2-DIMENSIONAL SEISMIC DATA INTERPRETATION,PETROPHYSICAL ANALYSIS AND FACIES ANALYSIS OF BADIN AREA, LOWER INDUS BASIN, PAKISTAN

By

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CERTIFICATE

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First praise is to Allah Almighty, on whom ultimately we depend for sustenance and guidance. With the grace of Allah, I have been able to overcome yet another task which was impossible without ALLAH's Blessings. I am really thankful to Allah Almighty that He makes me capable to complete my work.

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ABSTRACT

Badin area is a common example of extensional tectonics represented by Horst and Graben structures. Badin area lies in Southern Indus basin. The purpose of this work is to study structural variations of subsurface using seismic and well log data of Badin area. Seismic interpretation confirms Horst and Graben geometry in the studied area.

From time and depth contour maps of the horizons that are marked were generated to understand the spatial geometry of the structures and the nature of geological structures as identified by the seismic section of the area. Contour maps in time and depth domain show faults having northeast to southwest trend in study area.

Petro-physical results by using statistical analysis and facies modelling indicates the dryness of well Doti-01.

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Chapter 1

Introduction to the Study Area

Hydro-carbons are the main constituent of petroleum. The word petroleum comes from Latin word petroleum (literally **"rock oil")**. The study area is located in East of Badin district in Sindh province of Pakistan (Southern Indus basin). The district is placed between 24° 5'N to 25° 25'N Latitude and 68° 21' E to 69° 20` E Longitude. Structure of the area (Horst and Graben geometry), which forms the structural traps. The identification of these traps is one of the main task for the Geoscientists in exploration of hydrocarbons. Normal faults are more prominent in study area.

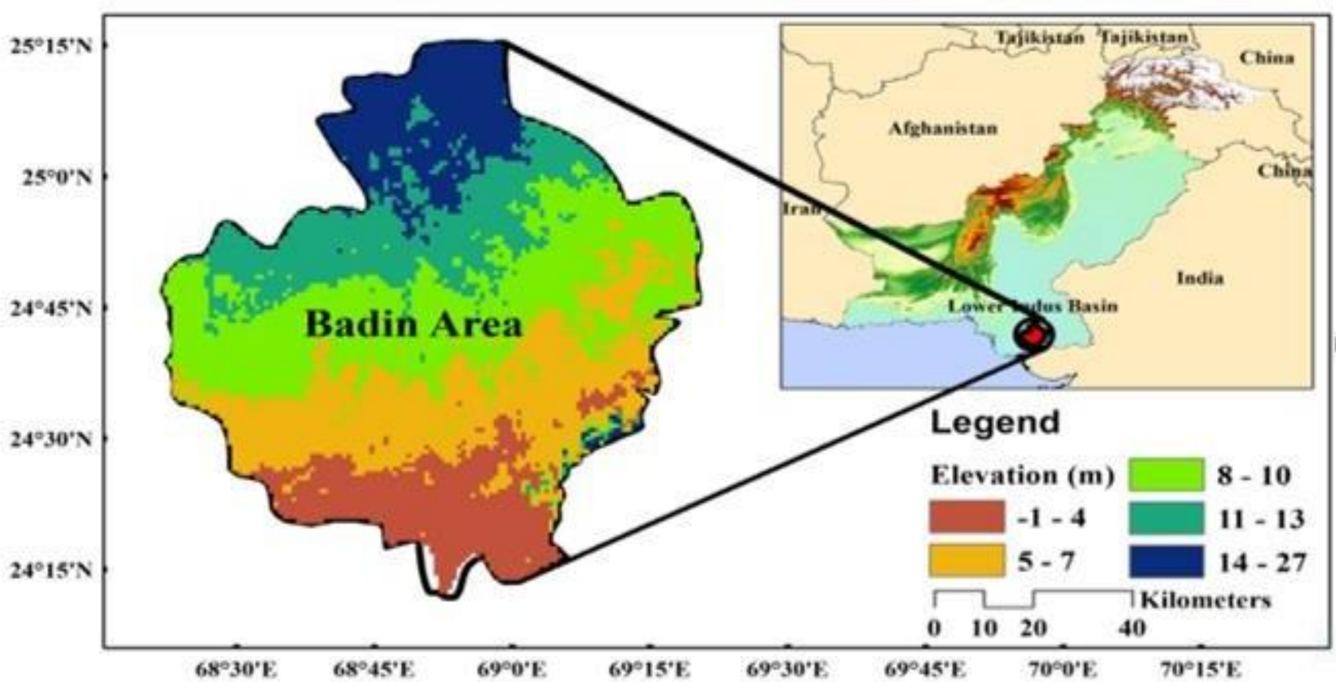

Fig 1.1 Elevation map of Pakistan showing location of study area within lower Indus basin (Kazmi., 1997)

1.1. Structural setting of area

During Cretaceous, there was period of tectonic instability. The spreading rate was high, ∼20 cm. Badin Rift Basin is located in Thar platform area of Lower Indus Basin. It is the Sargodha High in fact which is considered to be a divide for Upper Indus Basin and Lower Indus Basin (Kadri, 1995). Badin is characterized by a series of Horst and Graben structures present below the base Tertiary unconformity within Cretaceous and older strata. These Horst and Graben structures were formed as a result of rifting between India and Seychelles during the Late Cretaceous (Alam, 2002).

1.2. Software tools

- SMT Kingdom 8.8(32 bit)
- Microsoft excel

1.3. Data set

Following data set has been used for this research work.

- SEG-Y file
- Digital well logs (LAS file)
- Navigation file
- Formation tops

1.4. Seismic Data

The 2D seismic section has been utilized for marking horizons and identification of faults and structure.

1.5. Base map

Base map is a map on which primary data and interpretation can be plotted. This map shows the orientations of seismic lines and specify points at which seismic data were acquired. Orientation of lines is from north east to south west. Scale bar is also present in map and X,Y projections are in metre. Base map which is given below in a fig 1.2 shows the lines and well present in Badin area.

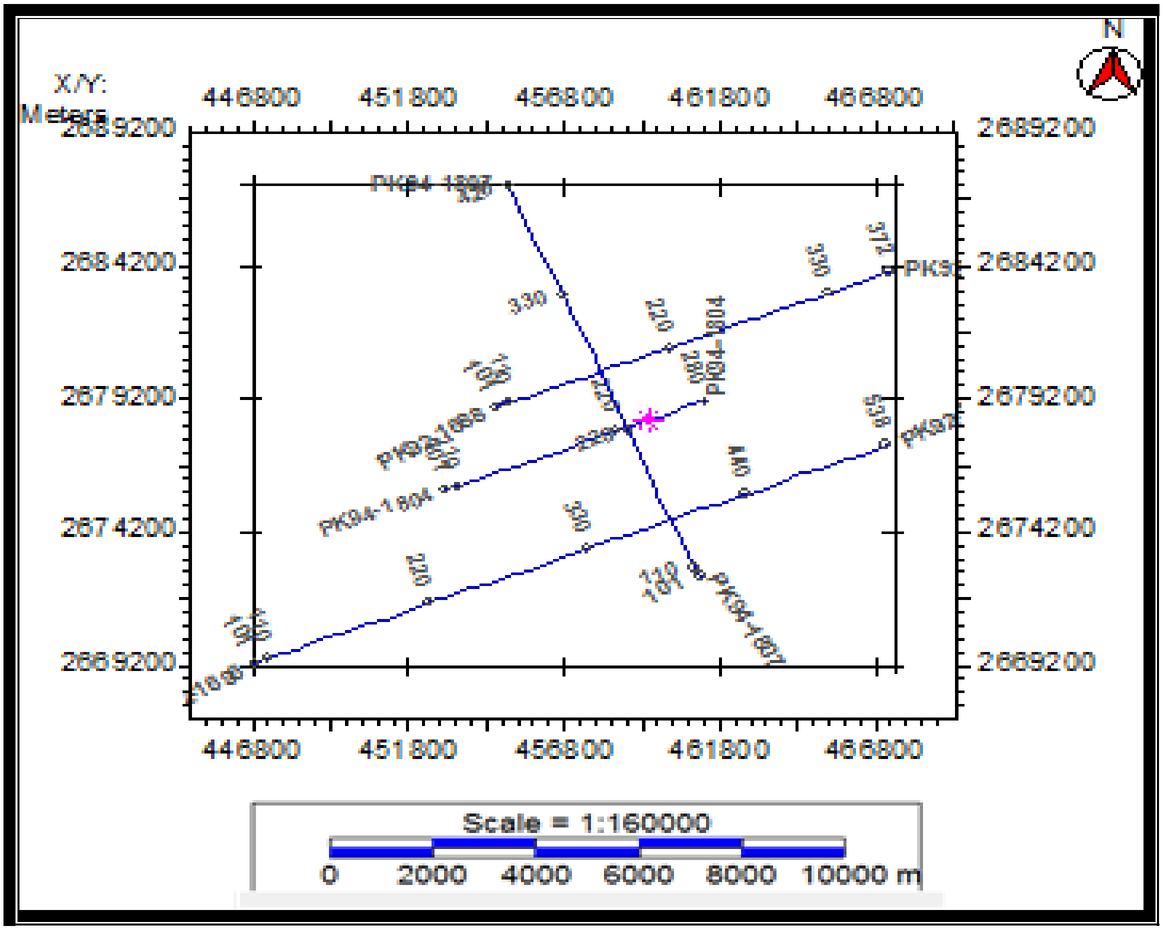

Fig 1.2 Base map of Badin area showing direction of strike and dip lines

1.6. Well Summary

Seismic lines and well which is used in this research work are given below in a table 1.1.

Table1.1. Description of Seismic reflection lines and well

Sr.NO	Line name	Line orientation	Trend	Well
1	PK92-1688	NE-SW	DIP	
2	PK92-1696	NE-SW	DIP	
3	PK94-1804	NE-SW	DIP	DOTI-1
4	PK94-1807	NW-SE	STRIKE	

1.7. Brief Methodology

The geological and significance of the area is considered as the first step of interpretation strategy then seismic and well data are integrated for detailed structural analysis. Synthetic Seismogram shows the correct position of interested horizons. A well correlation is also established to see the continuity and depth variations of the mark horizons. Petro physical studies are carry out to determine the reservoir parameters and to mark the favorable zones for hydrocarbon accumulation within the reservoir interval. In facies modeling, depositional sequences are identified.

1.8. Objectives

The objectives of this thesis are following:

- The main focus of this thesis is based on seismic interpretation of study area which involves marking of horizons, faults picking and to construct time and depth contour maps.
- Petrophysical analysis are confirm the potential of zone of interest of reservoir.
- Facies modeling of reservoir are used to differentiate the lithology.

Chapter 2

Geology and Tectonics of the Area

2.1. Introduction

Geology plays a significant role for interpretation of seismic data as it gives general information about the rock units, structural style and mode of deformation. For the exploration of underneath earth surface, the geology is of extreme importance. Geology is important for exploration of oil and gas. A geological history of basin can be compiled by considering basin forming tectonics. (Kingston et al., 1993).

This chapter deals with a brief description of the tectonics, structural setting and stratigraphy of the study area.

2.2. Regional geological setting

Eurasia is comprised of three broad geological divisions, from north to south and this divisions known as Laurasion, Tethyan and Gondwanian domains. Their origin may be traced back to late Paleozoic, when all the continents had drifted to form a continuous land mass, the super continent of Pangea (Wegnar., 1924). Pakistan is located at Junction of Gondwanian and Tethyan domains (Kazmi and Jan., 1997).

2.3. Tectonic framework

Tectonic is understanding of a region, it is basically a continuous process which evolves as more and more relevant evidence and becomes available for integration (Iqbal B. Qadri., 1995). Pakistan is unique as much as it is located at junction of these two diverse domains i.e Tethyan and Gondwanain domain (Kazmi., 1997). The south eastern part of Pakistan belongs to domain and presents a complicated crystal structures. Tectonic of Pakistan is characterized by two active convergent boundaries (Iqbal B.Qadri .,1995)

- In North East, there is an active continent-island arc- continent collision boundary.
- In South West, there is an active boundary of oceanic lithosphere.

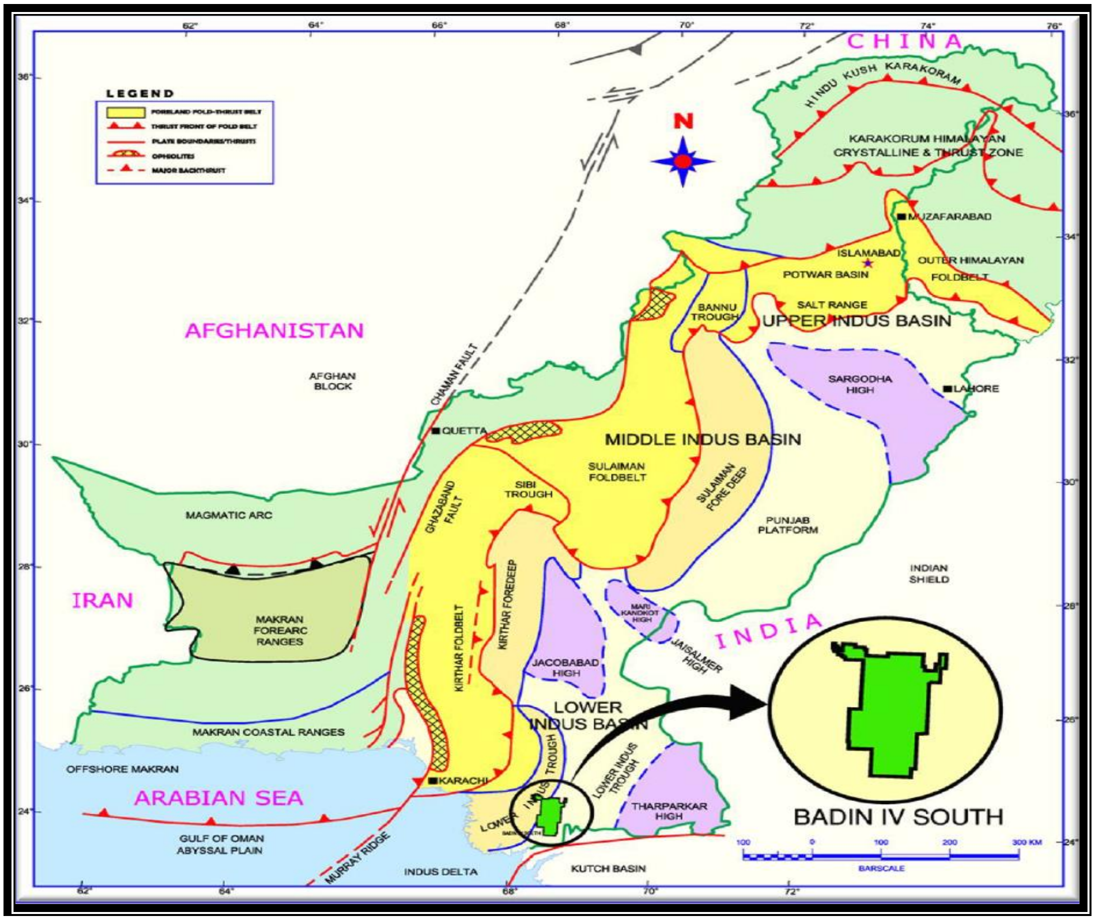

Fig 2.1. Tectonic setting of Indus Basin Pakistan (Wandrey et al ., 2004)

2.4. Sedimentary Basin of Pakistan

In term of different geological histories, Pakistan comprises two main Sedimentary basins. Indus Basin and the Balochistan Basin, they evolved through different geological episodes and were finally welded together during Cretaceous time period. Along Chaman strike slip fault, there is another newly identified smaller basin, known as Kakar Khorasan Basin. This basin is also called Pasheen basin (Ahmed, 1991). Pasheen basin carries its own geological history for most of its development. This basin came into existence due to interaction of Indian and Eurasian plate and is classified as median basin (Iqbal B.Qadri., 1995). So, there are three basins in Pakistan.

1) Indus basin
2) Balochistan basin
3) Pasheen basin

Indus basin

Indus Basin principally consists of the syntaxes & promontories. Most of them are trending point. The main feature which controlled sedimentation in proto-Indus basin upto Jurassic was Pre-Cambrian Indian shield whose topographic highs exist in form of Kirana hills (Sargodha high) and Nagar Parkar Ridge. Study area lies in Indus basin.

Indus basin is classified into two basins.

(a) Upper Indus basin
  (i) Kohat sub-basin
  (ii) Potwar sub-basin

(b) Lower Indus basin
  (i) Southern Indus basin
  (ii) Central Indus basin

Lower Indus Basin

Lower basin stretches in the direction of north-south along the Indus river and south of Khairpur-Jacobabad high towards Arabian sea (Mozaffer et al., 2002). Oldest rocks in lower Indus basin are Triassic Wulgai formation. The Jacobabad, Mari-Kandhkot and Lakhra highs, all have presence of horst blocks and probably formed in response to extensional tectonic style of the Lower Indus Basin (Quad Report, 1994).

Southern Indus Basin

Study area Badin belongs to Southern Indus basin. This basin is just located south of Sukkur Rift – divide between central and Southern Indus Basins. The southern Indus basin is bounded by Indian shield to East and marginal zone of Indian plate to West. Its southward extension is confined by offshore Murray ridge. The oldest rocks encountered in area are of Triassic age.

Central and Southern Indus Basins were undivided until Lower/Middle Cretaceous when Khairpur – Jacobabad high. This is indicated by homogenous lithologies of Chilton limestone (Jurassic) and Sembar Formation (Lower Cretaceous) across high Sand facies of goru Formation (Lower – middle Cretaceous) are also extending upto Kandhkot and Giandari area. This is further substained by Khairpur and Jhat Pat wells located on high (Iqbal B.Qadri.,1995)

The Southern & Central Indus Basins are separated by Jacobabad and Mari- Kandhkot highs together termed as the Sukkur Rift. (Raza et al., 1989). Scheme being used as follow.

- Southern Indus Basin:
  (a) Thar Platform
  (Sindh Monocline)
  (b) Karachi Trough
  (c) Kirthar Foredeep
  (d) Kirthar Fold Belt
  (e) Offshore Indus

Badin Rift Basin is located in Thar platform area of Lower Indus Basin. It is the Sargodha High in fact which is considered to be a divide for Upper Indus Basin & Lower Indus Basin (Kadri, 1995).

2.5. Basic structures

Basic structures within study area are classified into nine types where as the structural styles have been classified into various types which is horst and grabens, synthetic and antithetic, negative and flashlight structural style. The structures within the study area revealed evidence for three major structural episodes (Shabeer et al., 2018).

Episode 1: Structures link with rifting of Indian plate from Gondwanaland during Late Jurassic to Early Cretaceous.

Episode 2: Reactivation of previous structures while Madagascar rifted from Indian Plate during the Middle Cretaceous.

Episode 3: Inversion and reactivation of structures occurred when Indian Plate collided with Asia during Early Eocene.

2.6. Stratigraphy of area

Stratigraphy of study area comprises of rocks which consist of Wulgai formation to Alluvium (Raza et al., 1990). 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 source rock in the area. Lower Goru is further divided into five units i.e. Basal sand overlies Sembar formation, Lower Shale overlies Basal Sand, Middle Sand overlies Lower shale while Upper Shale lies between Middle and Upper Sand which in 5th 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). Fig 2.2 describe stratigraphy of Badin area.

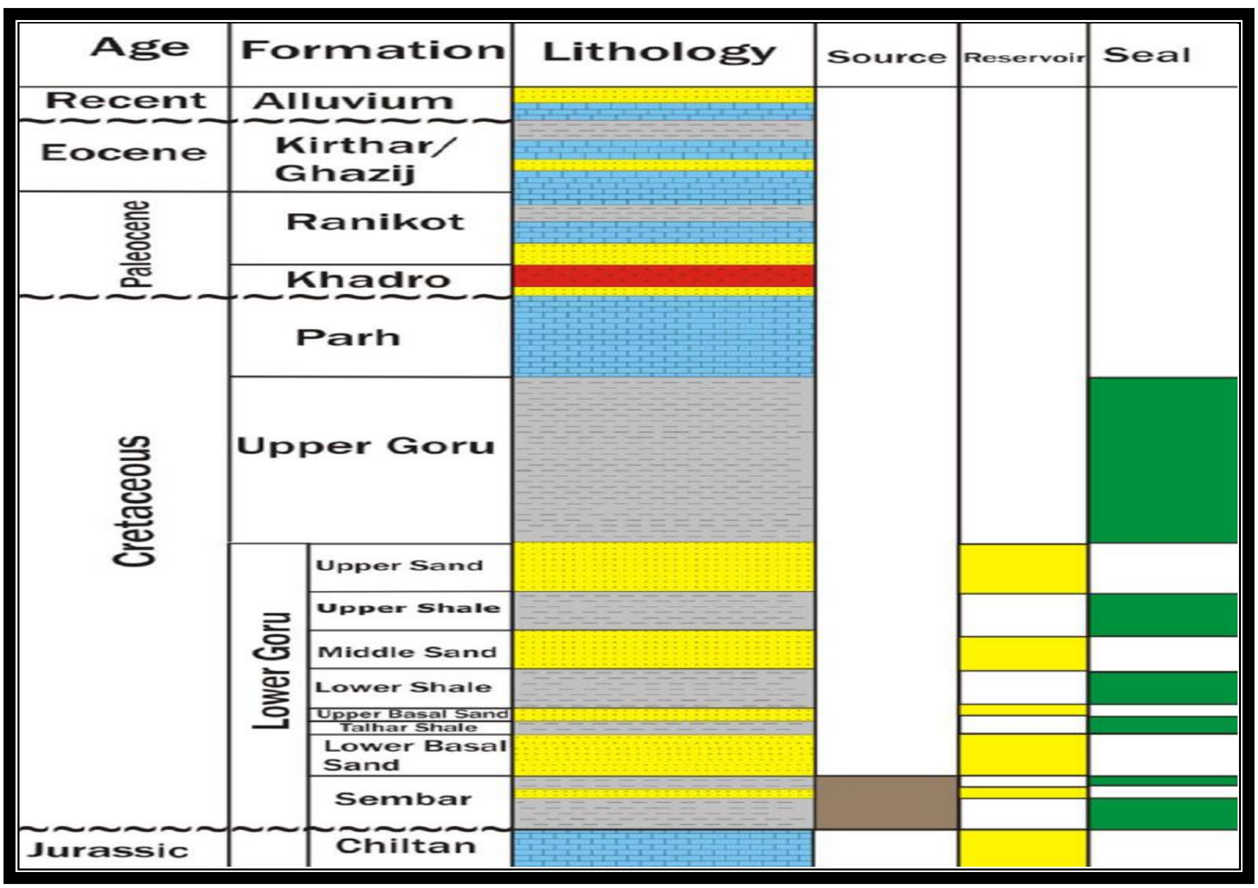

Fig 2.2. Generalised Stratigraphy of Lower Indus Basin (Mozaffar et al ., 2002)

2.7. Hydrocarbon Potential

Badin area is considered favorable for gas and oil. It has the best potential for shale gas. Thick shale deposits, hydrocarbons have been generated and exploited for the last 30 years (Raza et al, 1989 and 1990).

The maturity (at base tertiary level) data suggests that most of Badin oil has been generated on Platform rather in Karachi trough and migrated up dip via different pathways (Iqbal B. Qadri, 1997).

2.7.1 Petroleum play in study area

In study area, the Sember Formation is source rock, the Lower Goru having good porosity is reservoir rock and the Upper Goru Formation provides an excellent seal rock (Jamil et al, 2012)

2.7.1.1 Source Rock

Sember Formation is the source rock of Badin area. The source rock of Sember are composed of shale. They were deposited in shallow marine environment and thickness ranges from 0 to 260m (Iqbal and Shah., 1980).

2.7.1.2. Reservior Rock

The Basal sand of Lower Goru formation is the target formation in the area. Massive sand is another interesting producing reservoir from its various sandsheets of multiple thickness (Kadri., 1995)

2.7.1.3. Seal rock

Late Cretaceous Upper Goru shale provides excellent seal rocks. Lower shale and Sembar shale have the most uniform and best seal quality. The Upper Goru forms the top and Lateral Seals for the upper sand unit of Lower Goru Formation (Kadri., 1995).

2.7.1.4. Traps of Lower Indus Basin

Trapping mechanism are mainly provided by the traditional tilted fault blocks which are expected in badin area. Horst structures developed in the region act as very suitable tracks for hydrocarbon accumulation. The possibility of stratigraphic traps in the form of sand lenses cannot be ruled out. Transgressive shales of the upper and lower Goru Formation provide effective sealing mechanism for the entrapment of hydrocarbons in the lower Goru sand reservoirs (Quadri, 1986)

2.8 Oil window in study area

Badin area is the prolific oil producing region of Lower Indus basin. In this region also the geo thermal gradients increase away from the stable Indian shield (Nagar Parkar High). The wells drilled on the eastern part of Platform. Nabisar, Digh, Badin, Patar encountered geothermal gradient of 2.1 – 2.3˚C / 100 m. Oil window exists below potential source rock (Raza., 1986). Fig 2.3 shows character of oil window in Badin area.

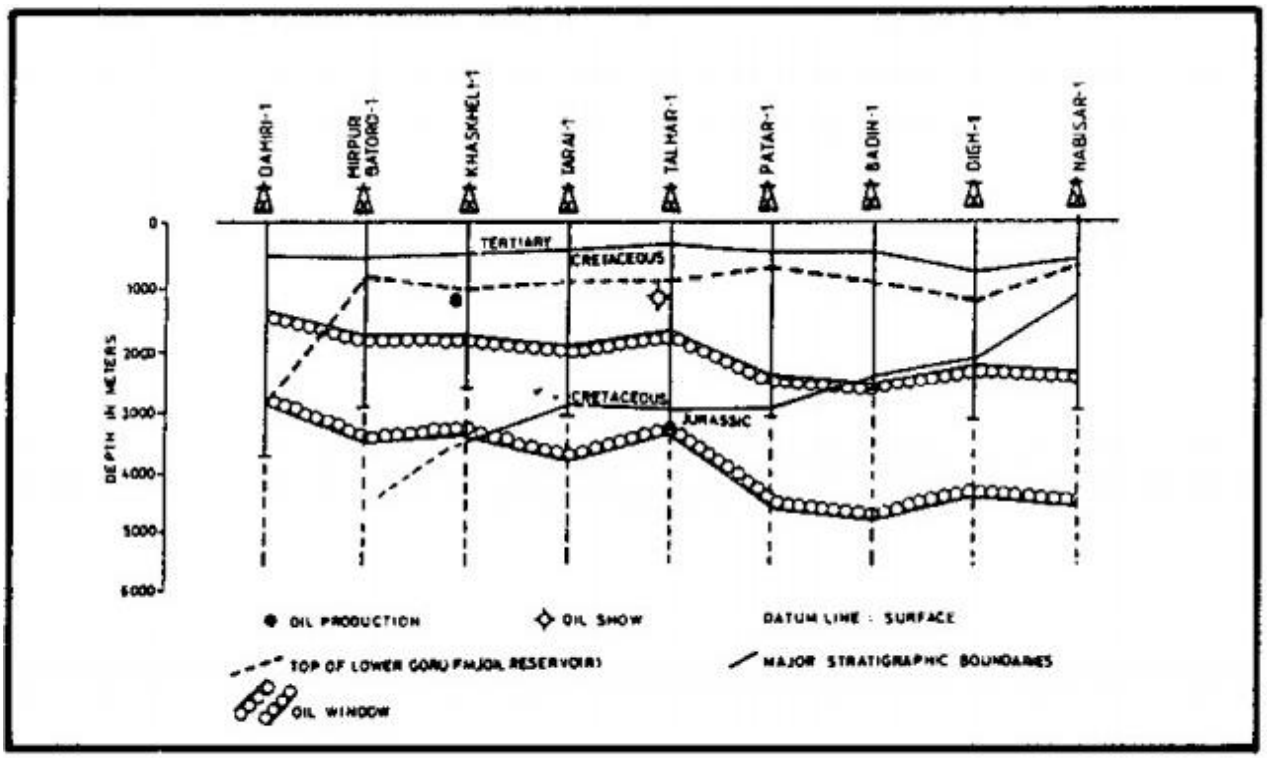

Fig 2.3. Corelation of ‘Oil window’ in Badin area (Raza., 1986)

Chapter 3

Seismic Interpretation

3.1. Introduction

The process of determining sub-surface information from seismic data is called seismic Interpretation. Interpretation is fundamental part of petroleum exploration (Hilterman, 2001). The goal of seismic interpretation is to identify possible geological patterns in seismic image. Usually stratigraphy and available well log data are encounter for the interpretation of an area (Dobrin., 1960)

3.2. Approaches of seismic interpretation

Following are the two main approaches for seismic data interpretation.

- Structural Analysis
- Stratigraphical Analysis

3.3. Stratigraphical Interpretation

According to Telford et al., (1990) stratigraphy analysis involves the delineating the seismic sequences, which present the different depositional units and identifying the seismic facies characteristic with suggest depositional environment and analysis of the reflection characteristic variation to locate the both stratigraphy change and hydrocarbon depositional environment.

3.4. Structural Interpretation

Structural analysis is the study of reflector geometry on the basis of reflection time. The main aim of structural analysis is to search out structural traps containing hydrocarbons. The most common structural features associate with hydrocarbons are anticlines and the other one is faults associated traps. Structural interpretation of seismic sections involve the 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).

3.5. Methodology of Seismic Interpretation

To start interpretation, We must have (Yilmaz., 1987)

- Base Map: shot point location
- Seismic sections
- Available Wells
- Velocity data from wells: from Check Shot, VSP
- Formation Top of the well: to determine the top of horizon
- Logs and reports: Sonic, GR, Density & other logs

3.6. Work flow of seismic Interpretation

All interpretation projects include a number of tasks which must be completed in order to meet project objectives. The sequence in which these tasks are performed is commonly referred to as an interpretation work flow. Procedure adopted for interpretation is given in Figure 3.1. Base map is prepared by loading navigation data and SEG-Y file in Kingdom software. Horizons of interest are marked manually with the help of synthetic seismogram. In this process, faults are identified and also marked. Horizons are also contoured to find out structural highs and lows. The different important steps are involved in interpretation workflow are discussed in Fig 3.1.

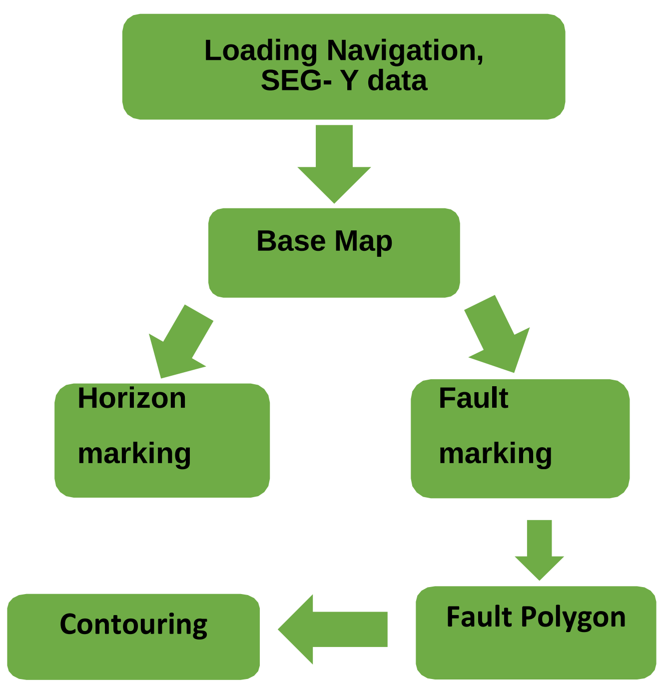

Fig 3.1 workflow of Seismic Interpretation

3.7. Synthetic seismogram

The synthetic seismogram is generated by convolving the reflectivity derived from digitized acoustic and density logs with the wavelet derived from seismic data. By comparing marker beds or other correlation points picked on well logs with major reflections on seismic section the interpretation of data can be improved. The quality of match between a synthetic seismogram depends on well log, seismic data processing quality and the ability to extract a representative wavelet from seismic data. The acoustic log is generally calibrated with Vertical seismic profile (VSP) before combining with density log to produce acoustic impedance. GR used as a reference log. The display of Synthetic Seismogram is shown in Figure 3.2.

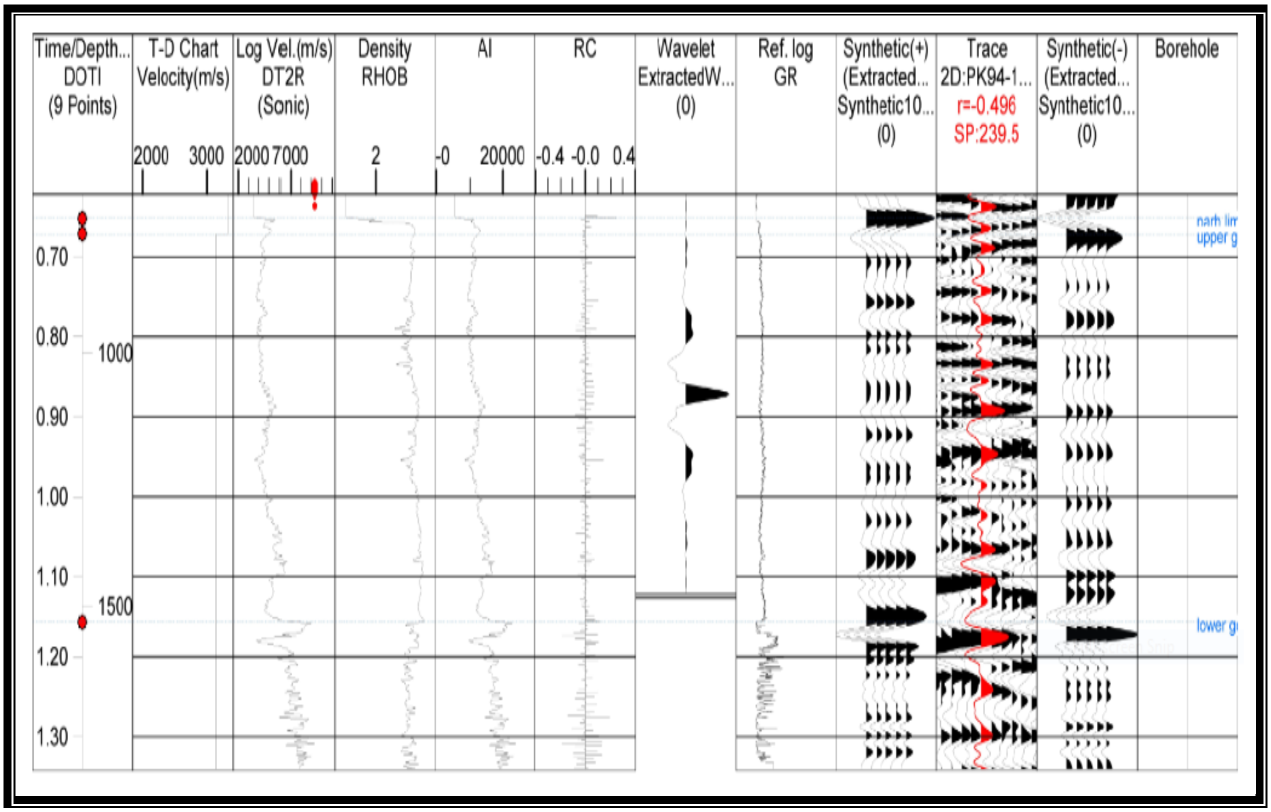

Fig 3.2 Synthetic Seismogram of Doti-01well

3.8. Picking up horizons

Picking is a reflection on a seismic section. It involves deciding what wiggles from trace to trace are from same reflection. 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 (Yilmaz., 1987).

3.9. Fault identification

Faults in a seismic section is called fault segment. Faults are typically identified as the breakage in continuity of a reflector, after marking all horizons, the faults were marked on seismic lines. Clues of normal faulting exist on all of interpreted lines. Following steps are followed to interpret the faults on the seismic data.

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

3.10. Marked Seismic Sections

Primary task of interpretation is the identification of various horizons as an interface between geological formations . Two seismic horizons Upper Goru and Lower Goru are marked. Interpreted seismic Section are shown in Figure 3.3, 3.4. These seismic sections shows the Horst and Graben structure. The horizons are named on the basis of well tops of well Doti-01. Horizon and fault marking were done on control line or reference line. On the basis of this control line I marked the other horizons and faults on remaining lines.

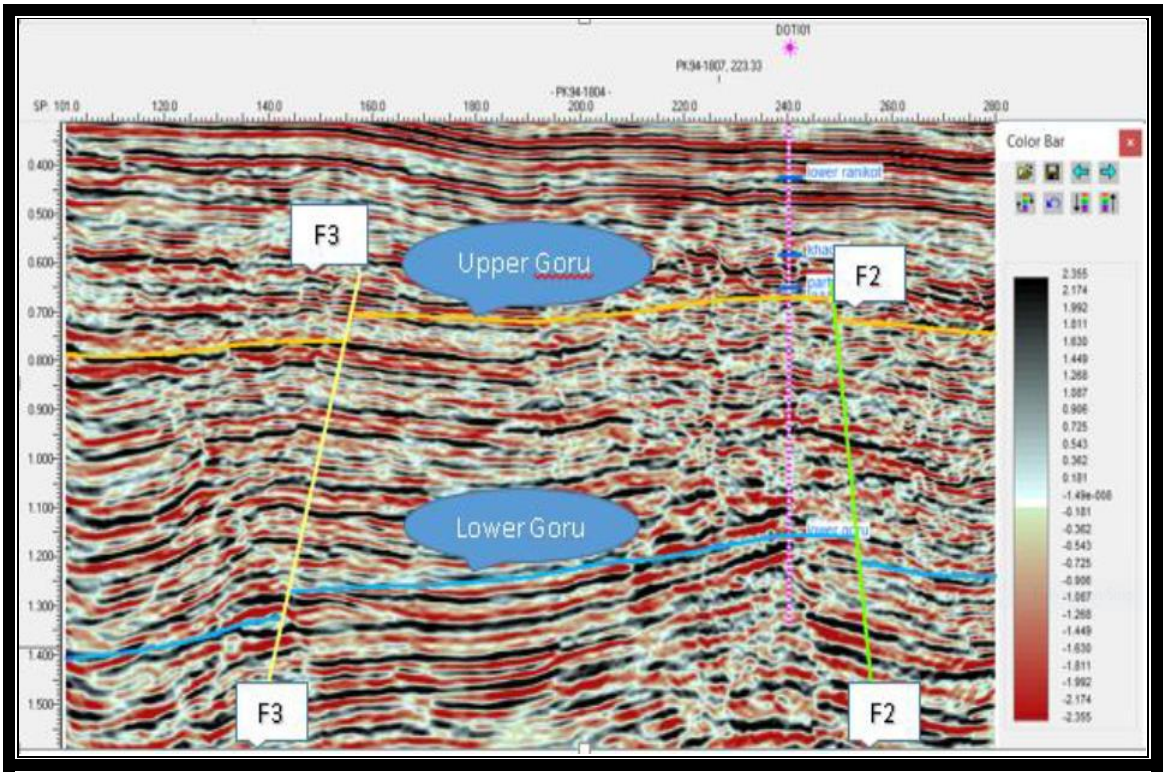

Fig 3.2 Interpretation of dip line PK94-1804

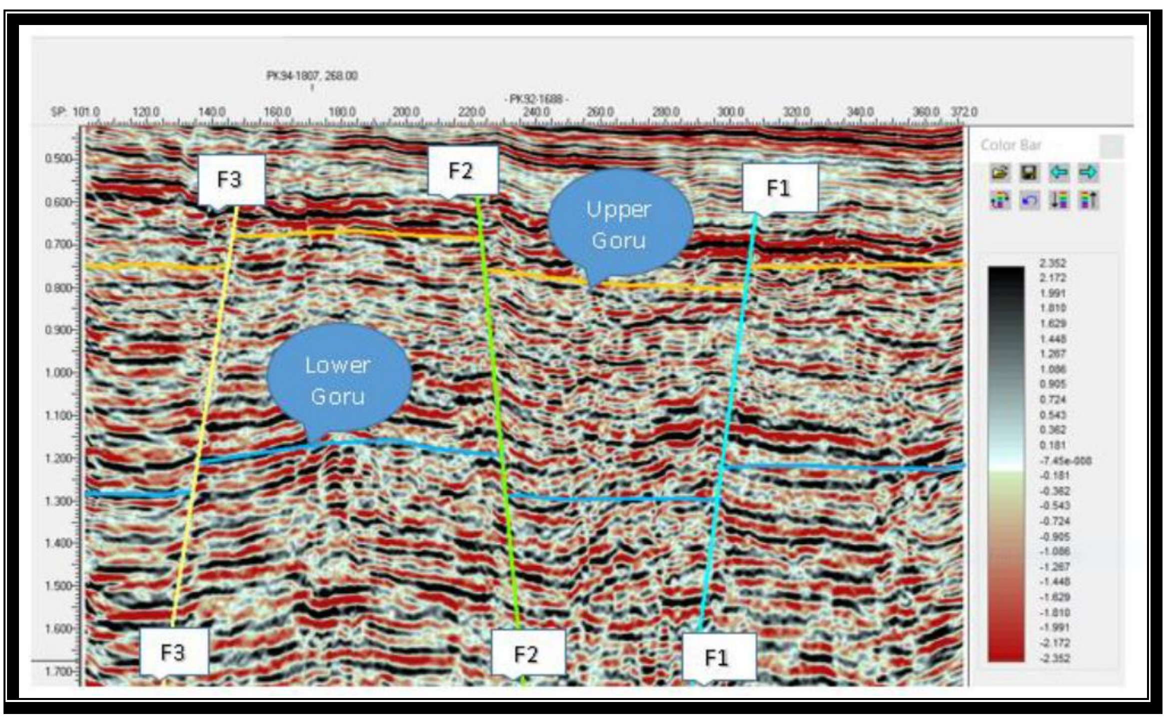

Fig 3.3 Interpreted Seismic Section of dip line PK92-1688

3.11. Contour map

The final products of all seismic exploration are the contour maps, time or depth. Contours are the lines of same time or depth drifted about the map as dictated by data. Seismic interpretation actually displays the most essential information extracted during interpretation in the form of time and depth contour maps (Coffen., 1986).

Time & Depth contour map

Figure 3.5 and 3.6 shows the time contour map and depth contour map of lower Goru formation. There are some reasons for making time maps. The pattern of time contour map confirms the shape of sub-surface structure. In this time contour map, the central parts indicating Graben trending north west to south east shows the deepest part on the color scale while the shallowest parts indicating horst. The depth maps are computed by using velocities of horizons from synthetic seismogram. Then by using velocities for respective formations.time maps are converted to depth maps by applying formula S=VT. Depth map shows that horizon is forming horst and graben structure.

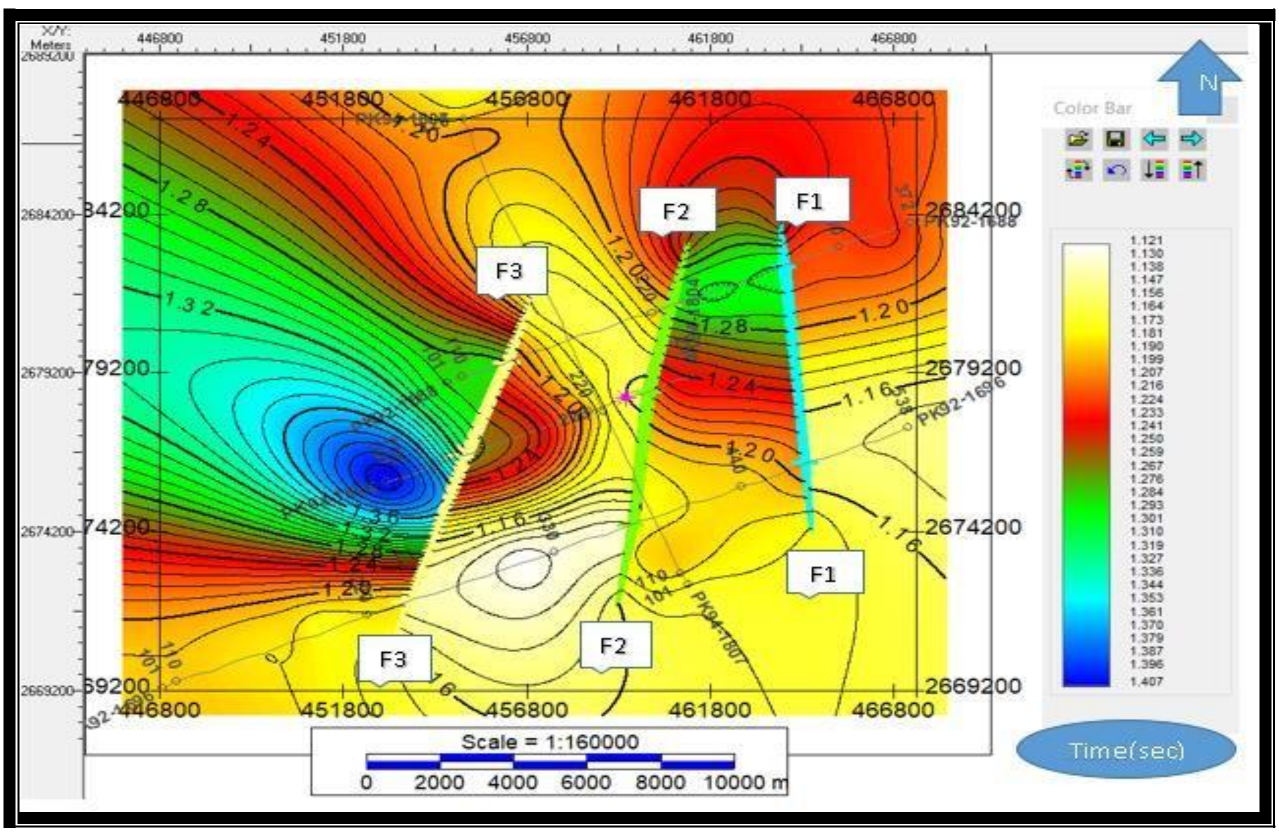

Fig 3.3.Time contour at Lower Goru level showing change in time on the base map

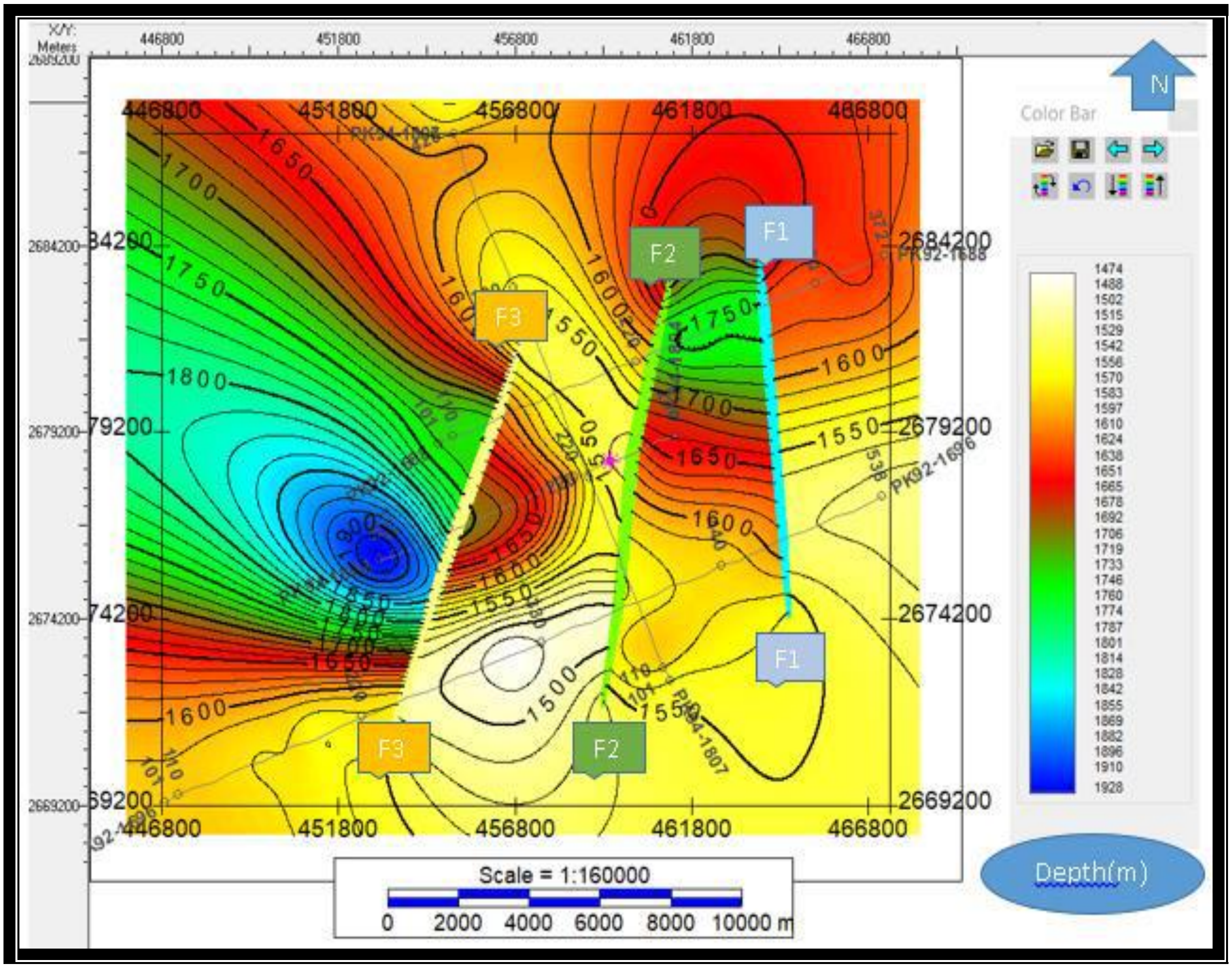

Fig 3.4 Depth contour map of Lower Goru

Chapter 4

Petrophysical Analysis

4.1 Well logging

To determine various properties of different lithologies and the actual depth, thickness, two way travel time and interval velocities of these lithologies is the main purpose of well logging. Well log interpretation is done on Top Lower Goru Formation. The purpose of study is to be able to identify the permeable zones, their fluid content and hydrocarbon saturation. In well logging different types of logs are obtained with the help of a sonde. In early ages different sondes are used for different type of logging in the well but now a day we use only one sonde which has ability to do all type of logging both cased or uncased logging (Rider., 2002)

4.1. Data set

The petrophysical analysis has been performed for reservoir characterization of Badin area. For this purpose the data of the drilled borehole, Doti-01 is used. Log run in this well which are:

- Gamma Ray (GR),
- Spontaneous- Potential (SP),
- Calliper Log (CALI),
- Sonic log (DT),
- Density (RHOB),
- Neutron Porosity (NPHI),
- Deep Laterolog (LLD),
- Shallow Laterolog (LLS)

These logs are represented by three tracks and are shown in Fig 4.1

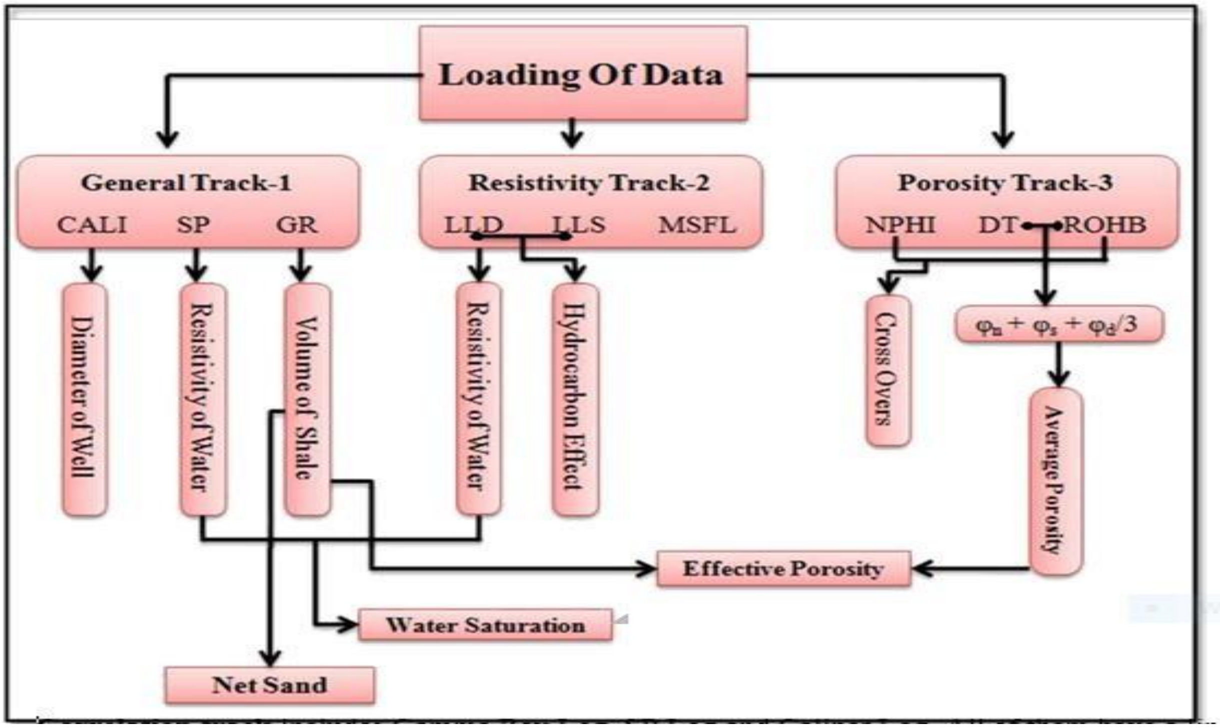

Fig 4.1 Flow chart for Petro physical analysis (Rider., 2002)

4.2. Log Curves

Log data of Well Doti-01 was available in Logging ASC II Standard (LAS) format. The log curves along with some parameters given in LAS file. File header are used to calculate all basic and advance parameters.

4.3. Petro-physical properties

Following are the petro-physical properties calculated for petro-physical analysis.

4.4.1. *Volume of shale*

The lithologies are marked by Gamma Ray log deflections; it is a good indicator of shale. Following formula is used from Rider, 2000

$$IGR = \frac{GR\log - GR\min}{GRmax \quad - GRmin}$$

Where,

IGR=Gamma Ray Index

GR_{log}= Gamma Ray reading of formation

GR_{min}= Minimum Gamma Ray (Shale)

GR_{max}= Maximum Gamma Ray (Clean sand)

Sand and shale lines are marked at the minimum and maximum values of Gamma Ray in selected zone of interest.

4.4.1. Determination of Water saturation

Water saturation determines the ratio of water present to that of hydrocarbons in reservoir. To calculate saturation of water in the formation, Mathematical equation was developed by Archie shown below.

$$Sw = \frac{aR_w}{Rt\varphi^m}^{1/n}$$

Where,

Sw= water saturation

R_W =water resistivity (formation)

Φ = effective porosity

m (cementation factor) = 2

a (constant)= 1

R_t= log response (LLD)

Rw has been calculated with help of the following formula:

$$Rw = \varphi^2 \times Rt$$

4.4. Estimation of true resistivity

Basically there are different types of electrical Resistivity Logs. These logs are used to measure the resistivity of the subsurface. Resistivity logs include the following.

• Laterolog Deep (LLD)

• Laterolog shallow (LLS)

- **LLD (Deep Laterolog)**

Laterolog log deep measures the true formation resistivity beyond the outer boundary of invaded zone This log is generally used for measuring the Formation resistivity. It has deep penetration as compared to the Shallow Laterolog (LLS).

- **LLS (Shallow Laterolog)**

LLS used for shallow investigation of invaded zone.DOI is smaller than LLD. These logs calculate true resistivity.

Estimation of resistivity of water (Rw)

The resistivity of water is calculated by Spontaneous potential log. The steps are discussed below;

1. Pick SSP from S-P log by using formula given by (Rider, 1996).

$$SSP = SP\ clean - SP\ shale$$

Where,

SSP = Static spontaneous potential

SP clean = Spontaneous potential for sand

SP sh = Spontaneous potential for shale

Formation temperature

Determine the **Formation temperature (TF**) against the depth (d), using formula shown in equation given by (Rider, 1996).

$$TF = \frac{BHT - Ts}{Td - Ts}$$

Where,

D= Formation depth

BHT=Borehole temperature

Ts= Temperature at surface

Td= Temperature at depth.

4.5. Porosity Determination

The pore spaces which are not occupied by the rock fragments are named as porosity. 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 (Rider, 2002)

$$\phi = \frac{ƒma - ƒb}{ƒma - ƒf}$$

Following terms have been used in the above formula:

ƒb= Bulk Density of the Formation.

ƒma = Density of the rock matrix.

ƒf = Density of the fluid occupying the pores.

ϕ= Density porosity of the rock.

Density is calculated by using following methods:

- **Density Porosity**

It is derived from density log using the following equation.

$$\textit{Density Porosity} = \frac{\textit{Density Matrix} - \textit{Density Log}}{\textit{Density Matrix} - \textit{Density Fluid}}$$

• Neutron Porosity

It is directly obtained from Neutron log values. The Average Porosity is obtained by taking the mean of the above two:

$$\textbf{Average Porosity} = \frac{\textbf{Density Porosity} + \textbf{Neutron Porosity}}{2}$$

Finally Effective Porosity is given by,

$$\boldsymbol{Effective\ Porosity = Averagae\ Porosity * Vmatrix}$$

Where,
V matrix is Volume of Matrix given by 1- Vshale.

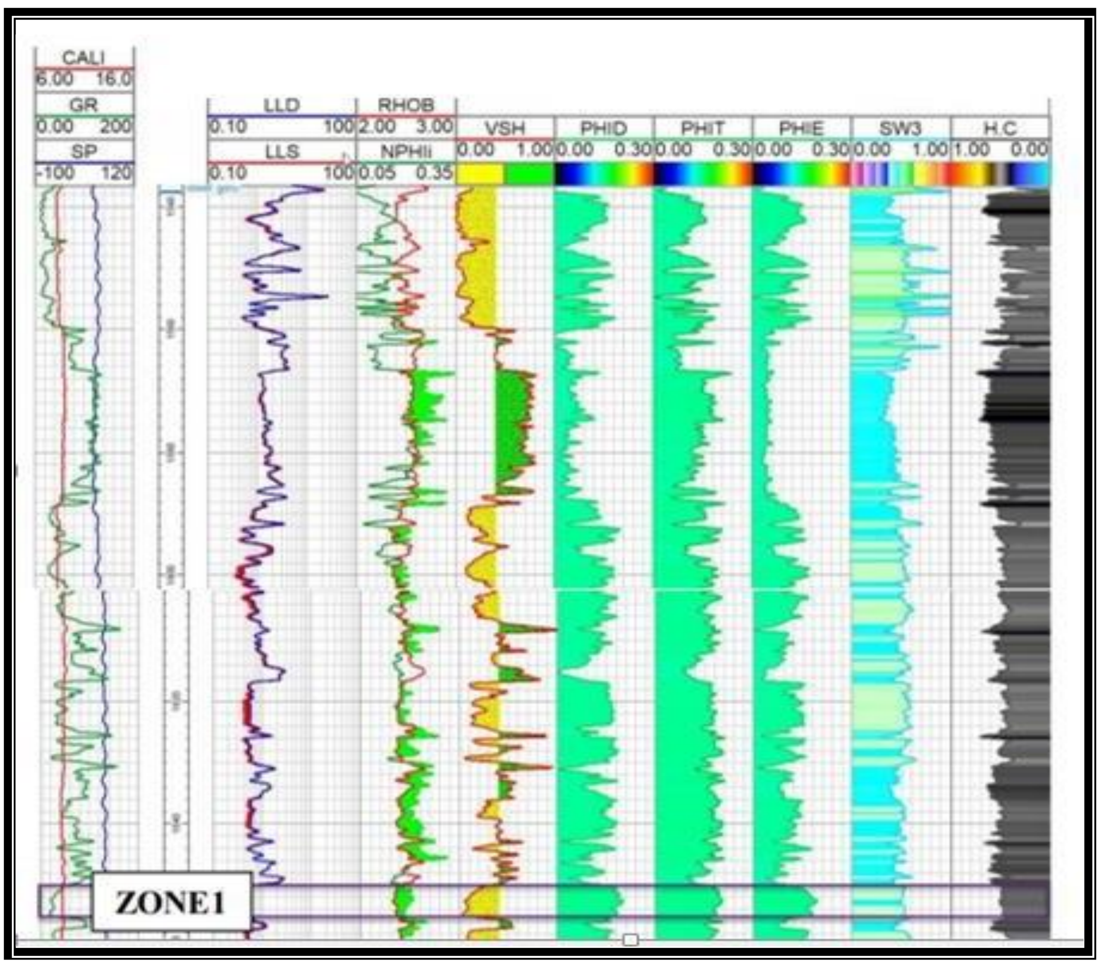

Fig 4.2. Petrophysical analysis of Lower Goru formation of well Doti-01

Results of Petro-physical analysis

Volume of Shale	19%
Effective porosity	15%
Water saturation	72%
Hydrocarbon saturation	23%

Conclusion

- In the marked zone, values of GR log is low, so it represents the clean lithology.
- Shaly content is less here so it indicates the presence of sand.
- There is a gap between LLD and LLS logs, gap represents the presence of Hydrocarbons.
- There is a positive cross over between neutron and density log. It represents the presence of hydrocarbons here.

All these conditions tells us the presence of Hydrocarbons in the marked zone but in less amount. Doti-01 is dry so percentage of water saturation is more and percentage of Hydrocarbon saturation is less here. Depth ranges from 1650-1656 m.

Chapter 5

Facies modeling

5.1. Introduction

In geology, a facies is a body of rock with specified characteristics. Generally, distinctive rock unit that form under certain condition of sedimentation that expose the environmental process. In this process the key challenge is identifying the facies from logging and core data, and degree to which the shale content effect the reservoir properties. This gives the main indication about the productive zone in the reservoir (Kurniawan, 3005).

Geological facies are also the observable attributes of a sedimentary rock body that reflect depositional processes environments that formed it. These depositional environments are classified as terrestrial, continental slope and the basin floor (Rais et al., 2012). Facies modelling is an important component of geostatistical reservoir characterization and facilitates construction of superior reservoir models for complex reservoirs.

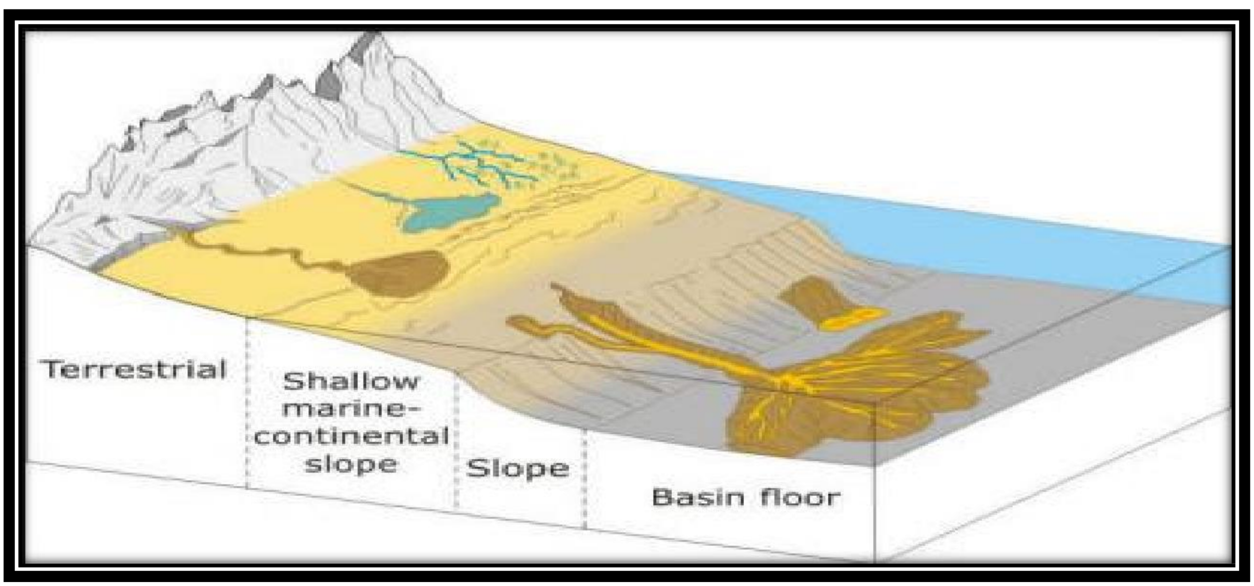

Fig 5.1 Major depositional environments (Rais et al, 2012).

5.2. Facies analysis

Fundamental to all subsurface geologic studies is an analysis of depositional facies. In geology, facies are the observable attributes of a sedimentary rock body that reflect the depositional processes or environments that formed it. These depositional environments are classified as:

- Terrestrial
- Continental slope
- Slope
- Basin floor

5.3. Cross plot of NPHI & RHOB

The neutron and density cross plot provides a good source of porosity data especially in complex lithologies. Gamma Ray used as reference log. The neutron log is measuring the hydrogen population of the formation. Therefore, it records a nearly constant response through sands and increases in shale. Since the population of hydrogen is nearly the same in water, oil, and wet clay, the Neutron log cannot distinguish between them. Hydrogen population is therefore no longer controlled by the pore distribution. The neutron log then measures increased hydrogen as the clay volume increases. Both log are difficult to use for grass lithology Identification (Rider., 1999).

High Gamma Ray log and Neutron Porosity log indicate the Shale while the low response of both logs shows the existence of clean sand. Moderate Gamma Ray log shows the shaly sand around shale sand boundary. Fig 5.2 shows the the lithology model for Doti-01 well.

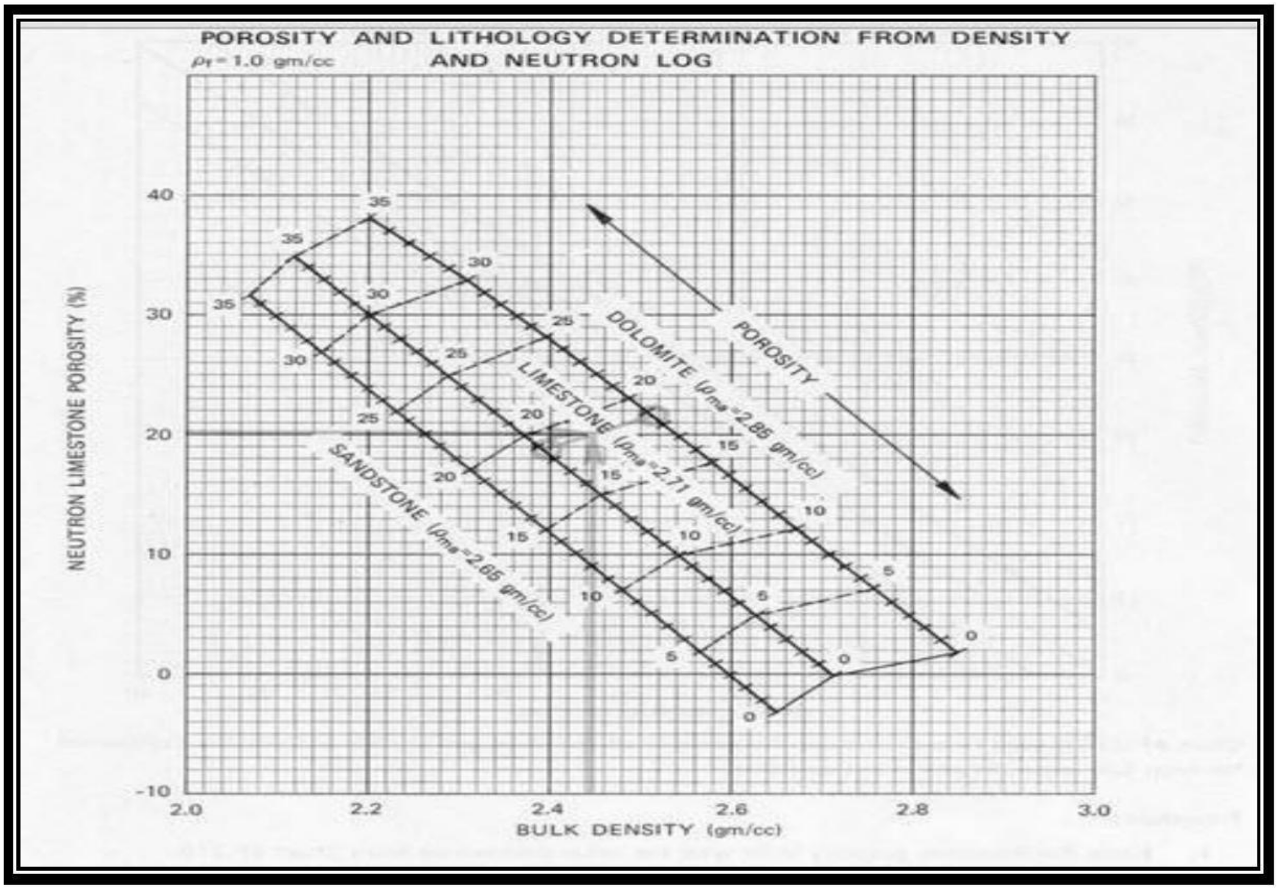

Fig 5.2. Standard cross plot between density and neutron (Rider., 1986)

Cross plot between LLD VS RHOB

A cross plot between LLD VS RHOB is prepared with log data of Badin Doti-01 with Gamma Ray log as a reference log at Z axis. This cross plot is also called lithology indicator (Rider., 1986).

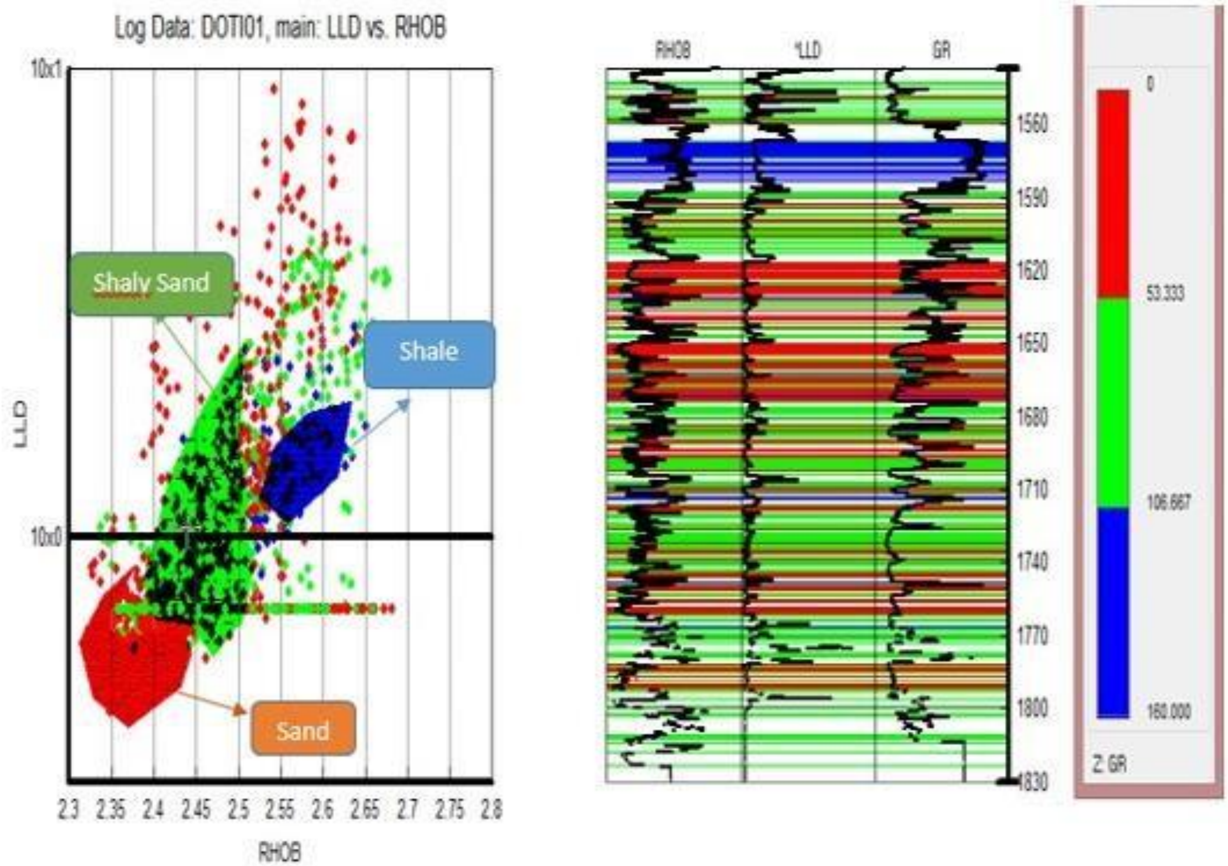

Fig 5.3. Cross plot of LLD VS RHOB showing different facies

Results

- Here in this cross plot, polygon with red color shows the lower value of resistivity, the lithology is marked as sand. In case of sand, resistivity values is in the lower side and response of Gamma log is also on the lower side which shows the presence of reservoir i.e Gas sand.

Cluster plot of shaly sand is thick in middle. So it is interpretated that reservoir is mainly comprise of shaly sand.

Cross Plot between SW VS PHIE

A cross plot b/w SW VS PHIE is prepared with log data of Doti-01, with the help of Gamma Ray log as a reference log at Z-axis. The depth range selected for this cross plot is 1537.64-1810.2 m because the major reservoir rock (Lower Goru) lies between these depths. This cross plot will help us identify what types of lithofacies are present in my area of interest.

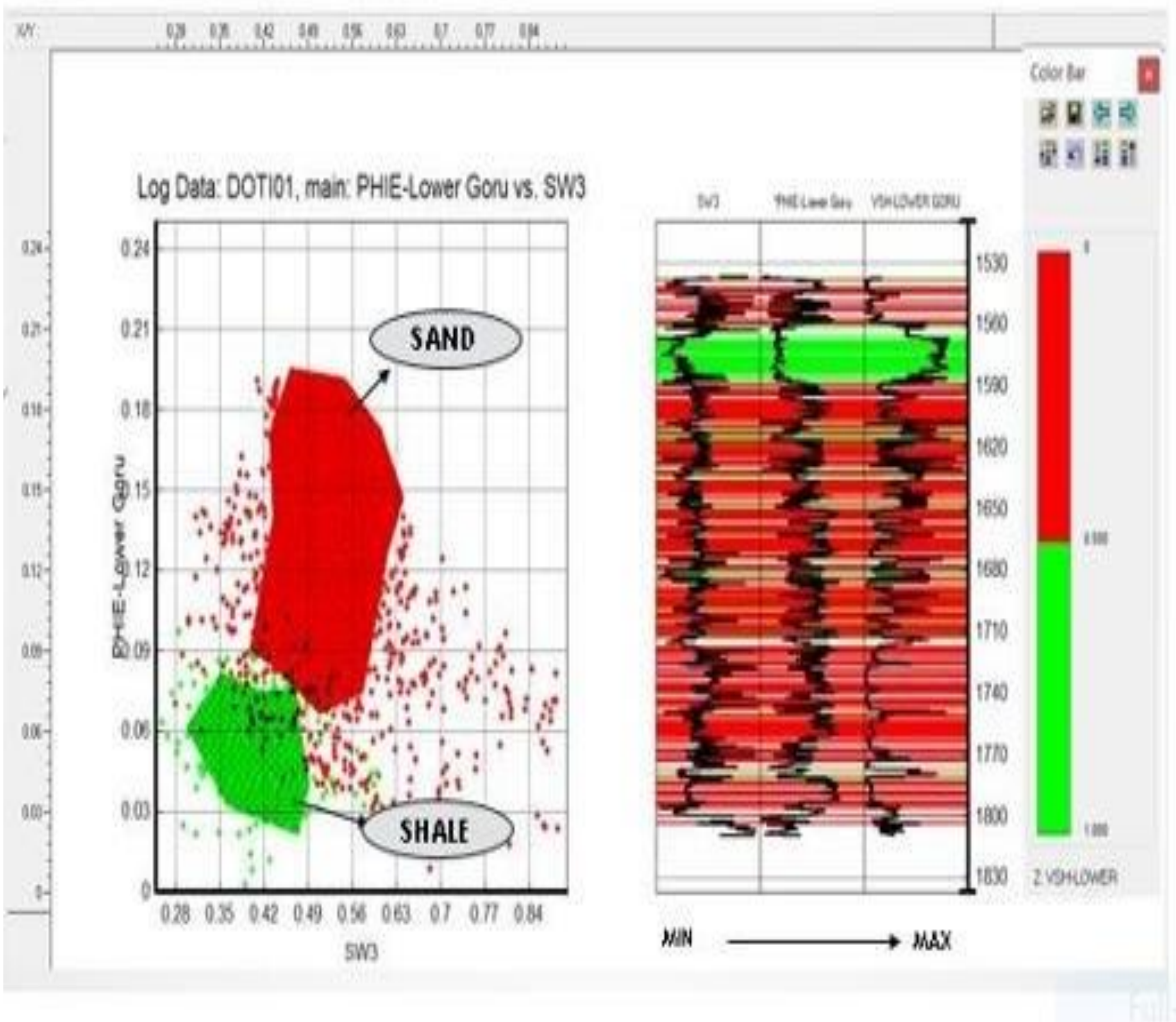

Fig 5.4. Crossplot of SW VS PHIE showing different lithofacies

- **Results**

As shown by results of effective porosity, cross plot with water saturation and with volume of shale log as a reference log, the beds of shale shows low effective porosity and therefore the low respective water saturation values. Most of lithology is made up of sand showing low volume of shale values with high effective porosity values and respective higher water saturation values. The lower Goru formation therefore seems to be a good reservoir with overall good effective porosity and typically thin beds of shale.

Conclusion

- Structural interpretation from time and depth contour maps of Lower Goru shows the presence of Horst and Graben structure and this structure act as trap in area, which is best for hydrocarbon.
- Synthetic Seismogram help to marked reflectors which confirm the presence of stratigraphic interpretation.
- Petro-physical analysis shows Lower Goru formations are good reservoirs.
- Petrophysical modeling and Facies modelling indicates that Lower Goru are hydrocarbon bearing zone and contains about 23% saturation of hydrocarbons in well Doti-01.

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