2D SEISMIC INTERPRETATION ALONG WITH PETROPHYSICAL ANALYSIS AND SEISMIC ATTRIBUTES OF BADIN BLOCK, LOWER INDUS BASIN PAKISTAN

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DEDICATION

DEDICATED TO MY FAMILY AND TO ALL THOSE WHO REPLACED THE DAYS OF GRIEF INTO DAYS OF MERRY AND HAPPINESS.

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 thank Allah for giving me strength and ability to complete this study.

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I also wish to thank the whole faculty of my department for providing me with an academic base, which has enabled me to take up this study I pay my thanks to the employs of clerical office who helped me a lot and all those their names do not appear here who have contributed to the successful completion of this study.

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ABSTRACT

The purpose of this work is to study structural interpretation, petro physical analysis of Badin area. Badin place is distinguished within the Lower Indus Basin for its hydrocarbon (Gas and Oil) structural traps. For interpretation of seismic traces two reflectors and normal faults were marked via the usage of the interactive tools of Kingdom software, polygon creation two way time contour and depth contour are also the part of the seismic data interpretation.

The marked horizons were diagnosed the use of formation tops from wells and their depths were confirmed through correlation with synthetic seismogram from Density log (RHOB) and sonic log. 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. The resulted seismic interpretation of these lines confirmed Horst and Grabben structures by normal faulting. Seismic attributes analysis of seismic section allows in figuring out the exclusive lithological limitations and also confirmed the structural disturbance.

Contents

CHAPTER 1:

INTRODUCTION TO THE STUDY AREA:-

1.1 Introduction

Pakistan has high potential of hydrocarbons in its southern (like Badin, Mari etc.) parts and Northern (like Potwar, Kohat). So study area is Badin that is located in East of Badin district in Sindh province of Pakistan. The total area of district is 6726 square kilometers. Badin has been a major producer of hydrocarbons for more than 30 years. 50% of oil production of Lower Indus Basin comes from Badin. The Badin block is a part of Lower Indus Basin which is located in Southern-Eastern part of Pakistan (Mozaffer et al., 2002).

Badin district is bounded on the north by the Tando Allahyar District, Northwest by the Hyderabad District, on the east by Mirpurkhas and Tharparkar districts, on the south by the Kutch district of India, and on the west by Sujawal and Tando Muhammad Khan District. 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). 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). Hydrocarbons are among the earth's most important natural resources and hydrocarbons are the main constituents of petroleum (literally, "rock oil"), also called "oil," and natural oil. They are commonly found in and extracted from the Earth´s subsurface. Petroleum is a mixture of liquid hydrocarbons, while natural gas is mainly constituted of methane gas.

The geographical coordinates of the area are:

- **Latitude:** 24° 5’N to 25° 25’N

- **Longitude:** 68° 21’E to 69° 20’E

The syn rift and post rift deposition of the Lower Goru and Upper Goru formations was continued during early to middle Cretaceous time which can be observed as relatively thin presence of Upper Goru on the top of the fault blocks (horst blocks) whereas thicker in the lows (Graben). The fossils fauna found in the Goru Formation in Badin Block suggest that deposition took place in varied condition, i.e., from continental, transitional, deltaic, shallow marine to deeper marin conditions. The reported thickness of combined Goru Formation (Upper and Lower Goru) is 2000ft to 7500ft. The oldest sediments have been reported in the well Marvi -1 (Total depth 17000 ft, drilled by Union Texas in 1997).

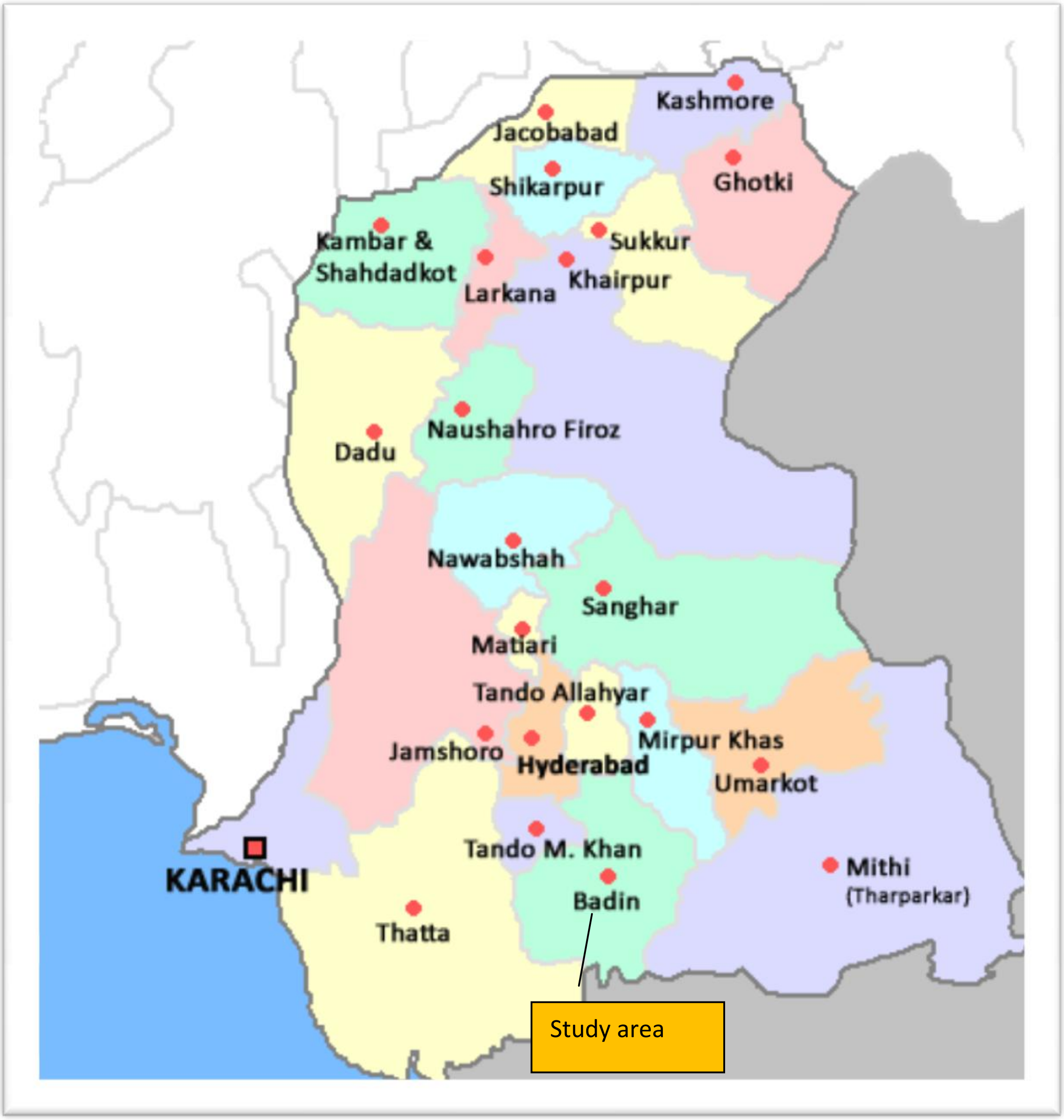


Figure 1.1 Location of Badin Area

1.2 Exploration History

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. Gravity surveys were carried out by SVOC in 1954-56, Sun Oil Company (SOC) in 1957-59, Pakistan Petroleum Ltd (PPL) in 1949 and 1956-60, Pak Hunt Petroleum

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 Khaskeli within the Badin Block. With this discovery, the Lower Indus Basin became the second largest oil producing sub basin of Pakistan, after Potwar (Afzal, 1996).

1.3. Prospectivity

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

1.4. Data description

To carry out this thesis, seismic reflection data, which comprises of 2D seismic reflection lines, was given by Directorate General of Petroleum Concessions Government of Pakistan (DGPC). The seismic reflection data was acquired and processed by OGDCL. The Data for subsurface interpretation of the study region is acquired from LMKR Company.

Data provided by DGPC includes seismic lines and well Doti-1 data. The data provided is as follows:

Sr .no	Line no	Line orientation
1	PK94-1804	NE-SW(DIP)
2	PK94-1807	NW-SE(STRIKE)
3	PK92-1800	NE-SW(DIP)

Table 1.1 Seismic Lines and line orientation.

1.5 BASE MAP

For a geophysicist a base map is that which shows the orientation of seismic lines and specify points at which seismic data were carried out. It is typically includes location of wells and seismic survey points.

The base map of the zone is created by loading data in Universal Transverse Mercator (UTM, Zone 43) geodetic reference framework in kingdom 8.8.

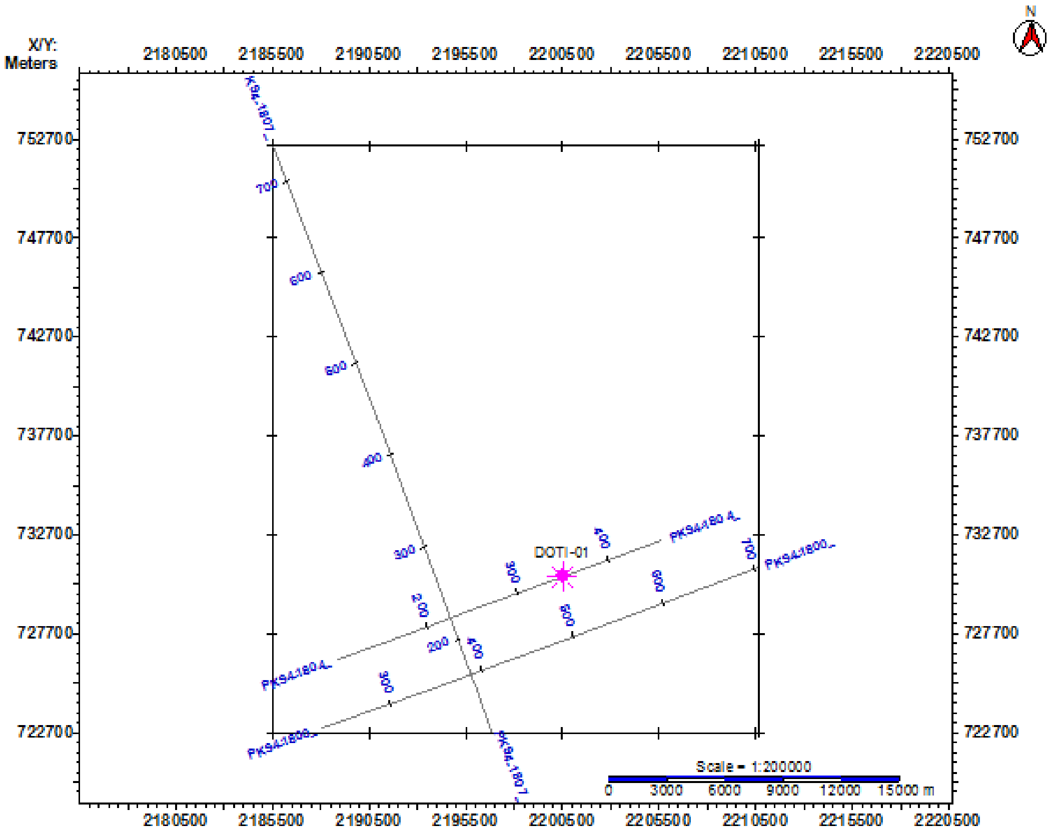


Figure 1.2 Seismic Lines and Location of Wells on Base map of Badin Area

1.6. Data Used

Seismic reflection data which consist of following formats;

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

1.7. Objectives

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

- 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.
- Structural interpretation using 2D seismic reflection data to understand subsurface geologic framework and its relation with surface geology.

- Generate time and depth contour maps on different levels of strata to analyze structural and stratigraphic trend of the area.
- To find the petro-physical properties of reservoir zone by using well data and identification of reservoir lithology.
- Seismic Attributes Analysis for the confirmation of the horizon marking.

CHAPTER 2:

GEOLOGY AND TECTONICS OF THE AREA:

2.1 Introduction

Geological and structural knowledge of the area is a key for interpreter to perform precise interpretation of seismic data. The main reason behind that, in many cases similar signature is obtained from different lithologies and vice versa. In order to deal with such complexities an interpreter must have background knowledge of geology about the area and its stratification, unconformities and major structures of area under study (Kamal & Jan, 1997).This chapter deals with a brief description of tectonics settings, structural geology and Stratigraphy of area under study.

2.2 Regional Settings and Tectonics of Pakistan

Pakistan comprises of three main geological subdivisions referred to as Caucasian, teething and Gondwanaland domains (Kamal, et al., 1997). Late Paleozoic is considered to be their origin. All the continents had drifted apart to form a super continent known as Pangaea. By late Triassic, Laurasia drifted to the north and Gondwanaland to the south separated by Tethys seaway resulting in the split up of Pangaea. Pakistan is located at the junction of Gondwanian and Tethyan domain. . The southern part has a boundary with Gondwanian land and is continued by Indo-pak crustal plate. The northern and western regions of Pakistan fall in Tethyans domain and present a complicated geology and complex crustal structure (Kamal & Jan, 1997).

Pakistan acquired its structural and Stratigraphy features from tectonic events associated with plate movements, which occurred from late Paleozoic time to present. From Permian through middle Jurassic time, the area referred to today as Indus Basin was situated in the southern hemisphere. (Wandrey, 2004) Tectonics of Pakistan is characterized by two active convergent boundaries;

- In the northeast there is an active continent-island arc-continental collision boundary. The west end of the Himalayan origin;

- In the southwest, there is an active boundary of oceanic lithosphere sub ducting arc trench gap sediments and continental sediments, the oceanic part of the Arabian plate passing under the Makran arc-trench gap and Afghan micro plate.

These two convergent boundaries are connected by a very large displacement north-south left lateral strike slip faults of Chaman-Transform Zone.

2.3 Tectonic Basins of Pakistan

Basin is an area characterized by regional subsidence and in which sediments are preserved for longer period of time. Pakistan comprises of three basins.

- Indus basin
- Baluchistan basin
- Pasheen basin

2.4 Indus Basin

The Indus Basin belongs to the class of basins. It is the largest sedimentary basin of Pakistan. The basin is oriented in NE-SW direction. Basement is exposed as outcrop at two places, one in NE as Sargodha High and second in SE as Nagar Parker High. It comprises of normal to moderate and some steeply dipping structures.

Indus Basin is classified as follows;

- Upper Indus Basin
- Middle Indus Basin
- Lower Indus Basin

2.5. Regional Geology:

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

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

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

2.6. Boundaries of Lower Indus Basin:

- Sargodha high
- Kirthar and Sulaiman Ranges
- Indian Shield
- Offshore

2.7. Division of lower Indus basin:

Lower Indus basin is divided into two classes:

- Central Indus Basin
- Southern Indus Basin

Southern Indus basin is my study area so my main concern on southern Indus basin, its geology, tectonics and other aspects.

2.7.1 Southern Indus Basin

The southern Indus basin (550 × 220 km) extends approximately between 24^o to 28^o N Longitude and 66^o to 71^o E Latitude (Qadri and Shoaib, 1986). It is characterized by several structural Highs.

- Thar Platforms
- Karachi Trough
- Kirthar Foredeep

- Kirthar Fold Belt
- Offshore Indus

2.7.2 Boundaries of Southern Indus basin

- Jaccobbad Khairpur High
- Kirthar Ranges
- Indian Sheild
- Offshore

2.8. Tectonic Zones

Two broad geological divisions of this region the Gondwanian and the Tethyan domains are discussed. In this scenario Pakistan is located at the junction of these two diverse domains. The southeastern part of the Pakistan belongs to Gondwana domain and is sustained by Indo-Pakistan crustal plate. The northern and western regions of Pakistan fall in teething domain and present a complicated geology and complex crustal structure.

On the basis of plate tectonic features, geological structure, orogenic history (age and nature of deformation, magmatism and metamorphism) and lithofacies, Pakistan may be divided into the following broad tectonic zones are:

- Indus Platform and fore deep
- East Baluchistan fold-thrust belt
- Northwest Himalayan fold-thrust belt
- Kohistan-Ladakh magmatic arc
- Karakoram block
- Kakar Khoarasan flysch basin and Makran accretionary zone
- Chagai magmatic arc
- Pakistan offshore

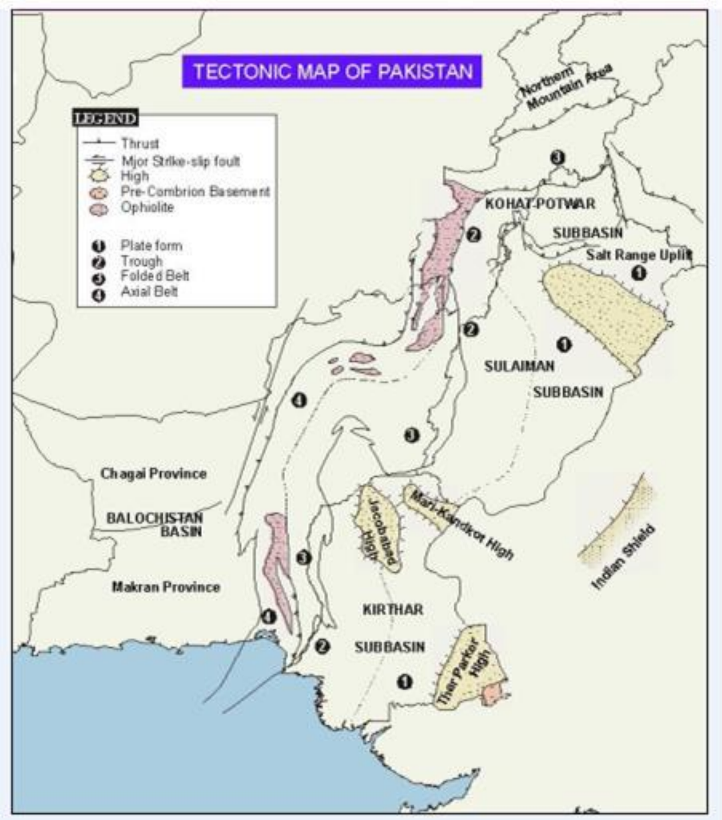


Figure 2.1: Tectonic map of Pakistan that shows the different Tectonic zone (Zaigham et al, 2000).

2.9. Generalized Stratigraphy

Stratigraphy of the study area comprises the rocks ranging from Wulgai Formation to Alluvium (Raza et al., 1990), as shown in figure 2.2. Distribution, age and lithology of the area are included in the Stratigraphy of Lower Indus Basin (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 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 Fig 2.2. Depositional environment of the Upper sand is shallow marine to deltaic and consider as good reservoir in the Lower Indus Basin (Alam et al, 2002).

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

The Basal Sand of Lower Goru Formation is target formation in the area. Massive Sand is another interesting producing reservoir from its various sand sheets of multiple thicknesses. The possibility of reservoir in Lower Goru overlain on Basal Sand could not be ruled out; however they have not yet proved to be such up till now (Kadri I.B, 1995). In general, the transgressive shales of the Cretaceous (Sember formation) and Tertiary (Bara-lakhlra, Laki-Gazij and Kirthar formation) acts as a seal in Southern Indus Basin (Zaigham and Mallick, 2000). Intra-formation shale of Lower Goru formation provides effective vertical and lateral seal. The shale units also provides cross fault seal. Fault may also act a seal. Upper Goru shale, Lower Goru and Talhar shale are the primary seal for Lower Goru reservoir sands (Kadri etal, 1995).

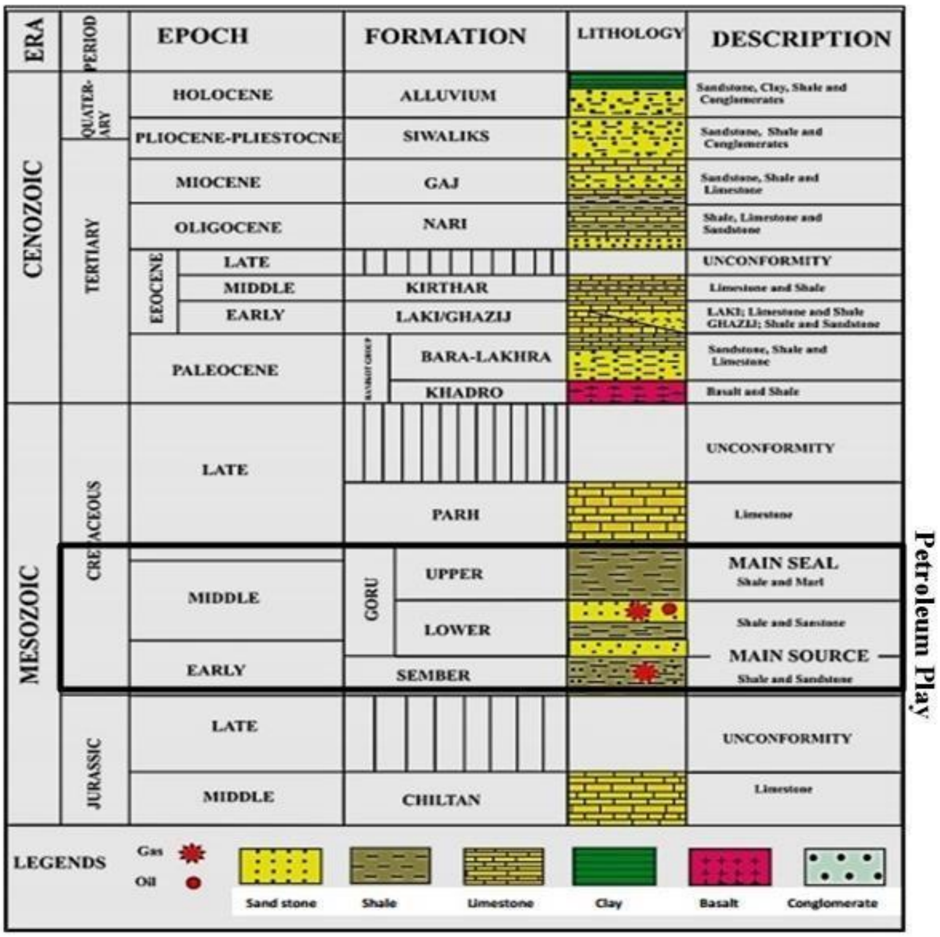


Figure 2.2 Generalized Stratigraphic Column of Badin area (Zaigham at al., 2000)

2.10 Formations Encountered in the Well:

Formations encountered in DOTI-01 is

- Ranikot
- Khadro
- Parh
- Upper Goru
- Lower Goru

2.10.1 Ranikot Formation

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

2.10.2 Khadro Formation:

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

2.10.3 Parh Limestone:

The age of Parh Formation is Early Cretaceous and lithology is hard, light grey, white, cream, olive green, thin-to-medium-bedded, lithographic and argillaceous limestone, with subordinate calcareous shale and marl intercalations. The formation is widely distributed in parts of the Axial Belt and Lower Indus Basin (Sulaiman and Kirther Province).. The environment of deposition is shallow marine. The lower contact of Ranikot Formation is with Goru Formation and upper contact is with Mughal Kot Formation (Kadri, I.B, 1995). The formation is richly fossiliferous. Forms (Globotruncana, Gumbelina) are dominant. No macrofossils are known (S. M. Ibrahim Shah, 1977).

2.10.4 Goru formation:

The Goru formation consists of interbedded sandstone, shale and siltstone. The limestone is grained, thin bedded, light to medium grey in color.

On the basis of lithology Goru Formation is divided in two parts:

- Lower Goru
- Upper Goru

2.10.4.1 Lower Goru

The lower Goru is main reservoir rock within the area. The lower Goru horizon as a general 5 divisions based on predominant lithologies.

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

2.10.4.2 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. 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. 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).

2.11. 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. A considerable amount of gas should have trapped in the non-permeable shale deposits. In the Badin area the top of Goru shale is encountered around 500-600 meter depth, so it is economical to drill. About a 1000m well could exploit shale gas in certain area. The gas rises and accumulates in shallower traps but it also gets stuck along its migration paths and may leads to shallower areas which are dominantly shale (Lower Goru and Upper Goru). Oil of Badin is of very high quality with API gravity of the range from 32-55. Oil in the southern part of the Badin area found to be very heavy and waxy. The depth of oil reservoir is from 2000ft to 13500ft. Khaskeli is the first and the largest oil field in the area so far. Golarchi, Bhatti, Turk, Tando Alam, Bobby and Pasakhi are also the largest oil and gas fields of this area whereas western part of the Lower Indus Basin (Kirthar hills and mountains) and adjacent area known for its gas potential. In Lower Indus, so far more than 12 Tcf (trillion cubic feet) gas reserves and more than 100 million bbls oil have been discovered in Lower Indus Basin whereas more than 90% oil production is from Badin area. OGDCL is the oil operators of this region (Raza et al., 1989 and 1990).

2.12. Petroleum System:

2.12.1. Source Rocks (Sember shale):

Sembar Shale and Lower Goru Formations are considered the main source in Lower Indus Basin and are also believed to be main source in the study area (Raza et al., 1990).

Sembar is the prime source of hydrocarbons in study area due to significant content of organic matter, oil/gas prone kerogen (type II and III) and adequate thermal maturity. Sembar is composed of silty shales and siltstones and its environment of deposition of these shales was deep marine, associated with turbidities. Total organic carbon content (TOC) is generally higher than 1% (Qadri, 1986).

2.12.2. Reservoir Rocks (Basal and Upper Sand):

Early Cretaceous Age Lower Goru Formation is the main productive reservoir. The principle reservoir in the Badin blocks formed in the Lower Goru Formation of early Cretaceous age is deltaic and shallow marine sandstone with layers of shale. Based on these layers, the Lower Goru Formation is divided into Upper, Middle and Basal sands. Sandstone porosities are as high as 30% but more commonly ranges from 12-16%. Permeability of these reservoir ranges from 1 to > 2000 millidarcy (md).

Reservoir quality generally diminishes in a westward direction but reservoir thickness increases (Alam, 2002).

2.12.3. Seal Rocks (Upper Goru marl):

Lower shale and Sembar shale have the most uniform and best seal quality. Badin shale has the lowest seal quality as it is made up of marl-argillaceous, chalky limestone. The Upper Goru Formation has the wide range of seal capacity as it contains a variety of rock types (Alam, 2002).

Threshold pressure analysis, carried out on samples from Turk-04, by Davies, indicated that upper Goru can hold and oil column of over 15,000 feet. In regional perspective upper Goru has a good sealing quality, particularly the Shaly lower portion. The carbonate rich upper portion of this formation may form a less effective seal. Seal potential of shale bodies within the upper basal sands, according to time tracks, keeping with their back barrier/lagoonal setting, are considered, mostly effective in the south of the block (Alam, 2002)

CHAPTER 3:

Seismic Interpretation

3.1 Introduction

The acquisition and processing of reflection seismic data usually result in a seismic image of acoustic impedance interfaces. If these interfaces are assumed to follow lithological boundaries, then the seismic image is actually an image of subsurface geological units and the structures they form. The goal of seismic interpretation is to recognize possible geological patterns in the seismic image. The process of determine subsurface structure from seismic data to locate prospects for exploratory wells. Usually Stratigraphy and available well log data are encounter for the interpretation of an area. Basically there is two type of seismic data interpretation (Dobrin 1960).

Sheriff (1999) describes that it is rare that the correctness or incorrectness of interpretation can be firmed because the actual geology is rarely known in well manner. A good interpretation is consistency with all of the available data. In oil and gas exploration, our focus is on finding an interpretation that is more favorable for hydrocarbon accumulation. As with many scientific investigations, interpretations are almost always non-unique (Sheriff, 1999).

According to Coffeen (1986), most common activity in interpretation is picking a horizon and marking faults. A horizon is a reflection that appears on the seismic section for a considerable geographical extent. The reflections are picked i.e. marked at shot points, along the vertical section over the area. The picks are timed by reading the reflection times. These times can then be plotted on a map and contoured, to show locally high places or other features that may be prospects for drilling.

3.2. Types of Interpretation

There are two types of seismic interpretation

- Structural Interpretation
- Stratigraphical Interpretation

3.3. Structural Interpretation

This type of interpretation is very suitable in case of Pakistan, as most of the hydrocarbon is being extracted from the structural traps. It is study of reflector geometry on the basis of reflection time. The main application of the structural analysis of seismic section is in the search for structural traps containing hydrocarbon. Most structural interpretation use two way reflection time rather depth and time structural maps are constructed to display the geometry of selected reflection events. Discontinue reflections clearly indicate fault sand undulating reflection several folded beds (Telford et al., 1990).

3.4. Stratigraphical Interpretation

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 the 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. Unconformity is example of stratigraphic traps (Telford et al., 1990).

3.5. Overview:

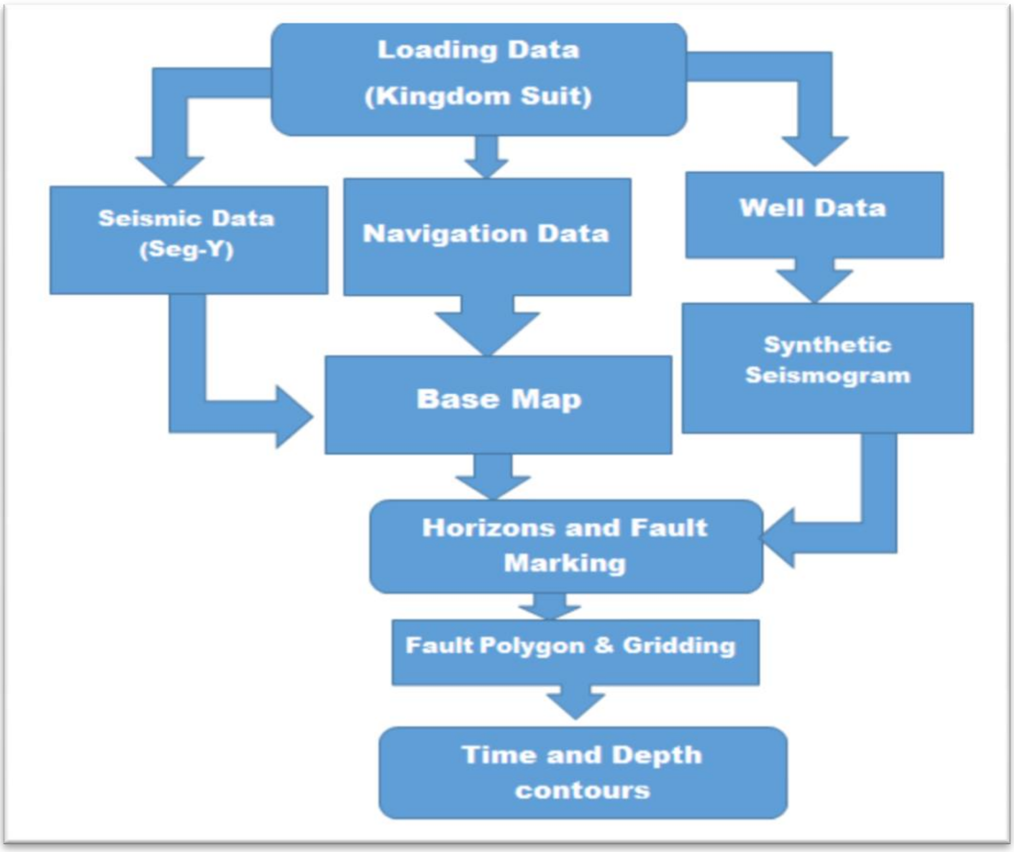
Badin area is distal to deformation locations due to which the degree of deformation is relatively low but progressively increases when moving from East to West. Badin area is considered favorable for oil and gas whereas Western part of Lower Indus Basin and adjacent area is known for its gas potential.

Badin area lies in extensional regime, the structural traps are simple and shallow so seismic can display fair enough results on shallow depths. Good quality shallower data can help analyzing any structural feature in this region.

3.6. Methodology of Interpretation

The following steps were followed for interpretation purpose

- Loading of SEG-Y and navigation data
- Preparation of base map
- Generation of synthetic seismogram
- Fault identification and marking
- Horizon marking
- Construction of fault polygon
- Gridding and contouring



Basic workflow of seismic interpretation

3.7. Generation of Synthetic Seismogram:

Synthetic seismograms are artificial seismic traces use to establish correlations between local Stratigraphy and seismic reflections. To produce a synthetic seismogram a sonic log is needed. Ideally, a density log should also be used, but these are not always available hence we can also used the constant density for that area. With the help of Doti-01 the synthetic seismogram was constructed shown in the (Figure 3-1) in order to mark the horizons. Synthetic seismograms provide a crucial link between lithological variations within a drill hole and reflectors on seismic profiles crossing the site. In essence, they provide a groundtruth for the interpretation of seismic data. Synthetic seismograms are useful tools for linking drill hole geology to seismic sections, because they can provide a direct link between observed lithologies and seismic reflection patterns (Handwerger et al., 2004). Reflection profiles are sensitive to changes in sediment impedance, the product of compression wave velocity and density. Changes in these two physical parameters do not always correspond to observed changes in lithologies. By creating a synthetic seismogram based on Sediment Petro-physics, it is possible to identify the origin of seismic reflectors and trace them laterally along the seismic line (Handwerger et al., 2004).

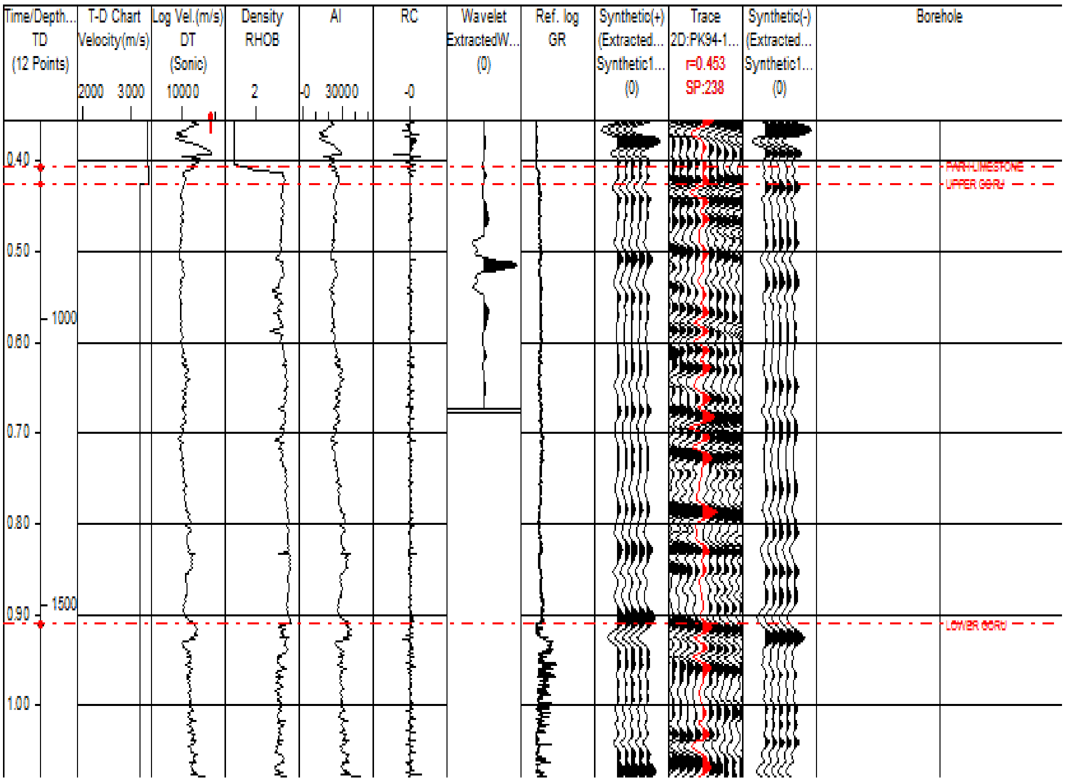


Figure 3.1 Synthetic Seismogram of Doti-01

3.8. Marking of Seismic Horizons:

In seismic section the depth was given in milliseconds, as it is the travel time of the wavelet. To pick up horizon, well tops are required. Well tops give the information about the depth of each formation in subsurface. So to mark horizon time depth chart was prepared. While marking the horizons, first the control line was chosen and the reflectors were marked on it. The control line was PK 94-1804. This control line was further used as a reference for marking horizons on other lines.

I mark both, the horizons and faults on the seismic section. Three horizons are picked and named on the basis of DOTI-01 well tops. I choose parh limestone, lower goru formation and upper goru formation.

3.9 Marking up of Faults

Faults are typically identified as breakage in the continuity of a reflector, after marking all the horizons, the faults were marked on the seismic lines. Following steps should be followed to interpret the faults on the seismic data.

1. Geology of the area
2. Marking faults on seismic sections
3. Correlation of the faults

3.10 Interpreted Seismic Sections

I interpreted seismic sections of the lines PK94-1807, PK 94-1800 and well line PK 94-1804. Three seismic horizons namely Parh Limestone, Upper Goru and Lower Goru were marked. Along these seismic horizons, faults were also picked. Horizon making 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. On dip line I marked both the faults and horizons but on strike line I just marked horizons because structural features cannot be formed on strike line.

Two dips and strike line are is as follows;

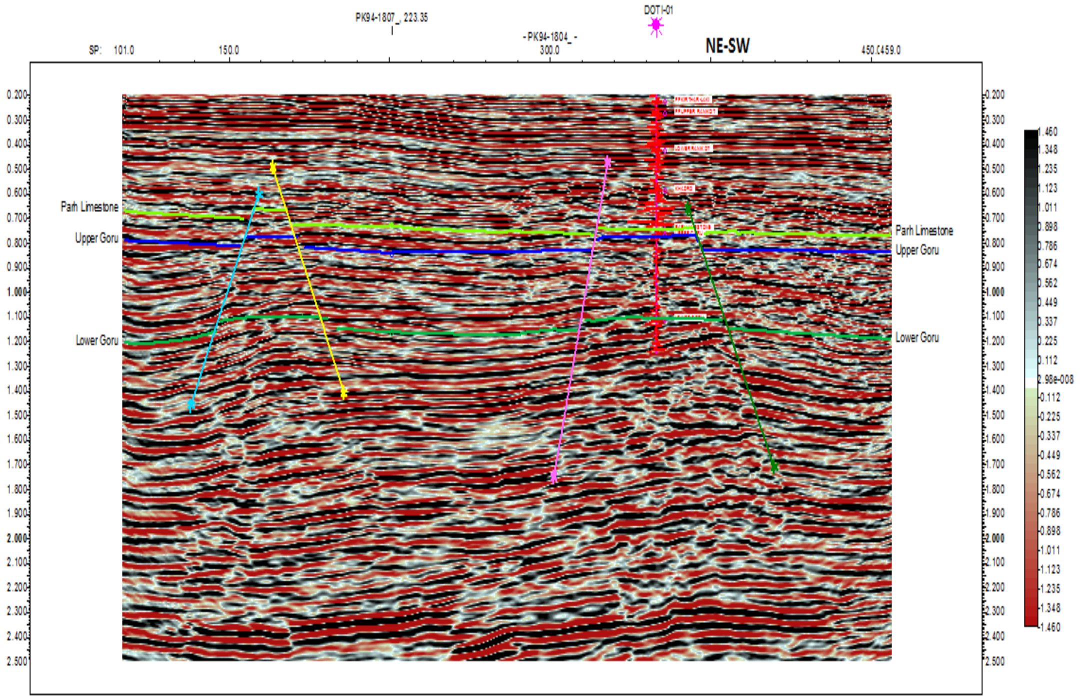


Figure 3.2 Interpretation of line PK 94-1804(Control line)

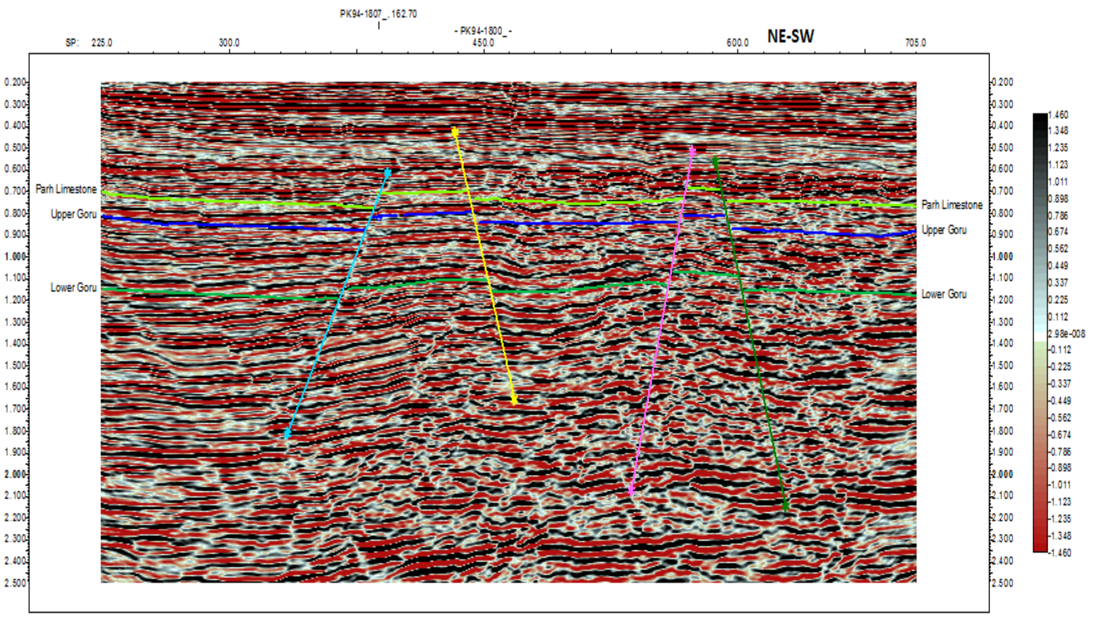


Figure 3.3 Interpretation of line PK 94-1800 (Dip line)

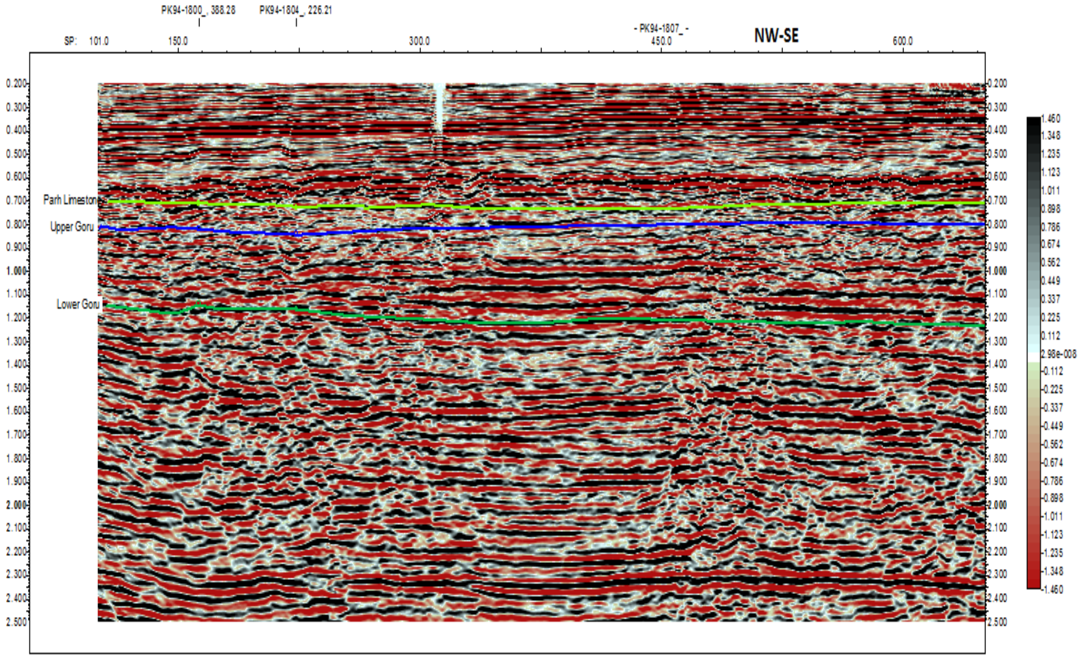


Figure 3.4 Interpretation of line PK 94-1807(Strike line)

3.11 Fault Polygons Generation

Fault polygons are created in the Polygon tab. A single fault polygon item contains all of the polygons associated with the faults that penetrate a single horizon. It is also often useful, when picking fault polygons, to see the intersections of faults with the displayed horizon. Fault exclusion polygons are a part of nearly every seismic interpretation workflow. They are commonly used in map presentations of seismic horizon interpretations and can even be used in the fault modeling process. The output is a surface that is gridded through the faults and fault exclusion polygons.

Before generation of 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 (represented by a “+” or a “x” sign by Kingdom software) can be manually joined to make a polygon.

As we know that generation of fault polygons is very important as far as time and depth contouring of a particular horizon is concerned. Any mapping software needs all faults to be converted in to polygons before contouring. Because if a fault is not converted into a polygon, the software doesn’t recognize it as a barrier or discontinuities, thus making any possible closures against faults represent a false picture of the subsurface.

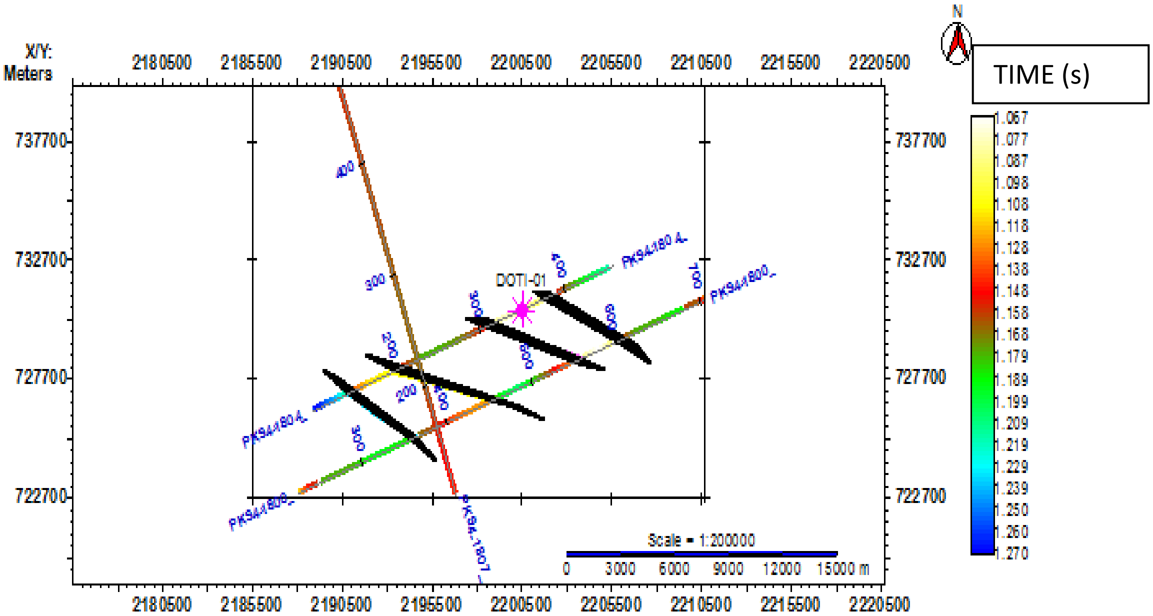


Fig 3.5 Fault polygon

3.12. Contour Maps

Contouring is the main tool used in the seismic interpretation. After contouring it becomes obvious that what sort of structure is forming a particular horizon. In constructing a subsurface map from seismic data, a reference datum must first be selected. The datum may be sea level or any other depth above or below sea level. Frequently, another datum above sea level is selected in order to image a shallow marker on the seismic cross-section, which may have a great impact on the interpretation of the zone of interest (Gadallah & Fisher 2009).

Following are the time contour maps of Parh Limestone, Upper Goru and Lower Goru formation. In these time contour maps high interval shows the deepest area while low time value represents the shallowest area.

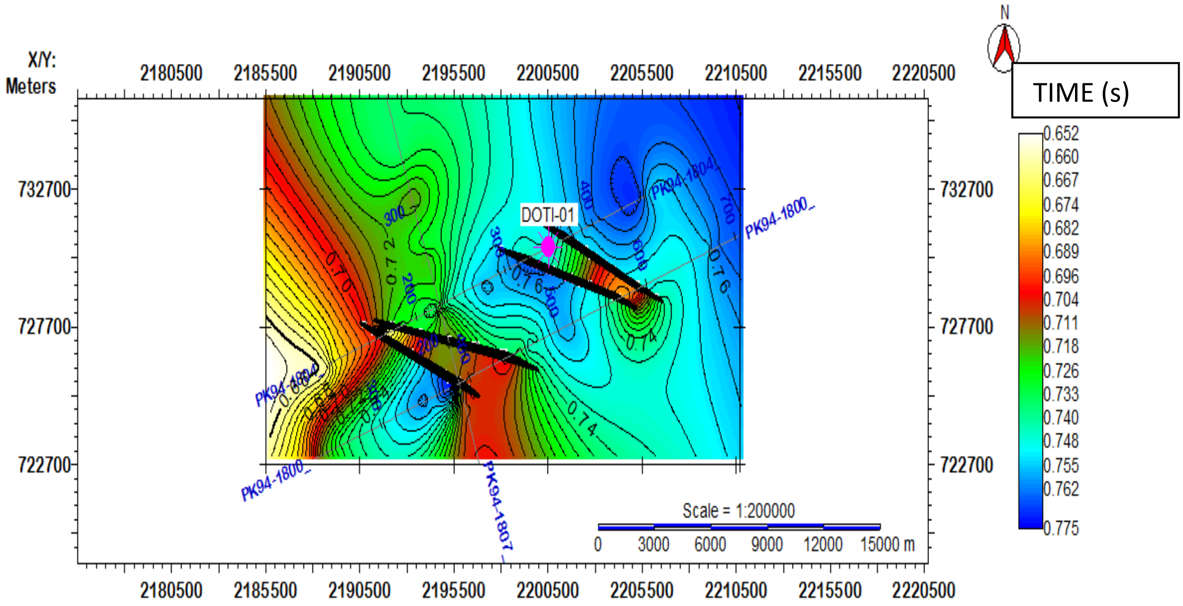


Figure 3.6 Time Contour of Parh Limestone

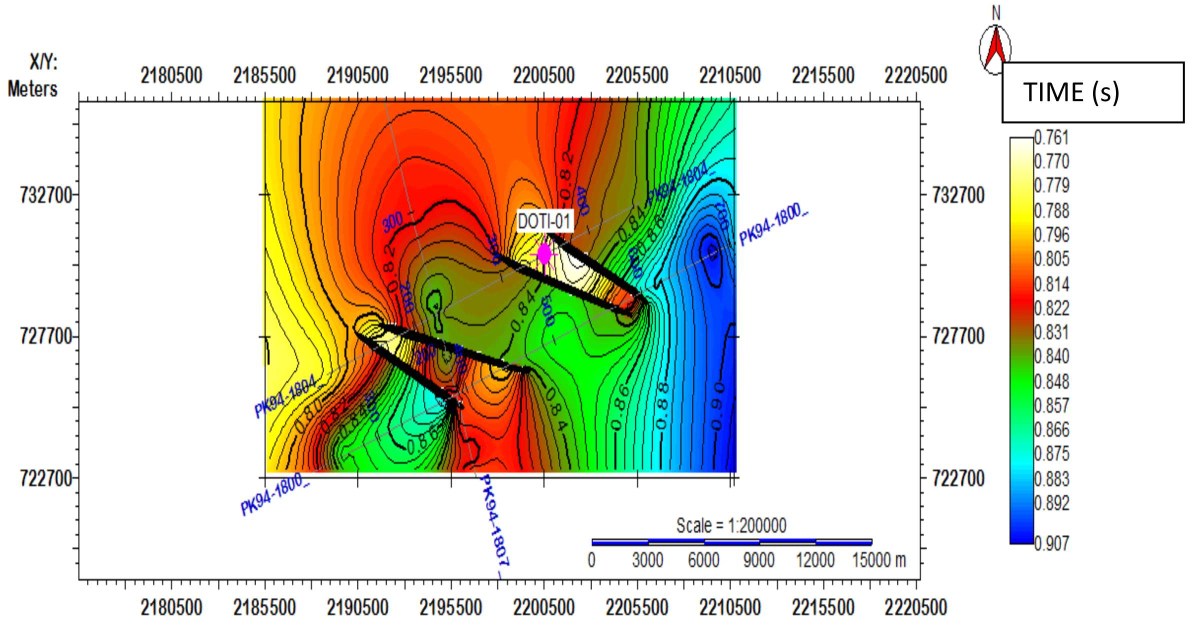


Figure 3.7 Time Contour of Upper Goru

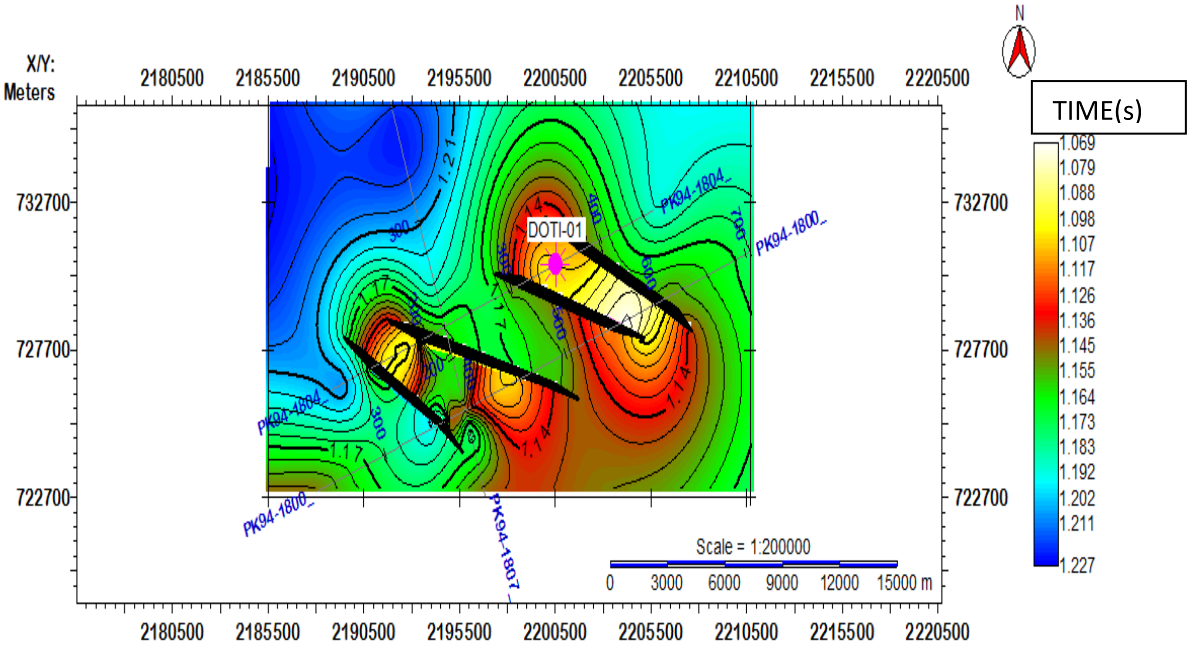


Figure 3.8 Time Contour of Lower Goru

3.12.1 Depth Contour Map of Marked Horizons:

The depth contour maps show the horizon depth variation .Following is the figures of depth contour maps of Parh Limestone, Upper Goru and Lower Goru formations. These depth maps show that horizon is forming horst and graben structures. As from scale the central portion is deepest than the surrounding area between fault polygons. It is noticed that pattern of depth and time is same because of no variation in time and depth.

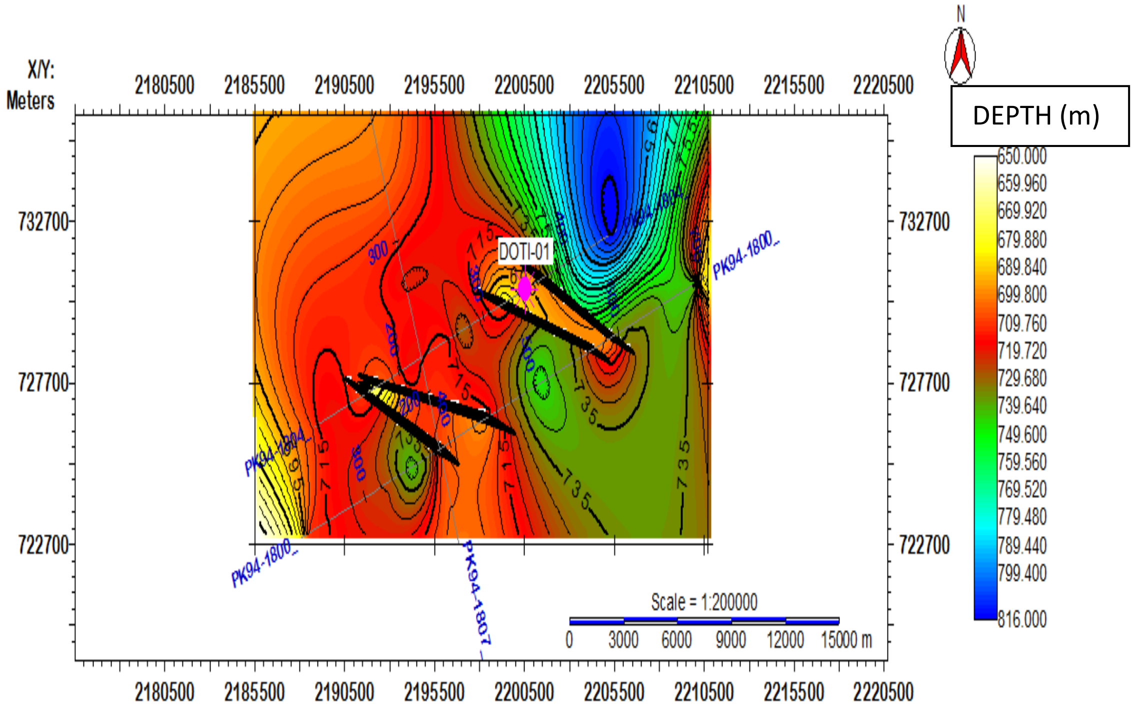


Figure 3.9 Depth Contour of Parh Limestone

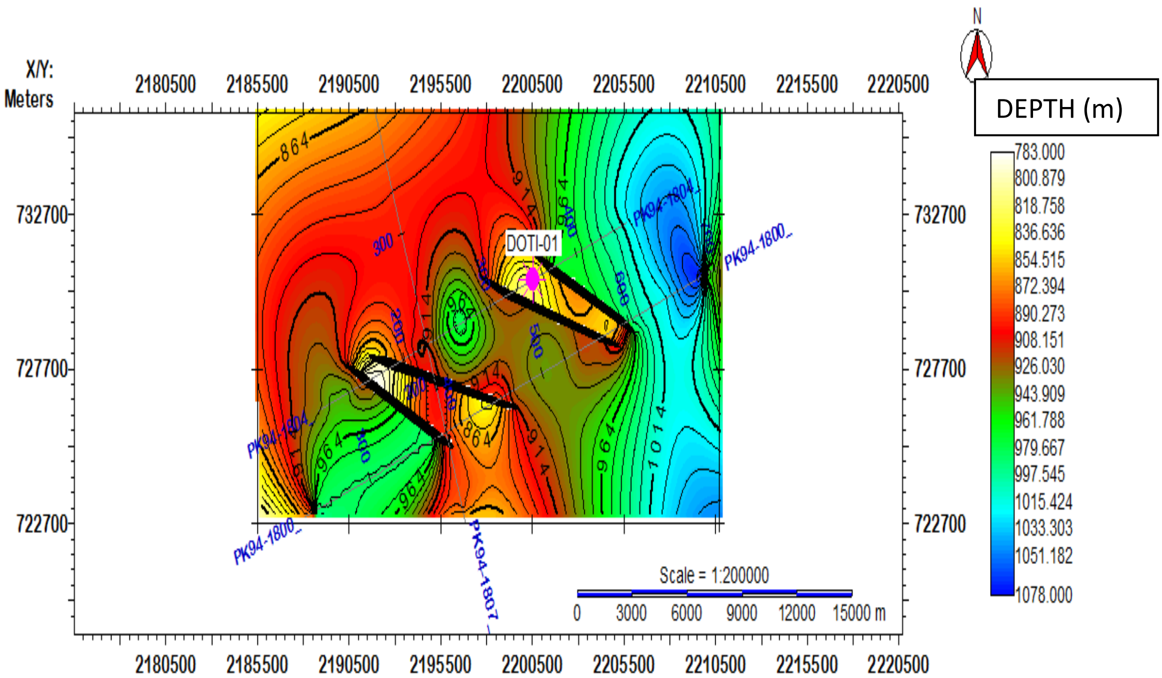


Figure 3.10 Depth Contour of Upper Goru

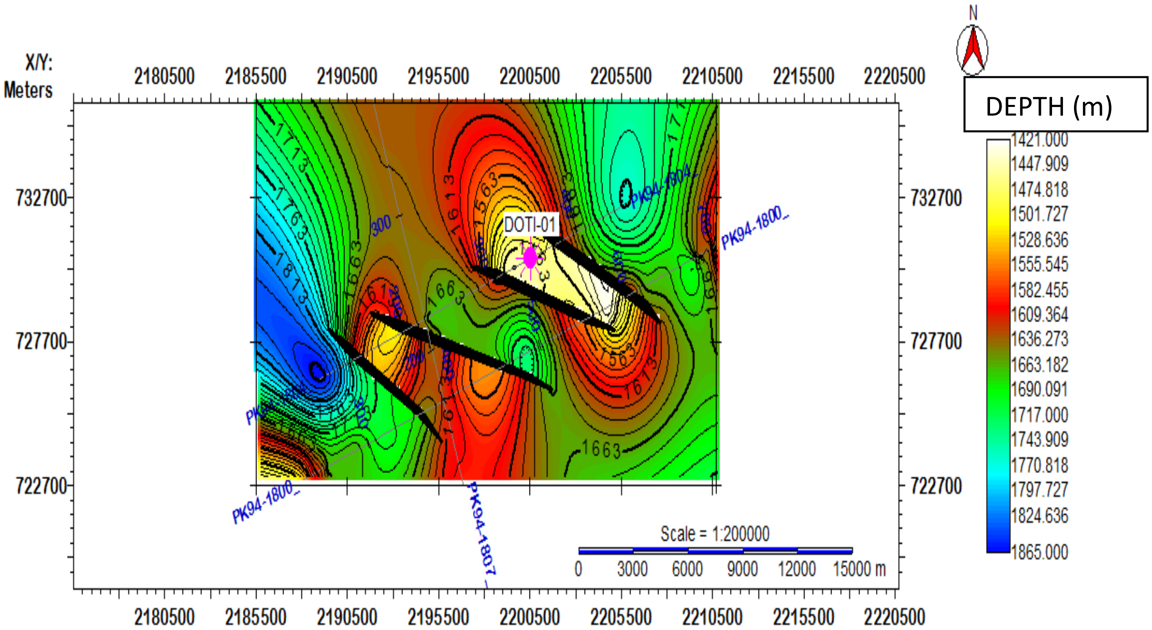


Figure 3.11 Depth Contour of Lower Goru

Chapter 4:

Petro physics

Petrophysics is the study of the physical and chemical properties that describes the occurrence and behavior of the rocks, soils and fluids. To accurately characterize an oil or gas reservoirs, measurements such as resistivity and density are made, from which effective porosity, saturations and permeability can be quantified.

4.1 Petro physical Analysis

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

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

4.2 Log Curves

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

4.3 working

The following processing steps were used while interpreting the well logs:

- Marking zones of interest
- Calculating volume of shale (GR log)
- Calculating porosity

- Estimating resistivity of water
- Estimating saturation of water
- Calculating saturation of hydrocarbons

4.4 Types of Logs

- Gamma Ray
- Spontaneous Potential
- Caliper
- Resistivity
- Sonic
- Density
- Neutron

For petrophysical analysis the following parameters are calculated for reservoir rock.

- Volume of shale (by Gamma ray log)
- Porosity of reservoir (by Sonic, Density)
- Water saturation (by LLD, LLS and SP logs)
- Hydrocarbon Saturation

4.4.1 Spontaneous Potential log

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

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

4.4.2 Caliper log

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

4.4.3 Resistivity log

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

4.4.4 Sonic log:

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

4.4.5 Density log:

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

4.4.6 Neutron log

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

4.5 Petro physical Properties

Following are the petrophysical properties calculated for petrophysical analysis by using Ms Excel.

4.5.1. Volume of Shale

Shale is more radioactive than carbonate or sand, gamma ray logs can be utilized to compute volume of shale in porous reservoir. The volume of shale would then be able to be connected for investigation of shaly sands. Computation of the gamma ray log is the initial step to decide the shale volume from a gamma ray log.

The following formula is used from Schlumberger, 1974.

$$IGR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

IGR= Gamma Ray Index

GRlog = Gamma Ray reading of the formation

GRmax=Maximum gamma Ray (shale)

GRmin = Minimum gamma Ray (clean sand)

The Gamma ray log shows maximum value when shale is encountered and shows a minimum value when clean lithology like sand is encountered. These values are calculated from given log response and then volume of shale is estimated by using the equation from Asquith and Gibson, 2004.

4.5.2. Calculation of Porosity from logs

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

- Sonic log
- Neutron log
- Density log

4.5.3. Determination of Water Saturation (Sw)

Water saturation is the fraction of formation water in the undisturbed zone. The saturation is known as the total water saturation if the pore space is the total porosity, but is known as effective water saturation if the pore space is the effective porosity. To calculate saturation of water in the Formation, a mathematical equation was developed by Archie shown below. All the parameters of Archie equation can be calculated from resistivity and spontaneous potential logs.

$$S_w = \left(\frac{aR_w}{R_t\phi^m}\right)^{\frac{1}{n}}$$

Where,

Sw= water saturation

Rw =water resistivity (formation)

Φ = effective porosity

m cementation factor) =2 , a(constant)=1

Rt= log response (LLD)

Rw has been calculated with help of the following formula:

$R_w = \Phi^2 \times R_t$

Where,

Φ = porosity in clean zone

Rt =Observed LLD curve in clean zone

4.5.4. Saturation of Hydrocarbons

It is denoted as Shc. Saturation of hydrocarbon is calculated by given form below;

Shc = 1-S**w**

Sw = Saturation of water

Shc= Saturation of hydrocarbon

Consolidated:

Vshale=0.33[2(2*IGR)-1]

Unconsolidated:

Vshale=0.883[2(3.7*IGR)-1]

4.6 Interest Zones

The zones of interest are defined on the basis of source, reservoir and seal rock formations given in well tops of Doti-01 well. The zone of interest which is marked as follows: Lower Goru

Zones Starting Depth (m)	Ending Depth (m)	Thickness (m)
1530	1800	270

Following conditions should be fulfilled in order to mark zone of interest for hydrocarbons.

1. There should be low value of Gamma Ray log, as low value represents clean lithology.
2. There should be positive cross over for density and neutron.
3. There should be significant difference between the resistivity values of LLS and LLD (Rider, 2002).

On the basis of the conditions mentioned above, I marked two zone of interest for sand reservoir in Doti-01 well in Lower Goru formation.

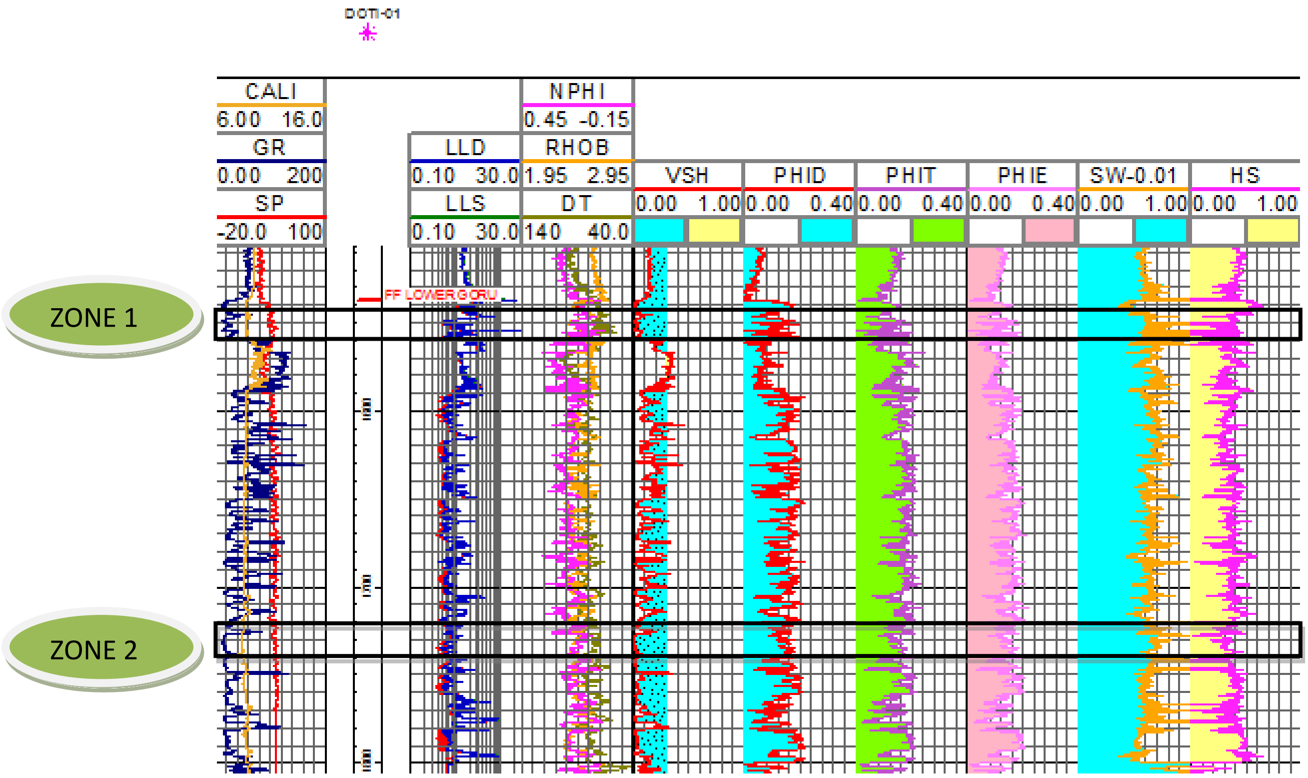


Figure 4.1 sand intervals in Lower Goru formation

4.7. Interpretation of marked zone:

In the marked zone, values of GR log are low, so it represents the clean lithology. Shaly content is less here so it indicates the presence of sand. There is a positive cross over between neutron and density log is not more prominent.

4.8. Result of petrophysical analysis:

Zones of interest	Starting depth(m)	Ending depth(m)	Thickness (m)	VSH	PHID	PHIT	SW	HS
Lower Goru	1537	1552	15	8%	13.1%	12.2%	59.9%	40.1%
Lower Goru	1727	1747	20	11%	14%	14.2%	70.4%	29.6%

According to its results, water saturation is more than hydrocarbons so there is not any promising zone.

Chapter 5:

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).

5.1 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

5.2 Types of Attributes

The default attribute of Seismic data is Amplitude. Attributes can be computed from pre-stack or from post-stack data, before or after time migration. The procedure is the same in all of these cases. Attributes can be classified into many types but there are two broad classifications of the attributes.

5.2.1 Geometrical Attributes

Geometrical attributes are used to enhance the visibility of the geometrical characteristics of seismic data; they include dip, azimuth, and continuity.

5.2.2 Physical Attributes

Physical attributes have to do with the physical parameters of the subsurface and so relate to lithology. These include amplitude, phase, and frequency.

5.3 Envelope of Trace

The envelope is the envelope of the seismic signal. It has a low frequency appearance and only positive amplitudes. It often highlights main seismic features. The envelope represents the instantaneous energy of the signal and is proportional in its magnitude to the reflection coefficient. The envelope is useful in highlighting discontinuities, changes in lithology, faults and changes in deposition, tuning effect, and sequence boundaries. It also is proportional to reflectivity and therefore useful for analyzing AVO anomalies. This attribute is good for looking at packages of amplitudes. This attribute represent mainly the acoustic impedance contrast, hence reflectivity. It always remains positive whether the reflection coefficient is positive or negative and it highlights the petroleum play as a bright spot. This attribute is mainly useful in identifying:

- Bright spot gas accumulation
- Sequence boundaries, major changes or depositional environments
- Unconformities
- Major changes of lithology
- Local changes indicating faulting

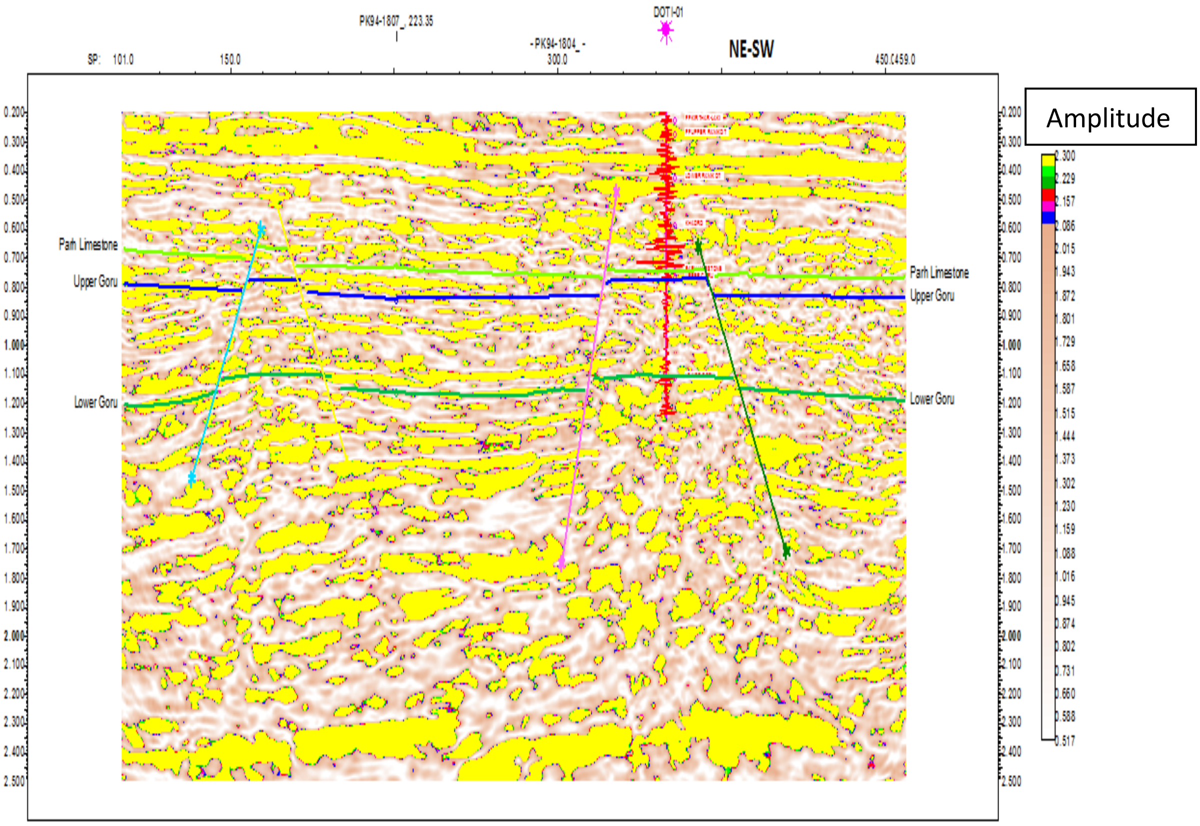


Fig 5.1 Trace Envelop Attribute Map of Seismic Line PK94-1804

5.4 Phase Attribute

The argument of the complex function is defined as the phase. The phase component is independent of seismic amplitude therefore can be used as a good indicator of reflector continuity. This attribute may make it easier to pick weak events due to its independence from reflection magnitude. It can be used to assist picking of horizons in low amplitude/high noise areas. The phase attribute is basically a physical attribute that can be effectively used as a discriminator for geometrical shape classifications:

- Best indicator of lateral continuity
- Has no amplitude information, hence all events are represented,
- Shows discontinuity, but may not be the best. It is better for showing continuity.
- Sequence boundaries.

This attribute is marking clear cut continuity of the reflectors as shown in the below figure.

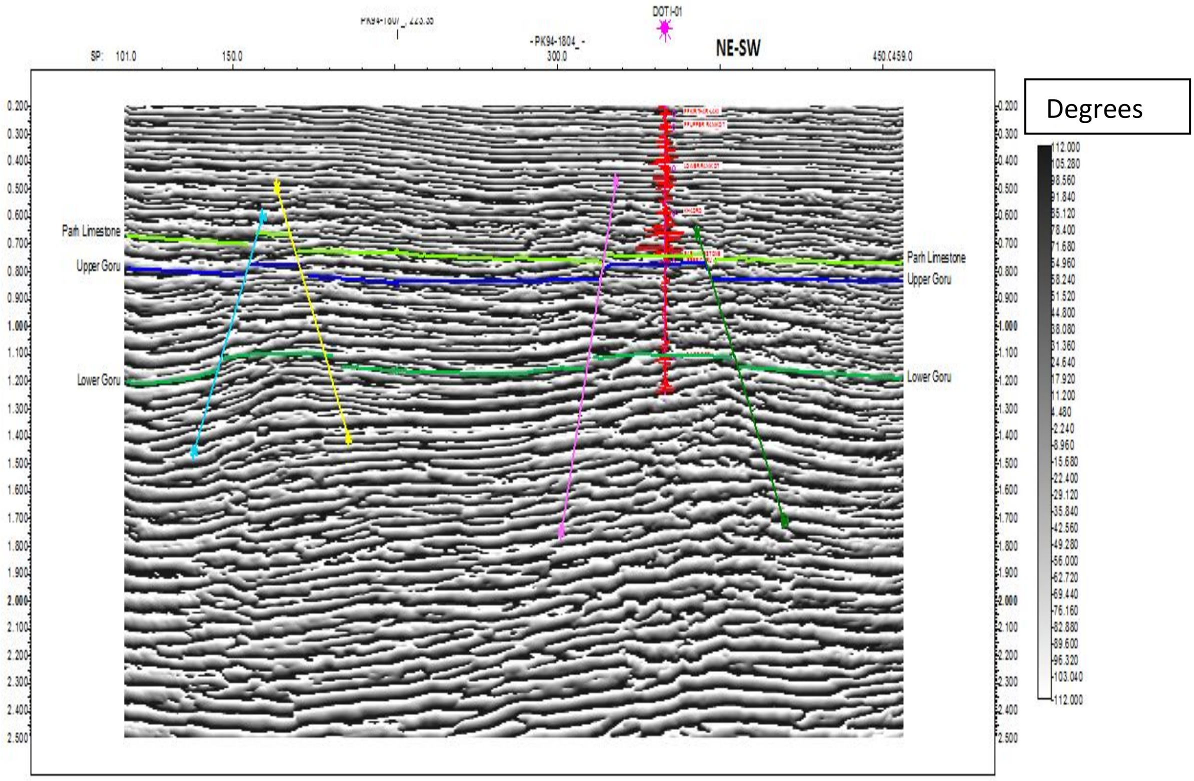


Fig 5.2 Phase Attribute of Seismic Line PK94-1804

5.5 Instantaneous Frequency:

The low frequency indicates the hydrocarbons and reservoir anomalies. The low frequency helps to find hydrocarbons in a lower Goru which shows its lowest value. So we easily find the right place to drill a well in a particular area.

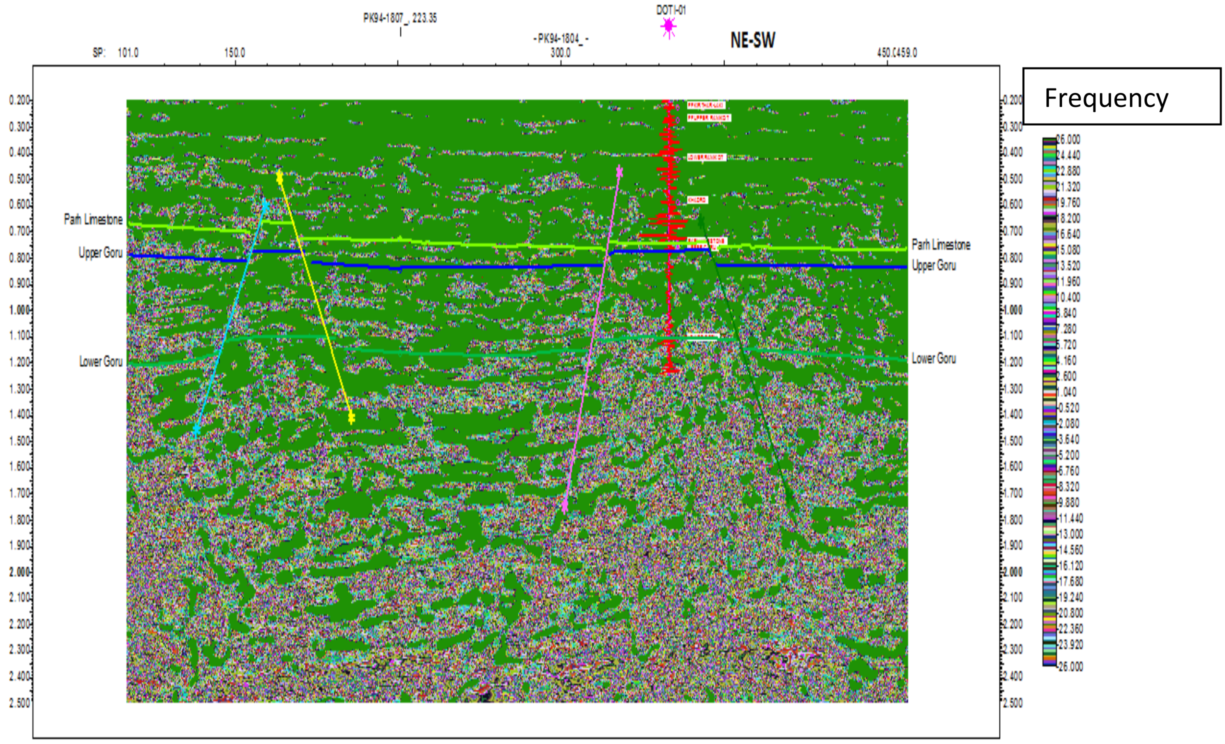


Fig 5.3 Frequency Attributes of Seismic Line PK-94 1804

Conclusion:

- Time and Depth contour maps of Lower Goru help us to confirm the presence of horst and graben structure in the given area. This structure acts as a trap in the area, which is best for hydrocarbon.
- Synthetic seismogram helps to marked reflectors which confirm the presence of stratigraphic interpretation.
- Attribute analysis is worked out for better structural interpretation.
- Petro physical analysis of the reservoir shows high water saturation.
- Results of seismic interpretation, well log interpretation and seismic attributes justified the dryness of well Doti-01.

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