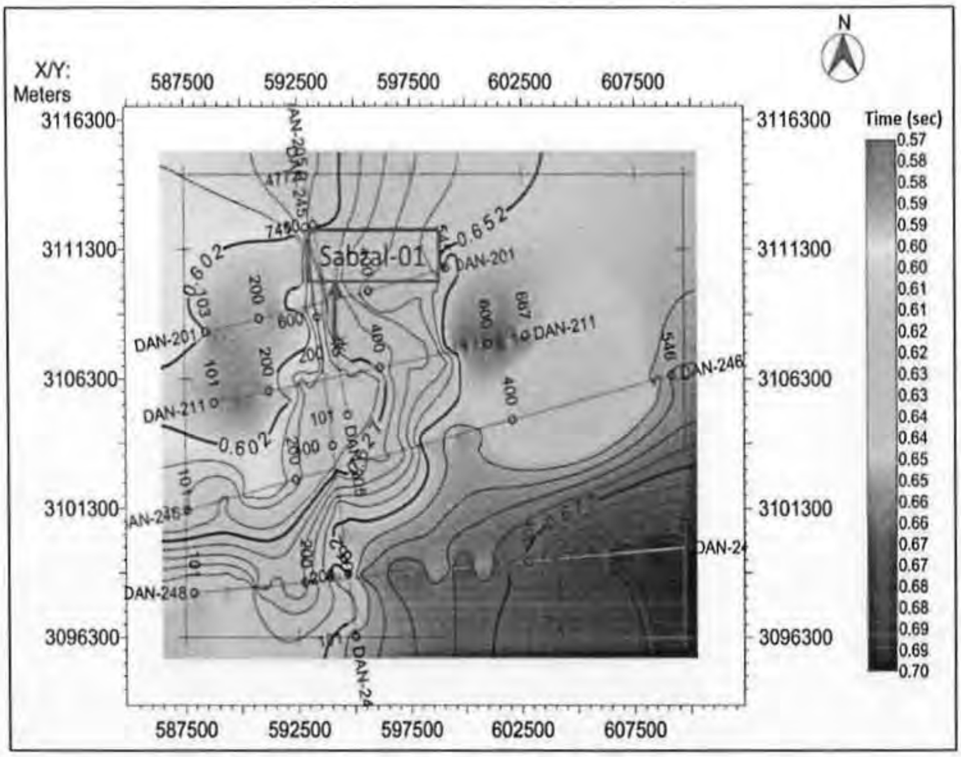

Figure 5.10 Time contour map of Habib Rahi Formation.

Time contour map of Habib Rahi Formation shows horizons are dipping towards South-East direction. Contour interval is 0.025. Red part shows shallow region in North-West which is a potential area for hydrocarbon exploration while dark blue part shows deepest region. The minimum limit of this map is (red) 0.57 sec and maximum limit is 0.70 sec (dark blue). If more seismic data is available on western side of the area the structure can be fully delineated.

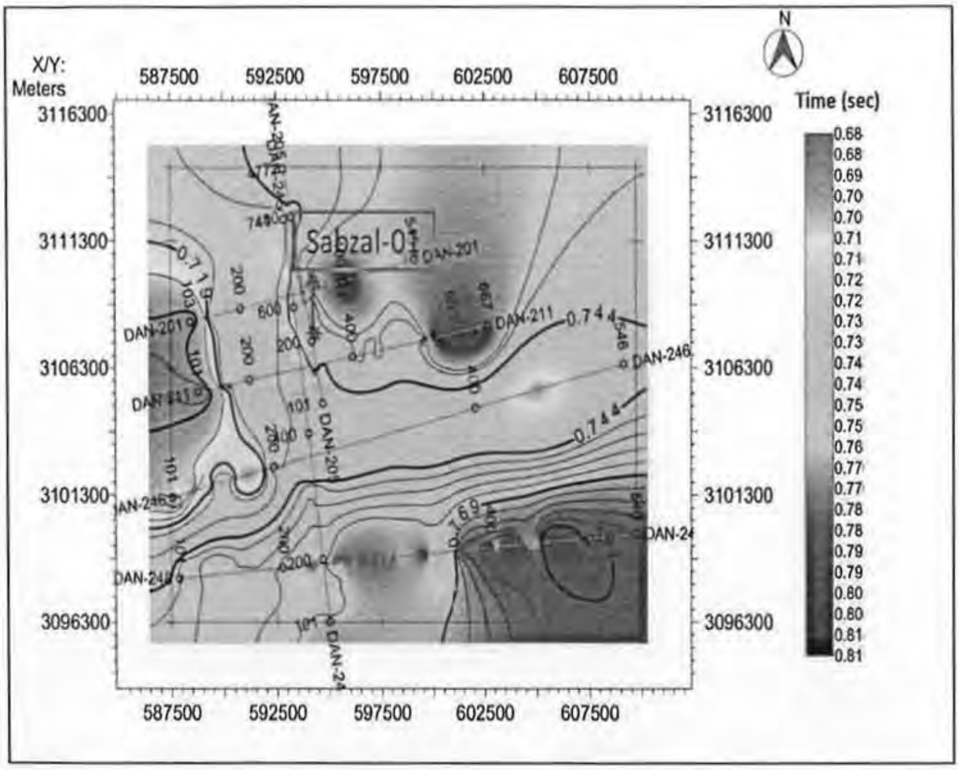

Figure 5.11 Time contour map of Ghazij Formation.

Time contour map of Ghazij Formation shows horizons are dipping towards South-East direction. Contour interval is 0.025. Red part shows shallow region while dark blue part shows deepest region. The minimum limit of this map is (red) 0.68 sec and maximum limit is 0.81 sec (dark blue).

5.2.7.2 Depth map

The depth maps are computed by using velocities of horizons from synthetic seismogram. Then by using the velocities for respective formations the time maps are converted to depth maps applying formula $S=\frac{VT}{2}$.

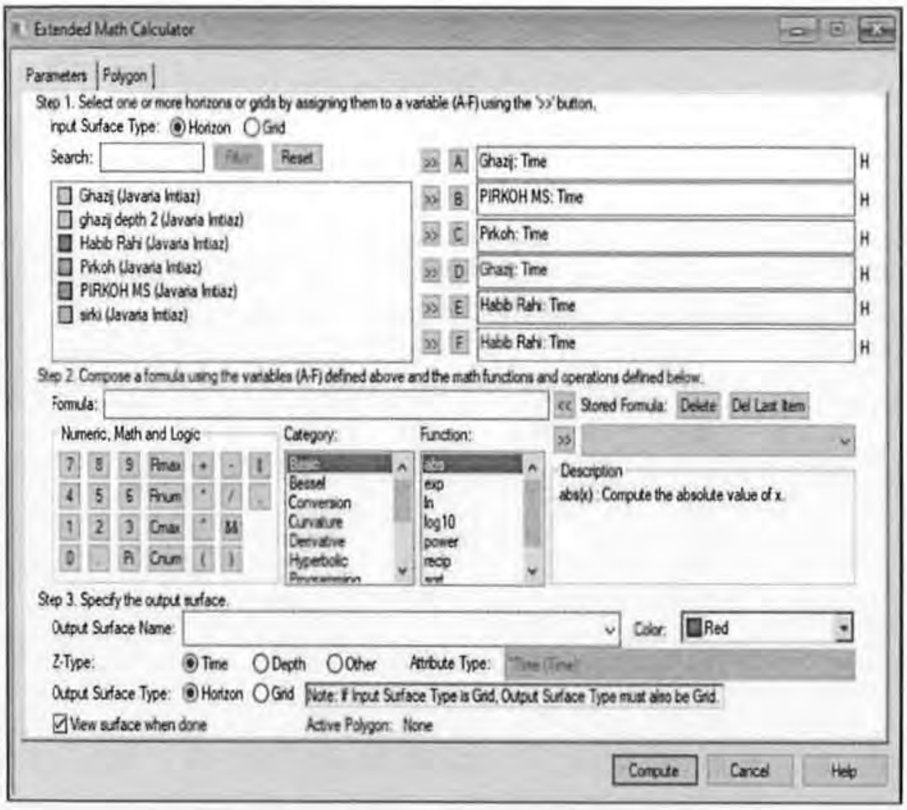

Figure 5.12 Time Depth conversion.

The depth converted map shows the depth variation of an individual horizon. Following are the depth contour maps of Pirkoh, Sirki, Habib rahi and Ghazij formations in figures (5.13-5.16).

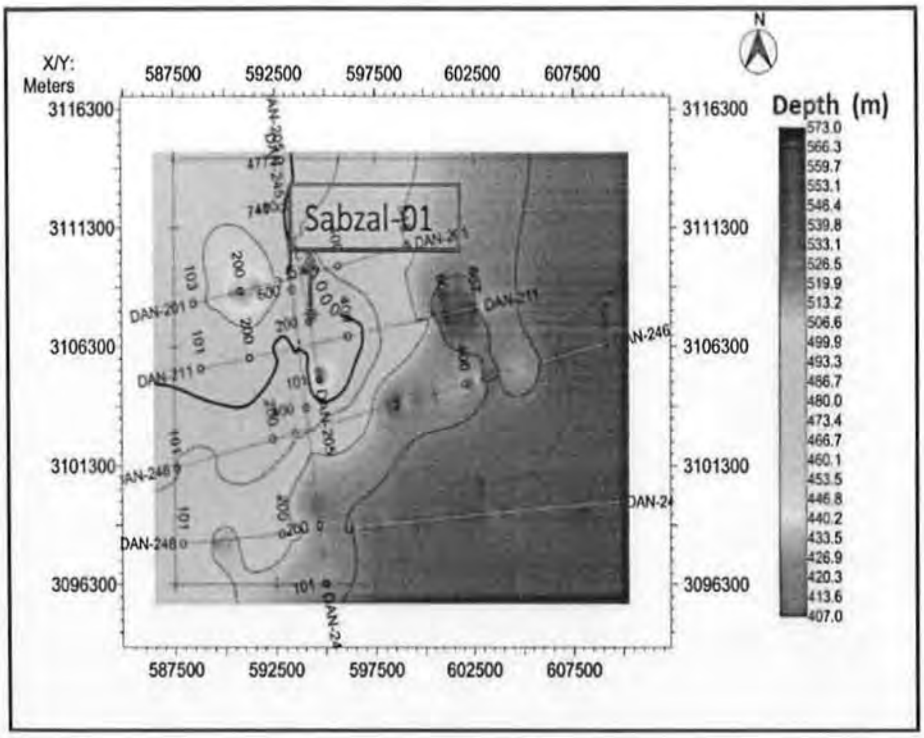

Figure 5.13 Depth contour map of Pirkoh Formation.

Depth contour map of Pirkoh Formation shows horizon is getting shallower towards West direction. Red region shows shallow depth, dark blue region colour represents deepest depth and greenish blue shows moderate depth. The minimum limit is 407m and maximum limit is 573m.

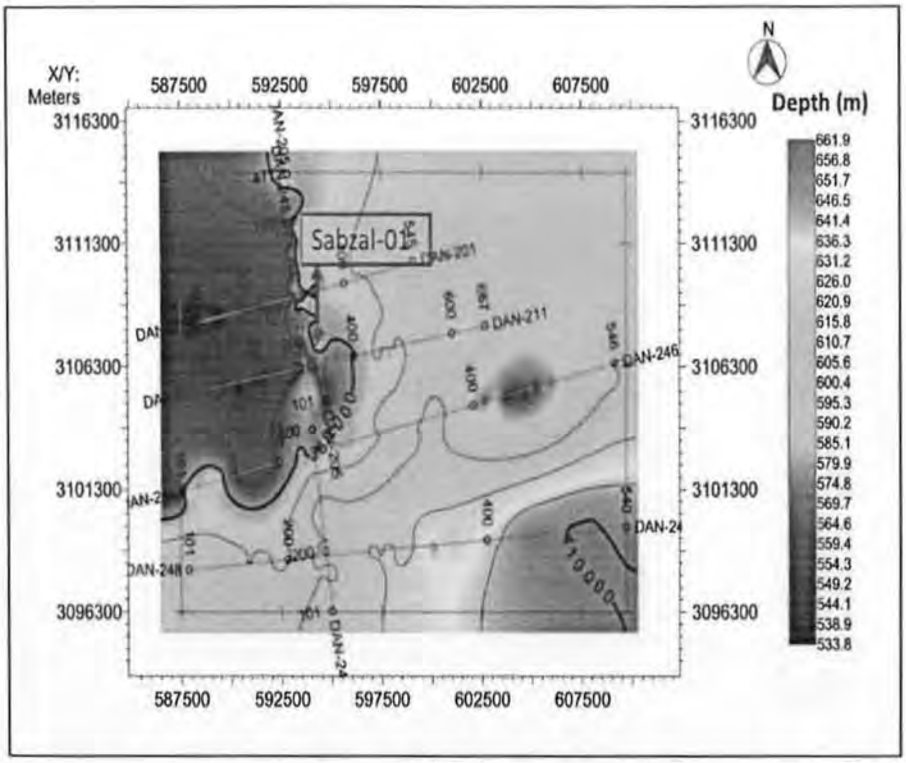

Figure 5.14 Depth contour map of Sirki Formation.

Depth contour map of Sirki Formation shows horizons is getting shallower towards North-West direction. Contour interval is 10m. Red region shows shallow depth, dark blue region colour represents deepest depth and greenish blue shows moderate depth. The minimum limit is 533.8m and maximum limit is 661.9m.

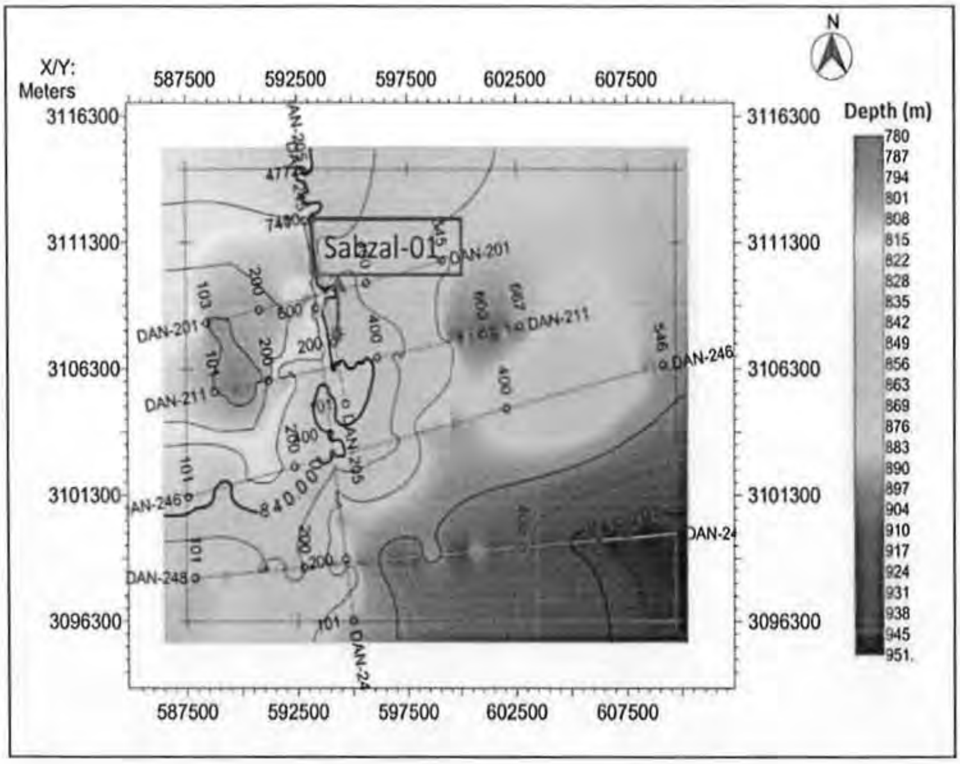

Figure 5.15 Depth contour map of Habib Rahi Formation.

Depth contour map of Habib Rahi Formation shows horizon is getting shallower towards North-West direction. Contour interval is 20m. Red region shows shallow depth, dark blue region colour represent deepest depth and greenish blue shows moderate depth. The minimum limit is 780m and maximum limit is 951m.

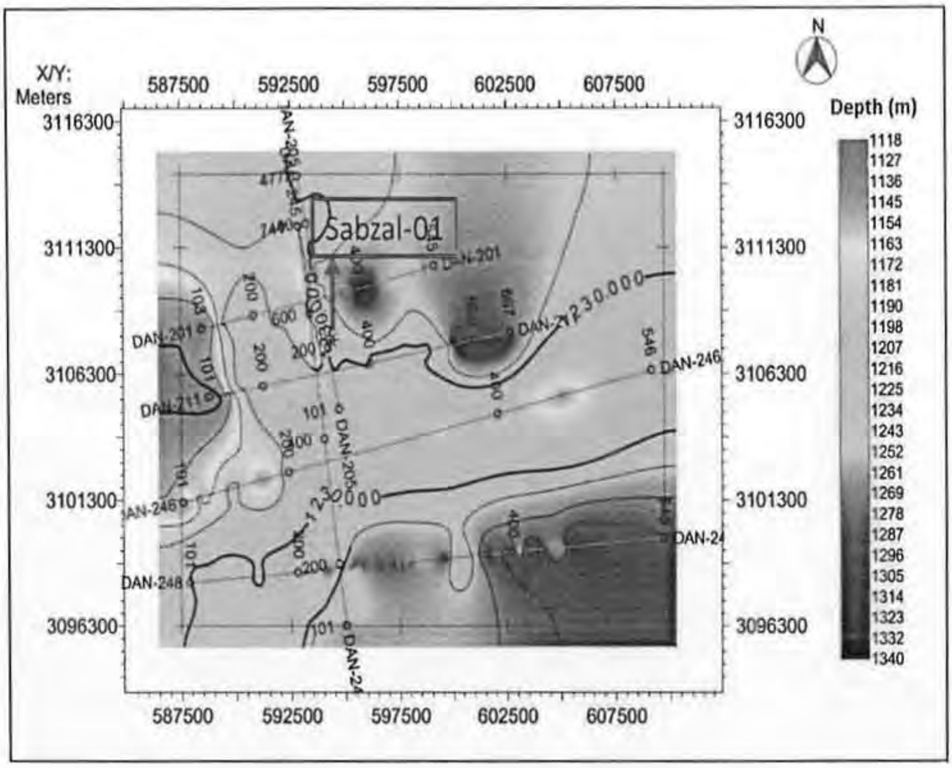

Figure 5.16 Depth contour map of Ghazij Formation.

Depth contour map of Ghazij Formation shows horizon is getting shallower towards West direction. Red region shows shallow depth, dark blue region colour represents deepest depth and greenish blue shows moderate depth. The minimum limit is 1118m and maximum limit is 1340m.

CHAPTER 6

SEISMIC ATTRIBUTE ANALYSIS

6.1 Introduction

The history of seismic attributes began in the 1950s with the earliest efforts to extract geological information from seismic reflection character. These efforts became feasible only with the digital revolution of the 1960s, which was sparked by digital recording in the field. Seismic attributes are filters that quantify properties of seismic images. The most useful seismic attributes are unique, comparable, easy to use, and geologically meaningful. Seismic attributes aid seismic interpretation by revealing hidden features, by identifying similar patterns, and by quantifying specific properties. Seismic attributes quantify properties of seismic data; seismic attributes describe seismic data. As seismic data can be described in countless ways, the potential number of seismic attributes is likewise countless. Attribute analysis decomposes data into attributes, but the decomposition is informal because no rules govern how to compute attributes or what they represent. Attribute computations act as filters that remove some component of the signal to reveal another component (Barnes, 2016).

6.2 Types Of Attributes

From the early days of seismic prospecting, Geoscientists used to draw conclusions about subsurface geology and drilling locations primarily from this single seismic data attribute. Attribute computations decompose seismic data into constituent attributes. There are no rules governing how attributes are computed. Any quantity calculated from seismic data can be considered an attribute. Seismic Attributes can be classified as seismic data domain as:

1) Pre-Stack Attributes

2) Post-Stack Attributes

Main focus is on post stack attributes. Poststack attributes treat seismic data as images of the earth. Poststack attributes are derived through filters, transforms, and statistics. They quantify stratigraphic and structural properties and are easy to compute and apply (Barnes, 2016).

6.3 Amplitude Defining Attribute

6.3.1 Average Energy Attribute

Average energy is a Amplitude defining 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 average energy attribute of seismic waves is a measure of reflectivity in the specified time window. The higher the energy should have the higher the amplitude. This attribute enhances lateral variations within seismic events, therefore, it's useful for amplitude anomalies and acoustic rock properties.

6.4 Instantaneous Attribute

The Instantaneous Attributes are computed for each sample of the input trace independently. The basis for the computation of most instantaneous attributes is the model of the seismic signal as a complex trace consisting of the real part f(t), which is the signal recorded by the geophone, and imaginary part g(t), which is known as noise.

6.4.1 Relative Acoustic Impedence

This attributes remove the noise from the data and can be used in conjuction with other attributes to give more better results. Since the seismic data does not contain any viable information at very low frequencies (due to band pass filtering in the field and during processing) these frequency trends cannot be utilized. These are removed with a low cut filter. The main uses of this attribute are; it shows acoustic impedance contrast, porosity and Indicates discontinuities (Manual, 2014).

Post Stack Relative Acoustic Impedence attribute is applied with Average energy attribute on one strike line 846-DAN-245 and two dip lines 846-DAN-246 and 846-DAN-248, to confirm the picked horizons of the well Sabzal-01 and stratigraphy . This is combination of two attributes so it is complex attribute. Figures 6.1, 6.2 and 6.3 shows relative acoustic impedence attribute in conjunction with average energy on sesmic lines. In these seismic lines, black colour show high acoustic impedence contrast than white colour. High impedence contrast shows high energy and low impedence contrast shows low energy.

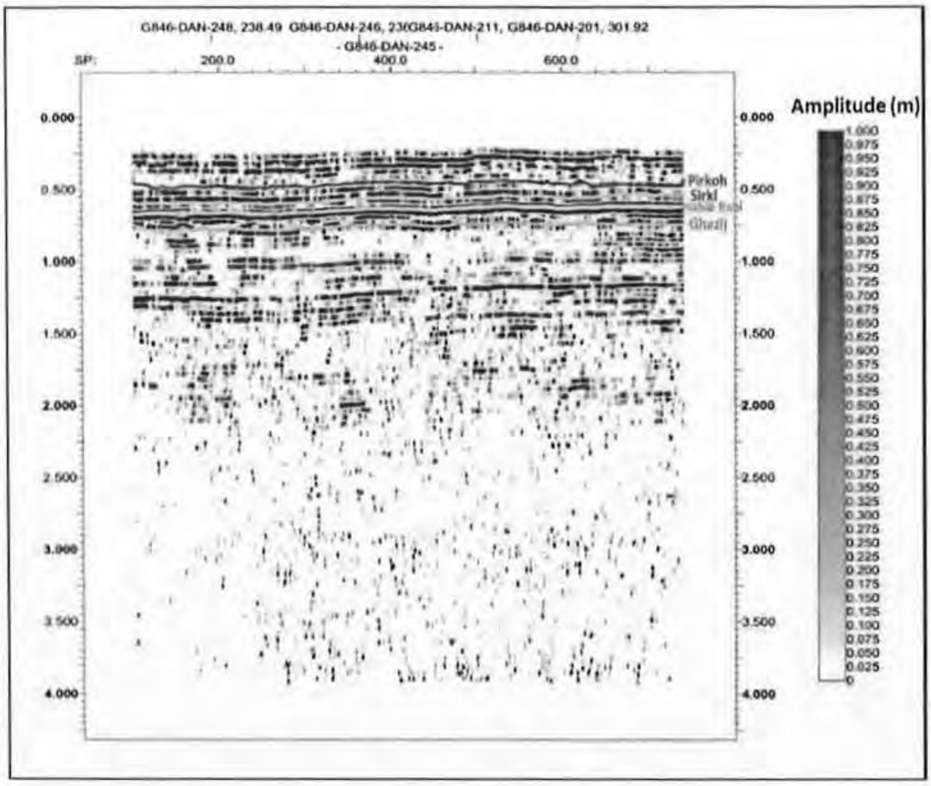

Figure 6.1 Relative Acoustic Impedence on strike line 846-DAN-245.

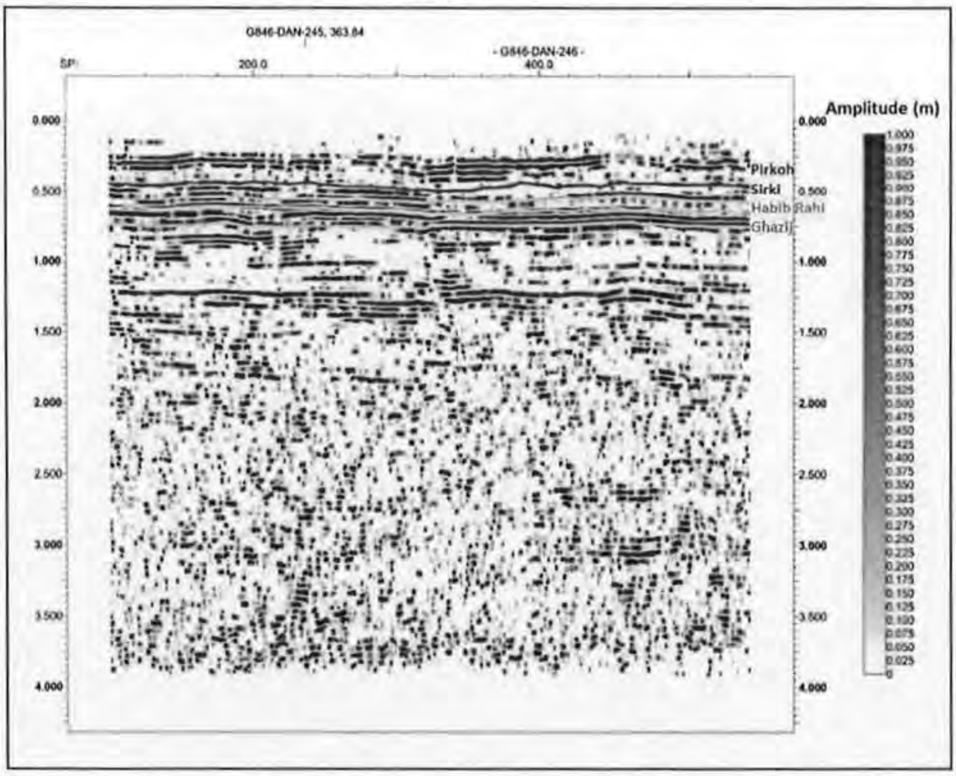

Figure 6.2 Relative Acoustic Impedence on dip line 846-DAN-246.

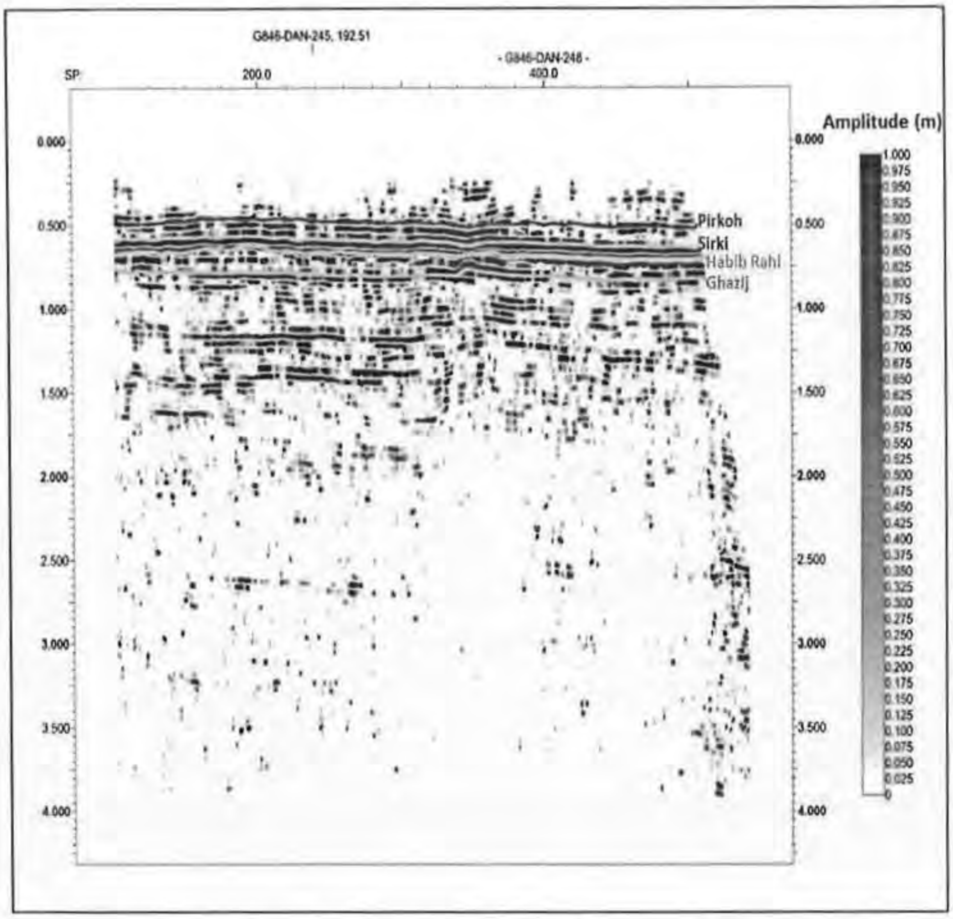

Figure 6.3 Relative Acoustic Impedence on dip line 846-DAN-248.

6.5 Wavelet Attribute

The Wavelet Attributes are similar to instantaneous attributes, but their values are computed at the peaks of the instantaneous wavelet envelope (Barnes, 2016).

6.5.1 Wavelet Dominant Frequency Attribute

Wavelet dominant frequency attribute shows the variations in frequency and amplitudes. Higher the frequency, lower will be the amplitude and vice versa. It also tells us about litholgy type that either it is consolidate or fluid exists. Figure 6.4, 6.5 and 6.6 shows Dominant frequency applied on seismic lines. Pink colour (1Hz) shows high frequency.

Habib Rahi is marked on pink colour which means in Habib Rahi there is high frequency and in high freuquencies, resistance is less so waves moves fastly so less time is taken which shows consolidated material exist. The reasons for high frequency are void spaces and data attenuation.

In Pirkoh, Sirki and Ghazij formations, the response is mix because of noise and attenuation. Attenuation is due to fluid present in the formation, more resistance, waves move slowly so more time is taken.

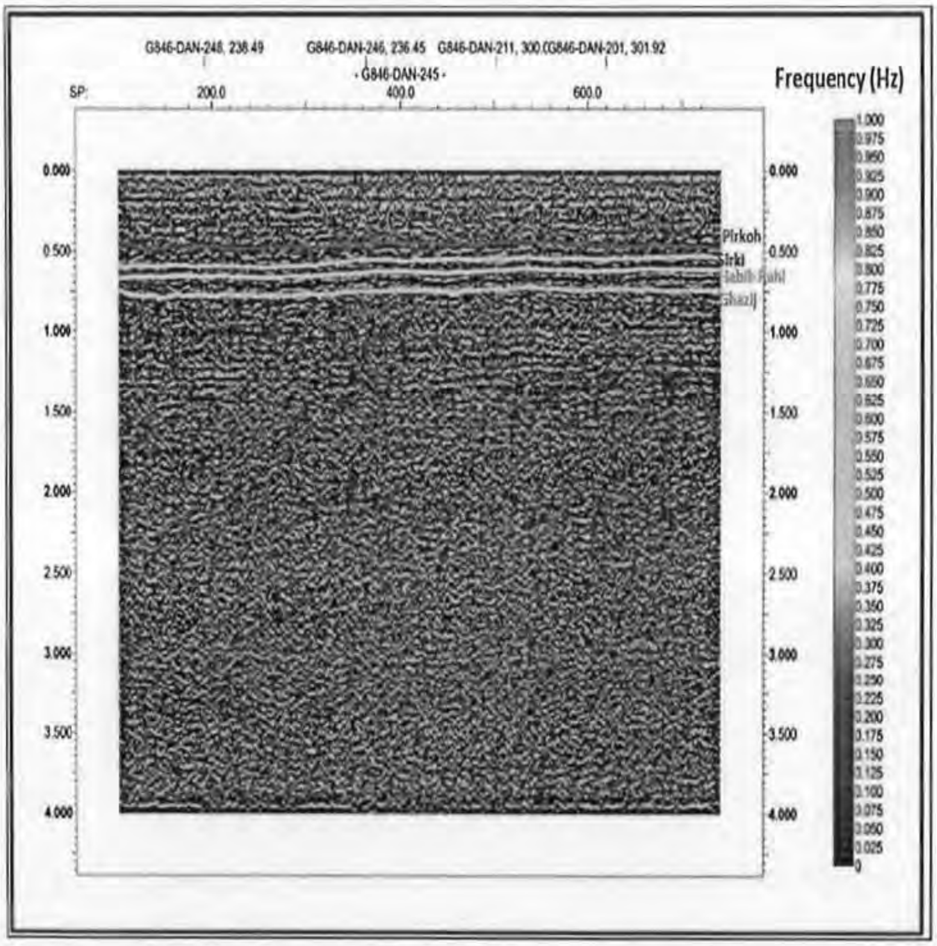

Figure 6.4 Wavelet Dominant Frequency Attribute on strike line 846-DAN-245.

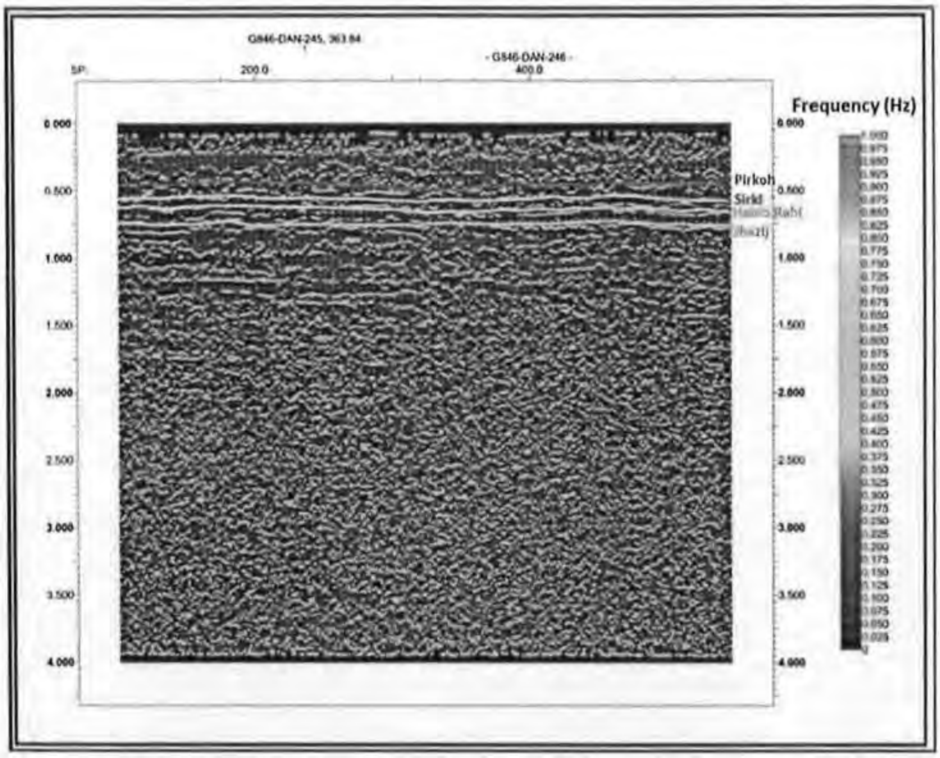

Figure 6.4 Wavelet Dominant Frequency Attribute on dip line 846-DAN-246.

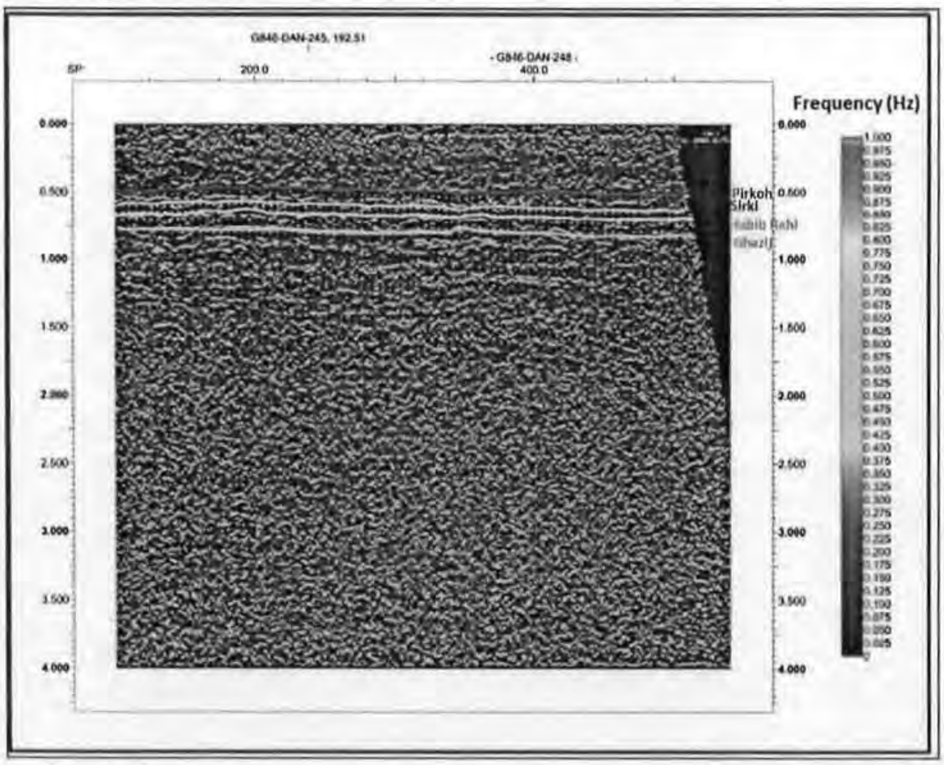

Figure 6.6 Wavelet Dominant Frequency Attribute on dip line 846-DAN-248.

CHAPTER 7

PETROPHYSICAL ANALYSIS

7.1 Introduction

Petrophysics is the study of rock properties and their interaction with fluid using wireline well logs. Different parameters can be used to analyze rock properties such as, volume of shale, hydrocarbon saturation, water saturation, porosity and lithology (Rider, 2002).

7.2 Work Flow For Petrophysical Analysis

For petrophysical analysis, proposed methodology covers following steps:

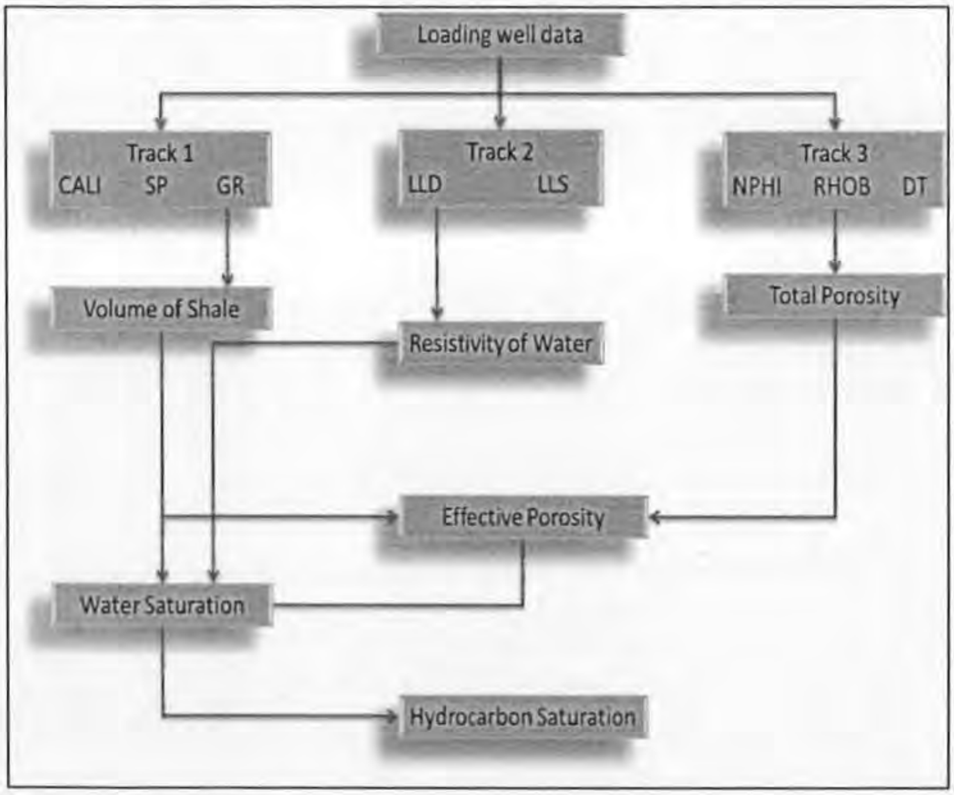

Figure 7.1 Basic steps followed for petrophysical analysis.

Petrophysics is performed by using different log curves. Petrophysical analysis is performed on depths within Habib Rahi Formation. As the well is dry, there is no zone of interest marked. Different parameters are calculated from this analysis which are volumne of shale, porosities, resistivity of water, water saturation and hydrocarbon saturation to calculate hydrocarbon potential for Habib Rahi Formation.

Table 7.1 Thickness of Habib Rahi in Sabzal-01.

Zone of interest Formation	**Formation Top (m)**	**Formation Base (m)**	**Thickness (m)**
Habib Rahi	894	1002	108

7.3 Log Used In Petrophysical Analysis

The log used in this thesis for petrophysical analysis are Caliper log (CALI), Gamma ray log (GR), Spontaneos potential (SP), Neutron porosity log (NPHI), Sonic log (DT), Density log (RHOB), Photoelectric log (PEF), Latero log shallow (LLS), Latero log deep (LLD) and Micro spherically focused log (MSFL).

7.3.1 Caliper Log

Caliper tool measures hole size and shape. The principal on which its measurements are based is, two articulated arms are pushed against the borehole wall. The arms are linked to the cursor of variable resistance. Lateral movement of arms is translated into movement of cursor along resistance and hence variation in electrical output. The variation in diameter is translated into diameter variation after simple calibration. The log is plotted in track 1.

7.3.2 Gamma Ray Log

The Gamma ray log is a record of formation's radioactivity. The radiations emits from naturally ocurring uranium, thorium and potassium. There are two types of Gamma log, these are Simple Gamma ray log and Spectral Gamma ray log. Simple log is recorded in track 1 on a linner scale with Caliper log, the scale are chosen locally but 0-100 and 0-150 API are common. Whereas spectral log is recorded in track 2 or 3. The depth from which radiations can be detected by simple gamma ray tool is generally small but difficult to be precise about.

7.3.3 Spontaneous Potential Log

SP log is used to Self-Potential between two electrodes where one electrode is placed in lower hole and other is placed at surface. The principle of this log is diffusion, which arises when solutions of different salinity are in contact through porous medium, and shale volume, arises when two same solutions are in contact through semi permeable membrane. This log run in track 1. The scale of this log is positive on right and negative on left. Depth of investigation is more because bed resolution is low.

7.3.4 Density Log

Density log is continuous recording of formation's bulk density. Bulk density is overall density of rock including solid matrix and fluid enclosed in pores. It also used to calculate porosity. The principle of this log is attenuation of energy due to collision. Denser the formation, more will be the collision means more energy loss. Density log run in 2 and 3 track. The scale is too sensitive and is fixed, 1.95g/cm^3 to 2.99 g/cm^3. Depth of investigation is very shallow because bed resolution is high.

7.3.5 Sonic Log

The ability of formation to transmit sound waves is measured by sonic log. The tool measures the time it take for a pulse of sound to travel from transmitter to reciever, which are both mounted on a tool. This log depends on formation matrix and type of fluid. Some of the typical matrix velocities are sandstone 18,000-19,500 ft/s, dolomite 25,000 ft/s (Rider, 2002). This log is represented in track 2 or 3 on a linner scale. Its depth of investigation is very less, it depends on source receiver distance, it is 2cm to 25cm (less than a feet).

7.3.6 Neutron Porosity Log

Neutron log provides continuous record of formation reaction to fast neutron striking, it is quoted in terms of neutron porosity units.

The principle of this log is compton scattering, includes collision and absorption. Collisions are mainly at higher energy states while absorption is at lower energy. The Neutron log is plot on a standardize arithmetic scale of neutron porosity units. The most common scale is 0.45 to -0.15 neutron porosity units. This log plotted across track 2 and 3. The depth of investigation is very small, most common is 15 to 25cm.

7.3.7 Photoelectric Factor Log

It records effective photoelectric information of a formation. The principle of measurement is photoelectric absorption. Photoelectric absorption occur when gamma ray have lost sufficient energy to be captured and absorbed electrically bound to atoms. This log is plotted in track 3 or 4 with Density and Neutron log. The scale is adjustable, minor environmental corrections has been made. It is almost 0 to 15barns/electron. Scale is in barns per electron. The depth of investigation is shallow but better than Density log.

7.3.8 Resistivity log

This log is used to find formation's resistivity. The basic resistivity tool arrangement was provided by conrad schulmberger in 1927. Currents were passed through the formation by means of current electrodes and voltages were measured between electrodes. These measured voltages provide resistivity determination for each device. Log is plotted either in track 2 alone or in 2 and 3. The scale is usually 0.2ohm to 2000ohm. Resistivity log has three types, these are Micro spherically focused log (MSFL), Latero logs, and Induction logs.

7.3.9 Micro Spherically Focused Log

It gives information about flushed zone's resistivity (Rxo), so that the bed resolution is high and depth of investigation is low. They consists of three electrodes. First electrode emits known current and potential difference between other two electrode is measured. The have electron spacing of few inches.

7.3.10 Latero Log Shallow (LLS) and Latero Log Deep(LLD)

Laterolog tool are generally used for High Resistivity Formation and Saline Muds. LLD is used for deep investigation of the undisturbed zone (Rt) and LLS is used for shallow investigation of the transition zone (Ri).

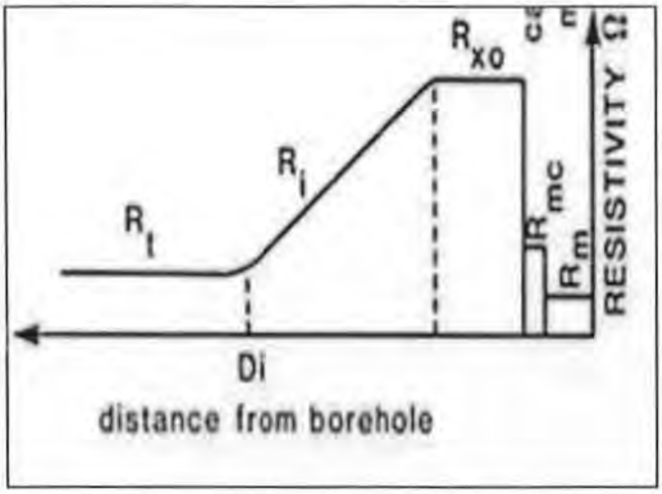

Figure 7.2 Borehole zones (Rider, 2002).

Deep and shallow tool readings are plotted side by side on a same track to allow direct comparison. The depth of investigation of LLD is high and depth of investigation of LLS is intermediate.

7.4 Scales Used For Different Log Tracks

The scales used for different logs track area explained in the below table 7.2.

Logs name	Abbreviation	Scale	Unit
Caliper log	CALI	6 to 16	Inches
Gamma ray log	GR	0 to 150	API
Latero log deep	LLD	0.20 to 2000	Ωm
Latero log shallow	LLS	0.20 to 2000	Ωm
Sonic log	DT	240 to 40	μsec/ft
Neutron log	NPHI	0.45 to -0.15	v/v
Density log	RHOB	1.95 to 2.95	g/cm^3
Spontaneous potential log	SP	-80 to 20	mV

7.5 Petrophysical Properties

The parameters that were directly read from the log track are:

Formation depth (in ft), Bulk density of formation (RHOB) scale 1.95 to 2.95, Bulk resistivity of the formation (LLD) scale 0.2-2000 ohm.m, Spontaneous potential (SP) scale -80 to 20mv, Neutron porosity (NPHI) scale 0.45 to -0.15.

For calculating hydrocarbon saturation, following steps is performed:

7.5.1 Volume of Shale

Different logs such as resistivity, SP and Gamma-ray log is used to calculate shale volume in the reservoir. There are different methods to estimated volume of shale but in this study we used non-linear method consisting gamma ray log for volume of shale calculation.

Vsh can be calculated from gamma-ray response. The mathematical relation for estimating the Volume of shale is given in equation 7.1;

$$Vsh = \frac{(GR\ log - GR\ min)}{(GR\ max - GR\ min)} \text{ (Rider, 2002)} \qquad (7.1)$$

7.5.2 Calculation Of Porosity From Logs

Porosity is the ratio of volume of voids to total volume of rock. Porosity is calculated for different zones of interest by using the following logs:

- Sonic log
- Neutron log
- Density log

7.5.2.1 Neutron Porosity

It is obtained from Neutron log given in Sabzal-01 well data.

7.5.2.2 Density Porosity

Density porosity is calculated from density log by using matrix density of the lithology of marked formation and density of fluid present in that formation. As the formation is Habib Rahi, it consist of Limestones so, matrix density of limestone is 2.71g/cm^3 and fluid density is 1.1g/cm^3. The mathematical relation for density derived porosity is mentioned in equation 7.2;

$$PHID = \frac{(RhoM - RHOB)}{(RhoM - RhoF)} \text{ (Rider, 2002)} \quad (7.2)$$

Where, RhoM is matrix density, RHOB is bulk density and RhoF is fluid density.

7.5.2.3 Average Porosity

For calculating average porosity, Neutron and Density porosity must be known. Average porosity is calculated by using formula 7.3;

$$\text{Average porosity}(\Phi) = \frac{(\Phi N.D + \Phi D)}{2} \text{(Rider, 2002)} \quad (7.3)$$

Where,

ΦN.D is Neutron porosity.

ΦD is Density porosity.

7.5.2.4 Effective Porosity

The effective porosity is the ratio between the pores volume of the rock and the total volume of the rock calculated after removing the effect of the shale. The effective porosity is used to estimate the water saturation. Formula used for calculating effective porosity is given in equation 7.4;

$$\Phi e = \Phi avg * (1 - Vsh) \text{ (Rider, 2002)} \quad (7.4)$$

7.5.2.5 Sonic Porosity

Sonic porosity is calculated from DT log by using transit time of matrix and fluid of formation. As mentioned above zone of interest is Habib Rahi and it composed of Limestones. So transit time of Limestone is picked up which is 53µsec/ft and that of fluid is 190µsec/ft because fluid is saline water. Formula used for calculating sonic porosity is mentioned in equation 7.5;

$$PHIS = \frac{(DT - DTma)}{(DTfld - DTma)} \text{(Rider, 2002)} \quad (7.5)$$

7.5.3 Resistivity Of Water (Rw)

Computing the resistivity of the water is the initial step in finding the saturation of the water. Schlumberger log interpretation charts along with several equations were used to find out Rw for calculating saturation of hydrocarbons, followings parameters are calculated for finding Rw.

7.5.3.1 Geothermal Gradient

Geothermal gradient is calculated by using formula 7.6;

$$\text{Temperature Gradient} = \frac{(BHT - St)}{T.D} \text{ (Rider, 2002)} \quad (7.6)$$

$$=(243-89)/3621.5$$

$$=0.042°F$$

Where;

BHT is borehole temperature.

St is surface temperature.

T.D is total depth.

7.5.3.2 Formation Temperature (Ft)

Ft is calculated using formula 7.7;

Ft=(geothermal gradient*formation top)+surface temperature (Rider, 2002) (7.7)

7.5.3.3 Resistivity Of Mud Filterate (Rmf)

Rmf is picked by using Gen 6 chart with the help of formation temperature computed from above step.

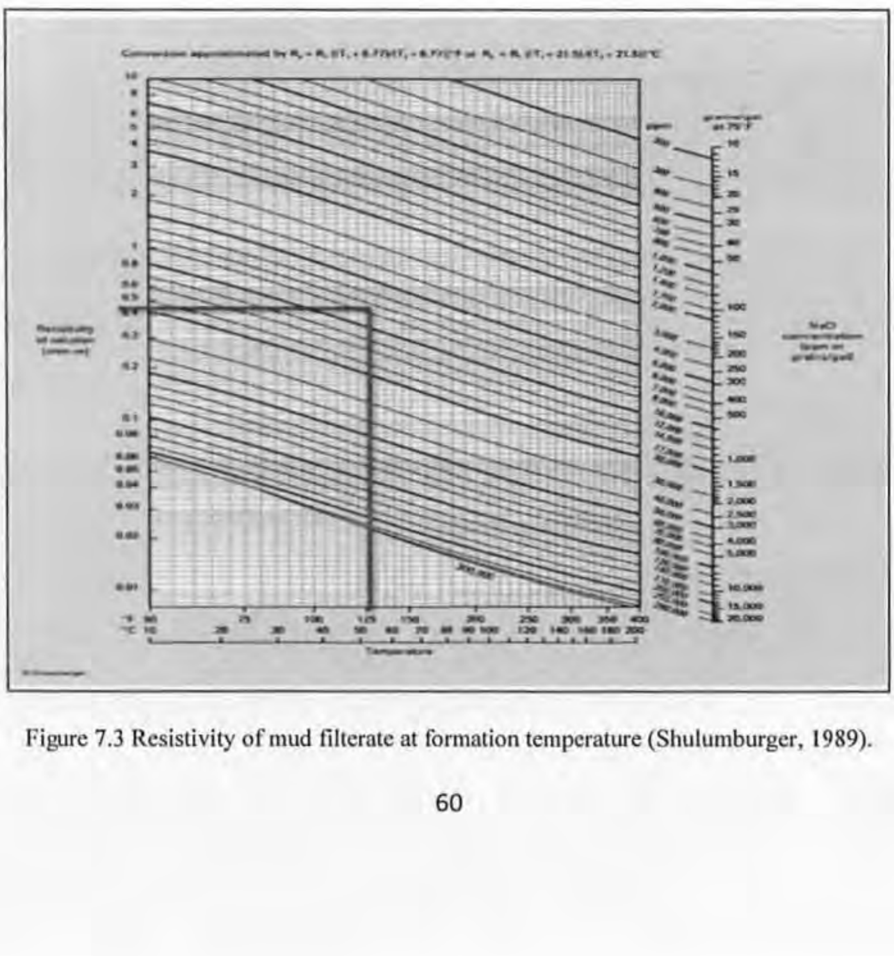

Figure 7.3 Resistivity of mud filterate at formation temperature (Shulumburger, 1989).

7.5.3.4 Rmfeq (equivalent resistivity of mud filterate)

Rmfeq is picked by using SP2 chart with the help of Rmf.

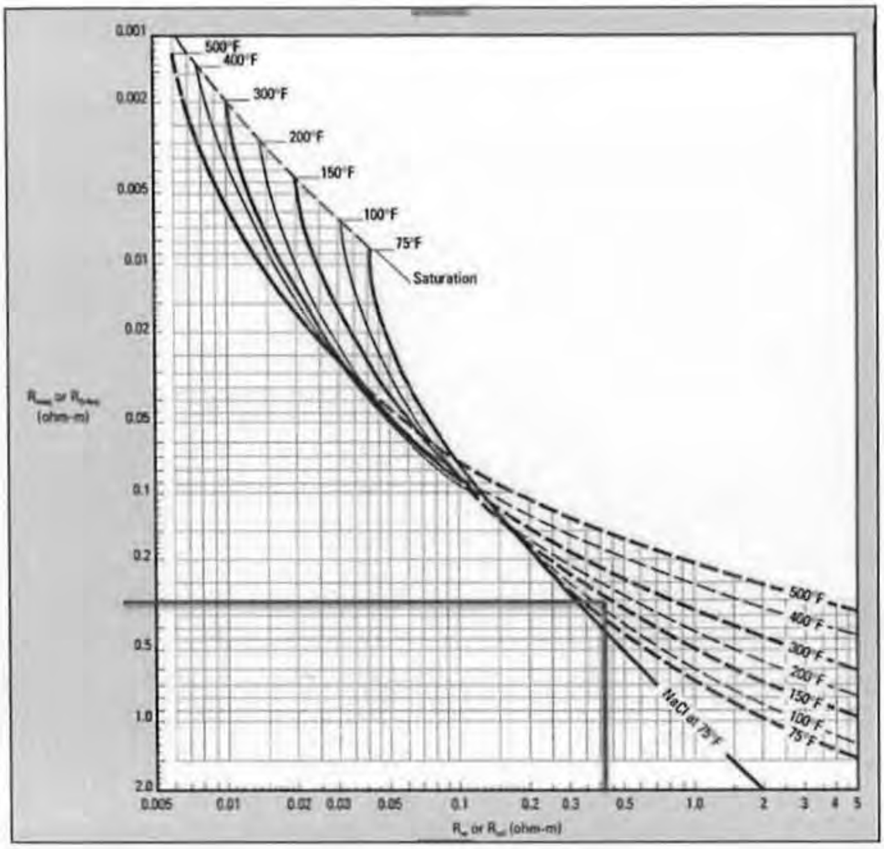

Figure 7.4 Equivalent resistivity of mud filterate at Rmf.

7.5.3.5 SSP (Static Spontaneous Potential)

SSP is calculated by measuring the gap between shale baseline and sand baseline. Computed value of SSP is -25Mv.

7.5.3.6 Rweq (equivalent resistivity of water)

By using SSP, Rweq and Rmfeq/Rweq is calculated at given temperature. SP1 chart is used here. The calculated Rweq is 0.08 (ohm.m).

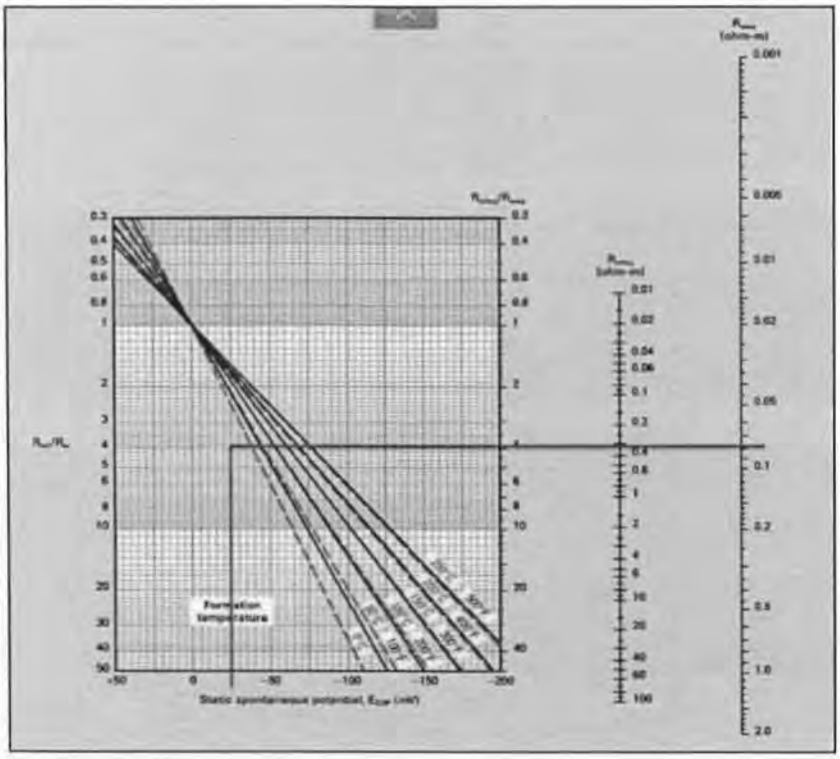

Figure 7.5 Equivalent resistivity of water (Shulumburger).

7.5.3.7 Calculation Of Rw

For measuring water saturation, the resistivity of water is very essential to be estimate. The Resistivity of water is picked by using SP2 chart mentioned in section 7.5.3.4, with the help of Rweq and temperature. It is same throughout the formation because SSP is same. The calculated Rw is 0.09 (ohm.m).

7.5.3.8 Saturation Of Water (Sw)

Sw is the ratio of water volume to pore volume. Water saturation is calculated by using Indonesian equation 7.8 mentioned below;

$$Sw = \left\{ \frac{\sqrt{\frac{1}{Rt}}}{\left(\frac{Vsh^{(1-0.5Vsh)}}{\sqrt{Rsh}} \right) + \sqrt{\frac{\phi e^{m}}{a * Rw}}} \right\}^{\left(\frac{2}{n}\right)}$$

(Rider, 2002) (7.8)

Where,

R_t is LLD log values

a, m and n are tortousity factors. The value of is a is 1, m is 2 and n is 2.

The value of Rsh is 5 (ohm.m).

Vsh is volume of shale

R_w is resistivity of water

Φe is effective porosity

7.5.3.9 Saturation Of Hydrocarbons

The fraction of pore volume filled hydrocarbons. Saturation of hydrocarbon is calculated by equation 7.9 given below;

$$S_{hc} = 1 - S_w \text{ (Rider, 2002)} \quad (7.9)$$

Where,

S_w is Saturation of water

S_{hc} is Saturation of hydrocarbon

7.6 Log Trend Of Habib Rahi Formation

Figure 6.6 shows log trend of Habib Rahi formation. Track 1 on the left having GR, Caliper and SP log. Track 2 has LLD and LLS log. Track 3 has DT,NPHI and RHOB log. Track 5 has VSH and track 6,7 and 8 has Effective porosity, Water saturation and Hydrocarbon saturation. Caliper log is mostly stable. GR log is on low side. Green colour in the figure shows portion of volume of Shale. There is no specific separation between resistivity logs. Purple colour shows effective porosity and blue colour shows Water Saturation which is predominanlty present in the well which is dry well, while grey coloured shading shows Hydrocarbon Saturation.

Hydrocarbon analysis is performed in Habib Rahi because all the logs are carried out in this formation. Due to data unavailability in other formations hydrocarbon analysis cannot be performed there, like Pirkoh and Sirki formation, density log is not shown so porosities will not be calculated there.

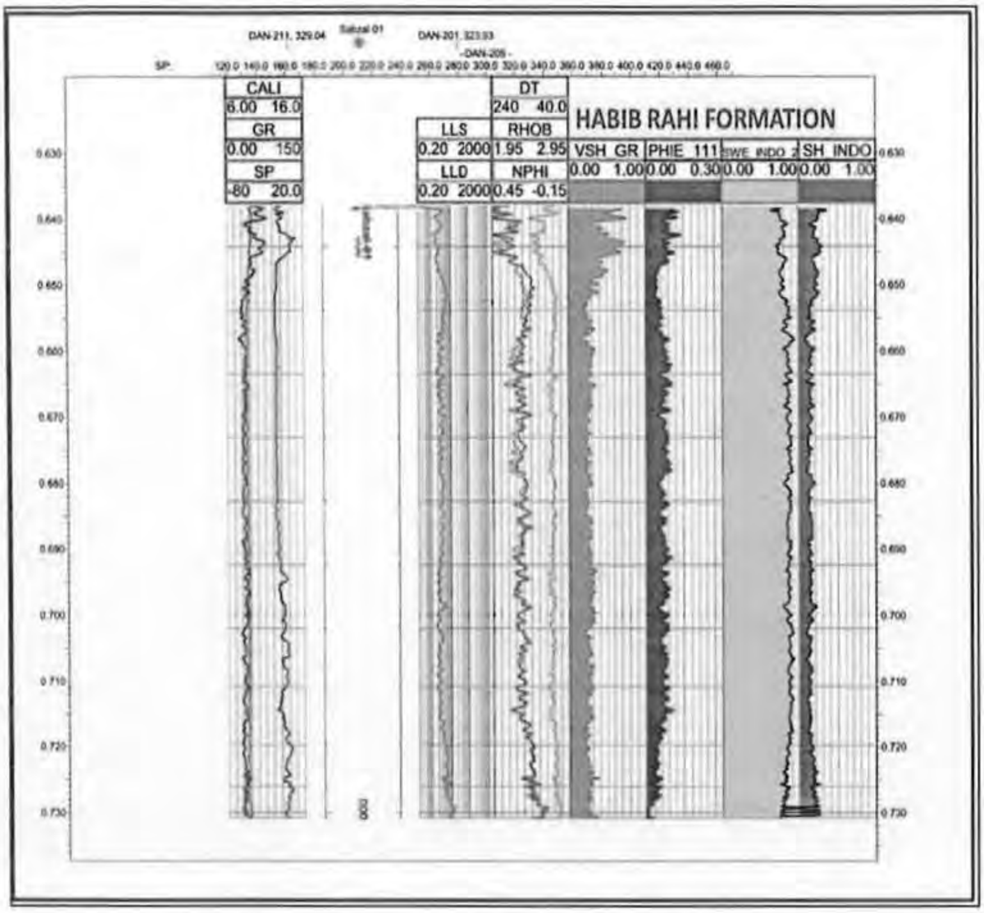

Figure 7.6 Log trend of Habib Rahi Formation.

7.7 Results

The results concluded from petrophysical analysis are shown in table 7.3.

Table 7.3 Results of Petrophysical analysis

Depth (m)	Vsh	PHIA	PHIE	Sw	Sh
Habib Rahi (894-1002m)	55%	15%	6%	81%	19%

Petrophysical analysis is performed on the Habib Rahi Formation because it is reservoir formation. Water saturation is 81% and hydrocarbon saturation is 19% because well is abundant well so water is predominantly present. average effective porosity is 6% which is ideal for formations having limestone lithology.

CHAPTER 8

FACIES ANALYSIS

8.1 Introduction

Facies analysis is defined as the classification of lithologies as revealed by petrophysical measurements of a reservoir. In facies analysis, cross plots between different logs are used to map lithology, porosity, density and minerals where it is available. When data points are connected in a cross plot then the properties like lithology, porosities can be predicted. A third variable can be presented at each point on the crossplot by assigning a color scale that is based on other well logs, often gamma ray or photoelectric effect etc (Watney, 1998).

8.2 Work Flow

Generalized work flow followed for facies analysis is;

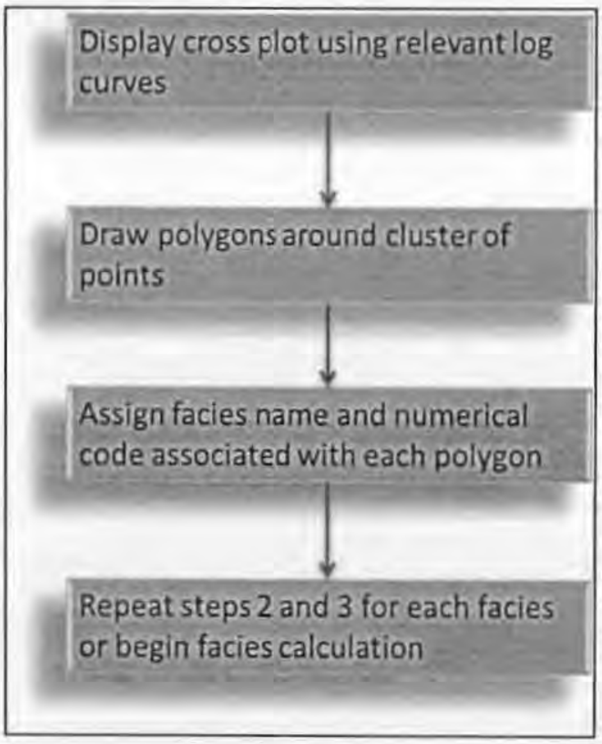

Figure 8.1 Work flow for facies analysis.

8.3 Petrofacies Analysis of Habib Rahi

An effort has been made in this thesis to plot various logs and by means of geophysical knowledge of the logs, to mark the facies present in the subsurface. Facies analysis of only Habib Rahi Formation has been done. The results are as follows:

8.3.1 Cross Plot of LLD and RHOB

Latero log deep versus density log cross plot is used to identify lithology on a basis of resistivity and density values. Two facies are encountered these are, limestone and Shaly limestone. Gamma log is used as reference log for further separation of facies. The zone marked by grey colour shows both high and medium range GR , thus indicating presence of shaly limestone. The brown color shows medium to low GR with density of about 2.7g/cm^3 thus indicating presence of limestone.

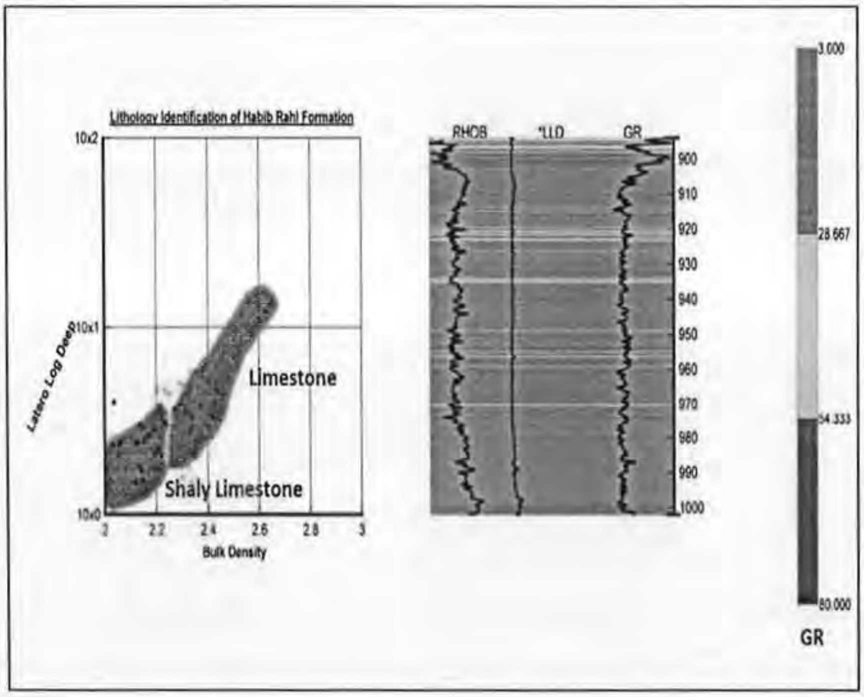

Figure 8.2 Lithology identification of Habib Rahi using LLD and RHOB.

8.3.2 Cross Plot of RHOB and NPHI

Both neutron and density log are difficult to use for lithology identification by themselves. However, once combined, they become the best lithology indicator.The neutron log and density log should be showing same lithology parameters like porosity. Plotted on a compatible porosity scales and it should be possible to superimpose two logs. In practice, this is the only case in Limestones which gives almost perfectly superimposable logs. The density of pure calcite is 2.71g/cm^3. A cross plot of density log values against neutron log values will show a straight line relationship. Point on a line coressponding a particular porosity. This is the clean limestone line. The straight line relationship only holds good for clean limestones because matrix material has variable effects on both logs. Clean limestones shows no separation (Rider, 2002).

Apparent neutron porosity is plotted along x-axis and bulk density is plotted along y-axis. GR log is used as reference log for defining lithologies, Two facies are marked. The Brown color shows the limestone with bulk density of 2.7g/cm^3 and grey color shows the shaly limestone with low bulk density.

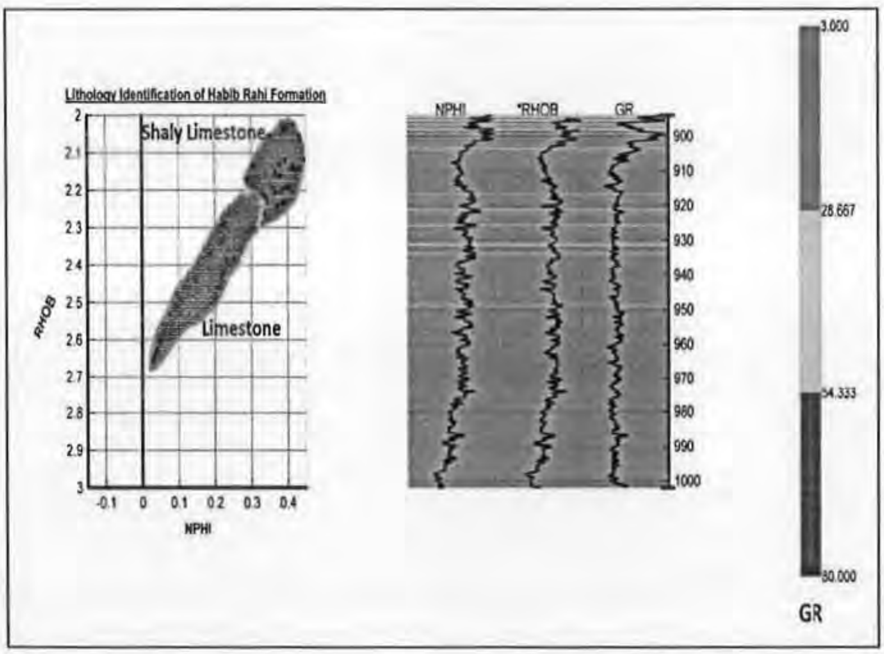

Figure 8.3 Lithology identification of Habib Rahi Formation.

8.3.3 M-N Plot

In more complex mineral mixtures, lithology interpretation is facilitated by use of the M-N plot. These plots combine the data of all three porosity logs to provide the lithologydependent quantities M and N. M and N are essentially independent of porosity, and a crossplot provides lithology identification (shlumberger, 1989). For M and N formulas used are given in equation 8.1 and 8.2;

$$M = \frac{t_f - t}{\rho_b - \rho_f} \text{ (shlumberger, 1989)} \qquad (8.1)$$

$$N = \frac{\varphi_{Nf} - \varphi_N}{\rho_b - \rho_f} \text{ (shlumberger, 1989)} \qquad (8.2)$$

Where,

t_f is transit time of fluid (saline water= 185μsec/ft).

t is sonic log.

ρ_b is bulk density.

ρ_f is density of fluid (saline water= 1.1 g/cm3).

φ_{Nf} is neutron porosity of fluid (salt water= 1 pu).

φ_N is neutron log.

In Habib Rahi Formation, the value of M calculated is 80.09 and N is 0.62. The standard M-N plot and cluster M-N plot is given in figures 8.4 and 8.5. Two facies are marked by comparing both figures, Limestone and Shaly region. Brown color shows limestone and grey colour shows shaly region. GR log is used as reference log for lithology identification.

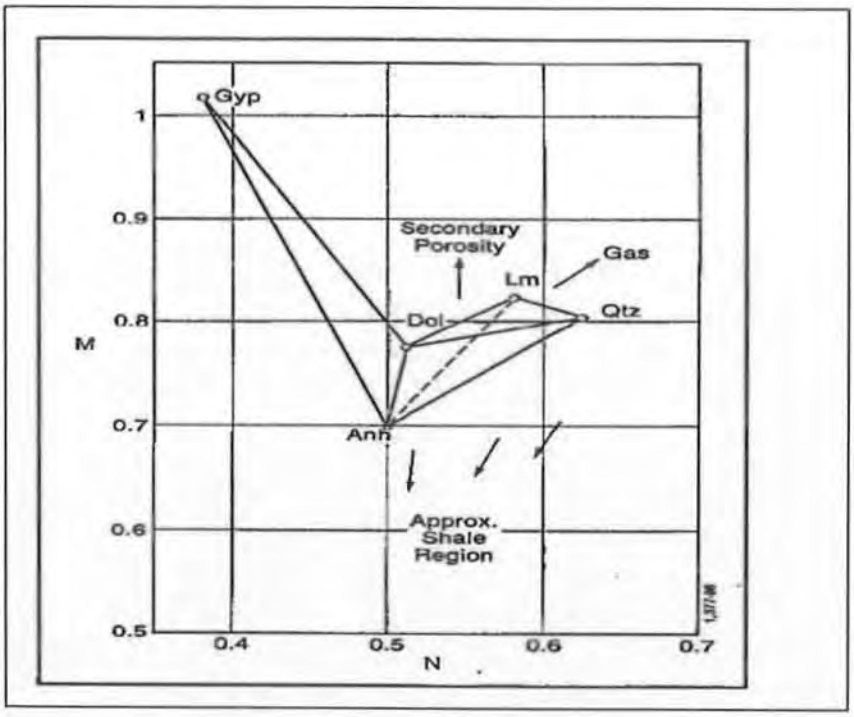

Figure 8.4 Standard M-N plot (shlumberger, 1989).

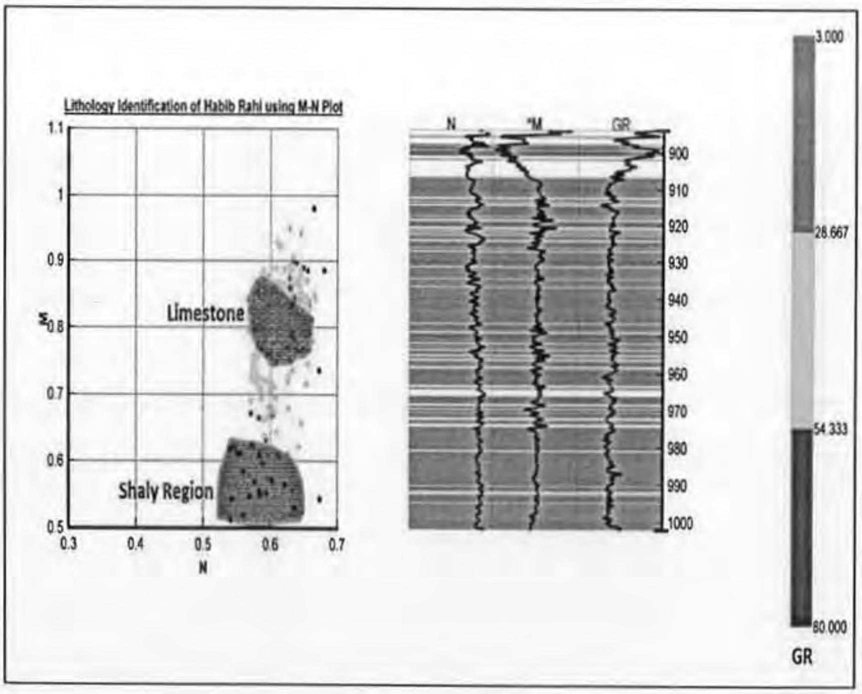

Figure 8.5 Clustered M-N plot.

8.3.4 Cross Plot of PEF and RHOB

The bulk density versus photoelectric crossplot can be used to determine porosity and to identify the mineral in a single-mineral matrix.The Photoelectric Factor log is plotted against Bulk Density. PEF log is on x-axis and RHOB is on y axis. GR log is used for lithology identification. Two facies are marked, limestone facie with high photoelectric and bulk density than shale, in brown colour and shaly limestone facie with low photoelectric factor and bulk density than limestone, in grey colour.

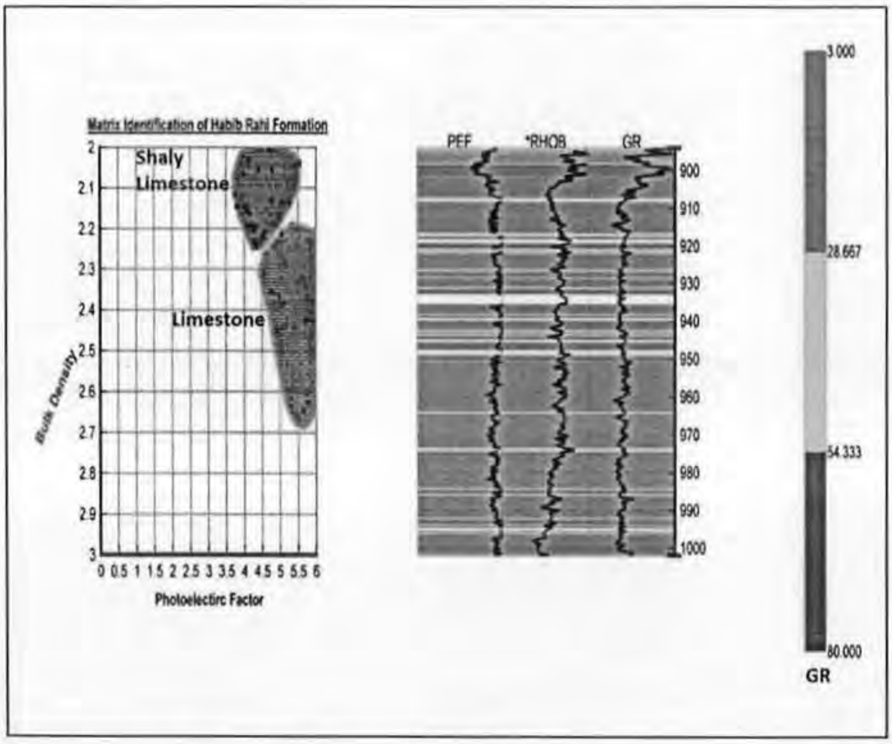

Figure 8.6 Clustered cross plot between PEF and RHOB.

CHAPTER 9

COLOURED INVERSION

9.1 Seismic Inversion

Geophysical inversion involves mapping the physical structure and properties of the subsurface of earth using measurements made on the surface of earth. Another way to look at seismic inversion is to consider it as the technique for creating a model of the earth using the seismic data as input. As such, it can be considered as the opposite of the forward modelling technique, which involves creating a synthetic seismic section based on a model of the earth (or, in the simplest case, using a sonic log as a one-dimensional model).

9.2 Coloured Inversion

Coloured inversion is designed to approximately match the average spectrum of inverted seismic data with the average spectrum observed impedance (Lancaster and Whitcombe, 2000).

The earth's reflectivity can be considered fractal, and the resulting amplitude spectrum favors high frequencies (spectral blueing). If there was no preferred frequency, then you would have a "white spectrum", but as there are some frequencies with more energy, then it is called "coloured".

Coloured Inversion include preparation of the well logs, investigating relationships between impedance and reservoir properties and tying the well logs to the seismic. After tying to the seismic, the well log data is used to estimate a seismic wavelet. By application of zero phase deconvolution a broad-band zero-phase dataset is obtained which forms the input to coloured inversion (Lancaster and Whitcombe, 2000).

Coloured inversion converts the seismic data to a relative impedance data set. The advantages of coloured inversion are the speed of calculation and avoidance of artifacts that may be introduced by a model. Coloured inversion, whether acoustic or elastic impedance (Cannolly, 1999) is an excellent qualitative interpretation tool.

A method was developed by Lancaster and Whitcombe (2000) which called Coloured Inversion (CI). The CI method is a simple and fast technique to invert the band-limited seismic data to relative impedance and can be done by generating a single operator to match the average seismic spectrum to the shape of the well log impedance spectrum.

Coloured Inversion enhances the seismic signal and adds the auto-picker. Often it can enhance features such as bed resolution, minor faulting, fracture zones and discontinuities due to channels and possibly the presence of hydrocarbons.

9.3 Work Flow

Work flow followed for coloured inversion is given below;

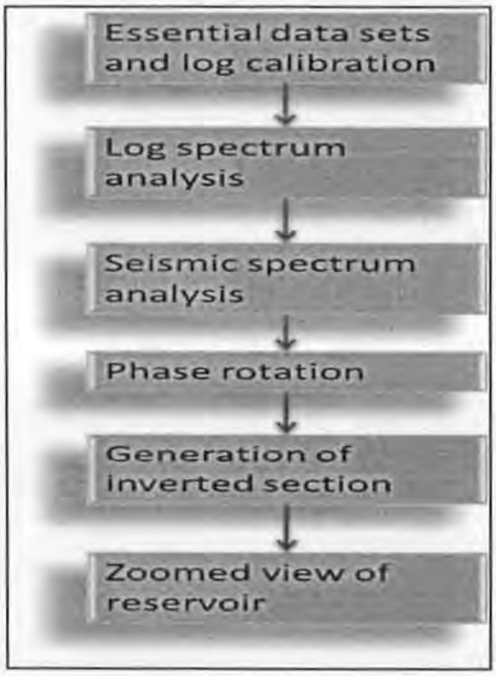

Figure 9.1 Steps for coloured inversion.

9.4 Coloured Inversion Computation

The coloured inversion computation requires the following as input:

- DT log

- RHOB log
- Formation tops
- TD chart

The amplitude spectra of the impedance logs (velocity * density) derived for the window of interest can be calculated and displayed on a log-log graph from which a linear spectral slope can be estimated. The fitted line can be expressed as the exponential α in the equivalent representation of the spectral trend in the form A*fα.

Butterworth filter is used to smooth and constrain the impedance log spectrum. The Butterworth filter is a type of signal processing filter designed to have as a flat frequency response as possible in the pass band.

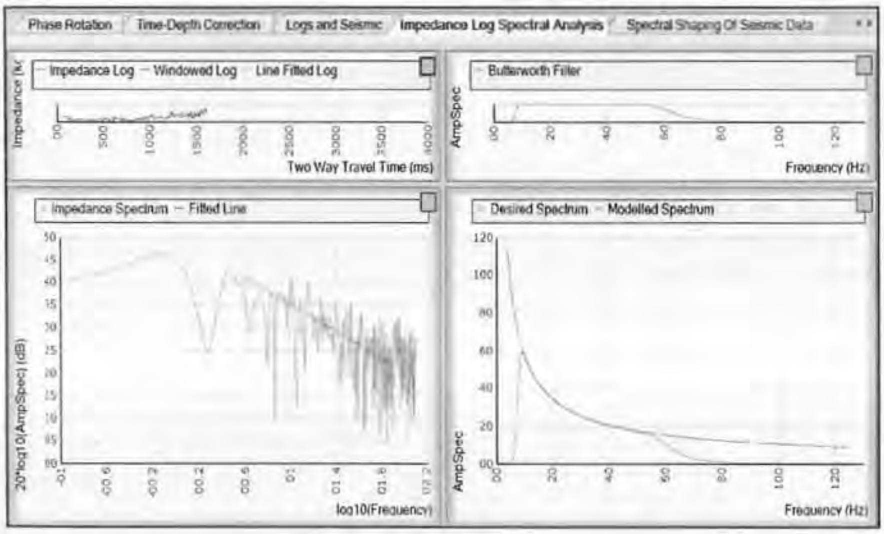

Figure 9.2 Smoothing of impedance spectrum using Butterworth filter.

The amplitude spectra are averaged and smoothed – to enable a smooth spectral shaping operator to be derived to operate on the data.

The phase of the operator is a constant -96° which is in agreement with the simplistic view of inversion to integration, and the concept of a zero-phase reflection spike being transformed to a step AI interface, provided the data are zero-phase.

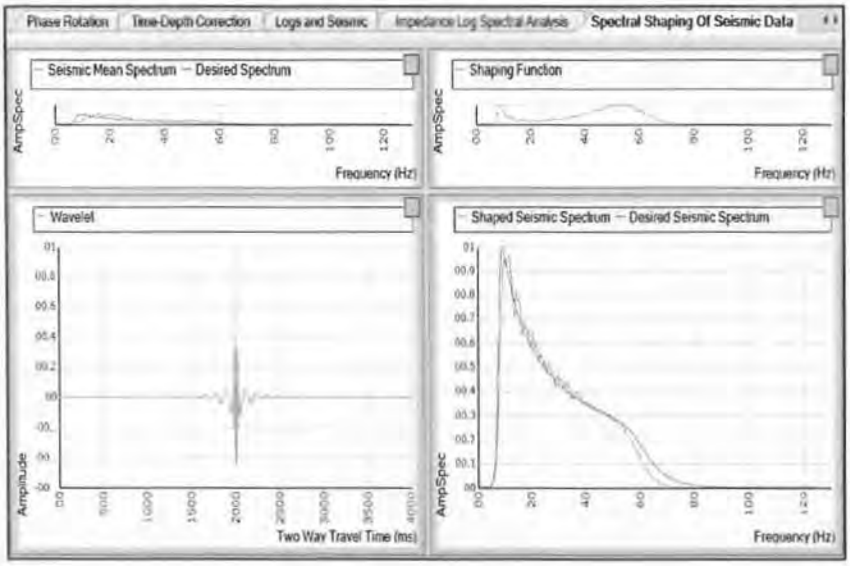

Figure 9.3 Spectral shaping and extraction of wavelet.

9.5 Coloured Inversion of Line 846-DAN-205

The colored inversion applied to the control line 846-DAN-205 gave the following results. The area in red colour (in figure 9.4) shows low acoustic impedence, which is favourable for Hydrocarbons. The reservoir Formation (Habib Rahi Formation) is marked on high acoustic impedence value (indicated by blue colour), so there is no hydrocarbon potential in Habib Rahi Formation. This is the justification for the dry Sabzal-01 well.

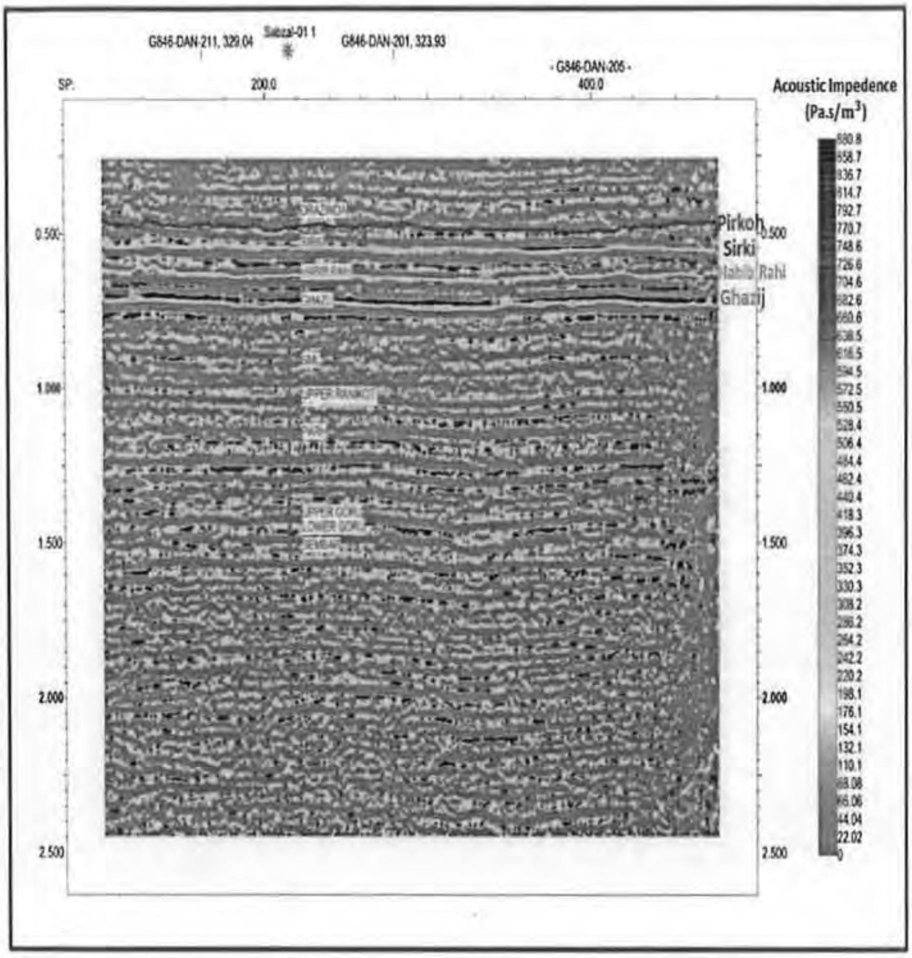

Figure 9.4 Coloured inversion of line 846-DAN-205.

CONCLUSION

- Four horizons are chosen, Pirkoh, Sirki, Habib Rahi and Ghazij Formation. These are marked on one strike line 846-DAN-245 and two dip lines 846-DAN-246, 846-DAN-248, the Horizons are nearly horizontal.
- Then grid contour map are created on Formations of interest in Time and Depth domain. Time Contour maps are generated by software and Depth Contours are created by single velocity function using extended maths calculator.
- Time Contour maps shows that the horizons are dipping towards South-East direction. Depth Contour maps shows that the horizons are getting shallower in North-West direction.
- In Attribute Analysis, relative Acoustic Impedence attribute, Average Energy attribute and wavelet Dominant Frequency attribute confirms that the reflectors are correctly picked and are nearly horizontalor sub-horizontal, also show high acoustic impedence and frequency in reservoir formation.
- The Petrophysics analysis is done on the Reservoir Formation which is Habib Rahi Formation, by loading lithology, resistivity and porosity logs and using different charts and formulas. Followig parameters are calculated by petrophysical analaysis, Volume of shale 55%, effective porosity is 6%, total porosity 15%, Water Saturation 81% and Hydrocarbon Saturation 19%. These results justify that there is no Hydrocarbon potential in Habib Rahi Formation and the well is dry.
- Facies Analysis confirms the lithology of Habib Rahi Formation that is limestone with interbeds of shale, by generating different cross plots between logs, so two facies are encountered, limestone Facie and shaly limestone facie.
- Coloured Inversion is performed on a control line 846-DAN-205, indicates that reflectors are nearly horizontal and justifies that Sabzal-01 is dry well, as the reservoir formation is marked on the high acoustic impedence values, which is not favourable for Hydrocarbons.

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