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

Ayesha Sajjad

BS. Geophysics

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Departments of Earth Sciences

Quaid-i-Azam University Islamabad,

Pakistan

بِسْمِ اللهِ الرَّحْمٰنِ الرَّحِيْمِ

"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

It is certified that **Ms. Ayesha Sajjad (Registration No. 04111613036)** carried out the work contained in this dissertation under my supervision and accepted in its present form by Department of Earth Sciences as satisfying the requirements for the award of **BS Degree in Geophysics.**

RECOMMENDED BY

Dr. Muhammad Toqeer
Assistant Professor/Supervisor ______________________

External Examiner ______________________

Dr. Aamir Ali
Chairman ______________________

DEPARTMENT OF EARTH SCIENCES

QUAI-I-AZAM UNIVERSITY

ISLAMABAD

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Dedication

First of all, thanks to Allah Almighty.

To my parents for their endless support and love.

To my friend Asia Hassan and Fiza Tariq and

to my all friends for their support

ABSTRACT

The aim was to understand the tectonics and geology of the Badin block along with the interpretation procedure of migrated seismic sections to check out the subsurface structures, that maybe possible lead for hydrocarbons. Using control line, horizons were marked, namely Khadru formation Lower Goru Formation, Upper Goru Formation. Badin area is prominent in the Lower Indus Basin for its hydrocarbon (oil and gas) structural traps.

For interpretation of these seismic lines three reflectors and normal faults were marked by using the interactive tools of Kingdom software, polygon construction, two-way time contour and depth contour are also the part of the seismic data interpretation. The marked horizons were identified using formation tops from wells and their depths were confirmed through correlation with synthetic seismogram.

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. Horsts or the elevated portions in the structure are suitable place for the accumulation of hydrocarbon. Petro physical results by using statistical analysis and facies modelling indicates the dryness of well Doti-01.

Contents

CHAPTER NO. 1
INTRODUCTION

Introduction to area

1.1 Introduction:

Badin district lies in Lower Indus Basin of Pakistan. The total area of district is 6726 km^2. Badin has been a major producer of hydrocarbons for more than 30 years. 90% of oil production of Lower Indus Basin comes from Badin. The Badin block is a part of Lower Indus Basin which is located in Southern-Eastern part of Pakistan (Mozaffer et al., 2002).

Badin district lies between Thar Desert and coastal stretches of Arabian Sea. It stretches North-South along the Indus River and South of Khairpur-Jacobabad high towards Arabian Sea. The area is under extensional regime so the area comprises structures like tilted fault blocks, normal faults especially horst and grabben 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). Hydrocarbons are among the earth's most important natural resources and hydrocarbons are the main constituents of petroleum (literally, "rock oil"), also called "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.

Hydrocarbon are mined from tar sands and oil shale. These reserves require distillation and upgrading to produce synthetic crude and petroleum. A future source of methane may be methane hydrates found on ocean floors.

The geographical coordinates of the area are:

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

The geographic boundary and the location of the study area is shown in Fig 1.1.

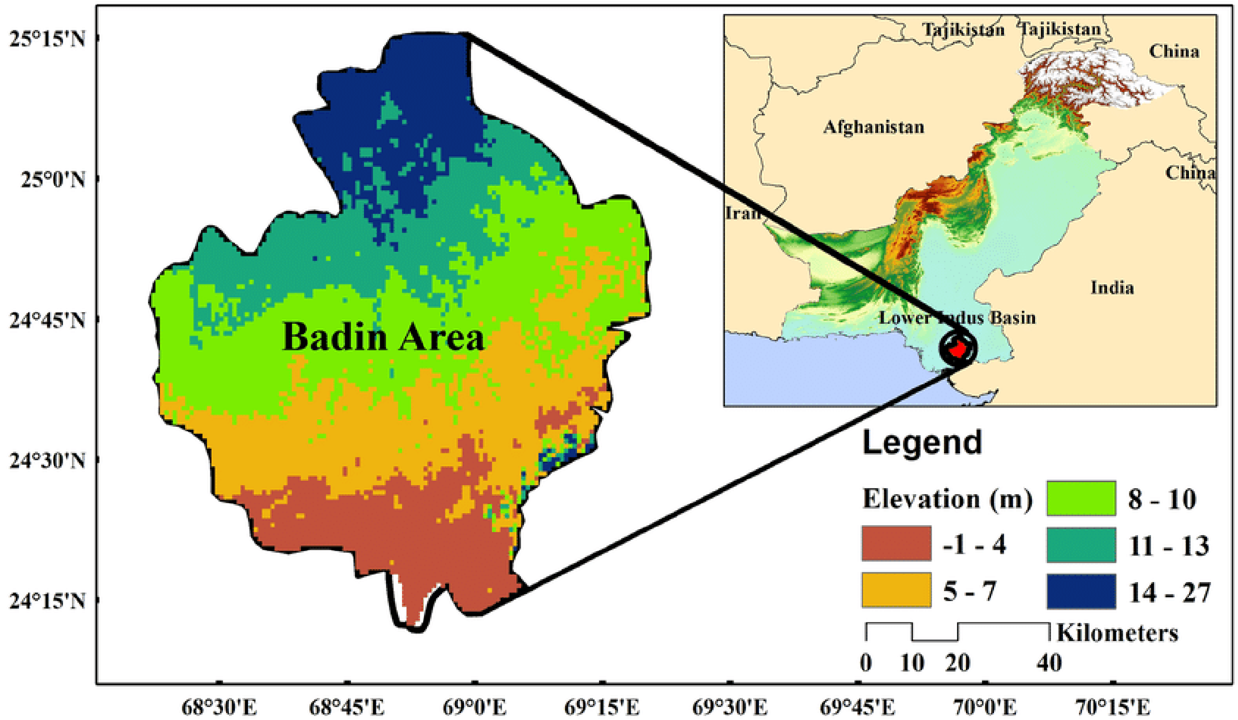

Fig 1.1: location map a badin block lower Indus basin (Nisar U.B et al., 2019)

1.2. Location and Accessibility:

Badin region is located between 24° 5‟N to 25° 25‟N and 68° 21‟ E to 69° 20‟ E and is surrounded on the Northern side by Hyderabad district, on Eastern side by Mirpur Khas and Tharparkar districts, on the Southern side by Rann of Kutch area and on the Western side it is surrounded by Thatta and some parts of Hyderabad district. Badin was classified as district on 1st January there are 46 union councils, 109 tapas and 511 dehs. Badin supports a proper road and rail networks which enables it to connect to all nearby major districts (Hashmi et al., 2012). temperature in the hot weather does not generally exceed 40 C, while the minimum in winter does not fall below 8 C. The autumn sets in September and lasts for almost 6 weeks (Hashmi et al., 2012).

Fig 1.2: District of badin (Alam et al. 2002)

1.3. Climate:

The climate of Badin district is moderate and is moderated by sea 1976. District Badin comprises of 5 taluks out of which 2 taluks are coastal; these taluks include Matli, Talhar, Tando Bago, Badin and Golarchi. More than 86% of population lives in rural area and breeze which blows for 8 months of the year from March to October, making the hot weather comparatively cool. The average rainfall is 125mm normally; during the monsoon period the sky remains cloudy with little precipitation. The climate is generally moist and humid. The cold season in Badin starts from the beginning of November when a sudden change from the moist see breeze to dry and cold North East wind brings about, as a natural consequence and immediate fall in temperature. The maximum

1.4. 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 (kazmi et al., 2005). In Badin block, since oil recovery is at best 61% (including secondary recovery) and Gas 84% (including compression). The actual recoverable reserves 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).

1.5. Aims and Objectives:

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. To find the petro physical properties of reservoir zone by using statistical analysis.

3. Identification of reservoir lithology

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

5. Generate time and depth contour maps on different levels of strata to analyze structural and stratigraphic trend of the area.

6. The identification of seismic horizons by using well tops.

7. Petro physical interpretation of the area to understand the subsurface rock properties and its contribution to the hydrocarbon generation.

1.6. Data Set:

2D seismic reflection and well data is obtained from Landmark Resources (LMKR) by permission of Directorate General Petroleum Concessions (DGPC) of Pakistan. Data provided by DGPC includes seismic lines and well data. The data provided is as follows

Table 1.1 Seismic Lines and line orientation.

Line no.	Line orientation
PK92-1684	NE-SW (Dip)
PK94-1800	NE-SW (Dip)
PK94-1804	NE-SW (Dip)
PK92-1681	NW-ES (Strike)

1.7. Previous Work:

Badin concession has been a prolific producer of hydrocarbons for more than 30 years. Various Petroleum Exploration companies in the Badin area have had an exploration success rate of about 43%, resulting in approximately 1.65 Tcf (trillion cubic feet) of gas and 225 MM bbls (Million Barrels) of oil found in almost 60 fields. The vast majority of the production is from the middle sand and basal sand unit of the Lower Goru Formation (Ahmed, 1999).

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

CHAPTER NO. 2

GEOLOGICAL SETTING OF THE AREA

Introduction:

The information about the geology of an area plays an important role for precise interpretation of seismic data, because same velocity effects can be generated from formation of different ideologies and also different velocity facts can be generated same lithological horizons. So as if we don't know geological formations in area we don't recognize the different reflections appearing in the seismic section. (Kazmi & Jan ,1997) For the exploration of underneath earth surface the geology is of extreme importance.

Pakistan is geologically divided into three main basins Indus, Baluchistan and Kakar Khorasan which are further sub-divided into different sub-basins.Indus basin is divided into Upper and Lower basins. Upper Indus basin is subdivided into Kohat Sub-Basin and Pothohar Basin and Lower Indus basin is divided into Central and Southern Indus Basins.

2.1. Regional Geology:

The Indus Basin, which covers an area of 535,580 km^2, is located on the northwest slope of the Indus Shield and includes the fold belt (Mozaffar et al., 2002). It is divided into Lower, Middle and Upper Indus Basins based on structural highs (Kadri, 1995). Badin is the part of Lower Indus Basin, located on the south eastern part of Pakistan. The Lower Indus Basin stretches north-south along the Indus River and south of Khairpur-Jacobabad High towards Arabian Sea. The Nagar Parker Granite in the extreme south-eastern corner of Pakistan is exposed part of the Indian Craton. The areas located to the west and north-west of Nagar Parker are the Tharparker slope that dips westward and north-westward and where Indus Basin most fertile hydrocarbon bearing territory is located (Mozaffar et al., 2002). The Badin Rift is characterized by a series of horst and graben structures present below the base Paleocene unconformity within the Cretaceous formations. These horsts and graben structures were formed because of rifting between India and Seychelles during the Late Cretaceous (Khan et al., 2013).

2.2. Tectonic setting:

The main tectonic events which have controlled the structures and sedimentology of the Indus Basin are rifting of the Indian Plate from Gondwanaland (Jurassic or Early Cretaceous). This rifting created NE-SW rift system, ridge push at the margins of the newly developed ocean caused uplift and eastward tilting at the start of Cretaceous. Tectonic evolution of Indus Basin starts with the rifting and breakup of Gondwana in Middle Jurassic (approximately 166 Ma) (Wandrey et al., 2004).

Throughout the Jurassic and Cretaceous what is now the African Continent was subjected to several rifting episodes. One of these was a multiple rifting event involving the separation from Africa of a large subcontinent, and its subsequent break-up into three pieces. The three pieces were, successively, Madagascar, The Seychelles Bank and India. During the Cretaceous period Pakistan and India were part of northward drifting passive margin, spreading away from Arabian and African Plate. In the latest Jurassic to early Cretaceous the Badin area was part of this passive margin. The Badin area is very distal to the rift zone that separated Madagascar from Africa (Besse and Courtillot, 1988).

Opening of the Madagascar Basin was a relatively short-lived event, followed by a period of relative quiescence from 121 Ma to 96 Ma marked by deposition of the Lowe Goru Formation. Throughout the Cretaceous time clastic and non-clastic sequence was deposited during a series of high order transgressive or regressive cycle. (Besse and Courtillot, 1988).

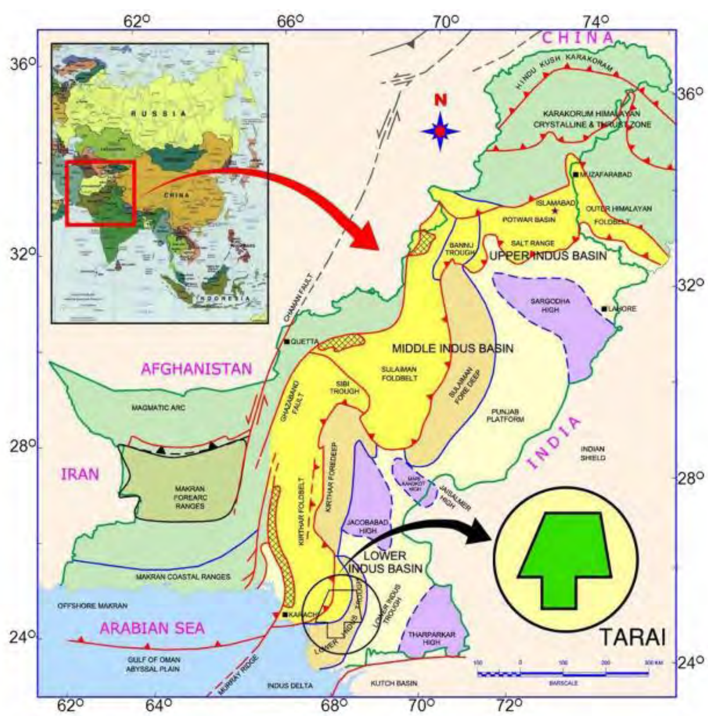

Figure 2.1 The tectonic and geological setting of the Pakistan (Banks and Warburton, 1986).

Shoreline was located NE to SW of the Badin area and deeper water facies deposited toward the Western side of the area (Wandrey et al., 2004).

The fossils fauna record suggests that Goru Formation in Badin block deposited in different conditions. Fossil record suggests continental, transitional, deltaic, shallow marine to deeper marine conditions. Thickness of Goru Formation (Upper and Lower Goru) is recorded as 2000 ft. to 7500 ft. (Hasany, 2011). Due to extensional tectonics tilted fault blocks trapping hydrocarbons are formed. In early Cretaceous the deposition of organic rich Sembar source rock took place, at that time rifting was continuous and the basin was opening followed by extensional faulting. The Goru Formation was subsequently being deposited. Structural traps in the block are the consequence of continuous rifting. Basaltic lava might have given thermal conditions for generation and maturation of hydrocarbons (Kadri, 1995).

The Syn-rift and post-rift deposition of Lower Goru and Upper Goru Formation was continued during Early to Middle Cretaceous time which can be observed as relatively thin presence of Upper Goru on the top of fault blocks (Horst blocks) whereas thicker in the lows (Graben). During the Late Cretaceous time, a phase of extensional faulting enhanced or imposed on this sedimentation which produced the tilted fault blocks structure of the Badin Rift. This extensional faulting terminated deposition of shelf sand through rapid deepening and resulted in the development of regional extensive Top Lower Goru Unconformities. The Upper Goru Formation consisting of Claystone, Mudstone was deposited in deep water which also provides a seal to tilted fault block Sandstone plays of the Lower Goru (Besse and Courtillot, 1988). The exact age of onset of rifting between Madagascar and Seychelles/India is poorly constrained, but the Seychelles/Indian Plate was well into the drift phase by 83 Ma (Hasany, 2011).

At the end of Cretaceous/Early-Paleocene, the Seychelles and Madagascar separated from India with associated faulting accompanied by Basaltic flows (Deccan Volcanic) in the southern part of Lower Indus Basin. After its separation from Madagascar the Seychelles/Indian Plate travelled relatively North to Northeast. During this same time period the combined Seychelles/Indian Plate underwent a time of relatively minor uplift and erosion. Separation of India from the Seychelles Bank followed soon after and was completed during the Early Eocene. The Indian Plate moved Northward at an accelerated rate of 15-20 cm/year. The separation of India and Seychelles does not appear to have had any impact on the Badin area (Wandrey et al., 2004).

After the Paleocene there was a continuing oblique convergence of India and Asia throughout Tertiary time. The Indian Subcontinent collided with the Asian Subcontinent during the Tertiary, resulting in the Himalayan orogeny. The collision of India with Asia caused a westward tilting of the entire region. Today, uplift of mountain ranges, crustal shortening and subduction of the Indian plate continues, and the growth rate of the Indian Delta remains high (Wandrey et al., 2004).

The Badin Area is located very distal to the collision zone but shows evidence of secondary effects from the subduction of Indian Plate beneath the Asian Plate. It does not exhibit the types of compressive structures seen in areas further North but was affected by uplift and erosion starting in the Mid-Tertiary that corresponds to the cause of the Himalayan Orogeny (Besse and Courtillot, 1988).

2.2 PETROLEUM GEOLOGY OF AREA

2.2.1. 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 The gas rises and accumulates in shallower traps but it also gets stuck along its migration paths and may leads kto 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 and BGP are the oil operators of this region (Raza et al., 1989 and 1990).

2.4 Petroleum System:

2.4.1. Source Rocks (Samber 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., 1989). 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) are generally higher than 1% (Qadri, 1986)

2.4.2 Reservoir Rocks (Basal 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. Apart from Lower Goru Sands, Sembar Sands are also of the reservoir quality. Potential reservoirs are as thick as 400m. 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).

2.4.3. 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).

2.4.4. Traps:

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

2.5. Structural Setting:

The Southern Indus Basin mostly exhibits extensional tectonics and as a consequence, normal faults are generated showing horst and graben structures with former being of great exploratory importance (Kemal et al., 1991). The extensional tectonism during the Cretaceous time created the tilted fault blocks over a wide area of the Eastern Lower Indus Sub-Basin. Seismic reflectors, representing Cretaceous and older layers, are broken by a system of faults with normal dip separation. The Cretaceous faults generally strike between N 30 W and N 50 W (Kemal et al., 1991).

Commonly the faults are arranged in en-echelon sets, aligned in zones that trend almost North-South. Fault associated structural closures are responsible for trapping oil and gas in Lower Goru Sandstone in the Thatta Block. The tilted fault block traps were in existence at the time of hydrocarbon generation. The under filling of the structures can be attributed to upward leakage across the extensive network of small faults. Later wrenching has complicated the earlier extensional structures and redistributed the hydrocarbons (Kemal et al., 1991)

2.6 Generalized Stratigraphy:

Stratigraphy of the study area comprises the rocks ranging from Wulgai Formation to Alluvium (Raza et al., 1990), as shown in figure 3.1. 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 Sembar formation and interbedded shale layer of Lower Goru formation are the main document petroleum source rock units in the southern Indus basin. Upper Paleocene marine transgressive shale acts as secondary source rock, deeply buried in the western half of the southern Indus Basin (Zaigham and Mallick, 2000).

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

In general, the transgressive shales of the Cretaceous (Sembar 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 provide 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).

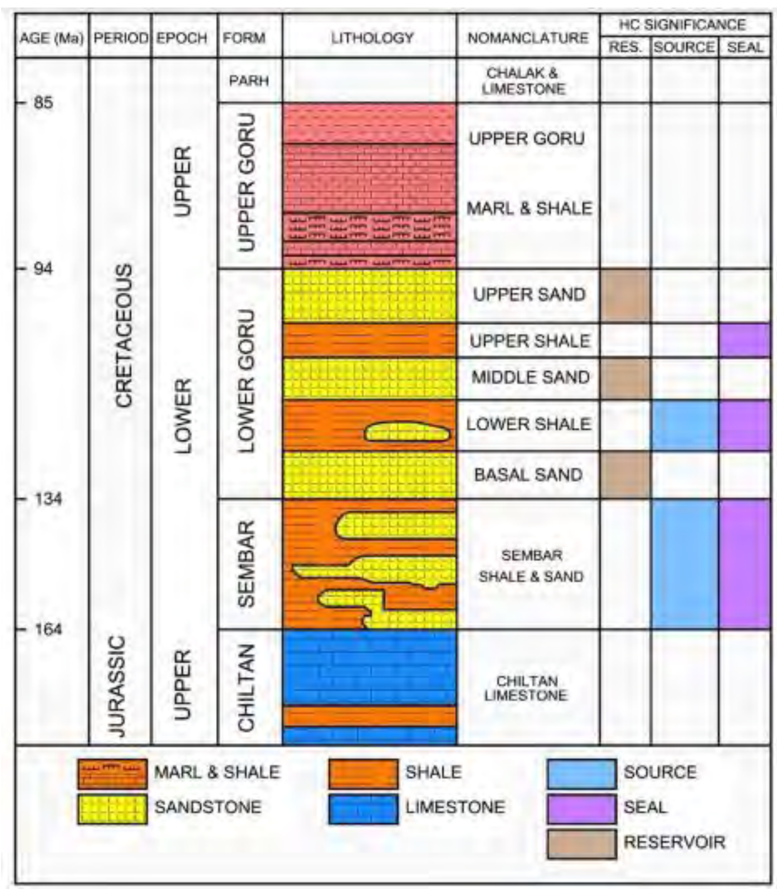

Fig 2.2 Generalized stratigraphic chart of the study area (Abbasi et al. 2014)

2.6.1. Ranikot Formation:

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

2.6.2. Khadro Formation:

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

2.6.3. Parh Limestone:

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

2.6.4. Goru Formation:

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

CHAPTER 3

SEISMIC DATA INTERPRETATION

3.1 Introduction:

The main goal after the entire seismic investigation is the identification of prospect in the sedimentary basin and this would be done with the most imperative step that is interpretation. It is simply the ability to interpret the seismic reflection data in geological terms. Seismic interpretation, whether for hydrocarbon exploration or geotechnical studies, is the determination of the geological significance of seismic data. It is the transformation of seismic data into structural and stratigraphic picture through a series of different steps. Thus threading together all the available geological and geophysical information including the seismic and then integrating them on a single picture can only give a picture closer to the reality.

3.2. Approaches of Seismic Interpretation:

There are two main seismic interpretation approaches:

1. Structural analysis
2. Stratigraphic analysis

3.2.1. Structural Analysis:

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

3.2.2. Stratigraphic Analysis:

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

3.3. 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. (Dobrin and Savit, 1976).

3.4. Methodology adopted in Interpretation:

The following steps were followed for interpretation purpose.

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

The interpretation was done on Kingdom which provides an interactive interface for marking horizons and faults, exporting horizon's time, velocity and depth data for contouring and for further analysis.

3.5 Interpretation workflow

Kingdom software (8.8) was used for completion of interpretation phase. Navigations and

SEG-Y of given seismic lines of badin area were loaded in software.

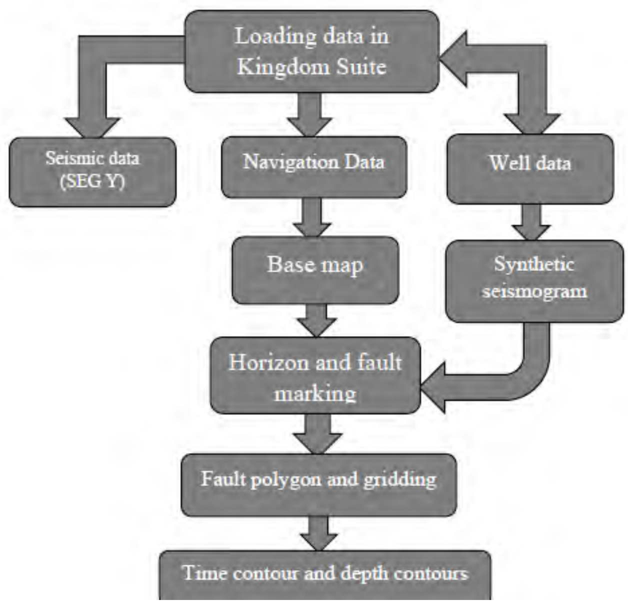

Fig:3.1 Interpretation flowchart

3.6. Preparation of base map

A base map typically includes locations of concession boundaries, wells, seismic survey points and other cultural data such as buildings and roads, with a geographic reference such as latitude and longitude or Universal Transverse Mercator (UTM) grid information. Geologists use topographic maps as base maps for construction of surface geologic maps. Geophysicists typically use shot point maps, which show the orientations of seismic lines and the specific points at which seismic data were acquired, to display interpretations of seismic data.

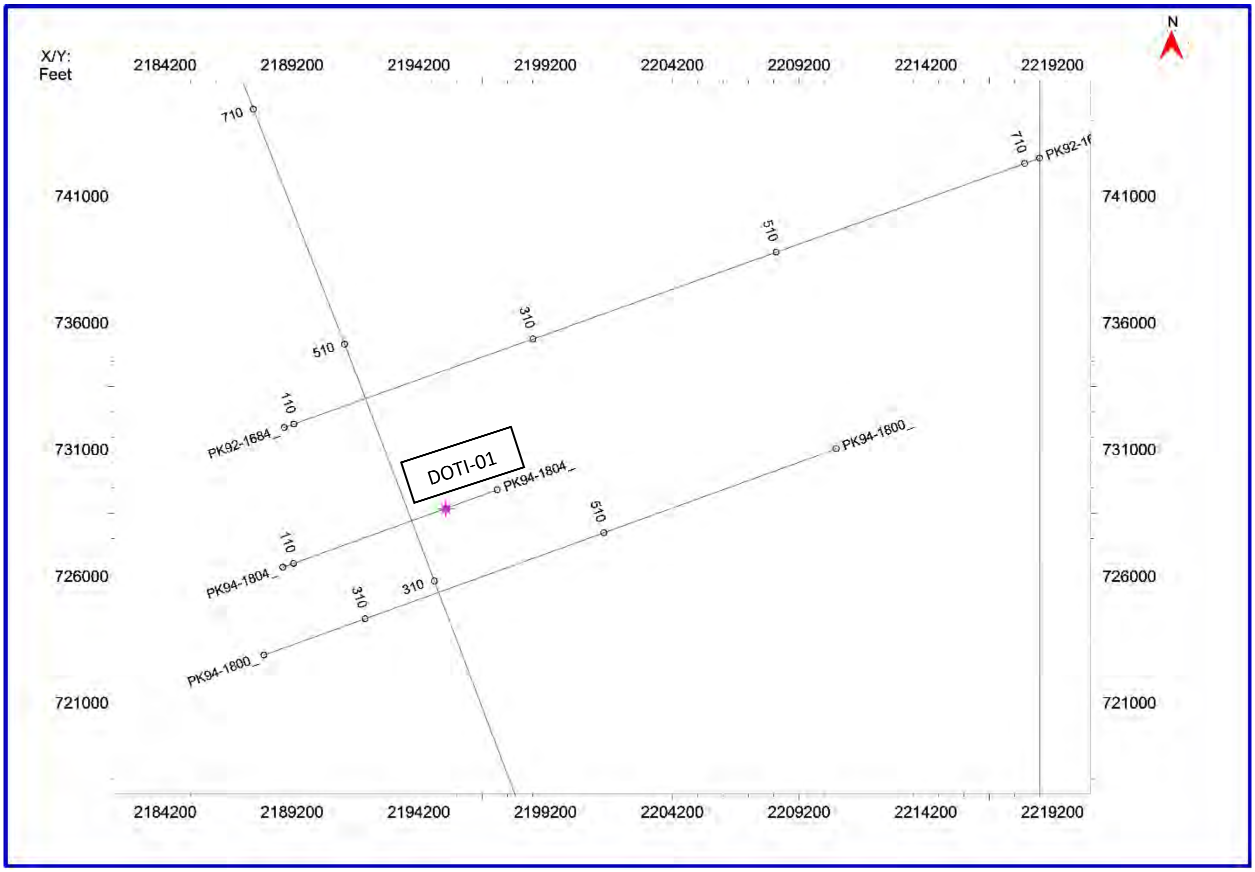

Fig 3.2 Base map of the area. (source kingdom software 8.8)

3.7. Generation of Synthetic Seismogram:

For the generation of synthetic seismogram two-way time for each well top is required. Two-way time for each well top or reflector is calculated by using depth, sonic log data of well and replacement velocity of the area. By using two-way time against each well top depth time depth chart is prepared. And then finally synthetic seismogram is generated. Tie this synthetic

seismogram with the Seismic line, on which well is located (PK94-1804). Actually seismic data is provided in time scale and well tops are given in depth so we cannot mark horizons in time form. So, the purpose of generation of synthetic is to find two-way travel time against each depth for marking of horizons. With the help of this synthetic seismogram two horizon were marked on this line. Tie marked Seismic with other lines and horizons are marked on these lines. During tie lines miss tie shift is applied.

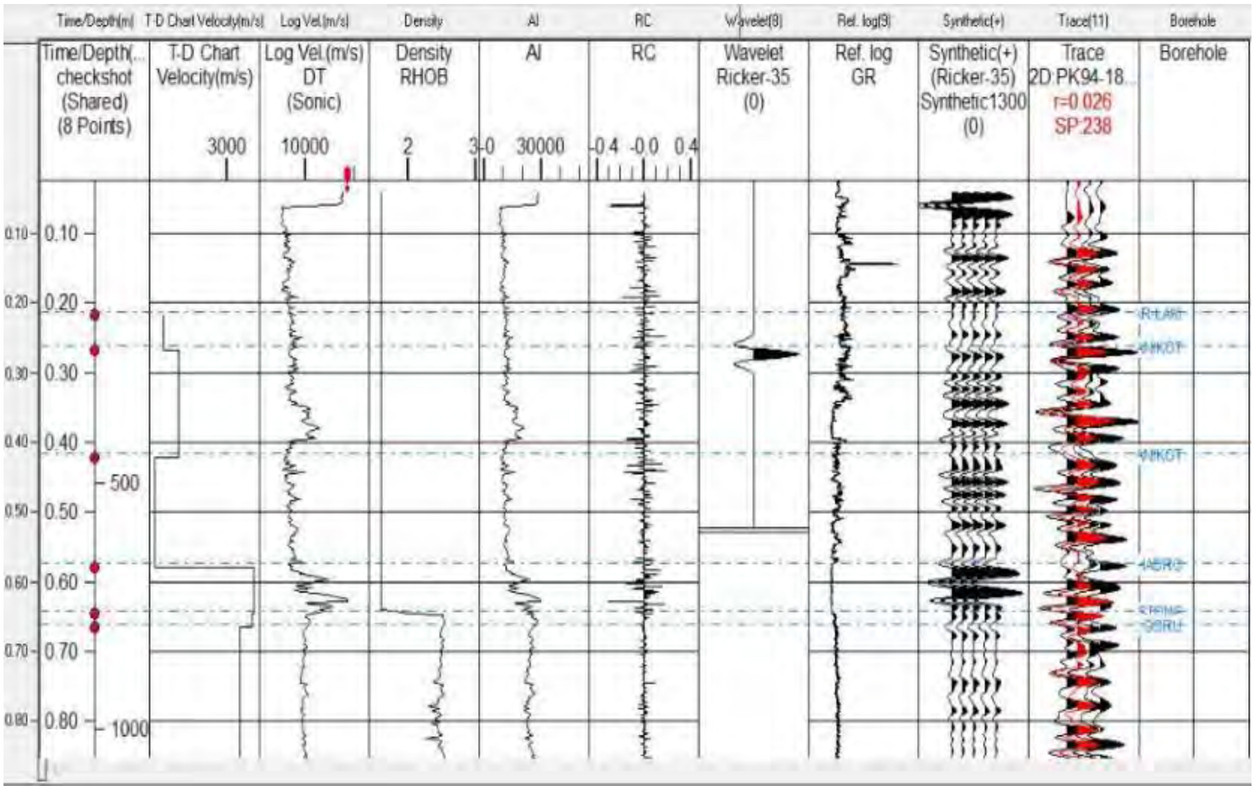

Fig 3.3 synthetic seismogram of the area

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. Both the horizons and faults are marked on the seismic section. Three horizons are picked and named on the basis of DOTI-01 well tops.

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 are 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:

seismic sections of the lines PK92-1681, PK92-1684, PK 94-1800 and well line PK 94-1804 were interpreted. Total three seismic horizons namely Khadru, 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 other horizons and faults are marked on remaining lines. On dip line the faults and horizons are marked but on strike line just horizons are marked because structural features cannot be formed on strike line.

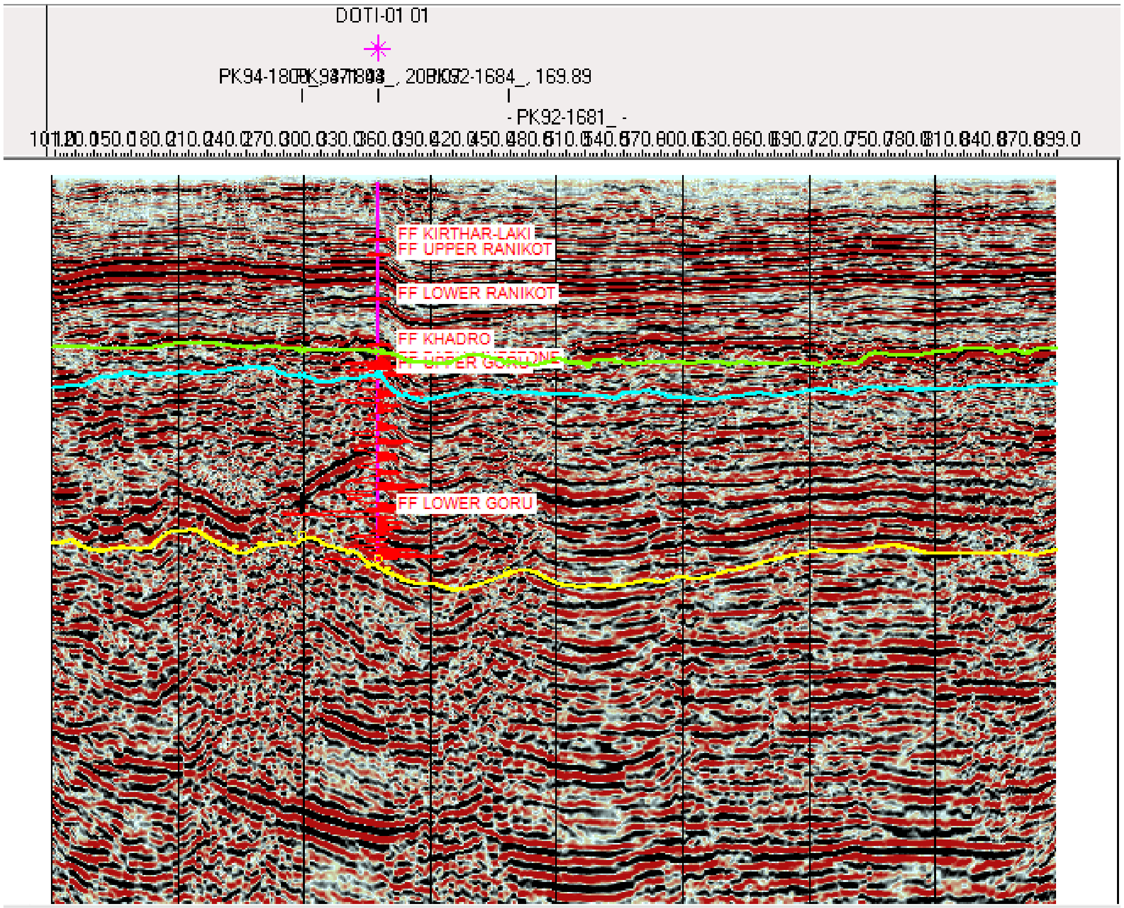

Fig 3.4 interpretation of strike line PK 92-1681

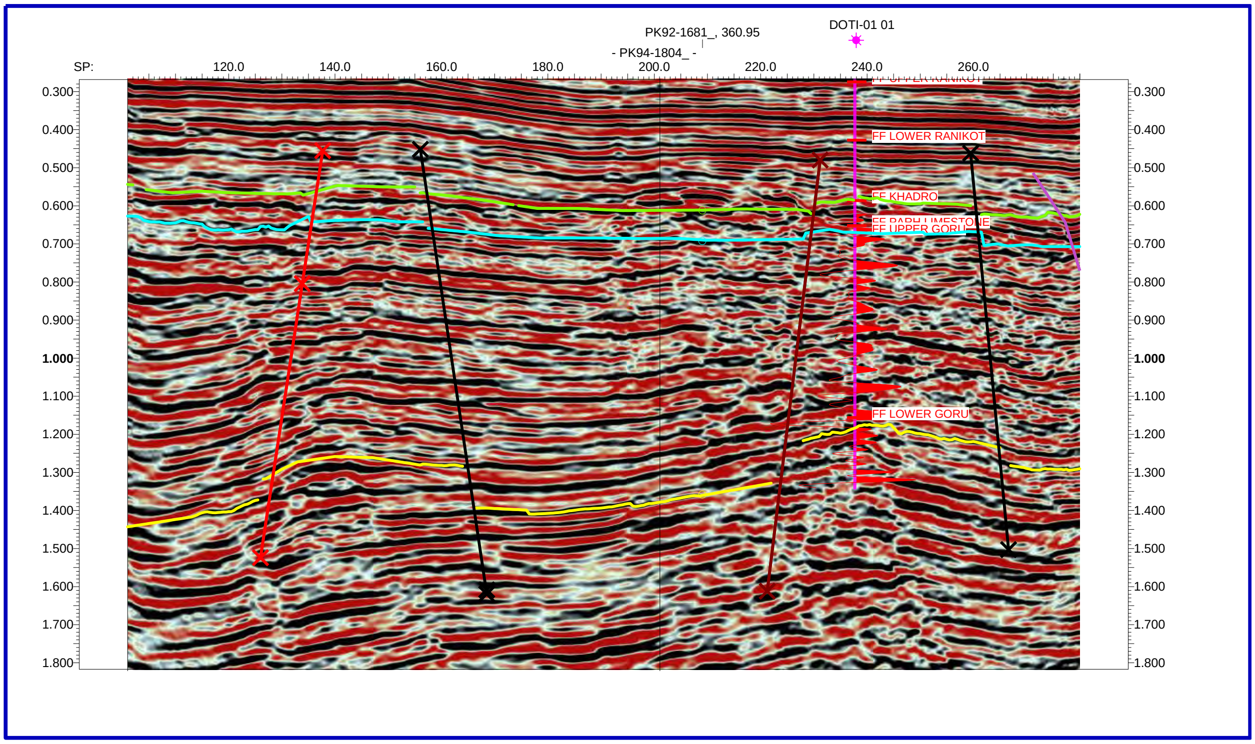

Fig 3.5 Interpretation of dip line PK 94-1804

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. Construction of fault polygons are 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 prior to contouring. The reason is that if a fault is not converted into a polygon, the software doesn't recognize it as a barrier or discontinuities, thus represent a false picture of the subsurface. Figure3.4 shows the fault polygons of lower Goru formation. the color bar shows the dip direction of fault polygons is dip symbols are not drawn.

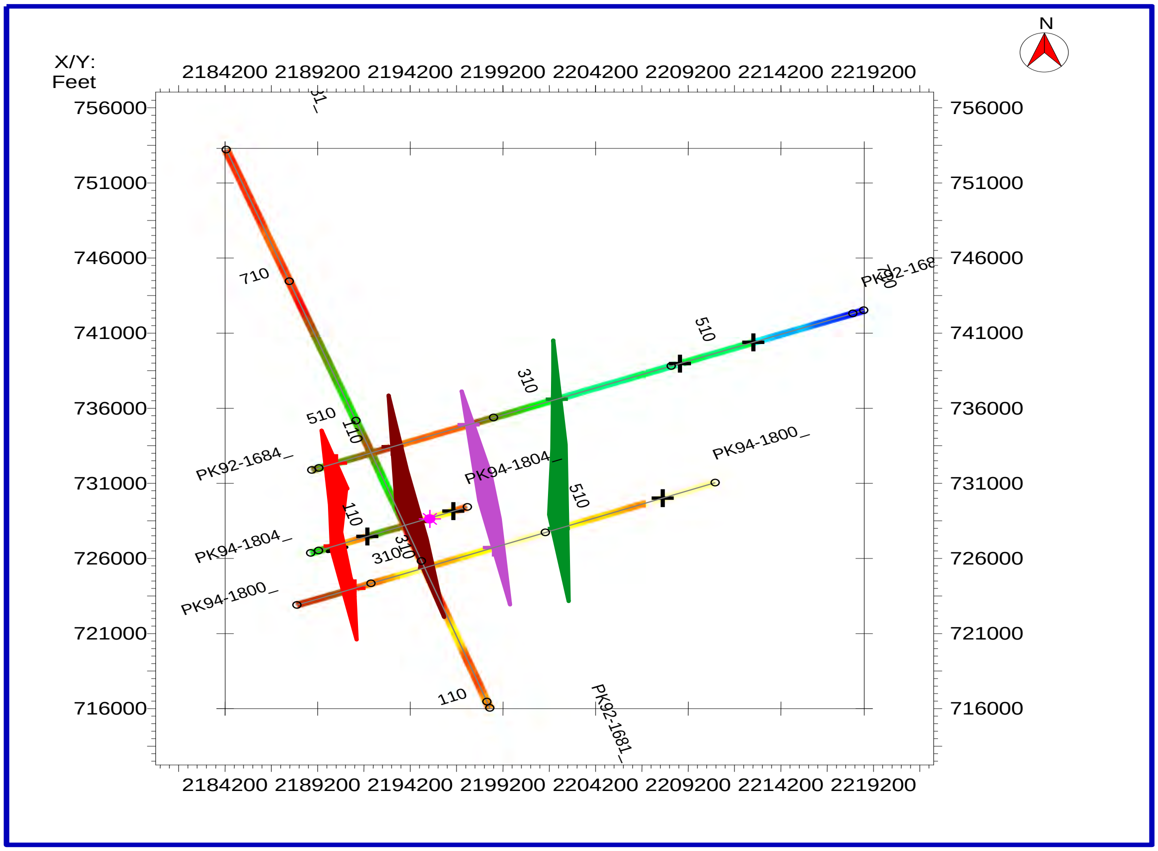

Fig 3.6 Fault polygon of lower Goru formation

3.12 Contour Maps:

At the end of interpretation, time and depth contour maps are prepared. As mapping is the part of interpretation, so time and depth contour maps are necessary. Contouring represents the three-dimensional Earth on a two dimensional surface. the seismic data is contoured which provides a clear interpretation of the area. Following are the time contour maps of Khadru formation and Lower Goru formation. In these time contour maps the central parts indicating Graben trending NW-SE shows deepest part on the color scale while the shallowest parts indicating horst.

3.13. Depth Contour Map of Marked Horizons:

The depth contour maps show the horizon depth variation. Figure 3.5a and 3.5b shows depth contour maps of Lower Goru and upper Goru formations. These depth maps shows 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.

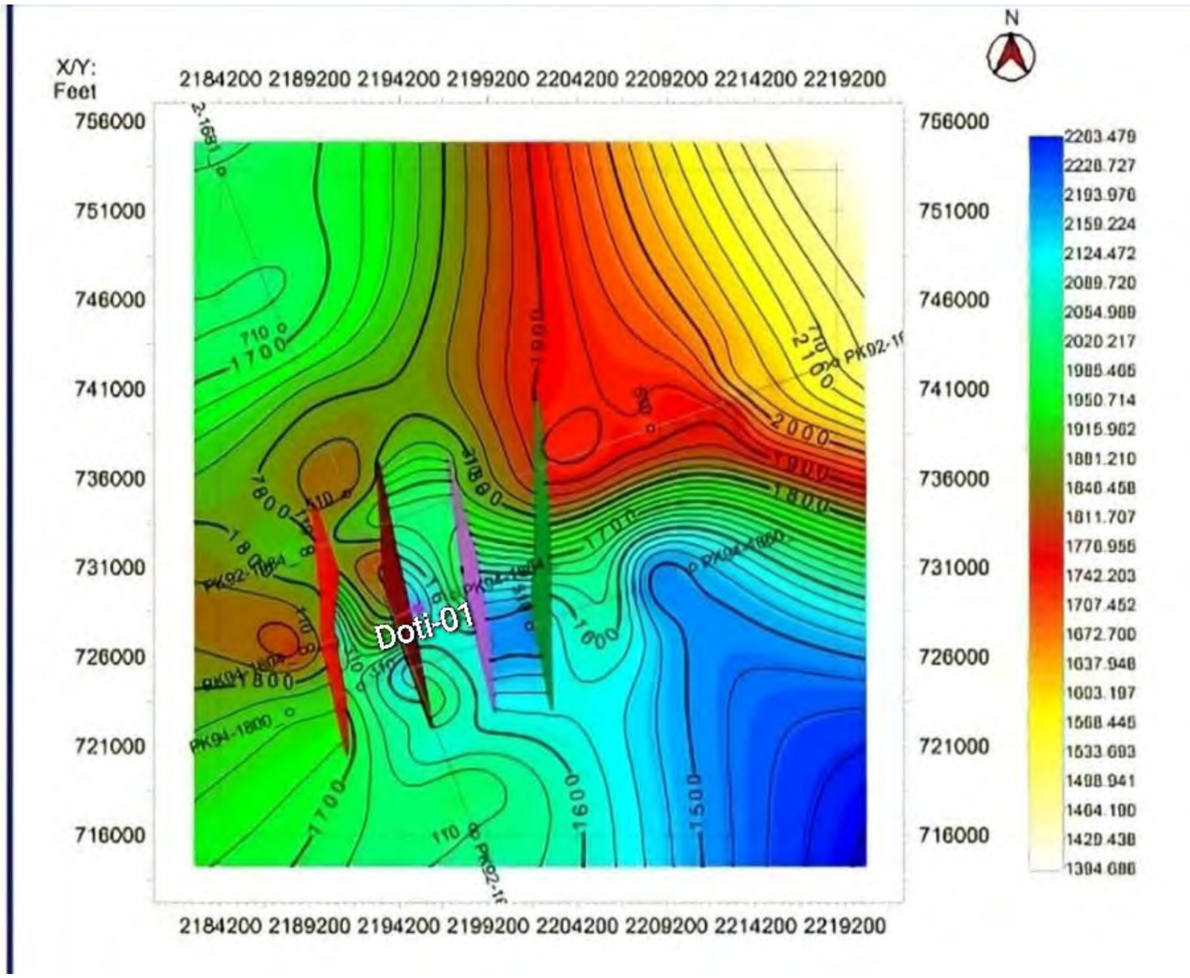

Fig 3.7 Depth contour of lower Goru

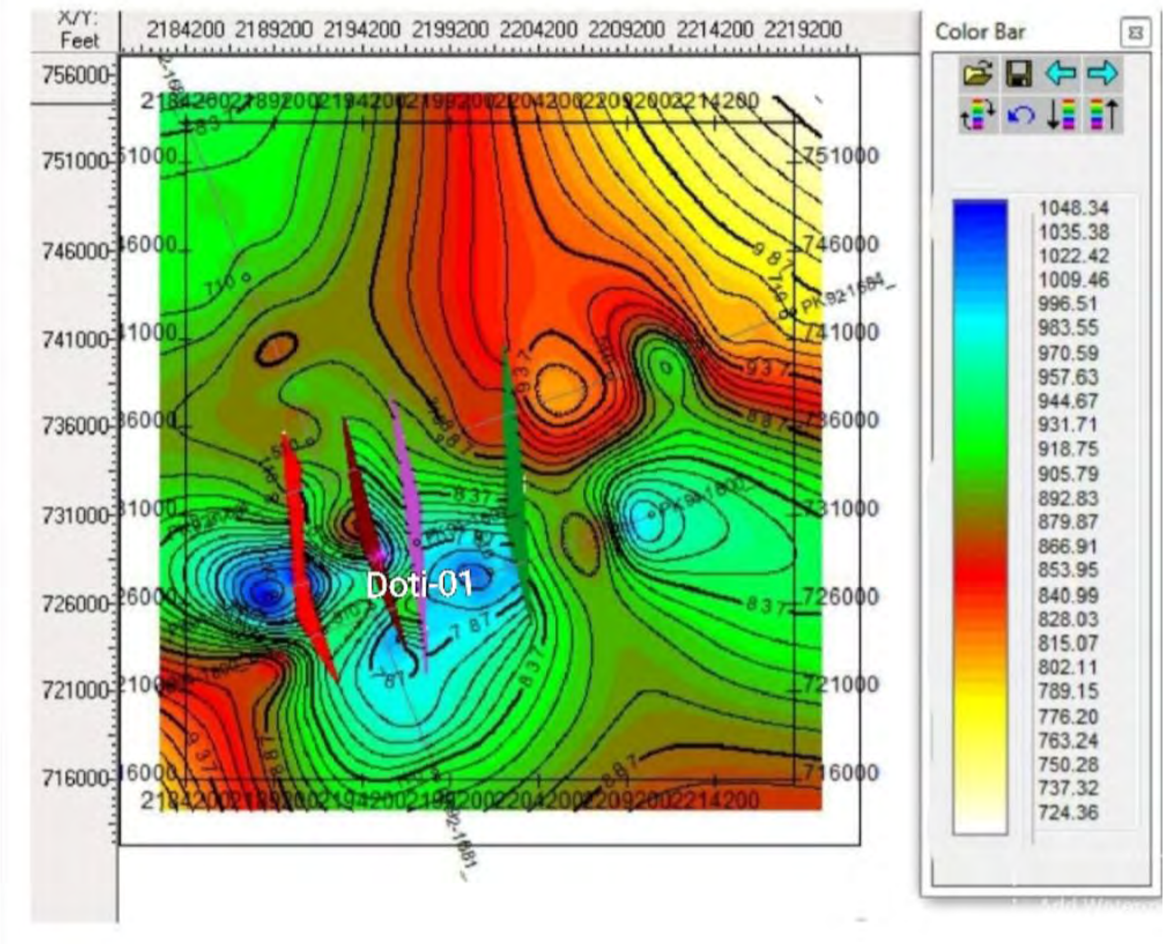

Fig 3.8 Depth contour of upper Goru

3.14 Time Contours maps of marked horizons:

After completing horizons and fault interpretation time contour maps are constructed. The times are read directly from the sections and are immediately available for mapping. The pattern of Time Contour map confirms the shape of the subsurface structure. Time contour maps of these formations show 2D-variations with respect to time and the hydrocarbons probably accumulate at those places where contour values are low.

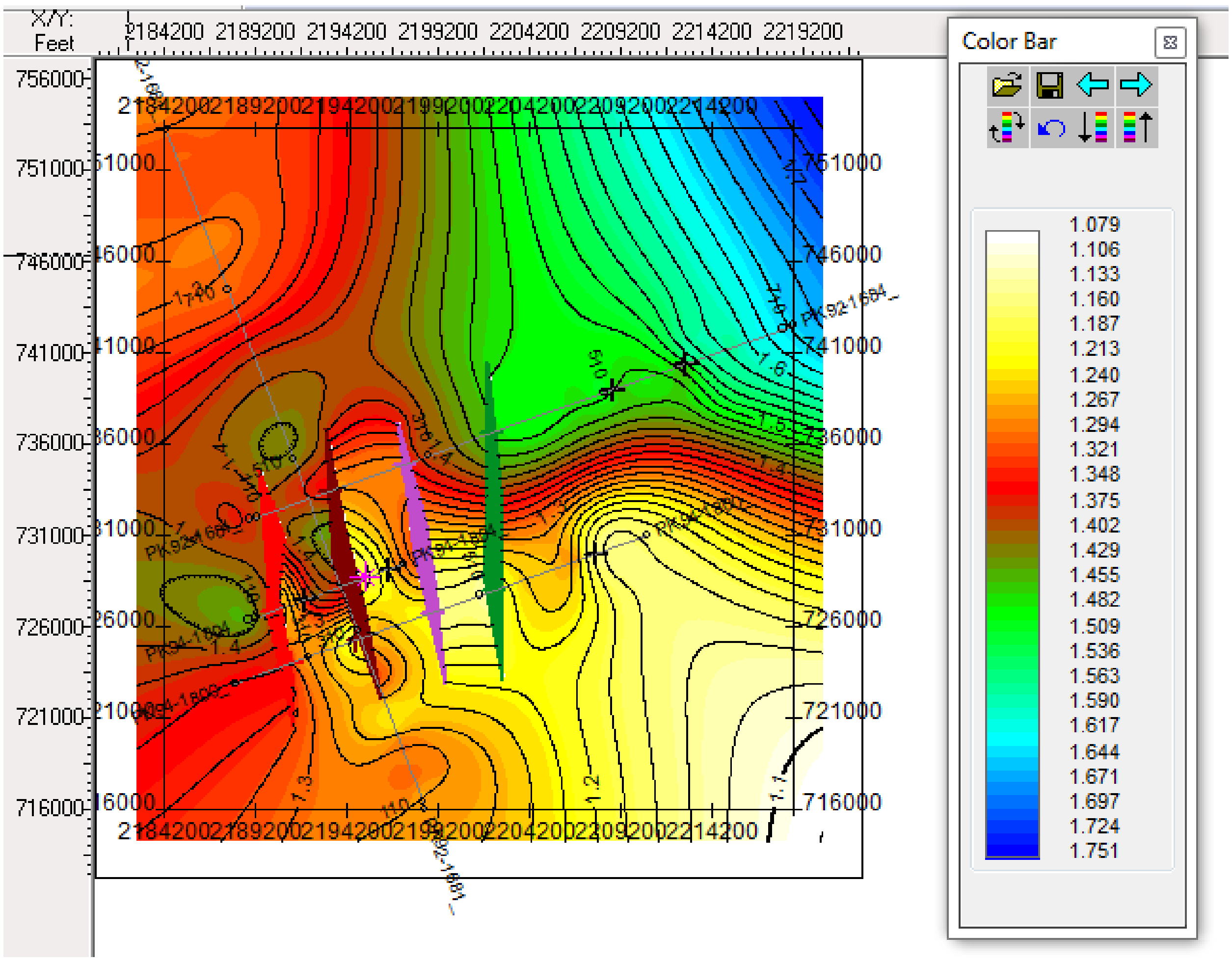

Fig 3.9 Time contour of lower Goru

Top of Lower Goru grid also shows the same color variation as the Basal Sand shows. Zone surrounded by the seismic lines is the shallower zone in the base map, so there is maximum chance of accumulation of hydrocarbon in that elevated zone.

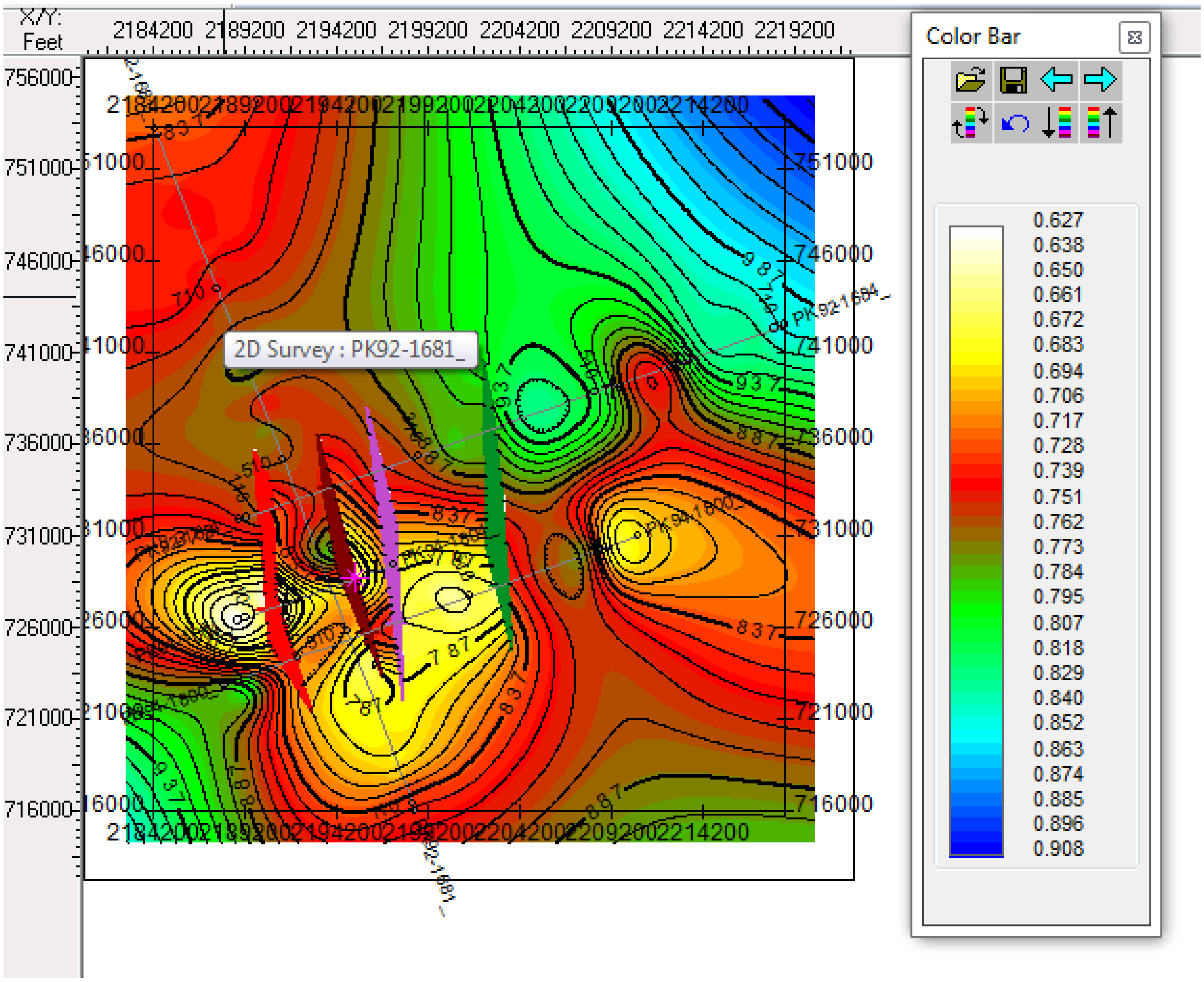

Fig 3.10 Time contour of upper Goru

In above Figure 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.

CHAPTER NO. 4

Petro-physical analysis

4.1 Introduction:

General Information:

Petro physics is study of the physical properties relating the frequencies, behavior of the rocks and liquids inside the rocks Reservoir think to be the is the key of oil and gas industry as it helps in characterizing the well and field potential so recognize the zones inside the reservoir which bears the hydrocarbons and can be trap (Bowman, T., 2010).

Doti-01 lies upon the seismic line 94-1804. It is exploratory but abandoned well. Badin block consists of a total of 380 exploratory wells and 59 oil and gas condensate discoveries. In Lower Indus, so far more than 12 TCF (Trillion Cubic Feet) gas reserves and more than 100 trillion barrels Oil have been discovered in Lower Indus Basin whereas more than 90% oil production is from Badin area (Mozaffer et al., 2002). Well log interpretation is done on Top Lower Goru Formation. The purpose of study is to be able to identify the permeable zones, their fluid content and hydrocarbon saturation.

In well logging different types of logs are obtained with the help of a sonde. In early ages different sondes are used for different type of logging in the well but now a day we use only one sonde which has ability to do all type of logging both cased or uncased logging.

The well logs analysis was carried out by using the following wire-line logs of Doti-01 issued by DGPC:

- Density log
- Neutron log
- Resistivity log
- Gamma Ray log
- Sonic log
- Caliper log

4.2 Petro physics:

Petro physical 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 (Dewar, 2001).

- Petro physics uses all kinds of logs, core data and 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 porosity, saturation, permeability, net pay, fluid contacts, shale volume, and reservoir zonation.

4.3 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. (Bowman, T., 2010). 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 indexes

- Porosity

- Lithology of the reservoir rock

4.4 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.

4.5 working:

The flowchart was used while interpreting the well logs:

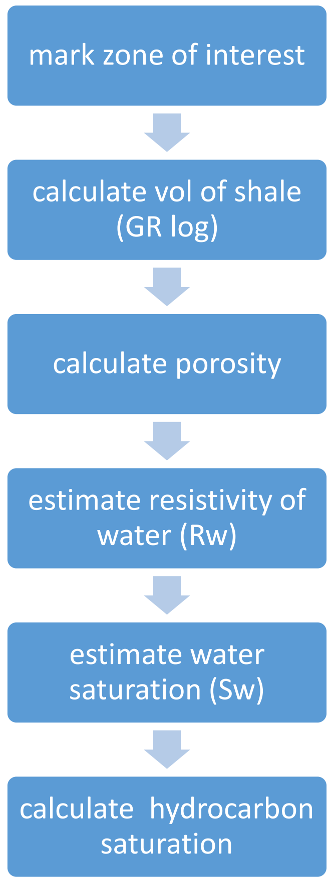

Fig 4.1 workflow of petro physical analysis

4.5.1 Zone of interest:

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

Zones	Starting depth(m)	Ending depth(m)	Thickness (m)
Lower goru	1530	1830	300

4.6 Log Interpretation Results on Lower Goru Formation:

The lower Goru formation in Doti-01 starts from the depth of 1537m, and ends at 1822m. By analyzing different well logs such as caliper log, Gamma ray log, Resistivity log, and neutron density cross over different zones of interest can be marked.

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 one zone of interest for sand reservoir in Doti-01 well in Lower Goru formation.

4.7 Classification of Geophysical Well Logs

Different classifications and some short explanation of geophysical well logs is 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

4.7.1 Lithology Track

In lithology track the following three logs are displayed which are explained as follow.

- Gamma ray (GR)
- Spontaneous Potential log (SP)

4.7.2 Gamma Ray (GR)

Log GR log is also known as shale log is measurement of formations radioactive contents. Since radioactive contents are present in shale so it gives deflection where shale is present that's why it is best log for lithology identification.

4.7.3 Spontaneous Potential (SP)

Log SP log measures the naturally occurring potential of geological formations no artificial currents are injected. It gives deflection opposite to permeable beds since shale is impermeable so it gives straight line opposite to shale known as shale base line. It is used ′ To indicate permeable zone ′ Identify bed boundaries ′ To calculate volume of shale. ′ To calculate resistivity of formation water

4.7.4 Caliper Log

Caliper log use to measure the borehole size. This log give us help to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. 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 reading. Hence caliper log is very important in Petrophysical logs

4.7.5 Porosity Log

DT, RHOB, and NPHI are porosity logs which are used to calculate pore volume of formations. With the combination of resistivity logs they are used to calculate water saturation of formations. Porosity log contains ′ Sonic log (DT) ′ Density log (RHOB) ′ Neutron Porosity log (NPHI)

4.7.6 Sonic (DT)

Log Sonic log produce compressional waves and measure the transient travel time of waves. Where 40 travel time is higher it is indication of porous media because wave is name of progressive disturbance of media if media is porous travel time is higher. It is used ′ Porosity (using interval transit. Time) ′ Lithology identification (with Neutron and/or Density) ′ Synthetic seismograms (with Density) ′ Mechanical properties of formation with (Density) ′ Abnormal formation pressures detection

4.7.7 Density (RHOB) Log

Gamma rays are bombarded on formation these are scattered from formation’s electrons higher the scattering higher the electron density and this electron density is related to bulk density of rocks. Lower the density higher the porosity of medium.

4.7.8 Neutron Log

Neutron log tool emit high energy neutron and the only resistive substance to neutron are hydrogen ions. If value of this log is high it means high hydrogen ions concentration is present. Since hydrogen ions are present in pore space so neutron log measures porosity. If gas is present than value of log is low because concentration of hydrogen ion is low.

4.7.9 Electrical Resistivity Log

Basically there are different types of electrical Resistivity Logs. Logs of LLS and LLD can separate only when (oil) high resistive fluid is present in the formation. It is explained in detail in Petrophysical interpretation. ′ Laterelog Deep (LLD) ′ Laterelog Shallow (LLS)

4.7.10 Laterelog Deep

Laterelog deep is used for deep investigation of the undisturbed zone (Uninvaded zone) and it is called Laterelog deep (LLD). This log is also used for saline muds also in case of fresh mud. This log is generally used for measuring the formation resistivity. IT having deep penetration as compared to the (LLS).

4.7.11 Laterolog Shallow

Laterelog shallow (LLS), used for shallow investigation of the transition zone / invaded zone. Because the depth of the investigation is smaller than the LLD.

4.8 Petrophysical analysis of the well

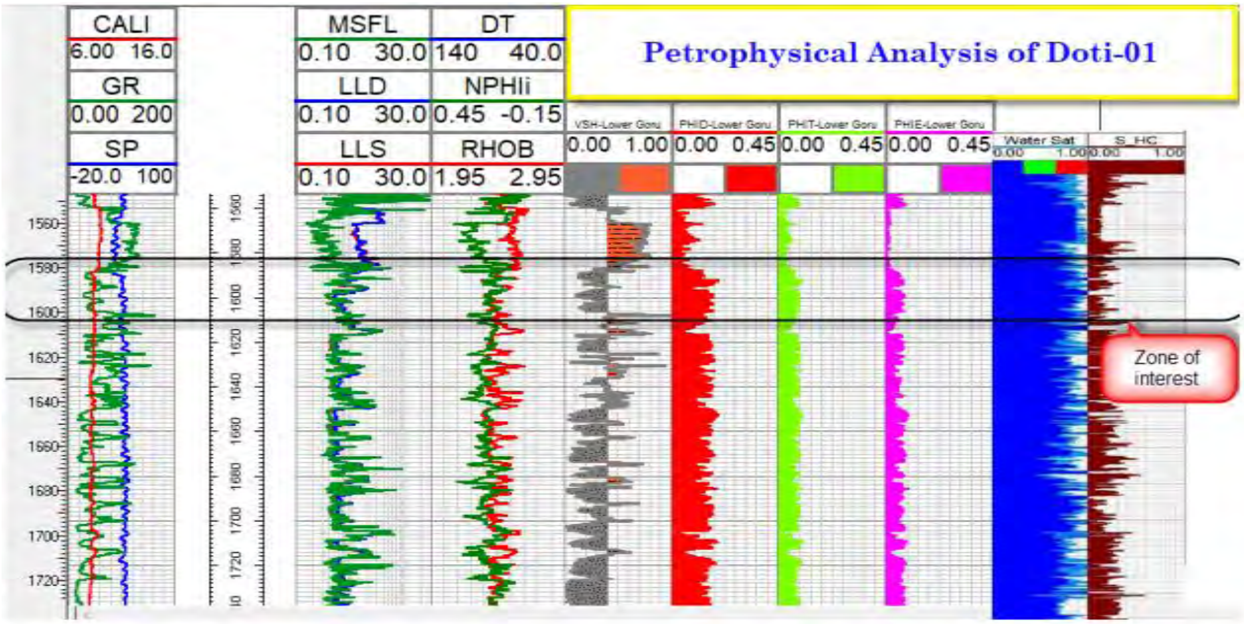

Fig 4.2 Petrophysical analysis of DOTI-01

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 gap between MSFL and LLD, LLS logs, gap represents the presence of Hydrocarbons.

All these conditions tell us the presence of Hydrocarbons in the marked zone but in less amount. Doti-01 is dry so percentage of water saturation is more and percentage of Hydrocarbon saturation is less here.

4.9 Results of petro physical analysis of lower guru formation:

Petrophysical properties	**percentage**
Volume of shale	25%
Effective Porosity	10-12%
Water saturation	75%
Hydrocarbon saturation	25%

Chapter: 5

Seismic attributes

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).

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 prestack 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 (Taner et al, 1994).

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. (Taner et al., 1979). This attribute is mainly useful in identifying:

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

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. The figure below shows the instantaneous phase computed for two versions of a seismic trace one with a normalized maximum amplitude of 1 and other with 0.2 thus by decreasing the amplitude by 20% it can be seen that with the decrease of amplitude the 2nd trace show very weak events while the instantaneous phase show no change for both the traces this indicates that the phase is independent of seismic amplitude thus it is useful for confirming the continuity of reflectors. As the variations in the amplitude occurs no change in the real and imaginary part of the seismic trace is observed however the change in the instantaneous phase is observed

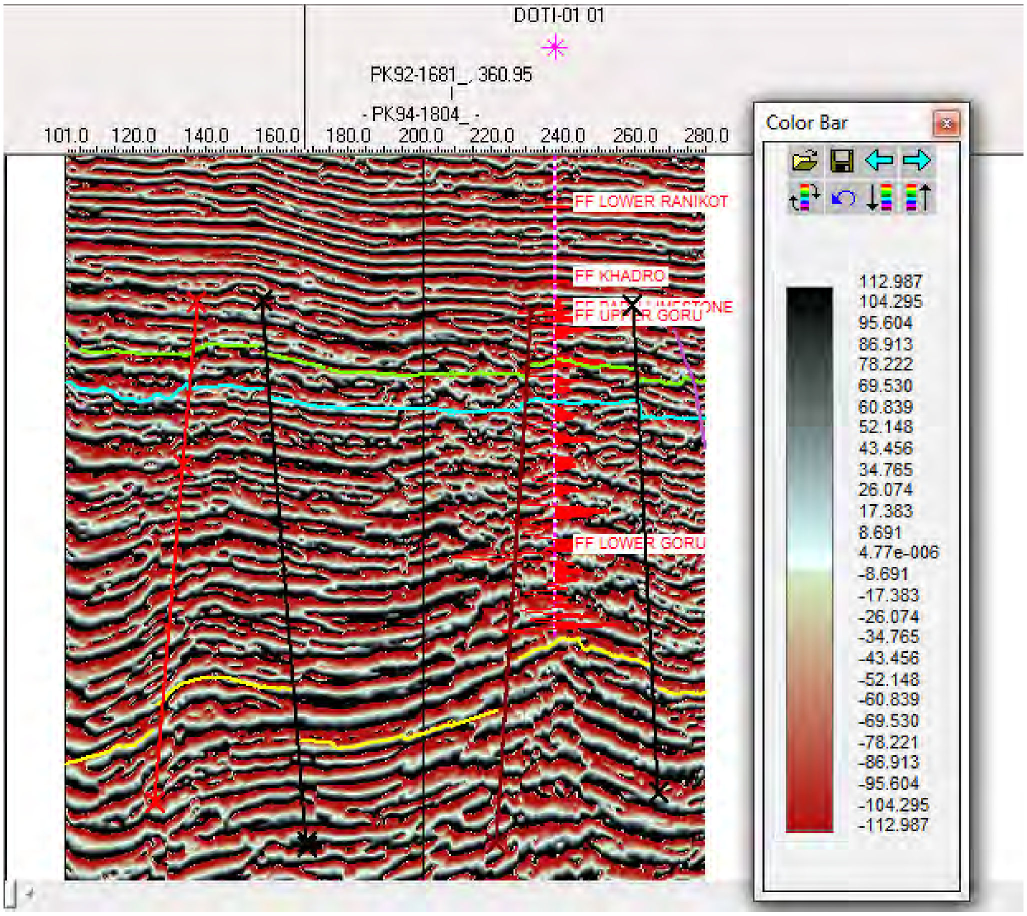

Fig 5.1 Phase attributes of seismic line Pk94-1804

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. Note, however, that it does show abrupt changes at +90 and -90 degrees (due to the arc tan function used to calculate the instantaneous phase). 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,
- Relates to the phase component of the wave-propagation.
- Has no amplitude information, hence all events are represented
- Shows discontinuity, but may not be the best. It is better for showing continuity.

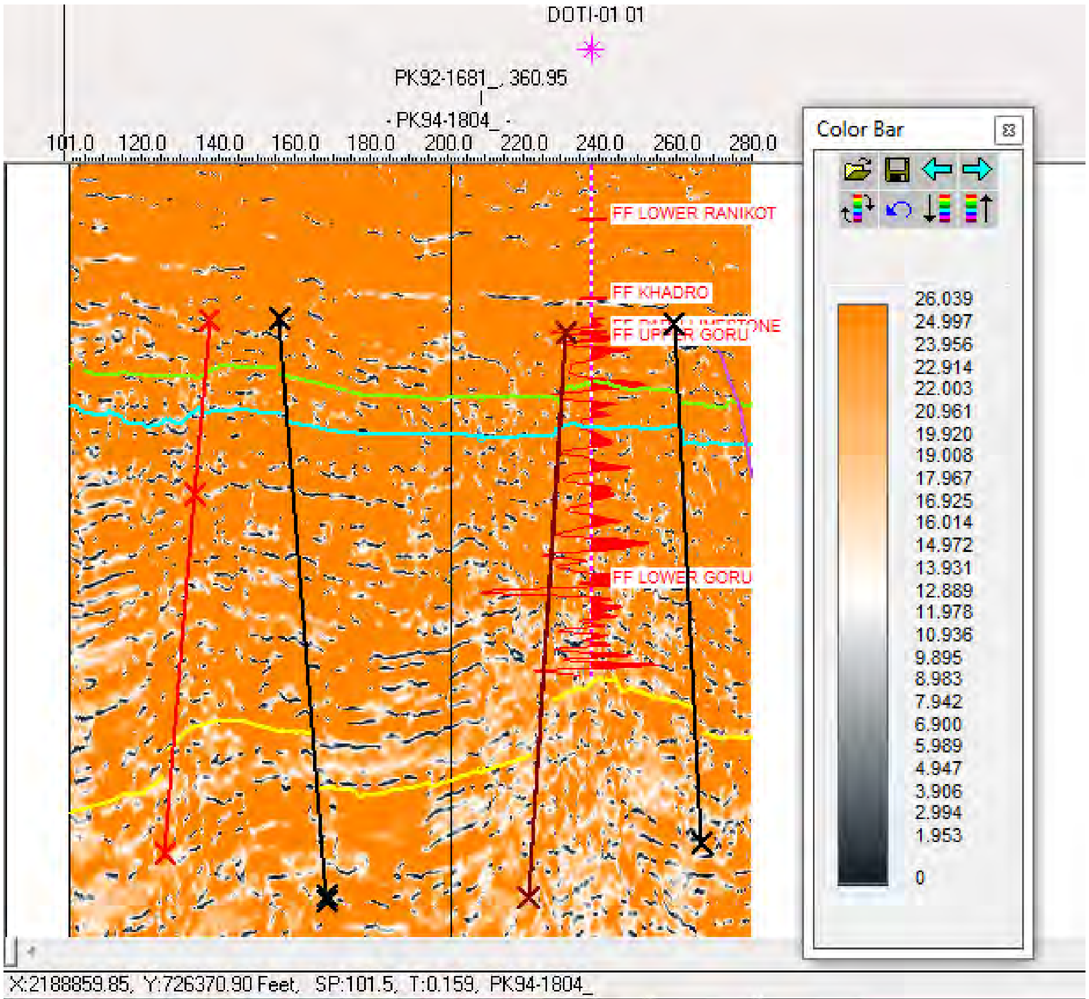

Fig 5.2 Frequency attributes of seismic line pk94-1804

5.5 Conclusion of Seismic Attributes:

Complex seismic trace attributes have become important qualitative and quantitative measures for geophysical exploration. Attributes have made it possible to define seismic data in a multidimensional form and neural network technology enables us to unravel the complex nonlinear relationships between seismic data and rock and fluid properties. Recently published case histories clearly show that multiple attributes overcome the failures associated with single attribute usage. Combined attributes translated by neural networks are becoming principal tools for lithology prediction and reservoir characterization. It is not too unreasonable to expect considerable improvement in the accuracy of predictions in the near future.

Conclusion

1. On the basis of provided seismic and well data different reflectors and faults are confirmed.
2. The seismic interpretation revealed horst and graben structure in Badin area.
3. Time and Depth Contour maps shows Horst and Graben Structure formed in the study area
4. Time and Depth contour maps of Lower Goru help us to confirm the presence of horst and grabben structure in the given area. This structure acts as a trap in the area, which is best for hydrocarbon
5. Petro-physical interpretation results showed low values of LLD and LLS as compared to MSFL. These low values indicate the presence of saline formation fluid.
6. Petro physical analysis shows Lower Goru formations are good reservoirs.
7. Application of Seismic attributes compliments the interpretation.

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