2D-INTEGRATED SEISMIC INTERPRETATION PETROPHYSICAL ANALYSIS AND FACIES ANALYSIS OF BADIN BLOCK LOWER INDUS BASIN PAKISTAN

BY

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“With the Name of ALLAH, the Most Gracious & the Most Merciful” And look at the mountain how they are set! And at the earth how it is spread out (AL-QURAN)

CERTIFICATE

This dissertation submitted by **Syed Ali Raza Kazmi** S/O **Syed Azad Hussain Shah** is accepted in its present form by the Department of Earth Sciences, **Quaid-I-Azam University Islamabad** as satisfying the requirement for the award of **BS** degree in **Geophysics.**

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Acknowledgement

First praise is to Allah, the most Beneficent, Merciful and Almighty, on whom ultimately, we depend for sustenance and guidance. I bear witness that Holy Prophet Muhammad (PBUH) is the last messenger, whose life is perfect model for the whole mankind till the Day of Judgment. I thanks Allah for giving me strength and ability to complete this study. I am especially indebted to my honorable supervisor **Dr. Muhammad Toqeer** for giving me an initiative to this study.

I warmly thank and appreciate my parents, brothers and sisters for their continuous spiritual support and encouragement in all aspects of my life. I could not have done this without their constant love, support and motivations. I would like to say heartfelt thanks for always believing in me and encouraging me to follow my dreams.

Finally, my thanks go to all those people who supported me to complete the thesis work directly or indirectly.

SYED ALI RAZA KAZMI

DEDICATION

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

ABSTRACT

Badin area is a common example of extensional tectonics represented by Horst and Graben structures. To carry out the structural and stratigraphic interpretation of the Badin area, two seismic lines are interpreted. Two-way time and depth mapping helped in delineated the structural trend and understanding the tectonics of the area.

Subsurface mapping reveals that major fault trend is NE-SW. There are indications of reactivation of faults indicating the occurrence of various tectonic periods. Existing structural trend of the area provides basic components of a profile petroleum system.

Based on Petrophysical analysis the average porosity values for the promising zone range from 10 to 15% and average values of water saturation range from 75-80%, which cause the failure of Doti-01 well.

Zone of interest is the Lower Goru. Porosity calculations are made to find out the hydrocarbon saturation is calculated. The main constituents of petroleum system are present, proven by a number oil and gas discoveries but there is still a requirement of advance techniques to improve seismic resolution and quality of interpretation.

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Introduction

CHAPTER 01

INTRODUCTION

1.1 Introduction

Hydrocarbons play a vital role in the growth of economy of any country and have wide uses at smaller scales in everyday life as well. Hydrocarbon exploration is basically major source of income in developing country, Pakistan is one of them. Pakistan is blessing country in petroleum point of view. Pakistan has a high potential of hydrocarbons and consists of three major sedimentary basins (covering more than 2/3rd of its area) namely Indus Basin in the east, Baluchistan Basin in the west and Pishin basin in the northwest.

Hydrocarbons are extracted from subsurface which is natural resource (oil and natural oil). These Hydrocarbons extract from subsurface and are refined by different process. For thirst of economy every exploration country focusing of unexplored area to know about geology and work out. Petroleum is consisting of hydrocarbons and gas (methane). Foreland and thrust are important area for hydrocarbon exploration. Hydrocarbon fuel extract from sedimentary basin in modern developing.

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

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

The geographical coordinates of the area are:

- **Latitude**: 24° 5‶N to 25° 25‶N
- **Longitude:** 68° 21‶ E to 69° 20‶ E

1.2 Exploration history

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

Exploration in the Lower Indus Basin started in 1939 by Burmah Oil Company (BOC) near Karachi. In 1948 second well was drilled on the Lakhra structure by BOC.

Aeromagnetic surveys were conducted by Standard Vacuum Oil Company (SVOC) in 1955 and by Oil & Gas Development Company (OGDC) in 1962-63. Surveys were carried out by SVOC in 1954-56, Oil Company (SOC) in 1957-59, Pakistan Petroleum Ltd (PPL) in 1949 and 1956-60, Pak Hunt Ltd in 1957-59, Tide Water Oil Company in 1959-60, OGDC in 1966-75 and Pakistan Texas Gulf in 1975. In May 1981, a joint venture of Union Texas Pakistan, Occidental of Pakistan Inc. and OGDC discovered oil at Khaskheli within the Badin Block. With this discovery, the Lower Indus Basin became the second largest oil producing sub basin of Pakistan, after Potwar.

1.3 Objectives

The main purpose of this thesis is to collect the subsurface information of study area and find the potential of reservoir zone. Our objectives are:

1. This dissertation is primarily focused on seismic interpretation of the study area, which includes marking of horizons, fault picking and construction of time and depth contour maps.
2. Interpret the subsurface that is very favorable for hydrocarbon accumulation.
3. Petrophysics analysis are conform the potential of zone of interest of reservoir.
4. Facies modeling of reservoir are used to differentiate the lithology.

1.4 Data Used

For this objectives DGPC (Directorate General Petroleum concession) provide seismic data, well data which shown in Table 1.1 and Table 1.2.

Table 1.1: Seismic data used in interpretation.

Sr. No.	Line Name	Orientation	Nature of line	Well Name
1	GPK85-0935	NE-SW	Dip	
2	GPK85-0937	NE-SW	Dip	
3	GPK85-0958	NE-SW	Dip	
4	GPK85-0960	NE-SW	Dip	
5	GPK85-0962	NE-SW	Dip	
6	GPK85-0964	NE-SW	Dip	
7	GPK85-0966	NE-SW	Dip	
8	GPK85-1042	NE-SW	Dip	
9	GPK85-KH01	NE-SW	Strike	
10	**GPK85-KH04**	**NE-SW**	**Strike**	
11	GPK85-KH06	NE-SW	Strike	
12	GPK86-1200	NE-SW	Dip	
13	GPK86-1202	NE-SW	Dip	
14	**GPK92-1678**	**NE-SW**	**Dip**	
15	GPK92-1680	NE-SW	Dip	
16	**GPK92-1682**	**NE-SW**	**Dip**	**DOTI_01**
17	GPK92-1685	NE-SW	Dip	

Table 1.2: Well data used in interpretation.

S. no	WELL Name	Types of well
1	DOTI _01	Exploratory ABANDONED
2	RAJO_01	Exploratory OIL
3	JABO-01	Exploratory GAS/CON
4	JABO-05	Development OIL/GAS
5	MEHRO-01	Exploratory ABANDONED
6	KEYHOLE G-01	Exploratory OIL

1.5 Base Map

Base map play an important role in interpretation. Base map is map that shows the orientation of seismic data and shot point at which seismic data is plot. This map includes the location of well, seismic lines and with reference to Latitude and Longitude. Base map consist a number of dip lines and strike lines Orientation of line is north east to south west.

1.6 Geographical Location of Study Area

The area of research is Badin block which is also called thar platform. Badin block is locating in eastern of district Badin province Sindh, Pakistan. Badin area is 160 km east of Karachi. Boundary on north side is Hyderabad and south side is Runn of Kutch and Arabian sea and east side is tharparkar district and mirpurkhas.

Table 1.3: Table showing well Doti 01 information.

S.no	Well	Doti-01
1	Latitude	24.219353°
2	Longitude	68.599725°
3	KB	8.23 **m**
4	Total Depth	1830.2 **m**
5	Status	Exploratory
6	Exploration	Abandoned
7	Company	Union Tax Pakistan
Formation Tops		**Depth(m)**
1	Kirther-laki	222.5
2	Upper-Ranikot	277.4
3	Lower-Ranikot	461.7
4	Khadro	629.4
5	Parh Limestone	739.1
6	Upper Goru	771.1
7	Lower Goru	1537.6

1.7 Analysis of flow work of seismic interpretation

Seismic interpretation is carried out by different seismic techniques and different process by using Kingdom software. Complete steps of interpretation are shown in flow work. Figure 1.1 shows the flow work which is complete picture of seismic interpretation.

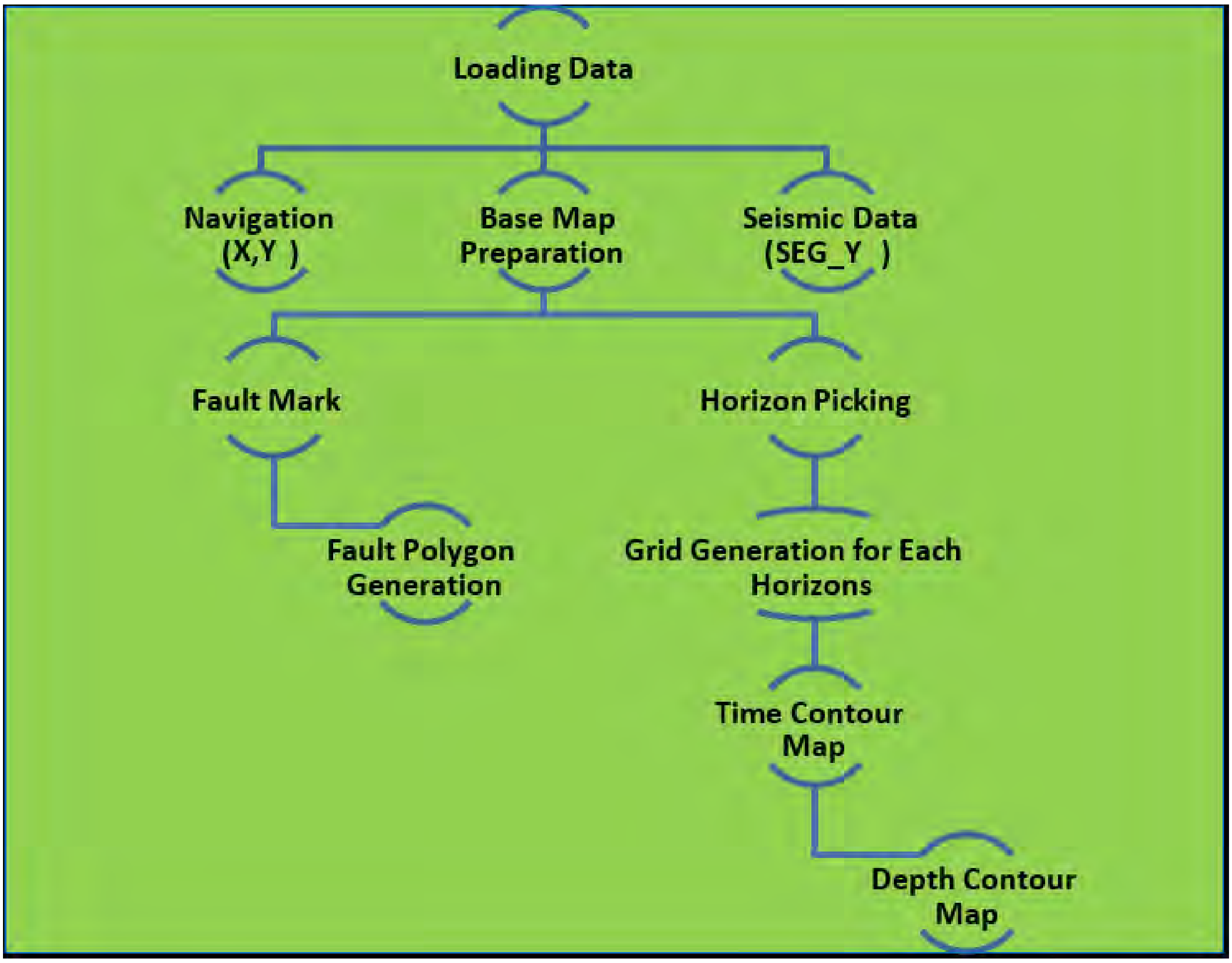

Figure 1.1: Flow work of interpretation

1.8 Thesis Organization

This dissertation is divided into eight chapters with first chapter is on an introduction. The 2nd chapter covers the Geological, tectonic setting and History of study area. In Chapter 2 southern Indus Basin is discussed more thoroughly and Stratigraphic Chart with Source, Seal and reservoirs of study area are mentioned. In Chapter 3 deals with the Basic goal of these work i.e., seismic interpretations of study area by using Seismic reflection methods.

In Chapter 4, various Petro-physical properties of reservoir zone in study are identifying by using well logs. Chapter 5 covers the Facies modeling. Following were the methodologies adopted to complete this work.

- Collection of geological & Geophysical data.
- Preparation of base map.
- Mark faults on seismic sections.
- Picking horizons on seismic sections.
- Determination of horizons by generating 1-D synthetic seismogram.

- Finding velocity of horizon using well data.
- Two-way travel time contour map generation.
- Depth contouring.
- Properties of reservoir with the help of log data.
- Identifying the depositional sequence by Facies modeling.
- Conclusions.

Chapter 2

Geology and Tectonics

CHAPTER 02

GEOLOGY AND TECTONIC

2.1 Introduction

The information about the geology of an area plays an important role for precise interpretation of seismic data because some velocity effects can be generated from formation of different lithologies and different velocity facts can be generated some lithological horizons. So as if we do not know about geological formations in the area, we do not recognize the different reflections appearing in the seismic section. For the exploration of underneath earth surface the geology is of extreme importance.

Basin study is very important for geological information. By means of three parameters namely:

- Basin forming tectonics
- Depositional sequences
- Basin modifying tectonics

2.2 Regional Geology

Sedimentary basin is geologically depressed space with thick sediments within the interior and thinner sediments at edges (Shah et al, 2009). In terms of genesis and totally different earth science histories, Pakistan includes three main sub basins:

- Indus basin
- Balochistan basin
- Pashin basin

The Indus Basin, which covers an area of 535,580 km^2, is located on the northwest slope of the Indus Shield and includes the fold belt (Mozaffar et al., 2002). It trends NE-SW for over 1600 kilometer on its axis and therefore the breadth varies significantly with a median of 300 km. The Indus Basin principally consists of the syntaxes, irregular ridges or promontories of the Indian protect and most of them are trending point (Shah et al., 2000). The Indus basin is further divided into two sub basin such as upper Indus basin and lower Indus basin.

The upper Indus basin is further divided into Kohat sub basin and potowar sub basin while the lower Indus basin is also divided into central Indus basin and southern Indus basin. Then lower Indus basin is further divided into central Indus basin and southern Indus basin.

Study area is Badin block which belongs to southern Indus basin. Southern Indus basin is characterized by many structural divisions that includes Thar platforms, Karachi trough, Kirthar fold belt, Kirthar foredeep and offshore Indus.

2.2.1 Geological description of southern Indus basin

In the present tectonic setting of Pakistan lies between the southern part of the Afghan craton northwestern corner of the Indian plate, and the northern part of the Arabian Oceanic plate. The western part of Pakistan is under pressure of tertiary convergence between Afghan craton (Makran flysch basin and Chagai arc). The eastern part of country is due to the pressure of Tertiary convergence between Indian subcontinents and northwest is afghan craton (Chaman Transform fault).

2.3 Tectonic Zones of Pakistan

Pakistan is unique as much as it is located at junction of these two diverse domains i.e., Tethyan domain and Gondwanan domain. The south eastern part of Pakistan belongs to the domain and presents a complicated crystal structure. Based on plate tectonic features, geological structure, organic history and lithofacies, Pakistan is divided into following tectonic zone. Pakistan may be divided into eight broad tectonic zones. (as shown in figure 2.1)

- Indus platform and Foredeep.
- East Baluchistan fold and thrust belt.
- Northern west Himalayan fold thrust belt.
- Kohistan Ladakh magmatic arc.
- Karakoram block.
- Kakar Khorasan flysch basin and Makran accretionary zone.
- Chagai magmatic arc.
- Pakistan offshore.

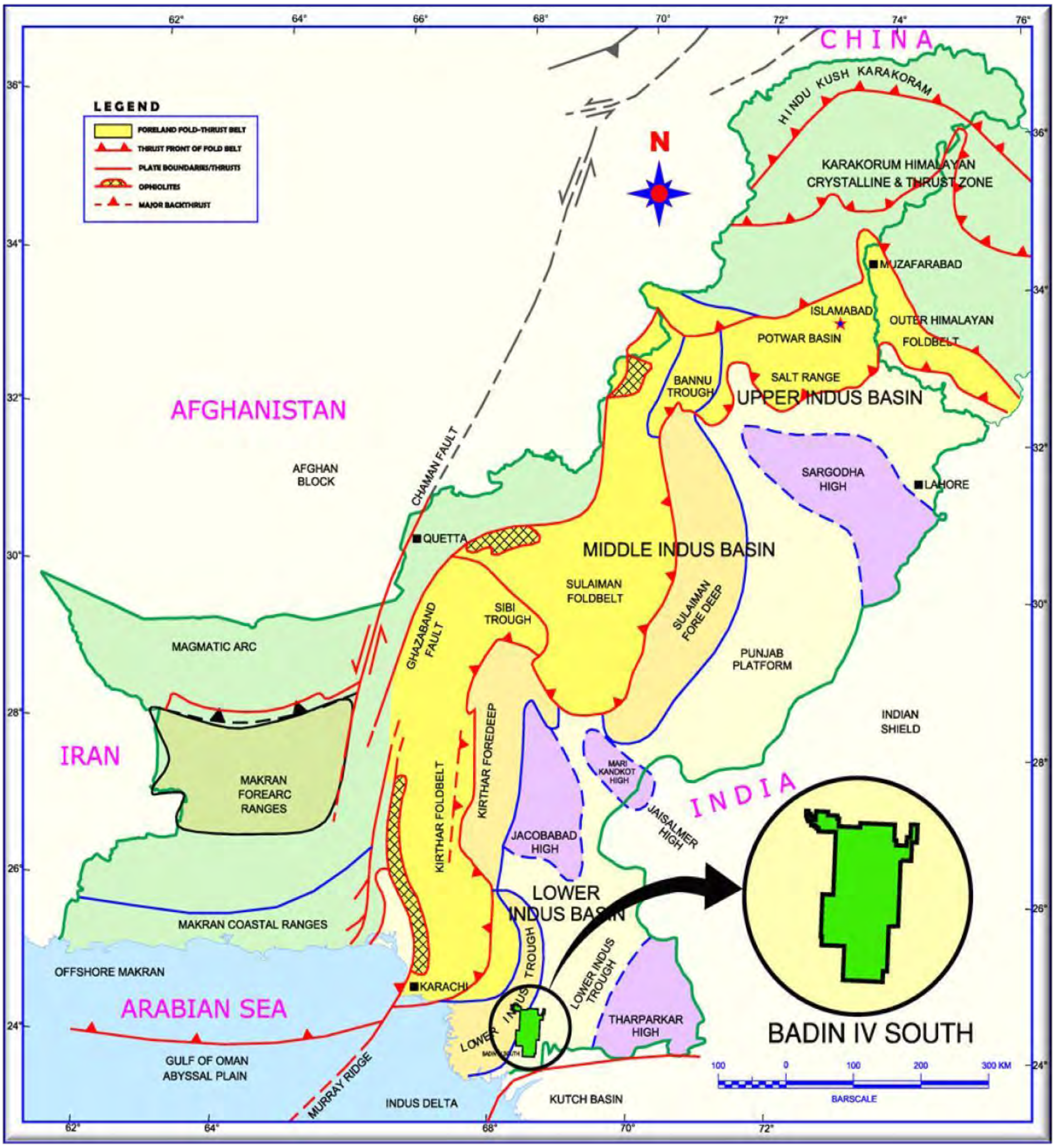

Figure 2.1 The tectonic and geological setting of the Pakistan *(Kazmi* & Snee, 1989)

2.3.1 Structure geology and tectonics of study area

Tectonic is instable during the cretaceous period 80-53 Ma and in cretaceous period spreading rate is high drifting rate approx. 20-30cm /a. Badin block is present in thar platform, Badin block is also called Sindh monocline (Asim et al.,2014).

Thar platform is subdivision of southern Indus basin. Sargodha high is boundary which separate lower Indus basin and upper Indus basin (kadri, 1997). Structural style of Badin basin is normal faulting horst and Graben. These horst and Graben structure are due to the rifting of Seychelles and India during late cretaceous. The most important designs seen are, overprinted rifting by shear modification and subsequently changed by doming the foremost periods can be characterized as: Distal rift throughout the Late

Jurassic and Early Cretaceous. Most common features are dome and rifting. Badin area is far from tectonic zone so is less deformed area. Increase of rate of deformation is east to west. Large area of tilted fault in lower Indus basin tells us about the extensional tectonics' history of cretaceous period. Cretaceous fault mostly strike direction is N 30° W and N 50° W. Fault are in En-echelon set trend north south due to block tilt hydrocarbon are trapped, that is why 50% exploration is in Badin block after the potwar basin (Kemal et al., 1991).

2.4 Stratigraphy of study area

Stratigraphy of study area is shown in Figure 2.2 in which the age of the formation ranges from Jurassic to Tertiary period. In Sindh Monocline Chiltan limestone of Jurassic age overlies Triassic sequence. About 610 m thick Sembar shale overlies the Chiltan limestone. On the top of Sembar formation is Lower Goru which is consider as major reservoir rock in the area. Lower Goru is further divided into five units such as Basal sand overlies Sembar formation, Lower shale overlies Basal sand, Middle sand overlies Lower shale, Upper shale lies between Middle and Upper sand which is 5th unit of the Lower Goru as shown in Figure 2.2. Depositional environment of the Upper sand is shallow marine to deltaic and consider as good reservoir in the Lower Indus Basin (Alam etal., 2002).

Stratigraphically, the shale of Sember formation is interbedded shale bed of Lower Goru formation are the main petroleum source rock units in the southern Indus basin. Sand is producing zone reservoir from its various sand sheets of variation in thickness. The possibility of reservoir in lower Goru overlain on Basal sand could not be ruled out, however that have not yet proved to be such up till now (Kadri,1995). Intra-formation shale of Lower Goru formation provides effective vertical and lateral seal. The shale units also provide cross fault seal. Fault may also act as a cap. Upper Goru shale, Lower Goru and Talhar shale are the primary seal for Lower Goru reservoir sands (Kadri etal,1995).

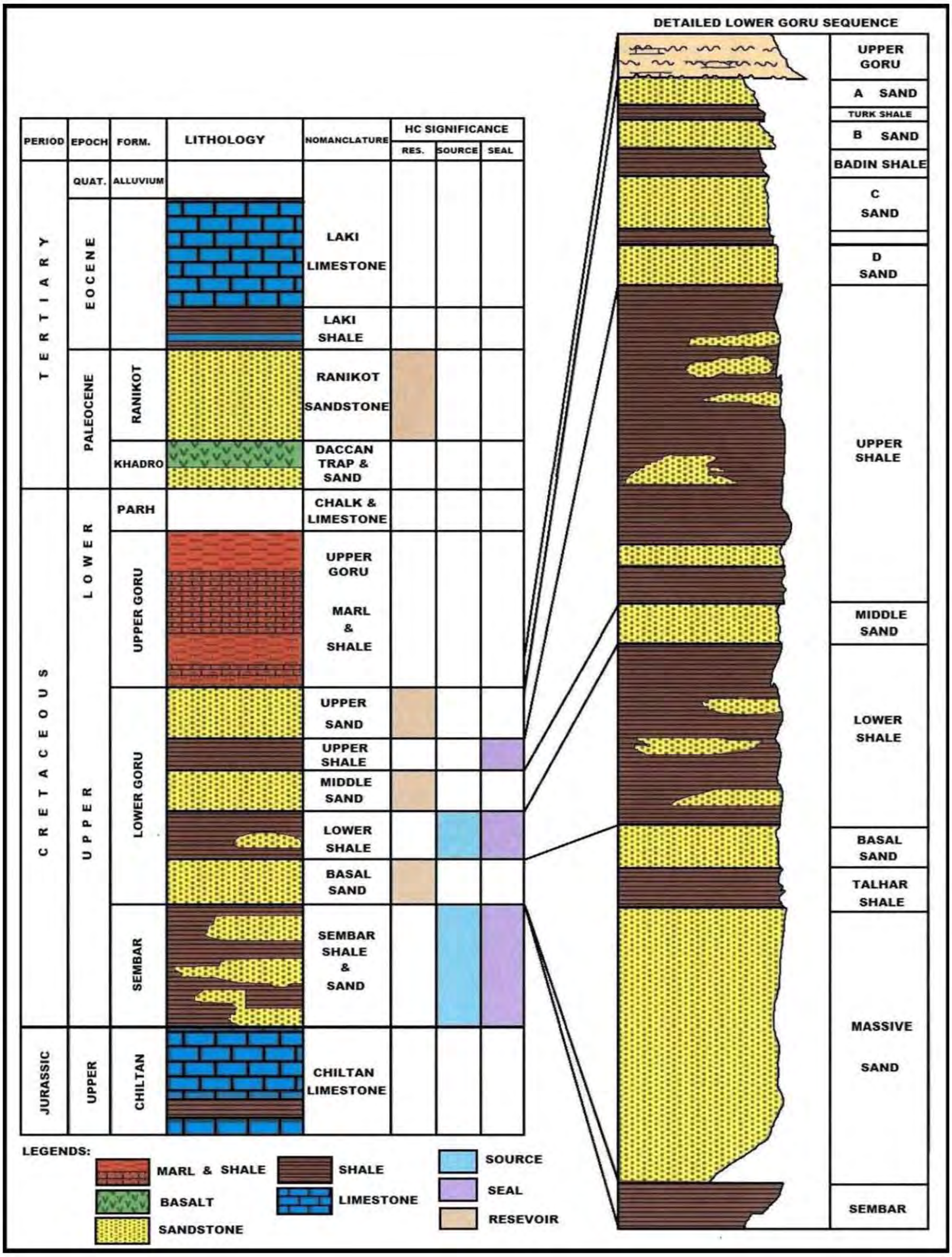

Figure 2.2: General stratigraphy chart of the Lower Indus Basin and study area in which Lower Goru is further subdivided into different units (Alam et al., 2002).

2.5 Structural Style and Play Type

The extensional tectonism during the cretaceous time created the titled fault block over a wide eastern lower Indus basin. Commonly the faults are arranged on en-echelon sets aligned in that trend almost north south. Fault associated structural closures are responsible for trapping oil in Lower Goru sandstone in the Badin block. The titled fault block traps were in existence. The goru formation consist of interbedded limestone. Limestone, shale and siltstone. The limestone grained, thin bedded, light to medium greyish olive in color. Limestone is dominant over higher and lower part of formation. The thickness of Goru Formation is 536m in type locality, 60m in Quetta, and 2360m in Badin area. The lower contact with the sember formation, though locally an unconformity has been reported by William (1959). The upper contact is Parh limestone is gradational. The formation contain foraminifers Tikes formation correlated with the lumshiwal formation of Kohat potowar province (Kadri,1995).

2.5.1 Parh Limestone

Parh limestone is distributed throughout the southern Indus basin. This is lithologically very distinct unit. It is light grey, white, creme to olive green, added argillaceous limestone. In type area its thickness is about 268m and max thickness is few in the west of kirthar range this formation is correlated with Khawagarh formation of Kohat potowar province (Kadri, I.B, 1995).

2.5.2 Goru Formation

The Goru formation consists of interbedded sandstone, shale and siltstone. The limestone is grained, thin bedded, light to medium grey in color (Shah, 1977).
On the basis of lithology Goru Formation is divided in two parts**:**

a. Lower Goru
b. Upper Goru

2.5.2.1 Lower Goru

The lower Goru is main reservoir rock within the area. The lower Goru horizon as a general five divisions based on predominant lithologies (Gilbert Killing et al). As shown in figure 2.2.

- The Basal Sand unit.
- Lower Shale.
- Middle sand unit (which has a good reservoir potential).
- Upper Shale.
- Upper Sand.

2.5.2.2 Upper Goru

The upper Goru sequence of middle to late cretaceous unconformable overlies the lower Goru formation which consists of mainly marl and calcareous claystone occasionally with inner beds of silt and limestone (Gilbert Killing et al). The Goru Formation is widely distributed in the Kirther and Sulaiman Province. The lower contact with the Sembar formation is conformable and is very locally reported unconformable by Williams (1959). The upper contact is transitional with the Goru formation may be correlated with the Lumshiwal Formation of the Kohat-Potwar Province. The formation contains foraminifers and bivalves and age given is Early Cretaceous (Shah, 1977).

2.5.3 Ranikot Group

Blanford (1876) was the first to give the name Ranikot group.Vredenberg (1909a) subdivided the Ranikot group into Lower Ranikot (sandstone) an Upper Ranikot(limestone). One division of Ranikot group suggests that it comprise of three formations which are Khadro formation, consists of olive, yellowish brown sandstone and shale with interbeds of limestone.

2.5.4 Khadro Formation

The formation consists of sandstone and shale with some limestone the thickness in sulaiman province and 67m in the type section. The lower contact with Moro Formation correlated is unconformable but upper contact with Bara Formation is confirmable (Kadri, I.B, 1995).

2.5.5 Sembar Formation

The Sembar formation consists of black silty shale with interbeds of black siltstone and nodular rusty weathering argillaceous limestone beds. In the basal part pyritic and phosphatic nodules and sandy shales are developed locally. Rock unit is glauconite. And it is proven a good source rock. This rock unit is widely distributed in Sulaiman and Kirther ranges. Its Lower contact with various Jurassic formations such as Mazar Drik formation, Chilian limestone and Shirinab formation is disconformable while the upper contact is generally gradational with the Goru formation. The Sembar formation is correlated with Chichali Formation of the Kohat-Potwar Province. This rock unit is richly fossiliferous, and the most common fossils reported are the belemnites, Mallocs and others and the age given is Early Cretaceous (Kadri, I.B, 1995).

2.5.6 Laki Formation

This Formation consists of mainly creamed colored limestone. It also contains shale, limestone and clay at some places. It is about 240m thick in the Bara Nai and 600m in Thatta. The Formation is unconformably underlain by Ranikot Group. Its upper contact with Kirthar Formation in of area is conformable (Kadri, I.B, 1995).

2.6 Brief Description of Petroleum Play of The Study Area

- Source Rock: Sember shale
- Reservoir Rock: lower Goru
- Cap Rock: Upper Goru marl

2.6.1 Reservoir Rocks

The B-Sand of Lower Goru formation is target formation in the area. Massive Sand is another interesting producing reservoir from its various sand sheets of multiple thicknesses (Kadri, 1995).

2.6.2 Seal Rocks

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

2.6.3 Source Rock

Sembar is source rock in the lower and middle Indus basins that has high vertical and lateral extension throughout the basins. Source rock in the study area is of early cretaceous. The Lower Goru Sands provides the accumulation of hydrocarbon while the Upper Goru shaly formation provides a trap. Normal faults provide as excellent seal to hydrocarbon (Kadri, I.B, 1995).

Chapter 3

Seismic Data Interpretation

CHAPTER 03

SEISMIC DATA INTERPRETATION

3.1 Seismic Surveying

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

3.2 Seismic Methods

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

- Seismic Refraction method
- Seismic Reflection method

3.2.1 Seismic Reflection Method

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

3.3 Seismic Data Acquisition

In Seismic data acquisition, continuous seismic signals from seismic stations are gathered and recorded properly. In data acquisition, earth response caused due to seismic source is recorded. (Kearey 2002) describes geophones are used to record seismic waves, in case of marine survey hydrophone is use. The basic field activity in seismic surveying is the recording of seismic data which may be defined as analog or digital time series that record the amplitude of ground motion as a function of time during the passage of seismic waves. The Acquisition starts from shot and ends at recording the seismic events through various steps. Different energy sources are used to produce seismic waves and array of geophones are used to detect the resulting motion of earth. The resulting data, combined with assumptions about the velocity of the waves through the rocks and the density of the rocks, are interpreted to generate maps of the formations. Fundamental purpose of seismic data acquisition is to record the ground motion caused by a known source in a known location. First step in seismic data acquisition is to generate a seismic pulse with a suitable source. Second is to detect and record the seismic waves propagating through ground with a suitable receiver in digital or analogue form. Third is the registration of data on a tape (Kearey et al., 2002).

3.4 Seismic Interpretation

Interpretation is a strategy by which we attempt to change the entire seismic data into structural or Stratigraphically model of the earth. Since the seismic area is the illustrative of the land model of the earth, by interpretation. Not just a decent interpretation steady with all the seismic information, it too essential to thoroughly understand the zone, including gravity survey and magnetic survey, well data, surface topography and additionally geologic and physical idea. Seismic interpretation and subsurface mapping are key skills that are utilized generally in the oil industry for investigation. Seismic interpretation decides data general data around a zone, find prospects for penetrating exploratory wells, or guide improvement of an as of now found field (Coffeen, 1986). Expectedly seismic reflection information which is consequence of seismic picture of acoustic impedance interfaces having parallel progression is used for picking and following along the side predictable seismic reflectors to map geologic structures, stratigraphy and supply engineering.

3.5 Types of Seismic Interpretation

Two principle approaches for examination of seismic information.

- Structural Interpretation
- Stratigraphical interpretation

3.5.1 Stratigraphical Interpretation

According to Telford et al., (1990) stratigraphy analysis involves the delineating the seismic sequences, which present the different depositional units, recognizing the seismic facies characteristic with suggest depositional environment and analysis of the reflection characteristic variation to locate both stratigraphy change and hydrocarbon depositional environment. 3-D work is especially important in recognizing the stratigraphic feature with distinct shape. The amplitude, velocity, frequency or the change in wave shape indicates hydrocarbon accumulation. Variation of the amplitude with the offset is also an important hydrocarbon indicator. Unconformities are marked by drainage pattern that help to develop the depositional environment. Reef, lenses. Unconformity is example of stratigraphic traps (Telford et al., 1990).

3.5.2 Structural Interpretation

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

There are two primary methodologies for the understanding of the seismic reflection information.

- Qualitative Interpretation
- Quantitative Interpretation

Qualitative interpretation is regular or conventional seismic system which is utilized fundamentally to map the sub-surface geology. In this thesis fundamental focus is on the basic traps in which structural plays a critical part. While quantitative interpretation is more profitable than conventional techniques. By making a few modifications in recorded information brings about better prospect assessment or predominantly store portrayals. The most essential of these strategies include post-stack amplitude analysis (bright spot and dim spot investigation), offset amplitude analysis (AVO analysis), acoustic and elastic impedance inversion, and forward seismic modeling and so on. In this thesis we have completed 1-D forward seismic modeling, AVO modeling and Facies displaying for deciding attributes and the sand class of the supply experienced in the investigation zone.

3.6 Interpretation Workflow

The Interpretation was completed by using different procedures and steps with each step include various procedures which were performed utilizing the software tools are introduce above. Flow work process is full image of thesis is given below which gives the entire picture how the thesis has been done. By loading of seismic data and SEG-Ys in HIS kingdom (8.8) software produce base map. Fault marking and Horizons picking of seismic section were then checked by synthetic seismogram.

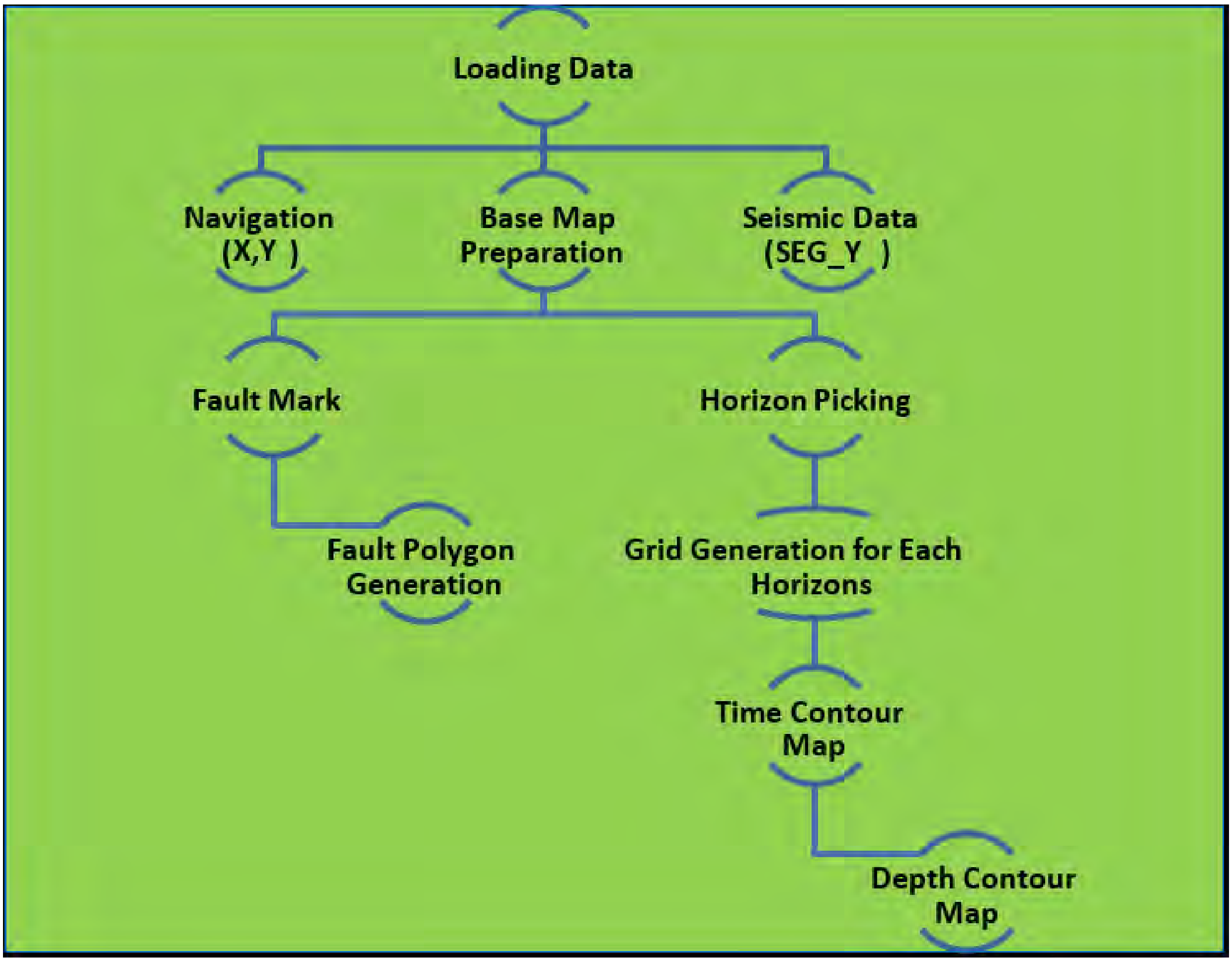

Figure 3.1: workflow chart of seismic interpretations.

3.7 Interpretation of the seismic lines

The Primary task of interpretation is the identification of various horizons as a reflector among geological formation. For interpretation, good structural as well as stratigraphy knowledge of the area is required (McQuillin et al., 1984). Thus, during interpretation process, we marked both, the horizons and faults on the seismic section by the information obtained from the synthetic seismogram generated from Doti-01. We marked the two horizons. The horizons are named on basis of well tops of the well Doti-01. Hence the first step before the Marking of the horizons is the generation of the synthetic seismogram.

Table 3.1: Interpretated Seismic lines.

Sr. No.	Line Name	Orientation	Nature of line	Well Name
1	**GPK85-KH04**	**NE-SW**	**Strike**	
2	**GPK92-1680**	**NE-SW**	**Dip**	
3	**GPK92-1682**	**NE-SW**	**Dip**	**DOTI_01**

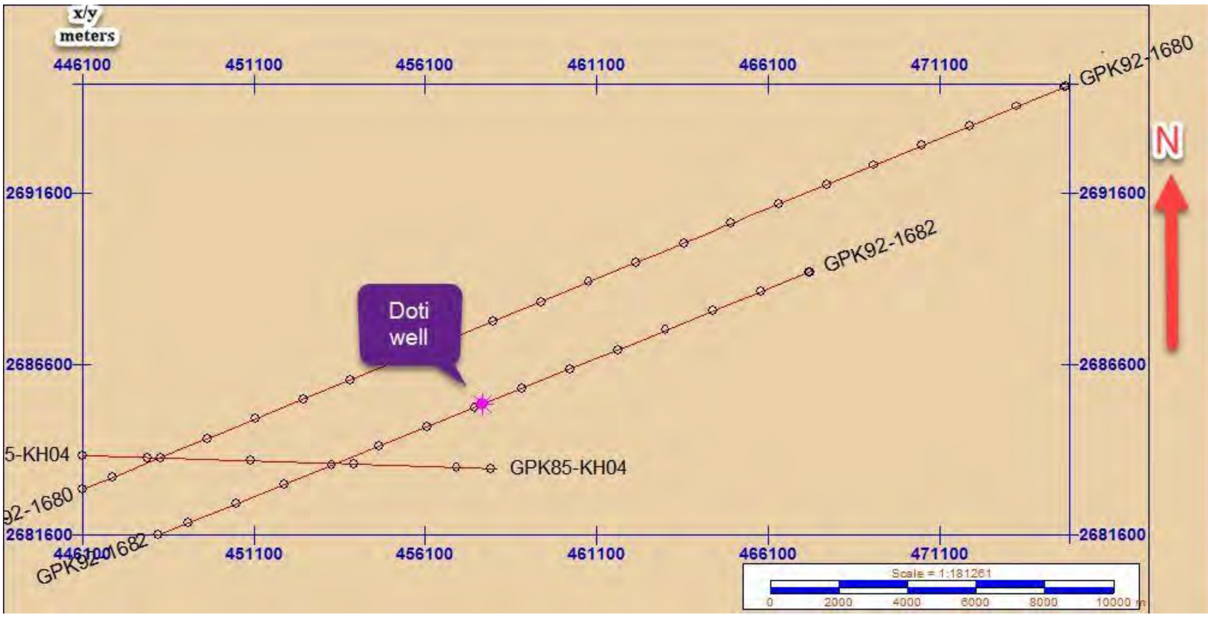

Figure 3.2: Base map of the area (source Kingdom software). Base map of selected lines two Dip lines (GPK92-1680, GPK92-1682), One strike line (GPK85-KH04) and Well is drill on (GPK92-1682).

3.8 Synthetic Seismogram

Synthetic seismograms are artificial seismic traces which extract from seismic data, use to establish correlations between local stratigraphy and seismic reflections. Synthetic seismogram is used for 1D forward modeling of the acoustic model energy traveling through different layers of earth. To create an engineered seismogram a sonic log is required. In a perfect world, a thickness log ought to likewise be utilized, however these are not generally accessible subsequently we can likewise utilize the consistent thickness for that zone. With the assistance of DOTI_01 the engineered seismogram was built shown in the (Figure 3.3) with a specific end goal to stamp the skylines. Fundamentally, they give a ground truth for the translation of seismic information. Engineered seismograms are valuable devices for connecting penetrates gap geography to seismic segments, since they can give an immediate connection between watched lithology and seismic reflection designs (Handwerger et al., 2004). Reflection profiles are delicate to changes in residue impedance, the result of pressure wave speed and thickness. Changes in these two physical parameters do not generally relate to watched changes in lithology. By making a manufactured seismogram in view of sediments Petro-material science, it is conceivable to distinguish the birthplace of seismic reflectors and follow them horizontally along the seismic line (Handwerger et al., 2004).

- Velocity ………………………………. DT
- Density ………………………………. RHOB
- Reference log …………………………GR
- Wavelet ………………………………. Extracted from seismic data.

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

a. Load the Las file of the well in the software.

b. Open 1D forward modeling Project and select the well logs.

c. Integrate the sonic log to rescale from depth in meters to two-way travel time in seconds.

d. Create a TD chart for the well from the velocity logs.

e. Compute Acoustic impedance log using velocity and density log.

f. Compute the reflection coefficients from the time-scaled velocity log.

g. Compute a source wavelet which extracted from seismic data.

h. Two-way travel time using a frequency in Hertz (35 Hz frequency is used in thesis study).

i. Convolve the reflection coefficient log with the source wavelet to generate the amplitudes of the synthetic seismogram.

Presently the synthetic seismogram is utilized to conform horizon. Basically, we have the log information just Doti - 01 is the main well in our accessible information that having the DT and ROHB log to produce synthetic seismogram. Hence because of the constraint of the well information the created synthetic seismogram just conform the B-interval however based on the arrangement highest points of the Doti-01. The show of the synthetic seismogram is shown in the Figure 3.3.

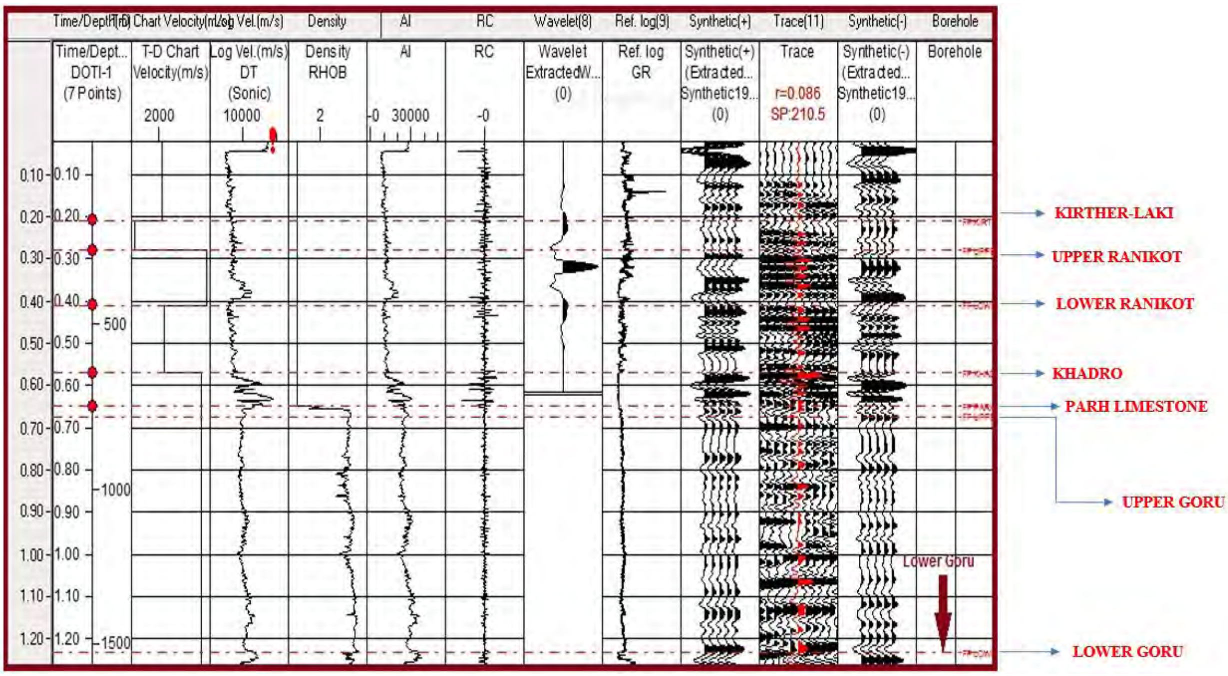

Figure 3.3 Synthetic Seismogram of _DOTI _01 well.

3.9 Fault marking

Primary task of interpretation is the identification of various horizons as an interface between geological formations. For this purpose, good structural as well as stratigraphic knowledge of the area is required. Thus, during interpretation process, I mark both, the horizons and faults on the seismic section. Seismic interpretation are skills that require experience and in Geography and Geophysics to be exact (Mc. Quillin et al., 1984). Fault marking is difficult work without knowledge of tectonics history of an area. Fault of area show the deformation of beds. Study area lies in extensional regime dominated by normal faults and associated horst and graben structures. The identification of faults was difficult to some extent due to data quality. The average throw of the faults is observed to be about 15 – 20 ms. Based on discontinuity in time, normal faults have been marked on the seismic sections of the line (Figure 3.4) forming the horst and Graben features. Clues of normal faulting exist on all interpreted seismic lines.

3.10 Horizon picking

The Prominent reflectors that are available are marked on the seismic areas, and then chosen those reflectors that have great characteristics they are well trace over seismic area. There are troubles in proceeding with the reflectors toward the finish of the seismic area and complexes are arrived where reflectors are mixed that might be because of sudden change in lithology, seismic noise, poor information quality or nearness of salt in the subsurface at these areas. The SEG - Y arrange information of seismic line GPK92-1680 and GPK92-1682 is interpreted by kingdom software for interpretation. After loading data in kingdom software of lines using the interactive tools and applications of Kingdom Software prominent horizons are marked following the trend and continuity of the reflectors. The lines comprise normal faulting which shows a strike slip nature and horst and Graben Geometry.

3.11 Seismic Time Section.

After marking seismic horizons and faults, the time of each reflector was noted at different vibrating points, and then the seismic time section is generated by plotting the two-way travel time of the reflectors and faults on y-axis against the shot points on x-axis. The seismic time section is simple, reproduction of an interpreted seismic section. The horst and Graben structure present on the seismic sections may be a suitable place for the accumulation of hydrocarbons. Time section is the developed section of reflectors, which shows subsurface structure in time domain. Time section of the Lines GPK92-1680 and GPK92-1682 is shown in Fig.3.4 and Fig 3.5 reflectors are marked by tying with the line which is marked by using well top data of Doti-01 well.

3.12 Interpretation of the of Dip line GPK92_1682.

Figure 3.4 shows well tie with time domain section. We marked horizons of lower Goru and upper Goru based on the change in the acoustic impedance also confirmed by the synthetic seismogram. The following color scheme is used to mark the horizon.

- ➢ Lower Goru ………………Green
- ➢ Upper Goru ……………… Hot Pink

The interpretation shows the horst and Graben are formed between conjugate normal faulting, which matches with our previous geological information. The faults have almost trend of NE-SW. The main purpose was to show the favorable structure for petroleum accumulation. The horst sand Graben structures are good structural traps for the petroleum accumulation.

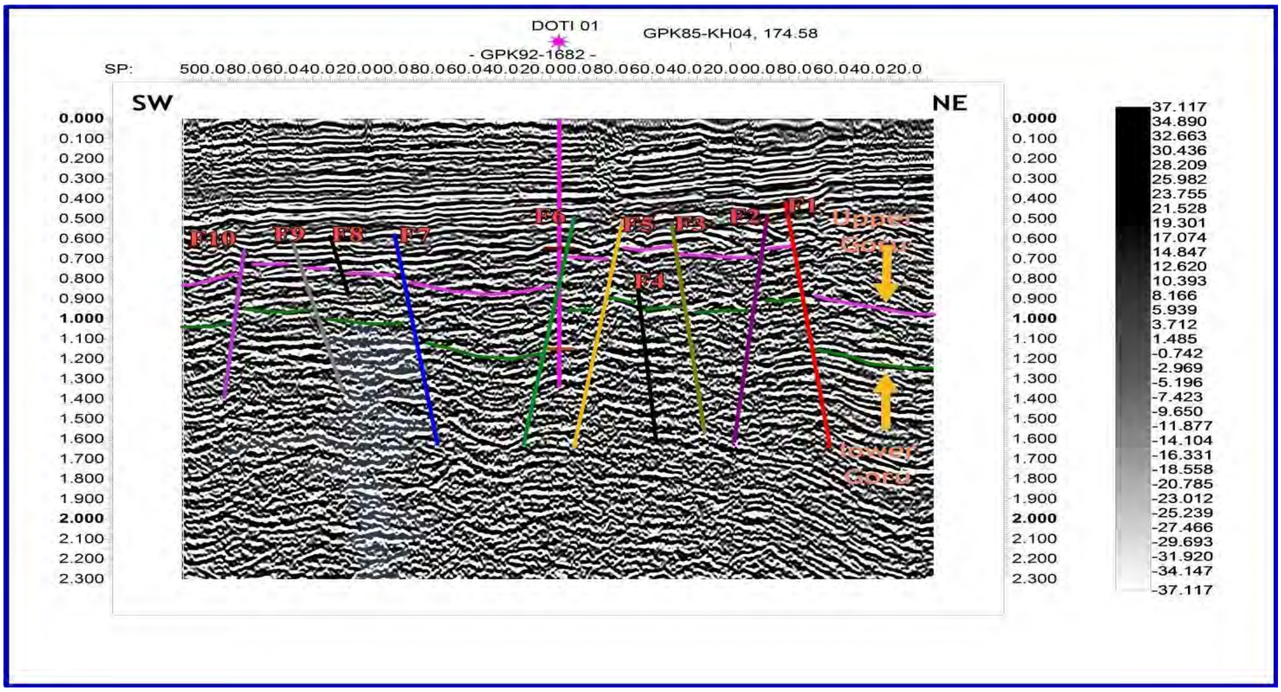

Figure3.4 Interpretation of the Dip line GPK92_1682.

3.13 Interpretation of the of Dip line GPK94_1680

Digitized strike line with dip line GPK94_1680 because this strike line was crossing all the dip lines which are shown in the base map. After digitizing this dip line, we marked the horizon and removed the miss tie. The faults were already marked on this seismic section. When faults and horizon are mark horst and Graben geometry has form as shown in the below. The main purpose to interpret this line was to show the favorable structures for accumulation of the hydrocarbon. The horst and Graben structures are good structures for petroleum system to accumulate the hydrocarbon after migration.

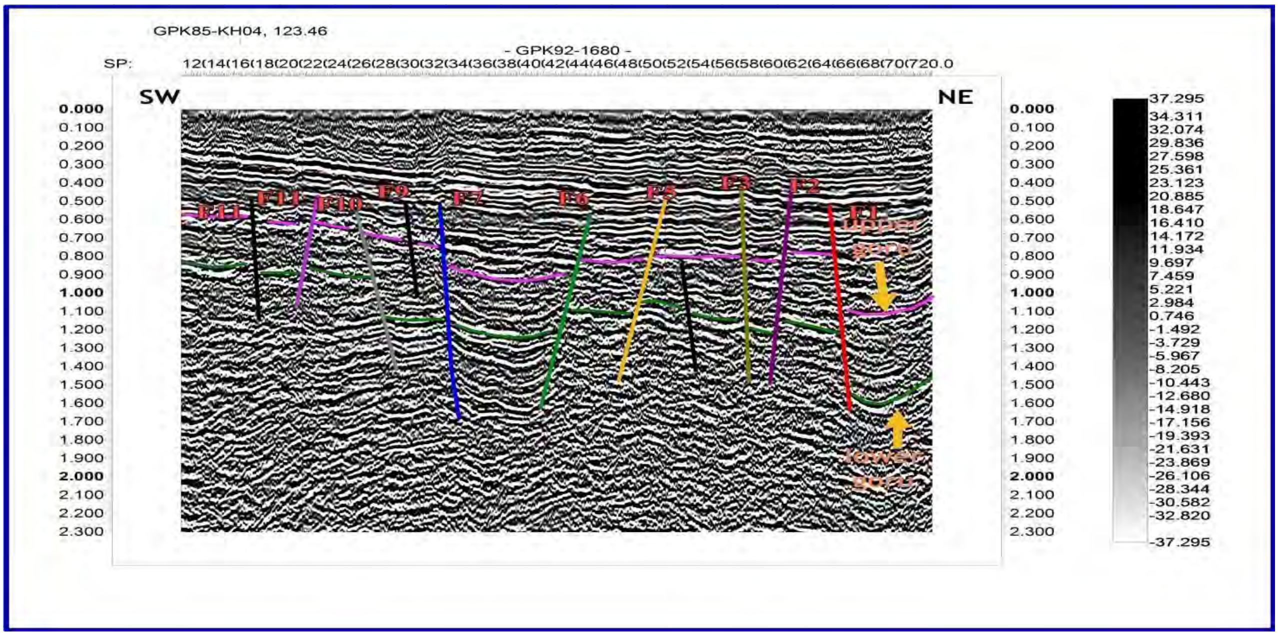

Figure3.5 Interpretation of Dip line GPK94_1680. Several faults are mark on section and two horizons.

3.14 Interpretation of the seismic GPK85-KH04

Using IHS kingdom we digitize the seismic line GPK85-1682 with the strike line GPK85_KH04.Then we removed the miss tie however, in the given seismic section does not show any faults. The reason behind is that the given line is a strike line, and the orientation of the line is against the basin configuration.

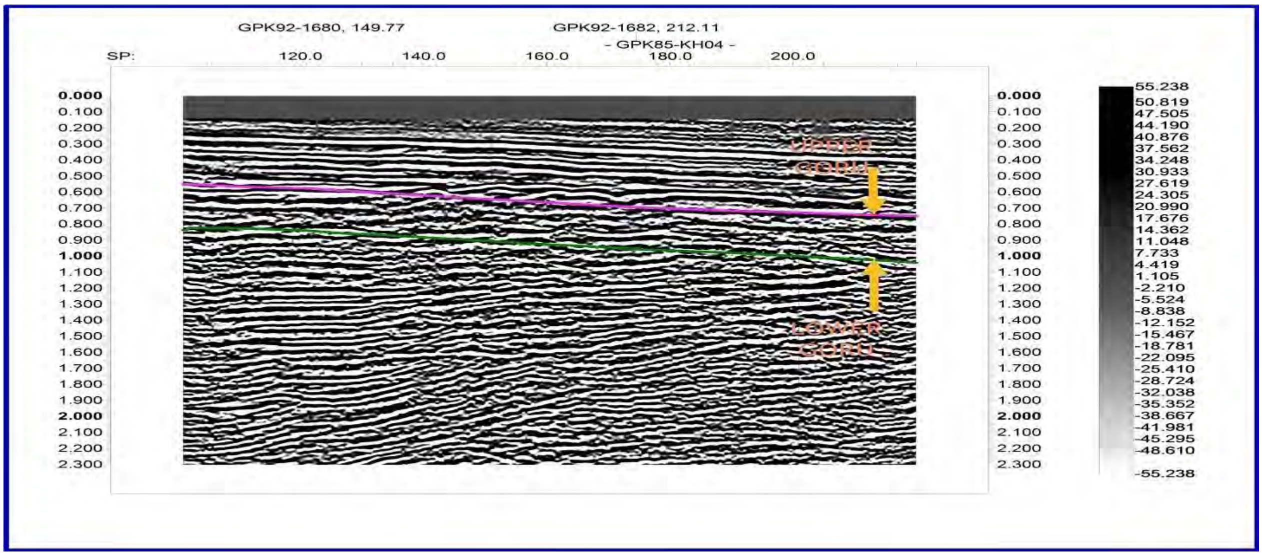

Figure 3.6 Interpretation of the seismic line GPK85_KH04, two horizons of Lower Goru (reservoir) and Upper Goru are mark.

3.15 Fault polygon generation

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

A fault polygon represents the lateral extent of dip faults or strike faults having same trend. Fault polygons show the sub-surface discontinuities by showing the contours. To generate fault polygons, it is necessary to identify the faults and their lateral extent by looking at the available seismic data. If one finds that the same fault is present on all the dip lines, then all points on base map can be manually joined to make polygon directions on a fault polygon if dip symbols are not drawn. Fault polygons are constructed for all marked horizons. Figure 3.7 shows polygon of lower Goru. At lower Goru and upper Goru level fault polygons are generated.

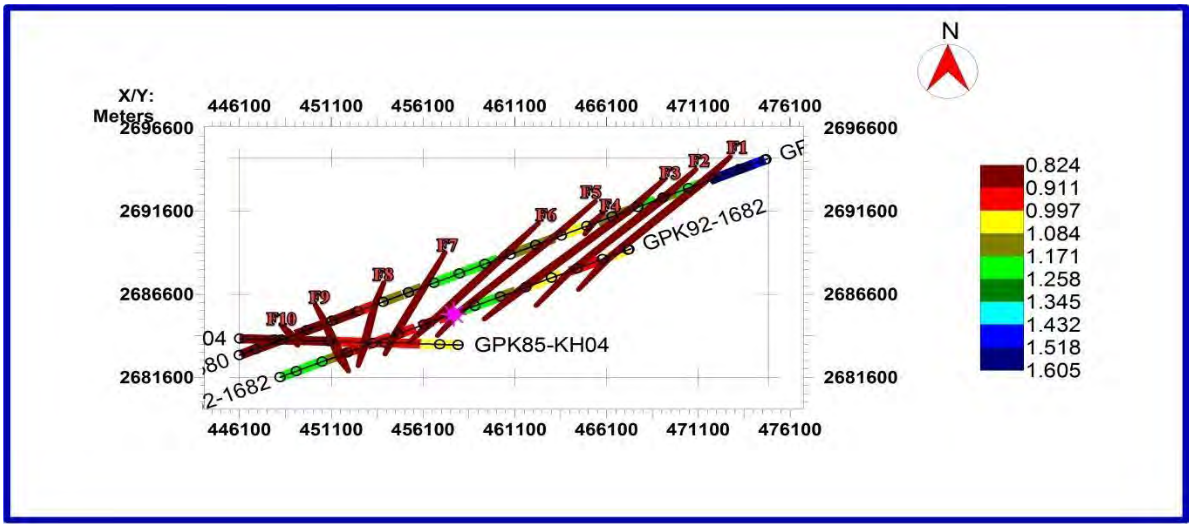

Figure3.7 Show fault polygons of Lower Goru formation

3.16 Contour Maps

Contouring is the essential constituent of the interpretation of the seismic data. Seismic interpretation displays the most essential information extracted during interpretation in the form of time and depth contour maps. The contours are the lines of the same time or depth roving about the map as dictated by. The results of all the seismic exploration are the contour maps, time or depth. The mapping is one of the most important part of the data interpretation on which entire operations depends upon. The contours are generally the lines which join the point of the equal depth and time (Coffeen,1986). Contours represent the three-dimensional earth surfaces into the two-dimensional earth surfaces. These contour maps represent the structural relief of the formation, any faulting and folding including dip of the strata. The following contours maps are generated in order to represent the two-dimensional view of the various layers within the area. These contours maps are generated with the help of the advanced micro seismic technology (IHS kingdom 8.6).

3.17 Time Contour Map of Lower Goru

The time contour maps are generated by using the kingdom software. The figure below shows the variation in color along both sides of the polygon. This alternate color variation is the sign of horst and graben geometry and time variation proves that it is normal faulting. Contouring also confirms the bookshelf model. Time contour map of Lower Goru, as shown in the figure 3.8.

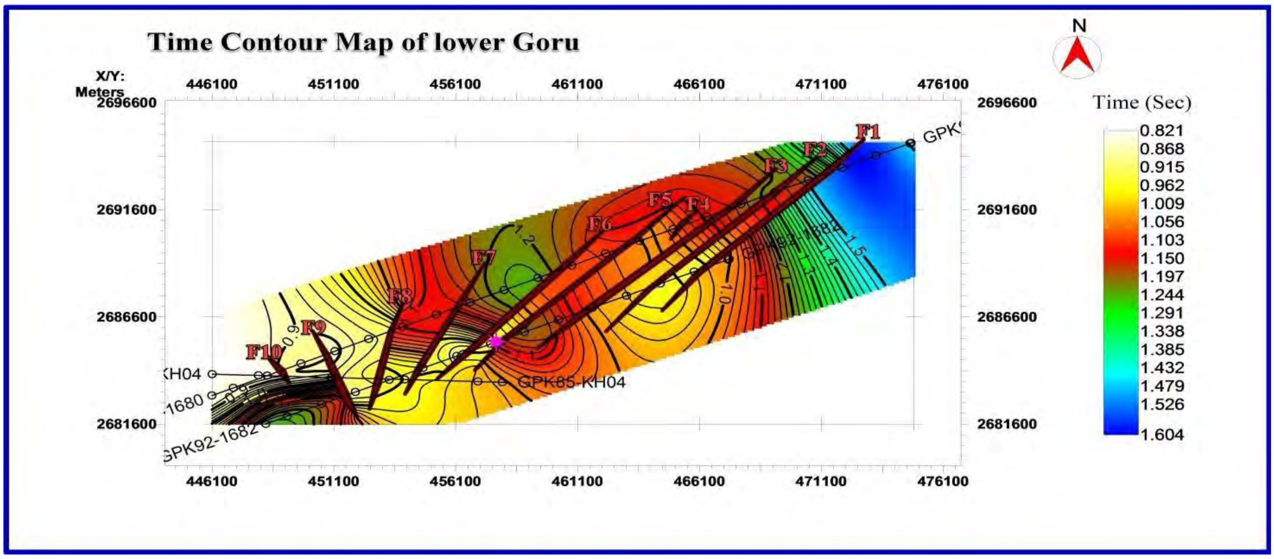

Figure3.8 Shows the time contour of Lower Goru.

3.18 Depth Contour Map of Lower Goru.

The depth contour maps show the horizon depth variation. It can easily be interpreted that horizon is forming a horst and Graben structures, as from the scale the central portion between fault polygons is deepest in depth than the surrounding area. It also be noted that that there is no change in pattern of time and depth contours because variation is same either with time or with depth.

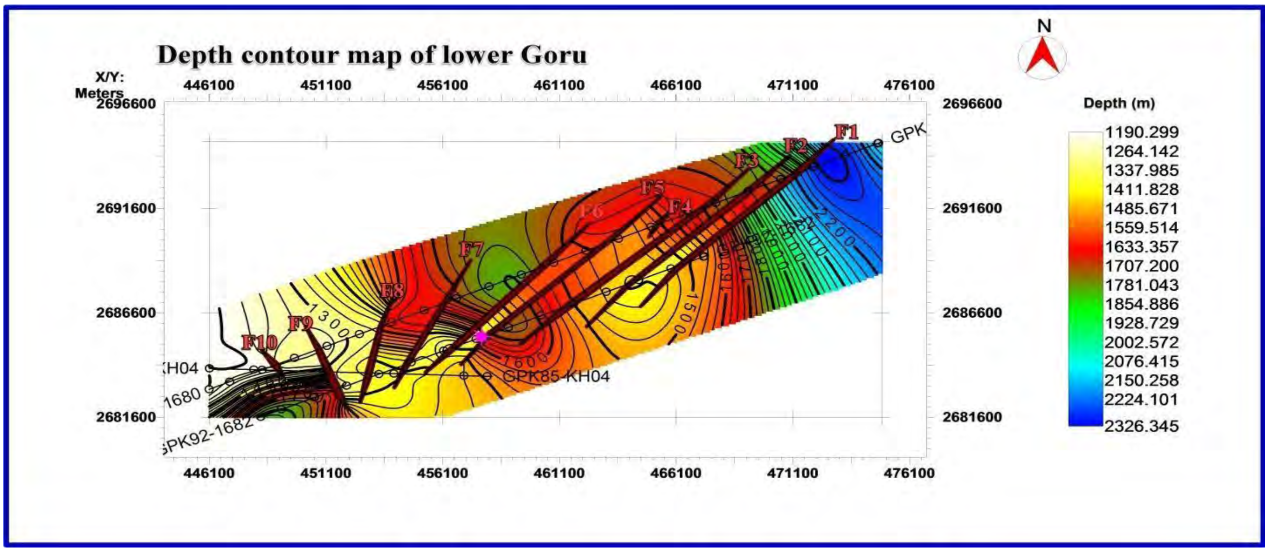

Figure3.9 Shows the depth contour of Lower Goru.

3.19 Conclusion

With help of seismic interpretation, we conclude the geological behavior on a seismic section and interpret the faults orientation and contour maps. All the contour maps show that deepest part is almost lying in the center of structure indicating Graben structures while the shallowest part have light color indicating horst structures. We encounter one Horsts and two Graben. The Seismic response and the marked horizons clearly indicate that there is an increased ground in the younger horizons above the Basement, specifying that the faults present in the interpreted section are normal e in nature and are directly linked with the splitting of Indian plate from Gondwanaland. Therefore, it is clear from the interpretations that the area is in highly extensional regime.

Chapter 04

Seismic Attributes

CHAPTER 04

SEISMIC ATTRIBUTES

4.1 Seismic Attributes

Seismic attributes are a set of properties computed from input seismic data in which the amplitude is the default attribute. Attributes can be calculated on the pre-stack as well as post-stack data. The most common post stack attributes are instantaneous attributes that are work out at each sample of seismic trace. The seismic energy is basically a mechanical energy which has two components kinetic and potential energy. Through experiments it has found that we can only measure the kinetic energy. Now to compute instantaneous attributes we need to calculate the imaginary potential energy component of seismic energy (Khan, 2010). The imaginary component is basically a 90^o degrees phase rotated version of the input seismic trace and therefore can be computed through the Hilbert transform (Taner et al., 1979).

4.1.1 Applications of Seismic Attributes

Uses of Seismic attributes include:

- To check seismic data quality identifying artifacts.
- Performing seismic facies mapping to predict depositional environments.
- Hydrocarbon play evaluation.
- Reservoir characterization.

4.2 Classification of Seismic Attributes

The Seismic Attributes are classified into two categories.

- Physical Attributes
- Geometric attributes.

4.2.1 Physical Attributes

Physical attributes are defined as those attributes which are directly related to the wave propagation, lithology and other parameters. The Process of interpretation is the same in all these cases. Each of these has sub-classes as instantaneous and wavelet attributes. Instantaneous attributes are computed sample by sample and indicate continuous change of attributes along the time and space axis. The Wavelet attributes, on the other hand represent characteristics of wavelet and their amplitude spectrum. The Attribute is a result of the properties derived from the complex seismic signal.

4.2.2 Geometrical Attributes

The Geometrical attributes are dip, azimuth and discontinuity. The Dip attribute or amplitude of the data corresponds to the dip of the seismic events. Dip is useful in that it makes faults more discernible. The amplitude of the data on the Azimuth attribute corresponds to the azimuth of the maximum dip direction of the seismic feature.

4.3Attributes Analysis

The following attributes were applied to line GPK92-1682 and interpret the following result.

4.3.1 Envelope of Trace (Reflection Strength / Instantaneous Amplitude).

Trace envelope attribute represent mainly the acoustic impedance contrast, hence reflectivity strength. It always remains positive whether the reflection coefficient is positive or negative. Figure (4.1) clearly shows reflection strengths of marked reservoir horizons. This attribute is mainly useful in identifying.

- Bright spots, gas accumulation.
- Sequence boundaries.
- Major changes in depositional environments.
- Local horizontal changes indicating faulting.

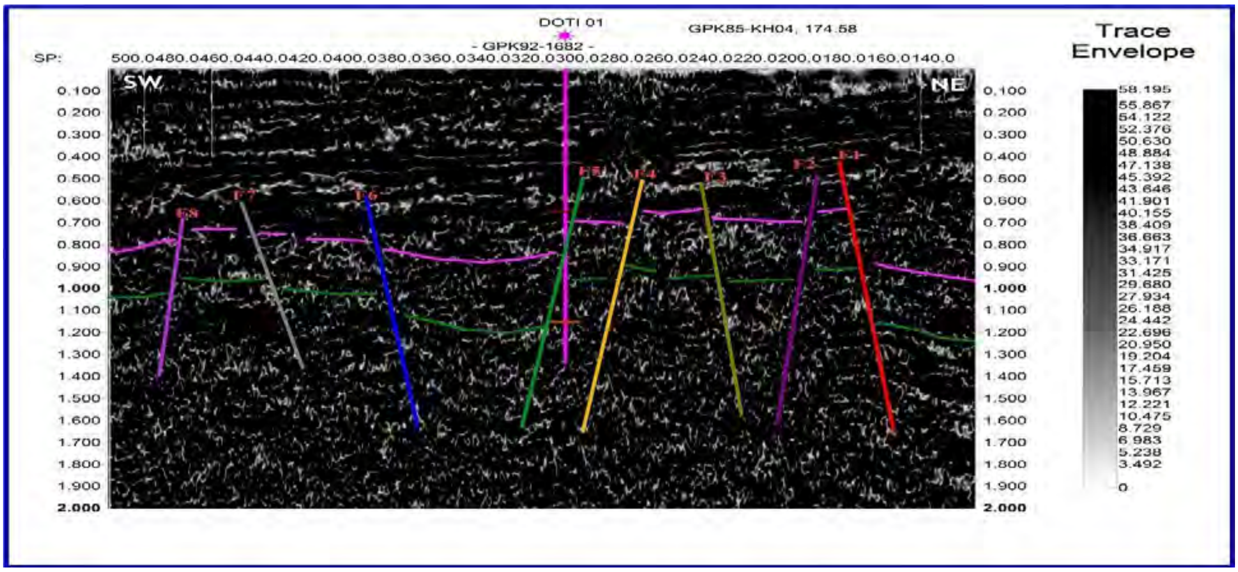

Figure 4.1: Trace envelope attribute line GPK92_1682

4.3.2 Instantaneous phase

It is independent of amplitude. Instantaneous phase is calculated in degrees (continuity and discontinuity of events). It shows bedding very well. Phase along horizon should not change in principle; changes can arise if there is a picking problem, or if the layer changes laterally due to sinkholes or other phenomena. This attribute is useful as

- Best indicator of lateral continuity.
- Relates to the phase component of the wave propagation.
- Has no amplitude information, hence all events are represented.
- Detailed visualization of bedding configuration.
- Used in computation of instantaneous frequency and acceleration.

- This attribute is marking clear cut continuity of the reflector as shown in the below Figure 4.2.

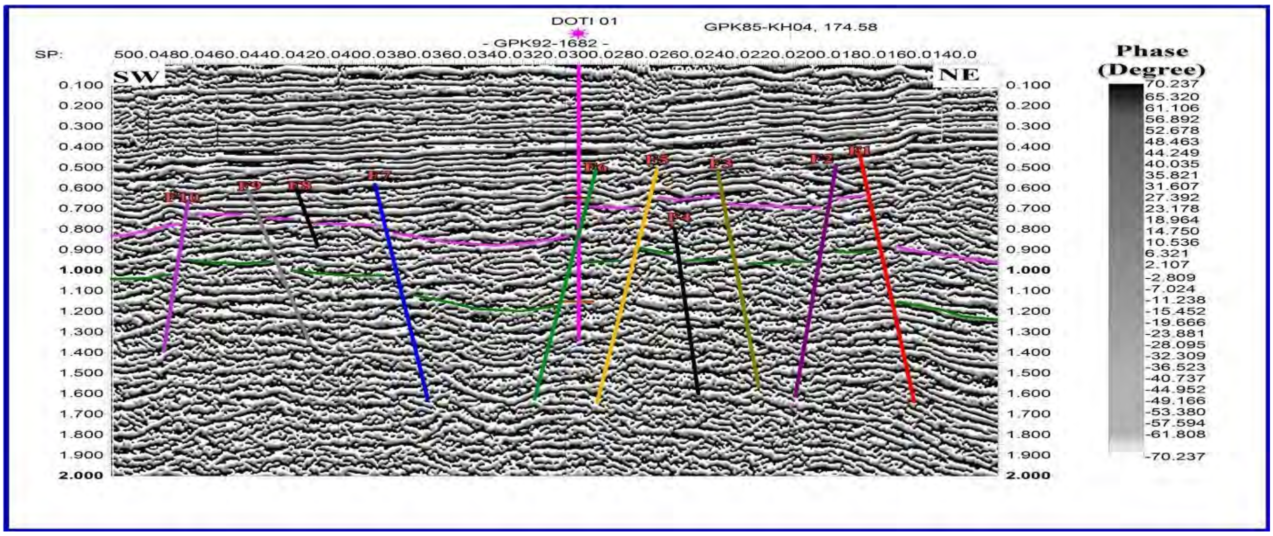

Figure 4.2 Instantaneous phase line GPK92_1682

4.3.3 Instantaneous frequency

These attributes are mainly direct Hydrocarbon indicator by low frequency anomaly in high resolution 3D data because this effect is sometimes accentuated by unconsolidated sands due to the oil content of the pores. Fracture zone indicator since fractures may appear as lower frequency zones. Higher frequencies indicate sharp interfaces such as exhibited by thinly laminated shale, lower frequencies are indicative of more massive bedding geometries, e.g., sand-prone lithology (Taner, 2001).

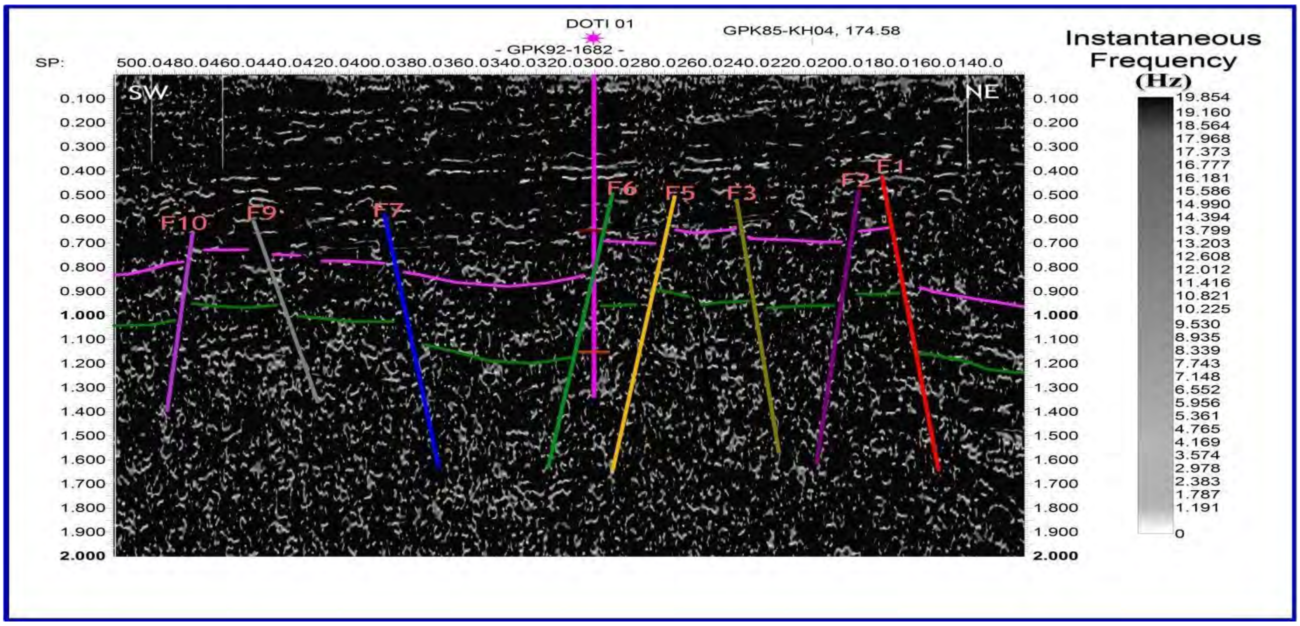

Figure 4.3: Instantaneous frequency GPK92_1682

4.4 Conclusion

At the end of interpretation, it is concluded that Badin area there are horst and Graben structures. The horst and Graben structures are formed in the results of the normal faulting which are also confirmed in the above interpretation. Hence, we have such type of structures formed in the result of the normal faulting for accumulation of the hydrocarbon in the Lower Goru area. This normal faulting is generated in the results of the rifting, during the initial Gondwanaland breakup. Subsequent Triassic and Jurassic rifting initiated a marine incursion from SE. All models shown above 2D show that clear horst and Graben structures which can act as a very good structural trap in the petroleum play point of view. From stratigraphy column discussed in previous chapter and Petroleum Plays in study area of the Lower Goru formations has potential for hydrocarbons and faults in the area are major migration pathways for hydrocarbon and in most places are acting as traps.

Chapter 05

Petrophysics

CHAPTER 05

PETROPHYSICS

5.1 Introduction

Petrophysical analysis is the detailed analysis of a carefully chosen suite of wireline services provide a method of inferring or deriving accurate values for the hydrocarbons and water saturations, the permeability, the porosity, and the lithology of the reservoir rock.

- Petro physics uses all kinds of logs, core data, production data and integrates all pertinent information.
- Petro physics aims at obtaining the physical properties such as porosity, saturation and permeability, which are related to production parameters.
- Petro physics is generally less concerned with seismic, and more concerned with using wellbore measurements to contribute to reservoir description.
- Petro physics can provide things like porosity, saturation, permeability, fluid contacts, shale volume, and reservoir zonation.

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

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

5.2 Data set

The Petrophysics analysis has been used in order to measure the reservoir properties of the Badin area using the borehole data of Doti_01. We used the log curves including caliper log (CALI), spontaneous potential log (SP), Gamma ray (GR), Sonic log (DT), Latero log deep (LLD), Latero log shallow (LLS), Neutron log, density log. For Petrophysics analysis the parameters are required based on the log curves are:

- Water saturation.
- Volume of shale.
- Hydrocarbon Saturation.

5.3 CLASSIFICATION OF GEOPHYSICAL WELL LOGS

Different classifications and explanation of geophysical well logs are as follow. The logs are explained according to the tracks in which they are run, and this is clear from the flow chart given below.

5.4 LITHOLOGY TRACK

In lithology track two logs are displayed which are given below as follow.

- Caliper Log (CALI)
- Gamma ray (GR)

5.4.1 Caliper Log (CALI)

The Caliper log used to determine the borehole diameter. This log gives us info to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. If this log is failed, then other logs are run. Because if any where there is say wash out then in front of the wash out the porosity and resistivity log will not give the correct values. Hence caliper log is very important in Petrophysics (Rider,2002).

5.4.2 Gamma ray log (GR)

By GR log we measure high-energy electromagnetic waves of the formation. By gamma ray log is the passive logging because we measure only the formation property without using any source. The gamma ray emitted from the formation in the form of the electromagnetic energy which are called the photon. When photon strikes with the formation electron hence, they transfer the energy to the formation electron, so the phenomenon of the Compton scattering occurs. Now this emitted gamma ray reached to the detector of the gamma ray and counted and displayed as count per second which is termed as the Gamma ray. Basic purpose of this log is to differentiate between the shale and non-shale (Archie, G.E., 1942). Nearly all the gamma radiation countered in the earth is emitted by the radioactive potassium isotope of atomic weight 40 (K40) and by the radioactive elements of the uranium and thorium series (Rider,2002).

5.5 Porosity Logs Track/ Porosity log

Porosity logs measure the porosity in the volume of the rock. This porosity logs are also helpful to differentiate between the oil, gas and water in combination with the resistivity log (Ellis & Singer,2008).

- Sonic logging (DT)
- Density logging (ROHB)
- Neutron logging (NPHI)

5.5.1 Sonic Log

Sonic log is also called porosity log or acoustic log. Sonic log device consists of a transmitter that emit elastic waves (sound waves) and a receiver that pick and record the waves as it reaches the receiver. They travel through rock as dispersion and attenuation. This log is a recording verses depth of time (t) which is required by a compressional wave to go across 1 feet of formation, called interval transient time Δt, while it is the reciprocal of the velocity of sound wave. Shale has low velocity (high transit time) than sandstone of similar porosity. sometime this log is used as a grain size indicator. Units of sonic log are us/ft. This transient time (Δt) is depended upon lithology and porosity of the rock (Ellis & Singer,2008). Sonic log can also be used for the following purposes in combination of other logs as given by

- Porosity (using interval transit Time)
- Mechanical properties of formation with (Density).
- Synthetic seismograms (with Density).
- Lithology identification (with Neutron and/or Density).
- Abnormal formation pressures detection.

5.5.2 Density Log (RHOB)

This log is used to calculate bulk electron density of rocks. In the density logging gamma ray strike with the electron in the formation and scattered gamma ray (Compton scattering) received on the detector which indicate the density of the Formation. Increase in the bulk density of the formation causing the decrease in the count rate and vice versa. Bulk density which is obtained from the density log is considered the sum of the density of the fluid density and the matrix density of the formation. However, density log use to separate and along with the other log to achieve the various goals (Rider,2002).

5.5.3 Neutron log (NPHI)

This is the type of porosity log which measure concentration of Hydrogen ions in the formation. Neutron is continuously emitted from chemical source in the tool of the neutron logging. When these neutrons collide with nuclei in the formation and results in loss of some energy. Hydrogen atom has same mass as that of neutron, maximum loss of energy occurs when electron collides with hydrogen atoms. Hydrogen is an indication of the presence of the fluid in the formation pores; hence loss of energy is related to the porosity of the formation. The neutron porosity is very low when the pores in the formation are filled with the gas instead of the water and oil, the reason is that gas having les concentration of the hydrogen as compared to water and oil. This less porosity by the neutron PHI due to the presence of the gas called the Gas effect (Ellis & Singer,2008).

5.6 Resistivity Logs Track

There are different types of Resistivity Logs including MSFL, LLD and LLS. Here we work only two logs that are available in my data which are simply explained as below. These logs measure the resistivity of the subsurface, and they measure the resistivity of the formation fluids. They are very helpful to differentiate between water saturated formation and the hydrocarbon saturated formations. Resistivity logs include the following.

- Latero log Deep (LLD).
- Latero log shallow (LLS)

5.6.1 Latero Log Deep (LLD)

Latero log deep is used for the deep investigation of the quietly uninvaded zone and it is called Laterolog deep (LLD). This log is also used for saline mud also in case of fresh mud. The Laterolog curve is shown in track 2. This log is generally used for measuring the formation resistivity. It having deep penetration as compared to the (LLS log) (Rider,2002).

5.6.2 Latero Log Shallow (LLS)

Laterolog shallow (LLS), use for shallow investigation of the invaded zone because the depth of the investigation is lesser than the LLD.

5.7 Scale Used for the Different Logs Track

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

Table 5.1 Scale used for the different logs track in SMT kingdom for Petrophysical logs.

Sr. No.	Log names	Abbreviation	Scale	Units
1	Caliper Log	CALI	6_16	INCHES
2	Gamma ray Log	GR	1_200	API
3	Laterolog Deep	LLD	0.10_20	Ωm
4	Laterolog Shallow	LLS	0.10_20	Ωm
5	Sonic Log	DT	140_40	µsec/ft
6	Density Log	RHOB	1.96_2.95	Gm/cm3
7	Neutron Log	NPHI	60_0.45	PU

5.8 Workflow for Petrophysical Analysis

Petrophysical interpretation is done using the kingdom software. First, the raw log curves are loaded step by step and different log properties are calculated. Different mathematical equations are used for the calculation of the different log properties. Workflow is given in figure 5.1. Raw log curves from the wells DOTI_01 are used for the Petrophysical interpretation. The main reservoir in the area is Lower Goru formation of the cretaceous age. The lower Goru is divided sand classes is acting as a reservoir. The top and the bottom is defined by the Petrophysical analysis. The zones of interest are also identified based on the Petrophysical interpretation Loading Well Data where there is chance of the presence of the hydrocarbon. The raw logs curves which are used are shown in the below interpretation workflow.

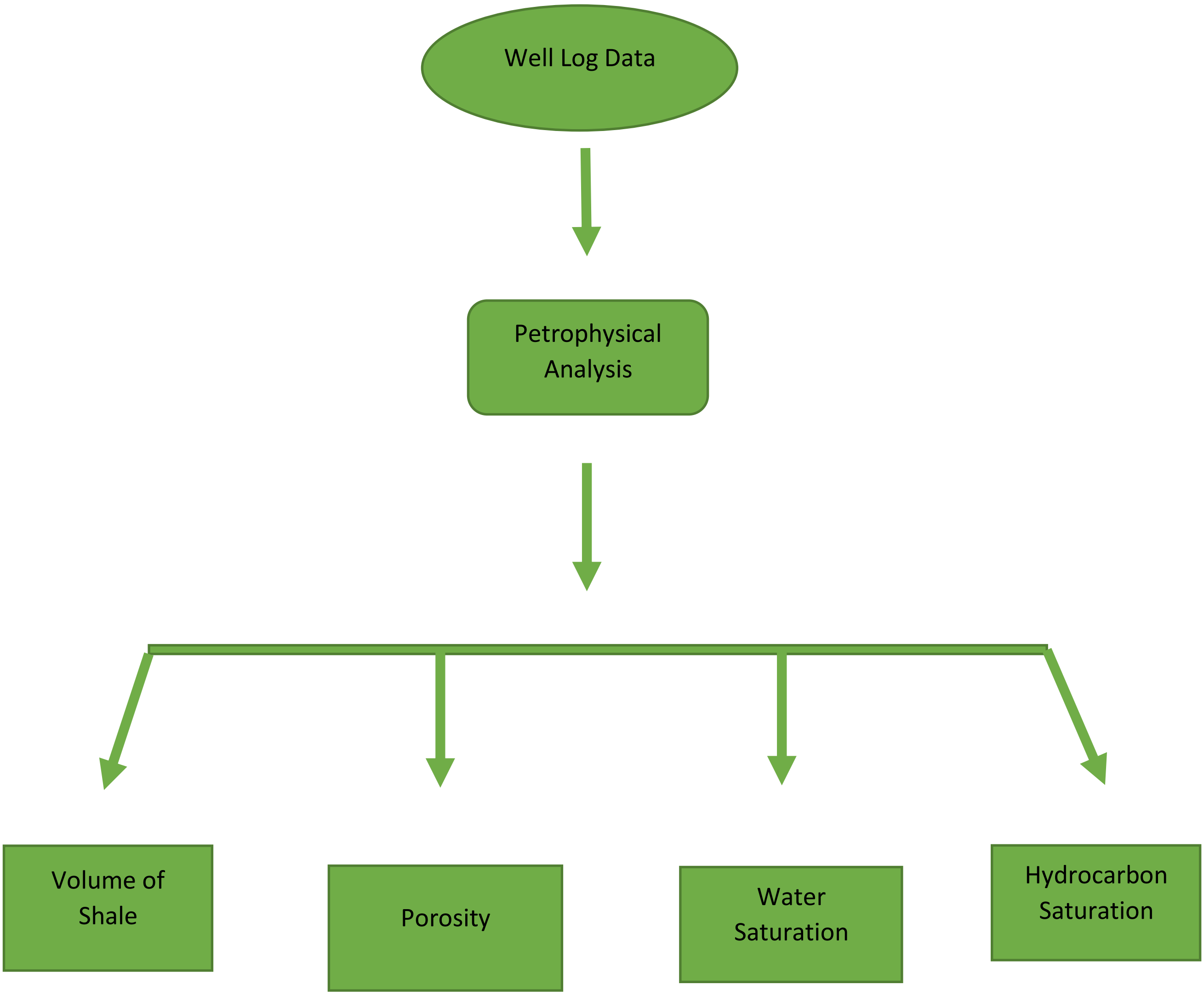

Fig 5.1 General workflow of petrophysical analysis

5.9 Calculation of Rock Properties

Many of the rock properties can be determined using geophysical logs. We have calculated the following properties using the different equations which are given in below:

$$\textbf{Static Spontaneous Potential}(\textbf{SSP}) = \textbf{SP}(\textbf{Clean}) - \textbf{SP}(\textbf{Shale})$$

SP(Clean)=Spontaneous potential for sand

SP(Shale)=Spontaneous potential for shale

$$\textbf{Sonic Porosity} = \frac{\boldsymbol{\Delta}\textbf{t}(\textbf{Log}) - \boldsymbol{\Delta}\textbf{t}(\textbf{m})}{\boldsymbol{\Delta}\textbf{t}(\textbf{f}) - \boldsymbol{\Delta}\textbf{t}(\textbf{m})}$$

Δt(log)=Interval transit time of formation

Δt(m)= Interval transit time of matrix

Δt(f)= Interval transit time of fluid. The interval transient time of Formation increased due to presence of hydrocarbon known as hydrocarbon effect. This effect should be removed because it affects the values of calculated porosities.

$$\textbf{Density Porosity} \equiv \frac{\textbf{Rho}(\textbf{m}) - \textbf{Rho}(\textbf{b})}{\textbf{Rho}(\textbf{m}) - \textbf{Rho}(\textbf{f})}$$

Rho (m) = Density of matrix (limestone = **2.7**)
Rho (f) = Bulk density of Formation
Rho (f) = Density of fluid (Salt mud = **1.1** fresh mud = **1**)

$$\textbf{Resistivity of mud filtrate}(\textbf{Rmf}) = \frac{(\textbf{Ts} + \textbf{6.77}) * \textbf{Rmfe}}{(\textbf{Ft} + \textbf{6.77})}$$

Ts= Surface temperature
Rmfe= Resistivity of mud filtrate equivalent.
Ft= Formation temperature

5.10 Zone of interest

Zone of interest can be identified based on seal, reservoir and source rock of formation given in well (Doti _01). Zone of interest is marked from the table shown below.

Table 5.2: Zone of interest in Lower Goru

Zones of interest	Starting Depth (m)	Ending Depth(m)	Thickness(m)
1 Lower Goru	1537	1552	15
2 Lower Goru	1580	1600	20
3 Lower Goru	1717	1730	13

5.11 Volume of Shale

The volume of shale is calculated using the (GR) log. This log is used to measure the natural radio activity of the formation. Hence it provides the concentration of the radioactive material present in the formation; hence it is very useful in order to identify the lithology. The value of the gamma ray is low in sand whiles it has higher value in the shale. The reason is that higher value of the radioactive material is larger in the shale as compared to sand. This will lead us to differentiate between reservoir and the non-reservoir rocks. The volume of the shale is estimated by using the following equations given below.

$$\boldsymbol{VSH\%} = \frac{\boldsymbol{Gr\ (Value) - Gr\ (Min)}}{\boldsymbol{Gr\ (\max) - Gr\ (\ Min)}}$$

5.12 Calculation of Porosity

Porosity is one of the most important properties to understand the petroleum system. The porosity is calculated by using the Neutron, Density, and the sonic log. Sonic log is acoustic measurement and the Neutron and Density log are nuclear measurement. The combination of these three logs gives the accurate estimation of the porosity. We have different types of the porosities which are given below.

5.13 Average Porosity

Average porosity is the sum of all porosity's logs divided by the number of the logs.

5.14 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. The effective porosity is calculated using the mathematical equation of the (Schlumberger, 1989). Now to calculate the Water saturation we have required the Resistivity of the water of formation. This is a lengthy procedure which is explained as follow. Effective porosity values of Lower Goru.

$$PHIE=\left(\frac{DPHI+NPHI}{2}\right)*(1-VSH)$$

PHIE=Effective porosity

DPHI= Density porosity

NPHI=Neutron porosity

VSH= Volume of shale

5.15 Mathematical relation for Water Saturation (Sw)

Water saturation in the formation can be defined as the percentage of the pore volume filled by water in the formation. The saturation of water in the formation can be calculated by the following Archie equation.

$$S_W = \sqrt[n]{\frac{F \times R_W}{R_t}}$$

where,

- **F** is formation factor which is.

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

- R_w represent the resistivity of water.
- R_t represent the true formation resistivity.
- **n** represents the saturation exponent.
- **a** is the constant and its value is 1 in case of sand.
- $\emptyset$ represent effective porosity.
- **m** represents the cementation factor and it value is taken 2 for the sandstone.

Mathematical relation for Hydrocarbon Saturation (**H**s),

$H_s = 1 - S_w$

Hydrocarbon saturation can be defined as the pore in formation is filled with hydrocarbon. It can be calculated by using the following mathematical relation Where S_w represent water saturation, **H**s represent hydrocarbon saturation.

5.16 Hydrocarbon Saturation

To calculate the saturation of the Hydrocarbon we subtract the saturation of the water from the pore space as given in the relation.

$$Hs = 1 - Sw$$

Hs=Hydrocarbon saturation

Sw=Water saturation

5.17 Petrophysical Analysis of Lower Goru DOTI_01

Petrophysical analysis is used to calculate the properties of DOTI _01. Caliper log and gamma ray log are used for correlation. These both logs are lithology indicator and displayed in track 1, at some part of depth caliper log indicator of shaly content which are conformed by gamma log. Here main zone of interest is Lower Goru. Lower Goru is reservoir rocks start from depth 1537m -1830m in this high resistivity values show high concentration of hydrocarbon. Volume of shale is low (6%), and sand is high. Effective porosity and average porosity are 11% and 16% respectively.

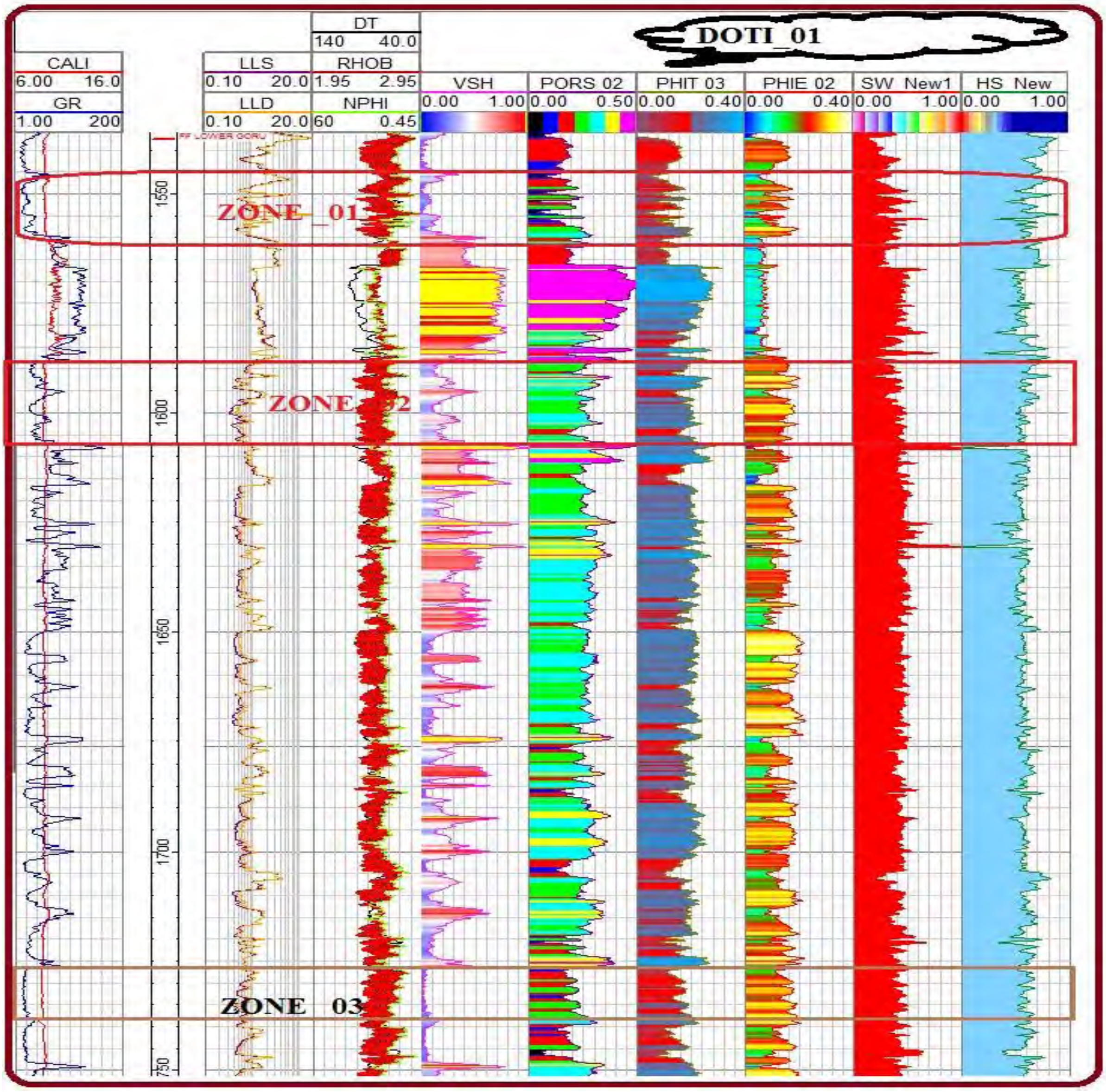

Figure 5.2: Petrophysical interpretation of DOTI_01

Table 5.3: Calculated parameters for sand in Lower Goru on Doti_01

Zones of interest	Starting Depth (m)	Ending Depth(m)	Thickness (m)	VSH	PORS_02	PHIE	SW	HS
ZONE 1	1537	1552	15	6%	28%	11%	31%	69%
ZONE 2	1580	1600	20	37%	16%	11%	38%	62%
ZONE3	1717	1730	13	11%	14%	17.1%	41%	59%

Chapter 6

Facies Modeling

CHAPTER 06

FACIES MODELING

6.1 Introduction

Geologically Facies is a rock body which having some specific characteristics which differentiate it from the other.

"A rock or stratified body distinguished from others by its appearance or composition."

Sedimentary facies are bodies of sediment that are recognizably distinct from adjacent sediments that resulted from different depositional environments. Generally, geologists distinguish facies by the aspect of the rock or sediment being studied.

Generally, the Facies is rock unit that form under certain condition of the sedimentation that pass through the environmental process. The differentiation between the shale and sand has been constantly challenged for the geoscientist. In this process the key challenge is identifying the Facies, from logging and core data, and degree to which the shale content affects the reservoir properties. This gives the main indication about the productive zone in the reservoir (Kurniawan, 2005). These Facies are related to the certain depositional environment. Basically, the depositional environment is specific type of place where the Facies are deposited. Such as the Glaciers, Lakes, Abyssal plain, Sea bottom, Stream, Delta etc. The different types of the sedimentary environment are shown in the below figure 6.1.

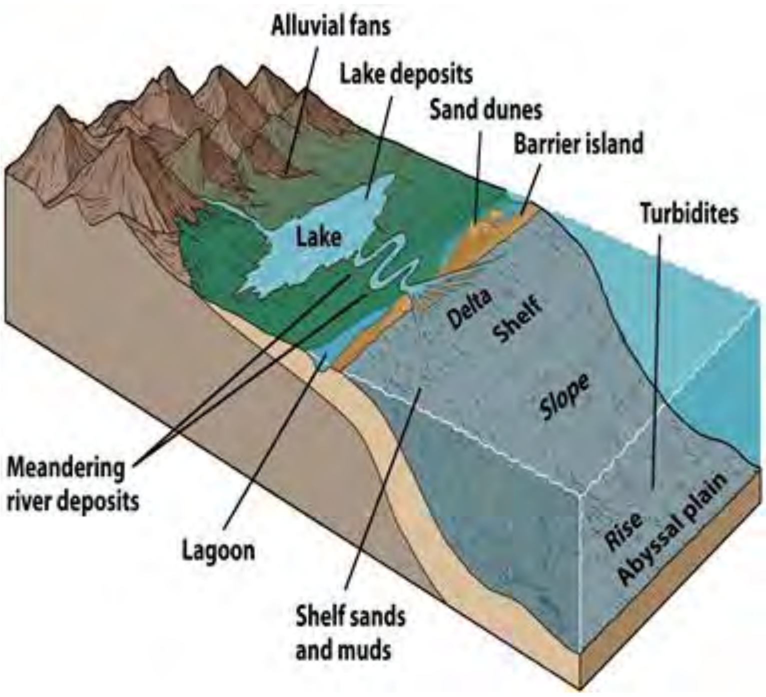

Figure 6.1: Sedimentary depositional environments (Emery & Myers,1996).

6.2 Facies modelling:

It is used for the act of modelling a reservoir using knowledge of the facies, that make up the reservoir and the depositional environments that the facies represent. The depositional characteristics will suggest rules concerning the geometries of the facies and the possible relationships between facies especially where the facies have been related to each other within a stratigraphic sequence or a cyclothem. Facies modelling is an important component of geostatistical reservoir characterization and facilitates construction of superior reservoir models for complex reservoirs.

Facies is a distinctive kind of sedimentary deposit, which was deposited in a distinctive setting. Sedimentary facies reflect the depositional environment and original composition that have resulted into the present characteristic of the rock units. A facies model is a general summary of the specific sedimentary environment. This involves the distillation of the facies and facies successions in several related environmental settings into a widely applicable model.

Facies modelling helps in understanding sedimentary features characterize a particular environment and the lateral and vertical distribution of facies within sedimentary deposits.

6.3 Facies analysis:

Fundamental to all subsurface geologic studies is an analysis of depositional facies. Development of a facies classification scheme is a particular challenging interplay between capturing enough information for environmental interpretation yet remaining simple.

"Every facies of a deposition shows well-defined petrographic, geognostic and paleontological properties which can be clearly differentiated from the properties of other facies in the same geological period." The necessity for interdisciplinary studies is clearly expressed in this definition given by Amanz Gressly in 1838. In facies analysis paleontological, sedimentological, geological, and geochemical data provide the basic information about the sedimentary environment, the lithogenesis, and the biotopes of organisms preserved as fossils (Emery & Myers,1996).

6.3.1 Facies Analysis of the Lower Goru.

The lower Goru is acting as reservoir in the Badin area and having the interbedded shale and sand which is extended in Thar platform mostly in southern area and the adjacent offshore (Qadri and Shoaib., 1988). The Lower Goru having the four different intervals division including the A, B, C and D intervals. The B interval is acting as reservoir in the Badin area, but the evidence of the hydrocarbons is also present the other units also. The porosity logs behave different in the shaly and sandy part. Hence some cross plots are plotted to differentiate between the lithology. Generally, the differentiation between the lithology on the basics of the cross plots is called the Facies modeling.

6.4 NPHI, DT and GR cross plot

The cross plot of the N-PHIE and GR is obtained from Badin for B-interval shown in Figure 6.2. According to the cross plots there is an inverse relationship between sonic and neutron log. Sand has low value of the NPHI due to gas effect and high value of the DT Comparatively to shale and low value of GR. The low value of NPHI in gas bearing reservoir is called the gas effect as in our reservoir area. Shale having the higher value of the GR and quite low value of the NPHIE. The Gamma ray (GR) is marked on the Z-axis with color dots. Purple color is representing the sand while the Green color is representing the shale.

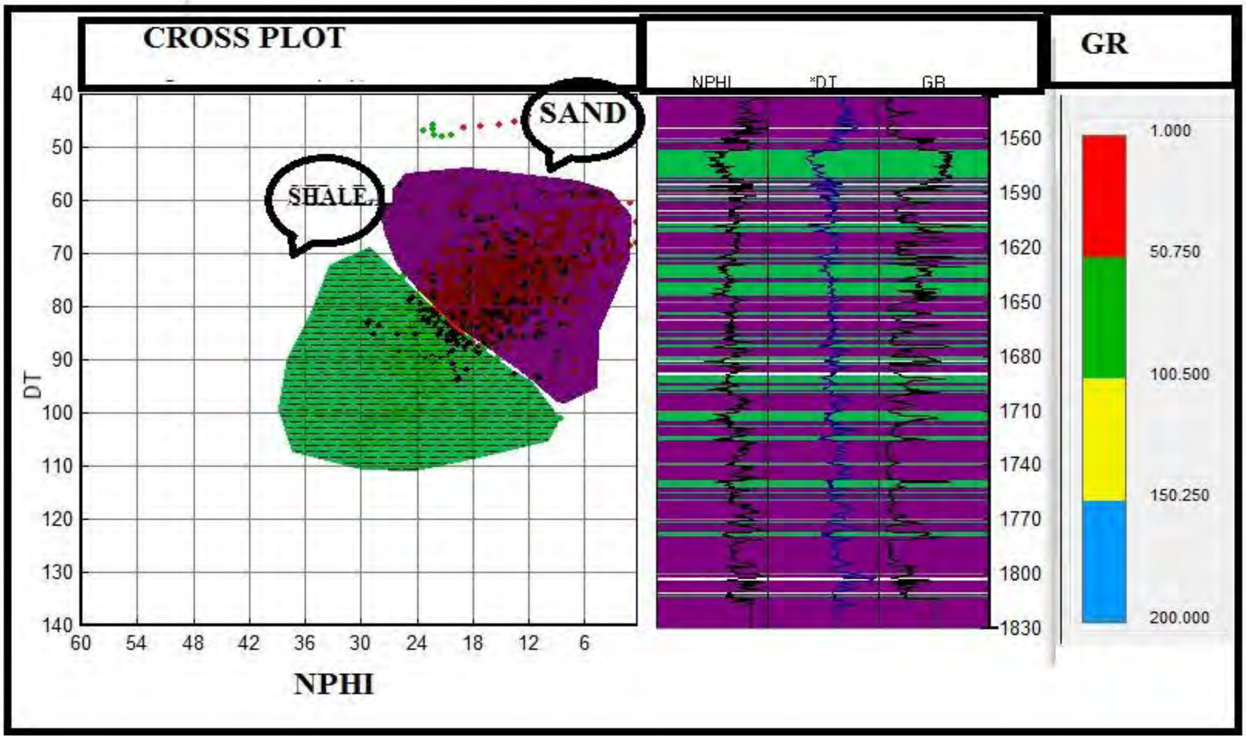

Figure 6.2: N-PHI, DT and GR cross plot DOTI_01

6.5 GR, LLS and RHOB Cross Plot

The cross plot of the GR, LLS and RHOB is obtained from the B-Interval of the DOTI_01. For the higher value of the Gamma ray and the lower value of the Resistivity log LLS the lithology is marked as the shale, while for the higher value of the LLS and lower value of the Gamma ray the lithology is marked as Sand. The reason is that hydrocarbons are present on the sand they have quite high resistivity and low value of the GR. Hence on these basics the pay zone can be identified. Here we have a Red color representing the sand while the blue color representing the shale.

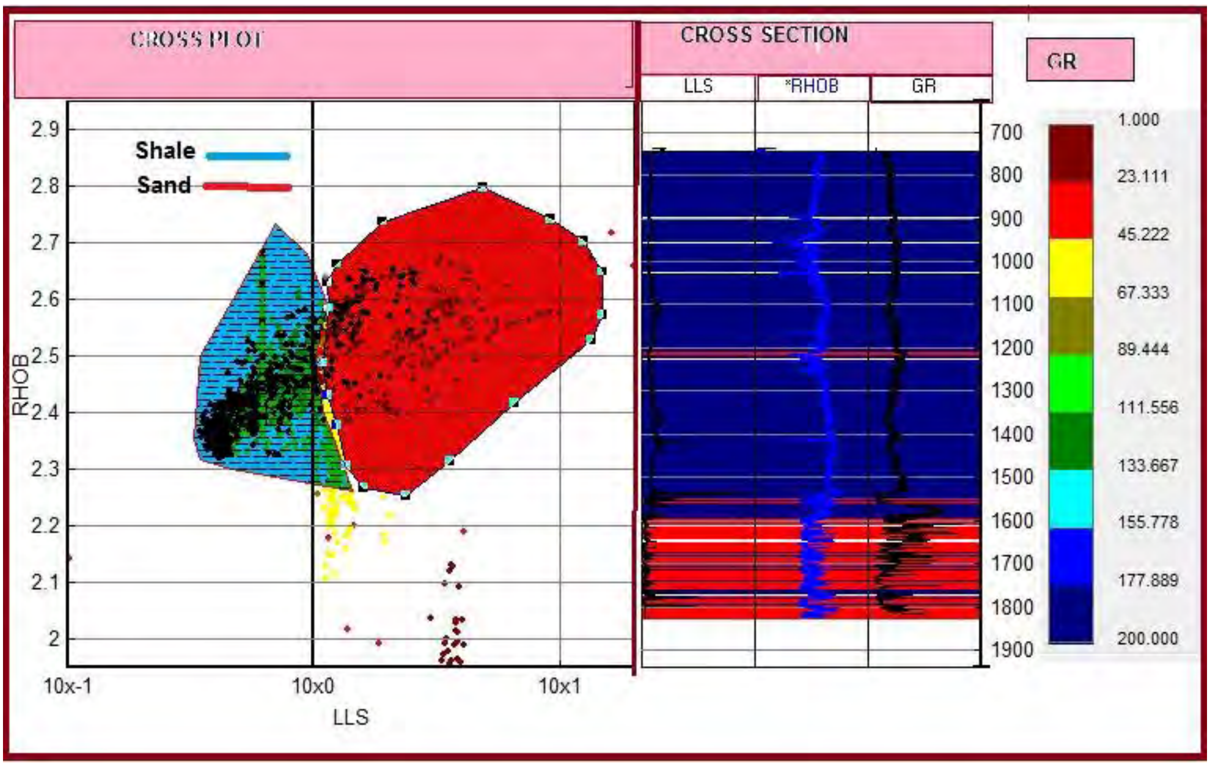

Figure 6.3: RHOB, LLS and GR cross plot DOTI_01

6.6 Sequence stratigraphy Analysis of the Lower Goru

The sequence stratigraphy is one of the main branches of the stratigraphy which represent the deposition of the sedimentary formations during the successive sea level rise and fall. The deposition of the sedimentary environment is interplay between the sediment supply and the accommodation space (Catuneanu, 2006). As the seal level changes than the Facies migration occurs.

6.7 Result from DOTI_01

It is distinct that sequence of the Lower Goru formation using the Gamma ray log data of the Doti_01. The results are shown in above figures, the results of the gamma ray show that in the Badin area when the Lower Goru was depositing there was the sea level fall. It was the period of the regression. Some comment about the system tract study of the Badin area from different papers is given below.

- Hence in the result of these fluctuation the prograding sequence are formed on the vast and the widespread ramp.
- There was a balance between the sediment supply and the accommodation space from the eastern side and E-SE, and ample sediment supply from the south east maintained the slightly aggradational package to the overall progradational profile on the sand.

6.8 Results obtained from the gamma ray log response for the Lower Goru

As in the Lower Goru is kept in the season of the Regression subsequently around then sediments supply rate was more than the accommodation space. As the settlement space was diminishing consequently the facies begin to move towards the distil side. We have the accompanying outcomes in this circumstance.

1. General Progradational system track is formed.

2. Topsets turn out to be thin.

3. Clinoform turn out to be thick.

4. Mostly base set likewise shaped.

5. Facies move from proximal to distil side.

6. Henceforth general we have sand affidavit towards the proximal side and the shale towards the distil side because of which in Gamma beam log reaction we can see obvious Coarsening upward as shown in the underneath.

7. Demonstrating that there are progradational group in bring down Goru development. Thus, we can state that when bring down Goru was saving in Cretaceous age that was the time of the Regression and Facies were moving towards the distil.

CONCLUSIONS

The seismic and well log data is interpreted by using different software tools, following results are concluded:

1. Based on seismic as well as well data reflectors of geological importance were identified.
2. The seismic interpretation revealed horst and graben structure in Badin area.
3. Synthetic seismogram was matched with the marked horizons and it has confirmed the structural interpretation.
4. Time and Depth Contour maps shows Horst and Graben Structure formed in the study area.
5. Petrophysical analysis shows good porosity, major fluid is water.
6. The structural and lithological interpretation is further confirmed through seismic attributes.
7. High concentration of shale clearly shows that there is only thin reservoir is present. Facies analysis shows the reservoir consist of sandstone with small shale packages.
8. The overall results indicate the economic viability of Lower Goru as a reservoir.

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