2-DIMENSIONAL MODELLIING AND RESERVOIR CHARACTERIZATION USING WELL DATA OF SINJHORO BLOCK, LOWER INDUS BASIN

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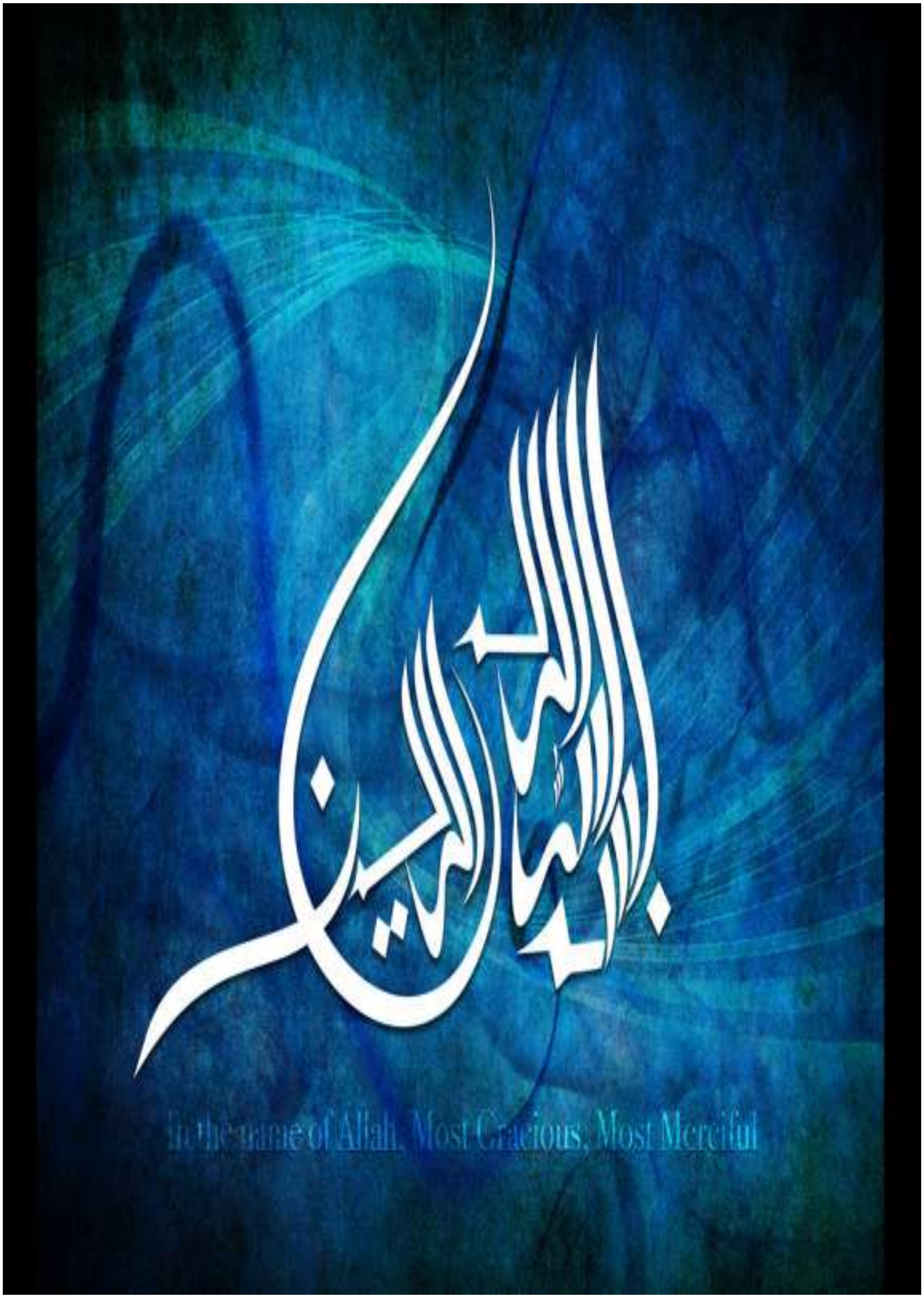
In the name of Allah, Most Gracious, Most Merciful

CERTIFICATE

This dissertation submitted by **RAMEEZ MUNAWAR** S/O **MUHAMMAD MUNAWAR** is accepted in its present form by the Department of Earth Sciences, Quaid-i-Azam University Islamabad as satisfying the requirement for the award of degree of BS Geophysics.

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DEDICATION

MY WHOLE THESIS WORK IS DEDICATED TO MY

PARENTS, MY BROTHERS AND SISTERS, TEACHERS,

FRIENDS

WHO BUILD ME SO HIGH

AND ALL

THOSE WHO LOVE ME AND WHOM I LOVE.

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.

I am especially indebted to my honorable supervisor **DR. MUHAMMAD TOQEER** for giving me an initiative to this study. I specially acknowledge the efforts and support of my seniors of MPhill (Nasir Saleem, Maarij , Mubashir, Umer Abdur Rehman) and my lovely fellows **Maryam Mazhar** and **Javed Iqbal** without which I was unable to reach at this stage.

I pay my thanks to the whole faculty of my department especially the respected teachers whose valuable knowledge, assistance, cooperation and guidance enabled me to take initiative, develop and furnish my academic carrier.

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ABSTRACT

The present study relates to integrated seismic analysis of Sinjhoro with special techniques. The area is part of southern Indus basin. The work is carried out on 4 seismic lines along with petrophysical logs of CHAK 66-01, using Kingdom 8.8 software.

The integrated study involves; structural interpretation of seismic data, time to depth conversion, synthetic seismogram and coloured inversion.

The seismic section shows Horst and graben structure bounded by normal faults. The horizons were identified using formation tops from wells and their depth were confirmed through correlation with synthetic seismogram generated from sonic and bulk density logs. Time, depth and horizon contour maps of the horizons of interest have been generated to understand the spatial geometry of the structures.

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CHAPTER# 1

INTRODUCTION

1.1 <u>INTRODUCTION TO THE STUDY AREA</u>:

Sanghar district is one of the largest district in the Sindh province of Pakistan, bounded by India on the east. The district capital, Sanghar, is itself a small city roughly 56 km south-east of the city of Nawabshah. Sinjhoro is about 2.25 km North-west from Sanghar city.

Sinjhoro is part of Lower Indus basin.The Sinjhoro covering an area of 179.31 square kilometer approximately. It is extensional regime and normal faults are present here. The location of area and its latitude and longitude is given below

Latitude of the area

Latitude of the area is 26° 00’ 00N to 26°15’ 00 N

Longitude of the area

Longitude of the area is 68° 35’ 00E to 69° 05 60 E

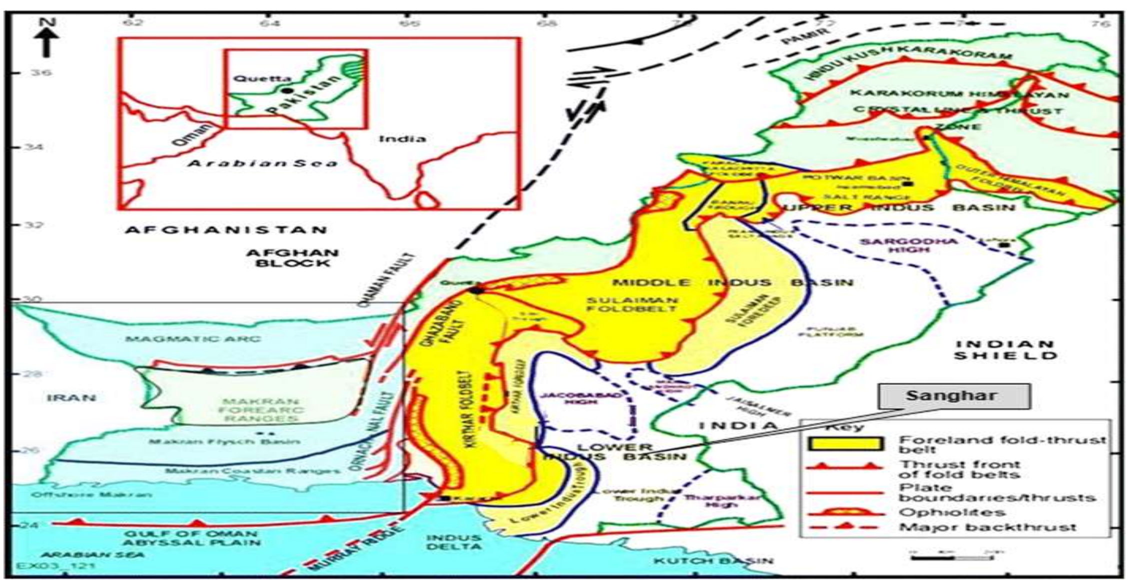


Figure 1 Location of Study Area(www.Google.com)

1.2 SEISMIC DATA :

Seismic reflection, well and navigation data which consist of following formats respectively;

- SEG-Y
- LAS
- Navigation

The project is given to interpret the seismic section along four 2D seismic lines 20017-SNJ-01 , 20017-SNJ-03 , 20017-SNJ-04 , and 20017-SNJ-23.A single well is in the study data to understand the subsurface geology. Dip lines contain short points while well is positioned along strike line. The data is provided by the Department of Earth sciences QAU.

Serial number	**Line number**	**Type**
1	20017-SNJ-01	Strike
2	20017-SNJ-03	Dip
3	20017-SNJ-04	Dip
4	20017-SNJ-23	Dip

Table 1 Seismic Lines Information

Well name	**Unique well ID**	**Elevation(m)**	**Depth Reference**	**Total Depth**	**Status**
CHAK-66-01	001212	0.00	KB	2999	Oil and gas

Table 2 Well Information

1.3 METHODOLOGY:

Seismic reflection data of the Lower Indus Basin of Sinjhoro area is given to us in order to interpret the sub surface structures. In this practice, software Kingdom 8.8 was used. After uploading the seismic lines data on kingdom, synthetic seismogram was generated, from given well i.e. CHAK-66-01 the faults and horizons were marked on seismic section..

1.4 BASE MAP:

A base map is a map on which primary data and interpretations can be plotted .A base map typically includes the locations of concession boundaries, wells, seismic survey points with geographic references such as latitude and longitude. Geophysicists typically use shot points maps, which show the orientation of seismic lines and the specific points at which seismic data were required to display interpretation of seismic data. The two major requirements for the construction of base map are navigation file and seg-y file. Steps for the construction of the base map are elaborated by the flowing flow chart.

Figure 2 shows Base map of Sinjhoro area, this consist of seismic lines 20017SNJ-01 ,20017SNJ-O3,2OO17SNJ-04 and 20017SNJ-23.Our well CHAK66-01 is located on line 20017SNJ-03,which is dip line and its orientation is NS-EW.

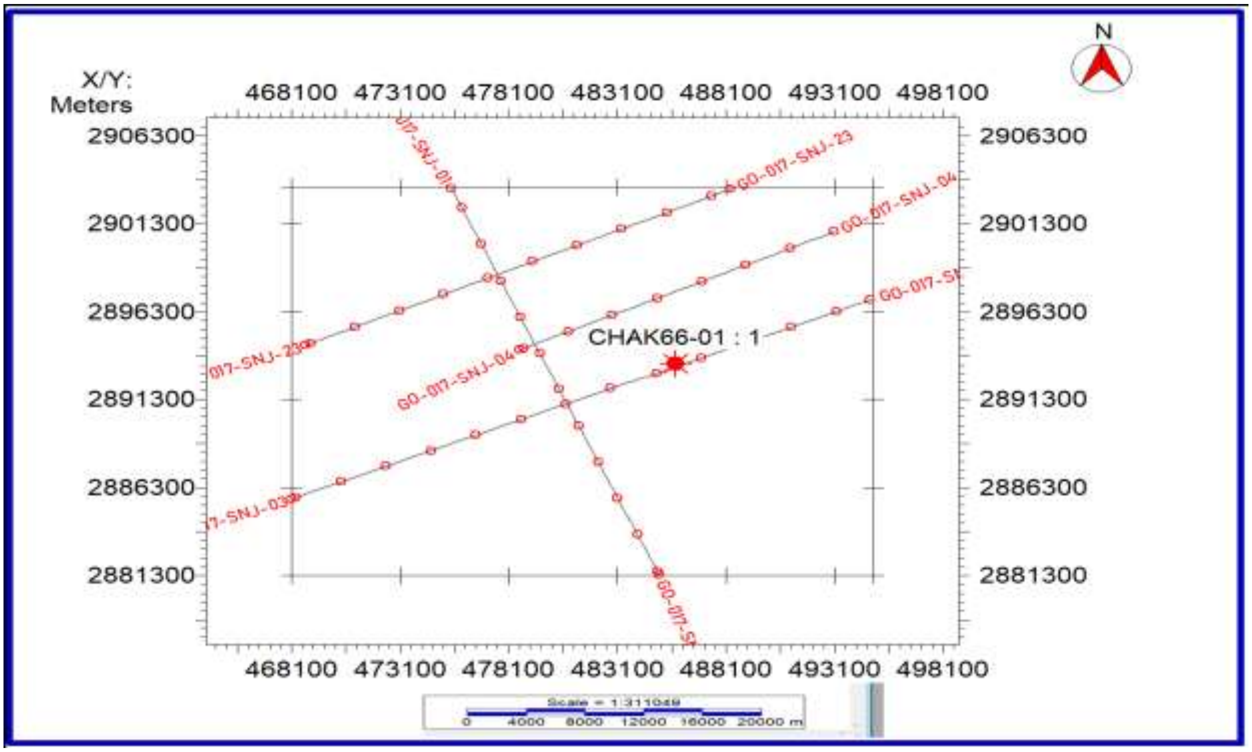


Figure 2 Base Map of Study Area

1.5 OBJECTIVES:

The purpose of this dissertation is to understand the stratigraphic and structural frameworks of the area by using the seismic and well data.

- 2-Dimensional Structural interpretation of Seismic lines shown in table 1 using interactive tool of Kingdom software.
- Study the geology of the area and understanding the structure types.
- Understanding the paleo-structure dynamics by interpreting the geological units.
- Preparation of Time and Depth sections and study their differences.
- Petrophysical analysis of the reservoir rocks using well data and preparation of synthetic seismogram.

CHAPTER# 2

GEOLOGY

2.1 INTRODUCTION:

The information about the geology of the area plays an important role for precise interpretation of seismic data, because some velocity effects can be generated from formation of different ideologies and from some lithological horizons. So as if we don't know geological informations in area we don't recognize the different reflections appearing in the seismic section.

2.2 REGIONAL SETTINGS:

It is considered that in the geological history of Indo- Pakistan shield was a part of Gondwanaland, which got separated from it as a Gondwanaland fragmentation. Indo-Pakistan plate started to move northward drift of Indian plate was near the end around 55my ago (Eocene)

According to (Kazmi and Jan,1997), the geology of Pakistan is divided into two regions, which are given below;

- Gondwana Domain
- Tethyan Domain

The southern part of Pakistan belongs to the Gondwanian Domain and is situated by Indo-Pakistan crustal plate. The north most and the western part of Pakistan falls in the Tethyan Domain and is present complicated geology and complex crustal structure.

2.3 TECTONIC ZONES OF PAKISTAN:

Pakistan is divided into eight tectonic zones, which are as follow (Kazmi and Jan,1997)

- Indus Platform and Foredeep
- East Balochistan Fold and Trust Belt
- Northwest Himalayan Fold and Thrust Belt
- Kohistan-Ladakh Magmatic Arc

- Karakorm Block
- Kakar Khoransan Flysch Basin and Makran Accretionary Zone
- Chagi Magmatic Arc
- Pakistan Offshore

2.4 BASINS OF PAKISTAN:

Pakistan comprises of three sedimentary basins (Riaz Ahmed, 1998)

- Balochistan Basin
- Pishin Basin
- Indus Basin

2.4.1. INDUS BASIN:

The Indus basin belongs to class of extracontinental trough down warp basins.It is largest and so far the only producing basin of Pakistan. The basin is oriented in NE-SW direction. Basement is exposed at two places, one in NE (Sargodha High) and second is SE corner (Nagar parkar high). It is characterized by a large easterly platform region, which dips gently and monoclinally towards NE, a ring of trough or depression in which platform dips and westerly folded and thrusted topographically uplifted region. The convergence between Indian and Eurasian plate has resulted in portioning of the basin into three parts. Upper, middle and lower called as northern, central and southern respectively. (Riaz Ahmed , 1998). Map of different basins of Pakistan and area of interest is shown in Figure 3.

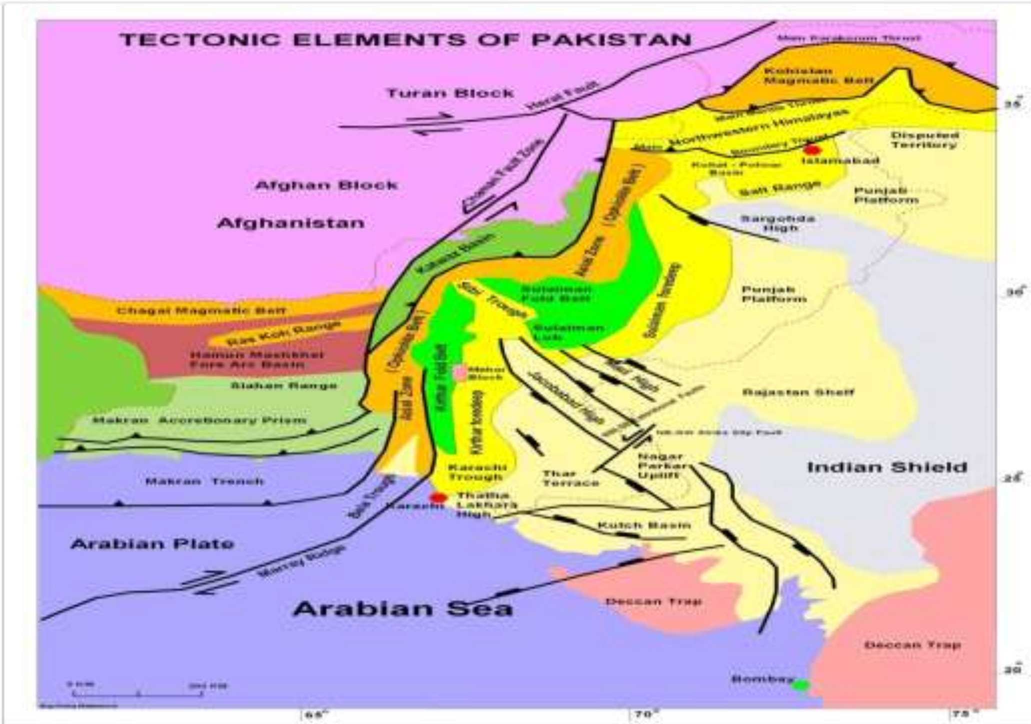


Figure 3 Map of Diffferent Basins of Pakistan(Kadri,1997)

2.4.2. NORTHERN INDUS BASIN:

The basin is characterized by complex structural styles and stratigraphic sequence ranging from Precambrian to recent. A number of oil fields occur in this zone. The Dhurnal Oil Field is the largest one and the reserves of about 52 million barrel of oil and 013 TCF of gas. This basin contains all the Source, Reservoir and Cap rocks. (Kazmi and Jan, 1997)

2.4.3 CENTRAL INDUS BASIN:

The basin is comprised of duplex structure characterized by large anticlines and domes in the passive roof sequence of Suleiman fold belt followed eastward by gently dipping strata of Punjab monocline. The basin contains a sedimentary sequence ranging from pre-cambrian to recent. It contains one of the biggest gas fields called as Sui Gas Field with 8.6 TFC.Central Indus basin is bounded by Jacobabad high in south, Sargodha high in the north, sulaiman foredeep in the west and Indian shield in east. (Kazmi and Jan ,1997)

2.4.4 SOUTHERN INDUS BASIN:

The southern Indus basin (550 by 220 km) extends approximately between latitude 24 degree and 28 degree N and from longitude 66 degree to eastern boundary of Pakistan (V.N.Quadri and S.M. Shoaib, 1986). It is characterized by several structural highs. The slope from the eastern limit of the lower Indus basin, which is bounded by the Indian shield on the east and folded axial belt towards west. It extends to offshore in the north south, whereas in the north it is separated from the central Indus basin by the feature, the Mari kandhkot high.

It comprises the following main units;

- Thar Pltaform
- Karachi Trough
- Kirthar Foredeep
- Kirthar fold belt
- Offshore Indus

2.5 GEOLOGICAL DESCRIPTION OF LOWER INDUS BASIN:

In the present plate tectonic setting, Pakistan lies between northwestern corner of Indian plate, the southern part of Afghan craton, and the northern part of the Arabian Oceanic Plate. The eastern part of Pakistan was effected by tertiary plate convergence , having intense collision between the Indian and Eurasian continent in the Karakorm Thrust Zone to the north, and the translation between the Indo-Pakistan subcontinent and the Afghan craton in the north west (Chamman transform fault).The western part of the country was also effected by the tertiary convergence between the Arabian Oceanic plate and Afghan craton (chaghi arc and the Makran flysch Basin), and between a segment of Arabian oceanic plate and western rift margin of Indo-Pakistan subcontinent.

The western margin of the subcontinent is characterized by the broad NS trending sedimentary basin i.e southern indus basin having a thick tertiary sequence underlain by Quaternary sediments.It had been relatively tectonically stable during the mesozioc, but the intensity of shallow tertiary folding increasing westward and become more pronounced in the strongly folded and faulted area of axial fold and thrust belt (N.A. Zaigham, 2000)

2.6 STRUCTURAL HISTORY:

Structural history of Sindh area is characterized by the extensional regime, which produce normal faulting , and basement related structure within late Paleozoic to quaternary sediments. These sediments were deposited on the penniplained Precambrian basement along the stable margin of Indian shield. A series of extensional events during the late Paleozoic , cretaceous as well as mid tertiary collision between indo-pak and Eurasian plate reactive old faults and produces new faults in the area.NW oriented main structural feature of Talhar fault zone are the results of this extensional tectonics.

2.7 STRATIGRAPHY OF SINJHORO AREA:

Sinjhoro is located in the Thar platform area of southern Indus basin. The sanghar area is characterized by the series of horst and graben structure present almost below the base Paleocene unconformity within the cretaceous. (Gilbert Killing etal, 2002).

2.8 BOUNDARIES OF SINJHORO AREA:

Sinjhoro area is bounded in the east by Indian shield merges into Kirthar and Karachi trough and in the north by Mari bughti inner folded zone. The Indus offshore platform in the south

2.9 TECTONIC ZONES AND GEOLOGY OF SINJHORO AREA:

Sinjhoro E.L is a part of Thar Slope Platform area of Southern Indus Basin. It is bounded in the east by Indian Shield and in the west by Kirthar and Karachi Trough and in the north by Mari-Bugti Inner Folded Zone. During the drift of the Indian plate towards the North-North East, which started in the Triassic, sedimentation took place along the leading edge of the plate in a marginal sag basin. Although several sedimentary cycles can be recognized within this phase, no major tectonic activity occurred until in the Cretaceous. In the lower Indus region, a depositional environment during the Paleocene resembled the pattern of the Mesozoic. However, later during the Eocene, the first orogenic changed completely with the emergence of a volcanic island arc, North West of present day Pakistan. The sediments derived from the arc entered marine environments towards South East and independent decenters developed in various parts of Pakistan. The marine sediments became restricted to a narrow but rapidly subsiding trough in the

Kirthar Area. The clastic supply from the rising Himalayas and from the local positive regions of the axial belt was so abundant that a spectacularly thick sequence of molasses sediments reached more than 7000m. Towards the end of the Paleocene, the Indus Basin was filled with sediments and must have resembled a vast flood plain with braided stream, the only elevation being the hills of the folded belts. This part of Lower Indus Basin represents progradational Mesozoic sequences on a westward inclined gentle slope. Every prograding time unit represents lateral facies variations from continental and shallow marine in the east to dominantly basinal in the west. In Thar Slope Area, all Mesozoic sediments are regionally plunging to the west and are truncated by unconformable volcanic (Basalt of Khadro Formation) and sediments of Paleocene age. Two broad geological divisions of this region the Gondwanian and the Tethyan domains are discussed. In this scenario Pakistan is unique inasmuch as it is located at the junction of these two diverse domains. The southeastern part of the Pakistan belongs to Gondwanian domain and is sustained by the Indo-Pakistan crustal plate. The northern most and western regions Pakistan fall in tethyan domain and present a complicated geology and complex crustal structure. Tectonic zones of lower Indus basin are shown in Figure 4.

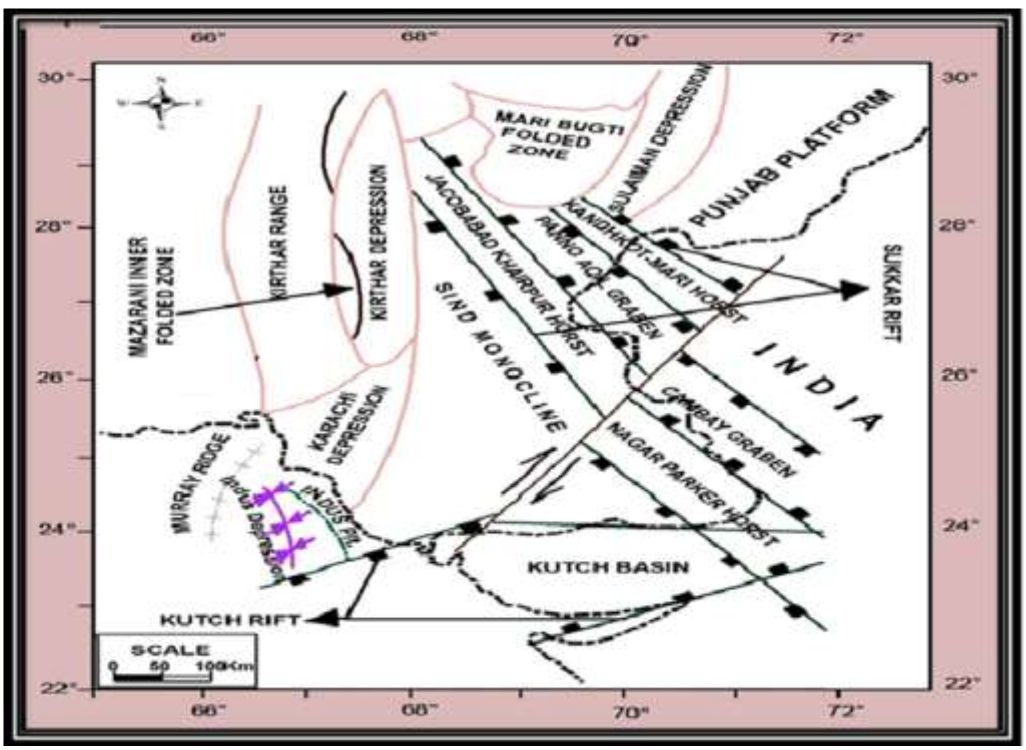


Figure 4 Tectonic Zones Of Lower Indus Basin(www.Goole.com)

2.10 STRUCTURES OF STUDY AREA :

The structure is the result of a normal faulting on the west dipping Indus plain. The fault planes act as way for the migrating fluids from underlying shaly source sequence. Trends of faults and contour are mapped utilizing all well and seismic control for the field.

Seismic interpretation constitutes the basis for the structural interpretation as no surface outcrops are found over the field. The lower guru hydrocarbon accumulation in project area is bounded on the east and on the west by regional extension faults dipping to the east and trending NW-SE.

2.11 HYDROCARBON POTENTIAL OF STUDY AREA :

The oil production has been established in the lower guru sandstones, in layers l, ll and lll of cretaceous age. Progressive rifting of the indo-Madagascar plate commenced, as stretch troughs. Early in the cretaceous period, during the initial phase of the evolution of the rift system the sember formation with significant organic content was deposited under restricted circulation. The formation, along with the basal shale of the lower guru formation, represents the major source of hydrocarbon in the lower Indus basin. With the evolution of the rift system into a more mature half graben stage, the extensional tectonics resulted in tilted fault blocks over the Thar slopes. The lithosphere during the evolution of the rift system underwent readjustment causing subsidence and uplifts.

Coupled with the worldwide eustatic pulses, the changes in sea level influenced depositional environments, resulting in sequence of delta related sand bodies and marine shelf shale deposits. The tectono-eustatic oscillation also creates a number of minor disconformities and marine transgressions. During mid-cenozonian in one such marine submergence,’’ Sinjhoro shale’s” were deposited under more open marine environments and characterized by greater carbonate content (marls and thin limestone bands).After subsequent uplift, many reservoirs in the region.

Following a prominent depositional break, tournian marine transgression created environments for pelagic sedimentation of the upper guru formation. These plastic marls and shale’s provide the capping mechanism with a thickness approaching 1,000 meters in the project area. Tilted fault blocks and horst draped by upper guru ductile lithologies; possibly, along the up dip truncation of post-Sinjhoro shale sand bodies by Tournian disconformities form the prevalent play types. (ECL, 1988)

2.12 <u>SOURCE ROCKS OF STUDY AREA</u> :

The lower cretaceous shale of sember formation are proven source for oil and gas discovered in the lower Indus basin because of its organic richness in oil-prone kerogen type and thermal maturity. The lower part of the guru formation is moderately rich in organic shale having fair to good genetic potential. This shale was geochemically analyzed at shadapur well. Studies based on virginities reflectance infer that the kerogen is virginities dominated and immature up to a depth of 2977 m in lower guru formation. Where amorphous organic matter rich oil prone kerogen become dominant and can be regarded as " potential source rock" paralyses result of shahdadpur well indicate that in lower guru formation from 2925 m to bottom depth, there is a zone of maturity transition from oil and wet gas generation to dry gas generation

2.13 <u>RESERVOIR ROCKS OF STUDY AREA</u>:

Basal sands lower guru (cretaceous) formation is the primary objective in this area. These sands are proven in this area. Average porosities for these sands are around 11% in the prospect area.

2.14 <u>CAP ROCKS OF STUDY AREA</u>:.

A thick Stratigraphy sequence of shale and marl of upper guru formation serve as cap rock for underlying lower guru sand reservoir. Shale of lower guru formation also has same properties

2.15 <u>MAJOR FORMATIONS OF THE AREA</u>:

Followings are the major formations of Sinjhoro area;

2.15.1 <u>CHILTAN LIMESTONE</u>:

It is massive, thick bedded and dark limestone. It shows variation in color and texture. The color varies from black, dark gray, gray, light gray, bluish gray to white. Pisolitic limestone beds are present locally. Texture varies from fin-grained to oolitic. Veins and nodules of black or rusty weathering chert are present locally, thickness of chiltan limestone varies from place to place the chiltan limestone has not yielded identifiable fossil though poorly preserved fragmentary remains are occasionally. The upper contact of chiltan limestone is gradational with mazar drik formation. It has disco formable contact with overlying sember formation. Chiltan limestone correlates with the samanasuk formation of upper Indus basin.

2.15.2 SEMBER FORMATION:

This name was introduced by Williams, after sember pass in the Mari hills, to include lower part of the "belemnite beds". It consists of black silt shale with interbreeds of black siltstone & nodular rusty weathering, argillaceous limestone beds or concretion. Glauconitic is commonly present. Pyretic and phosphate nodules and sandy shale are developed locally in basal part. Thickness is 133 m to 262 m. its upper contact with Chillan limestone & shirinab formation is disco formable while upper contact is generally gradational with guru formation. The formation is reported to contain foraminifers, but most common fossils are belemnites. The age of formation is late Jurassic. The sember formation is correlated with chinchilla formation.

2.15.3 GORU FORMATION:

The name goru formation was introduced by Williams for rocks included by Oldham in the upper parts of his "belemnites beds". Goru formation consists of interceded limestone, shale and siltstone. The limestone is fine grained, thin bedded, light to medium gray. Limestone is dominant in the lower and upper part of the formation. It is 536 m thick in type locality, but decreases to 60 m. the lower contact with the sember formation is conformable, though locally an unconformity has been reported, the formation contains, foraminifers and belemnites, the age of formation is assessed mainly as early cretaceous. It may be correlated with Lumshiwal formation of the kohat-Potwar-province.

It is divided in two parts;

- Lower Goru
- Upper Goru

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.

The basal sand unit, lower shale, middle unit (which has a good reservoir potential), upper shale and upper sand.

UPPER GORU:

The upper goru sequence of the middle to late cretaceous unconformable overlies the lower goru formation, which consist of mainly marl and calcareous clay stone occasionally with inbreeds of silt and limestone. (Gilbert Killing etal,2002).

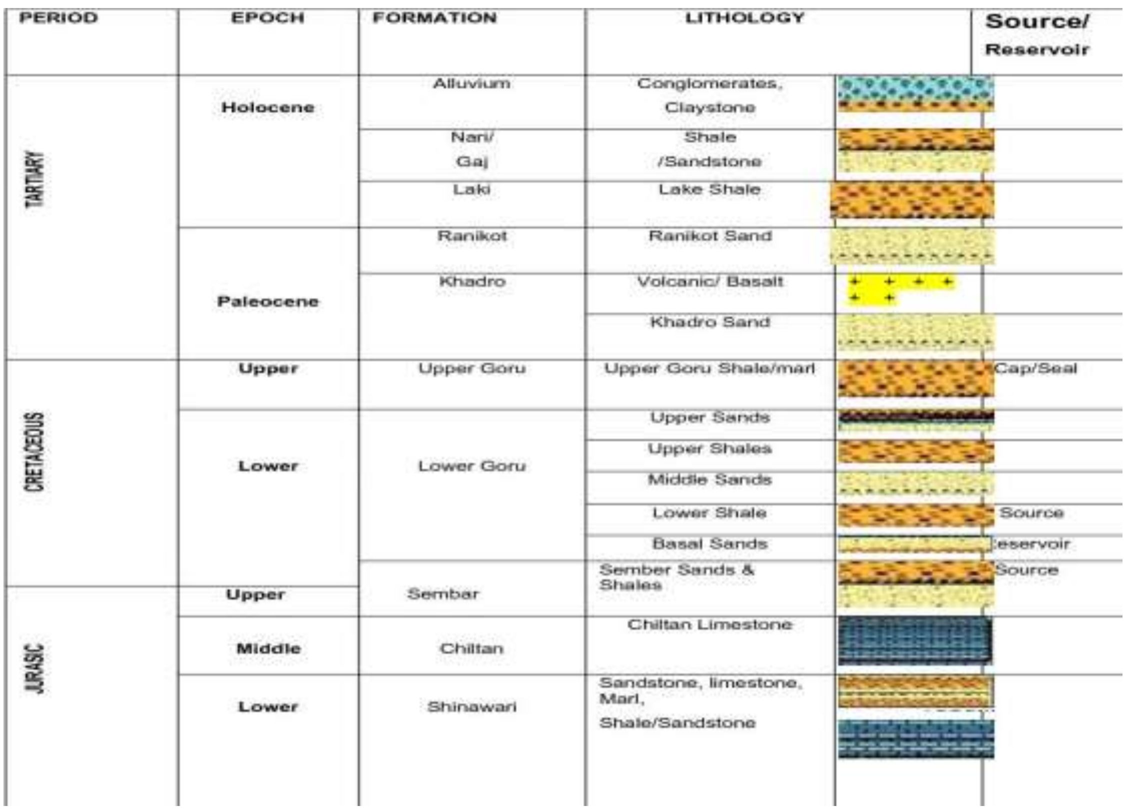


Figure 5 Stratigraphy of The Area(Zaigham and Mallick etal,20000)

2.15.4 PARH LIMESTONE:

It is very distinct unit. It is hard, light grey, white, cream, thin to medium bedded, argillaceous, occasionally platy to slab limestone. It is widely distributed in lower Indus basin. In the type area the thickness is 268 m but varies from 300 m to 600 m. the formation is rich in foraminifers and is dated as late cretaceous. The formation is correlated with the kawagarh formation of the kohat-

Potwar-province.

2.15.5 RANIKOT GROUP:

It is considered to comprise 3 formations, which, in ascending stratigraphic order are, khadro formation (cardita beaumonti beds), Bara formation (lower ranikot) and lakhra formation (upper ranikot).

KHADRU FORMATION:

Cardita beaumonti beds of Branford and later workers were renamed khadro formation by Williams. Both sandstone and limestone are fossilIiferous. Top of unit is usually marked by volcanic flow. It is 170 m thick but may vary from 140 m to 180m. this formation consist of formation, the age of formation is regarded as early Paleocene. It may correlated with the lower part of the Rakhshani formation.

BARA FORMATION:

Ahmad and Ghani have proposed the name Bara formation for the “lower ranikot” of vredenburg and lower ranikot of later workers. The formation consists of dominant sand stone with lesser shale and minor volcanic debris. Sandstone is varicolored, fine to coarse-grained, soft and crumbly. Massive looking beds ranging in thickness from few cm to 3m are common. It is calcareous, ferruginous ripple marked and coarse stratified. Both shale and sandstone are carbonaceous. Ferruginous nodules are usually present. The formation is widely distributed in the Kirthar province and axial belt it is 450 m thick at the type locality , 600m at ranikot and 50 m in subsurface. The formation conformably overlies formation and under lies the lakhra formations at places where the overlying lakhra formation is absent; it is unconformable overlain by the laki formation. No fossils have been reported, except for some oysters, reptile’s remains and carbonized leaf impression. The formation is correlated with Hangu formation of kohat-Potwar-province.

LAKHRA FORMATION:

Ahmed and Ghani proposed the name lakhra formation after lakhra, for “upper ranikot” of vredenburg and “upper ranikot” of later workers.

The formation consists of dominant limestone, which is gray with yellowish staining and weathers brown and buff. It is thin to thick bedded, nodular, and a brecciated texture. Some of the fossiliferous beds are coquina like. It is widely distributed in Kirthar-province and the axial belt. It is 242 m thick at the type section, 135 m at the northern flank of the lakhra anticline and 50 m at Bara nai. In the Kirthar province, it is unconformably overlain by the laki for. Khan, M.H. has recorded presence of rich assemblages of foraminifers, corals, mollusks and echinoids.

CHAPTER# 3

SEISMIC DATA INTERPRETATION

3.1 INTRODUCTION:

Conventional seismic interpretation implies picking and tracking laterally consistent seismic reflectors for the purpose of mapping geologic structures, stratigraphy and reservoir architecture. The ultimate goal is to delineate hydrocarbon accumulation and their extent and also calculate their volumes. Conventional seismic interpretation is an art that requires skill and experience in geophysics and geology.

Seismic interpretation can also be defined as "Transformation of seismic data into structural picture". Similarly,(Coffeen, 1986) writes "Seismic interpretation is the process of determining information about subsurface by using different types of seismic data". It can also act as a development of already established field.

Seismic interpretation is the process of determining the subsurface information of the earth from seismic data. It may determine general information about an area, locate prospects for drilling exploratory wells, or guide development of an already-discovered field (Coffeen, 1986).

To meet the challenges of exploring ever increasingly complex targets, there have been tremendous advancements in data acquisition equipment, computer hardware and seismic processing algorithms in the last three decades (Khan, 1995). The seismic method has thus evolved into a computationally complex science. The computer based working (Processing & Interpretation) is more accurate, precise, efficient and satisfactory which provides more time for further analysis of data. This whole work is carried out using a combination of computer software products, which include Kingdom suit 8.8 etc.

3.2 MAIN APPROACHES FOR INTERPRETATION:

There are two main approaches for the interpretation of seismic section:

- **Stratigraphic Analysis**

- **Structural Analysis**

3.2.1 STRATIGRAPHIC INTERPRETATION:

Stratigraphic analysis involves the subdivision of seismic sections into sequences of reflections that are interpreted as the seismic expression of genetically related sedimentary sequences. Basic principle in the seismic stratigraphic analysis is that reflections are taken to define chronostratigraphic units because interfaces that produce them are the strata surfaces. Unconformities can be mapped from the divergence pattern of reflections on a seismic section. The presence of unconformable contacts on a seismic section provides important information about the depositional and erosional history of the area and environment existing during the time, when the movement took place. The success disconformities, Facies changes, pinch-outs and other erosional truncations. (Sheriff, 1999).

3.2.2 STRUCTURAL INTERPRETATION:

In structural interpretation main emphasis is on the structural traps in which tectonics play an important role. Tectonic setting usually governs which types of structures are present and how the structural features are correlated with each other's, so tectonics of the area is helpful in determining the structural style of the area and to locate the traps. Structural traps include the faults, anticlines, duplex etc. (Sheriff, 1999).

- Reflection configuration
- Reflection continuity
- Reflection Amplitude
- Reflection Frequency
- Internal Velocity
- External Form

Seismic sections can predict the structure that scale up to few tens of kilometers. For large scale interpretation we have to use the grids of seismic lines. Immigrated section is not suitable for structure interpretation, because it creates many problems like synclines becomes narrows and vice versa. Even a migrated section not fully fit for complex area like the area of study.

Some seismic section contains images that can be interpreted without any difficulty. Discontinuous reflectors clearly indicate faults and undulating reflections reveals folded beds. Most interpretation of structural features are directly marked on seismic time sections (Robinson & Coruh, 1988). Work flow for interpretation is shown in Figure 6.

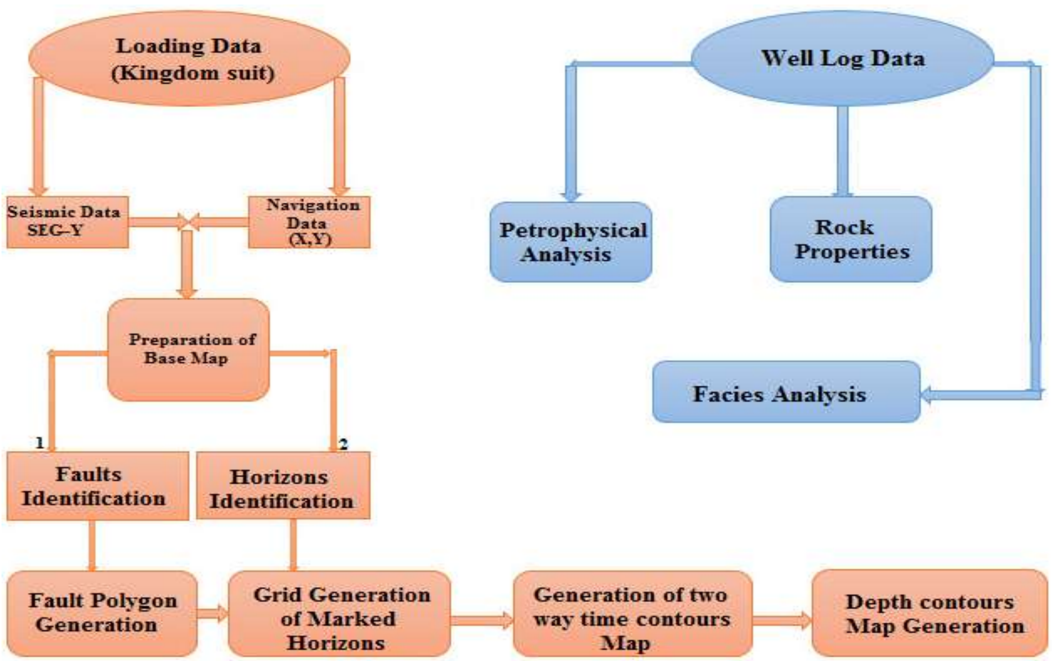


Figure 6 Work Flow For Interpretation

3.3 SYNTHETIC SEISMOGRAM:

A synthetic seismogram, commonly called a synthetic, is a direct one dimensional model of acoustic energy traveling through the layers of the Earth. The synthetic seismogram is generated by convolving the reflectivity derived from digitized acoustic and density logs with the wavelet derived from seismic data. By comparing marker beds or other correlation points picked on well logs with major reflections on the seismic section, interpretation of the data can be improved. Synthetic seismogram is shown in Figure 7.

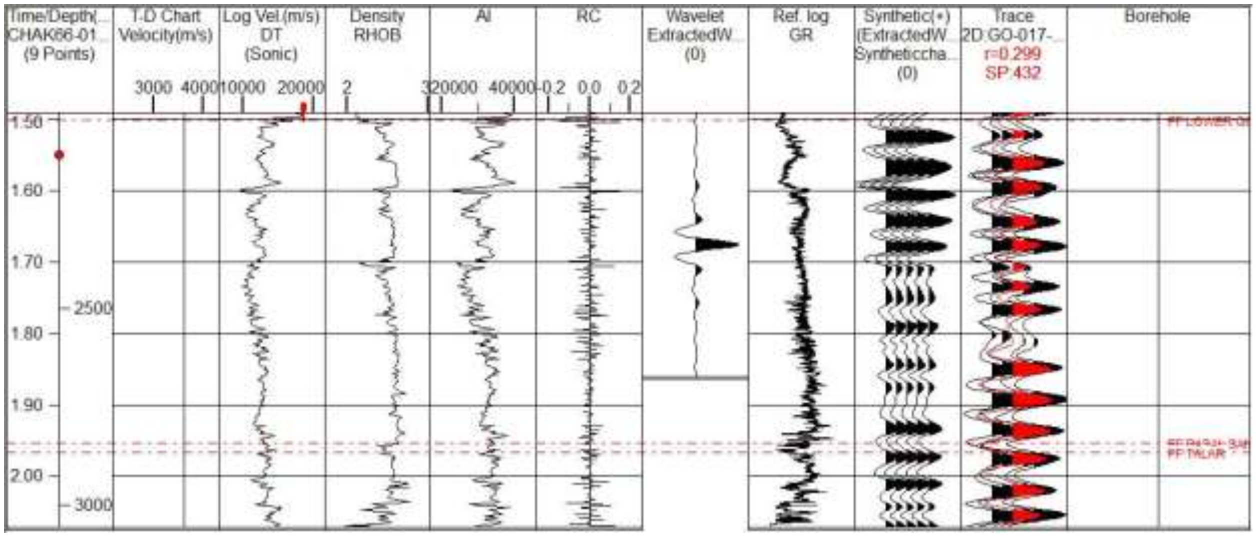


Figure 7 Synthetic Seismogram

3.4 <u>OBJECTIVE OF WELL SEISMIC TIE</u>:

- Well seismic tie allow well data, measured in units of depth, to be compared with seismic data measured in units of time.
- This allows us to relate horizon tops identified in a well with specific reflections on seismic sections.
- We use sonic and density logs to generate synthetic seismogram trace.
- The synthetic trace is compared with the real seismic data collected near well location.

3.5 <u>HORIZON PICKING AND FAULT MARKING</u>:

Primary task of interpretation is the identification of various horizons as an interface between geological formations. For this purpose good structural and stratigraphic knowledge of the area is required.Thus during interpretation I mark both, the horizons and faults on seismic section

The SEG -Y format data of seismic line 20017-SNJ-01, 20017- SNJ-03 and 20017- SNJ-04 is loaded by kingdom software for interpretation. After loading data in kingdom software the horizons are marked on line 20017-SNJ-03 by using the available TD data of CHAK66-01 and by the correlation of synthetic seismogram which is made by using Sonic and Density logs of the same well. Since Sinjhoro area lies in the extensional regime so it comprise of normal faults thus the following sections shows horst and Graben Geometry Figure 8,9,10

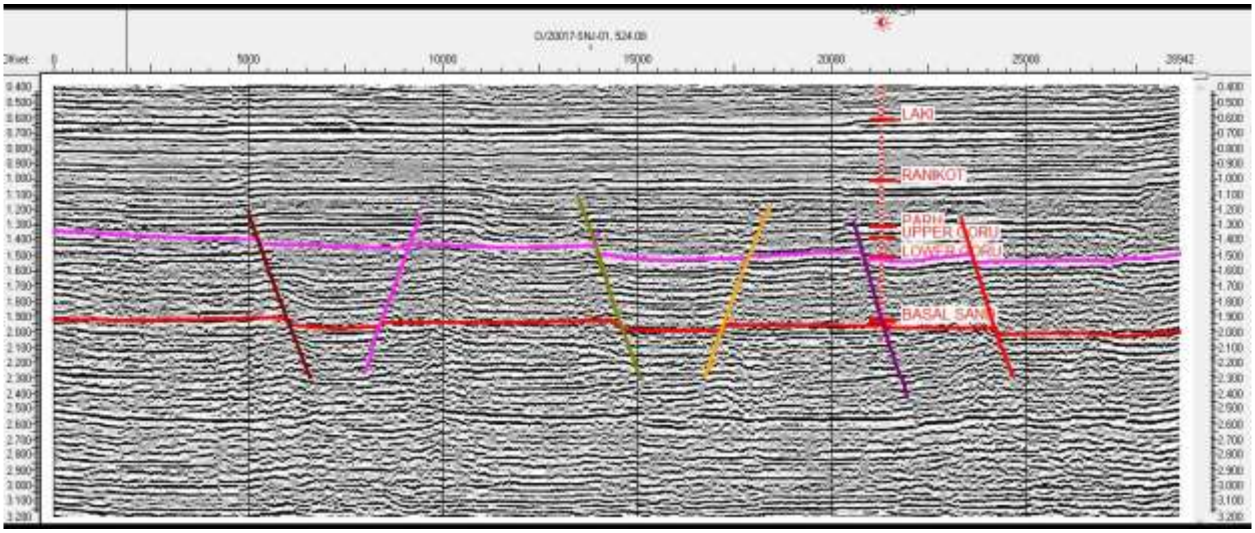


Figure 8 Interpreted seismic section of line 20017SNJ-03

Our well is located on line 20017SNJ-03.It is dip line.Six major faults are marked on this line along with two horizons. As normal faulting occur so horst and grabben structures clearly seen.

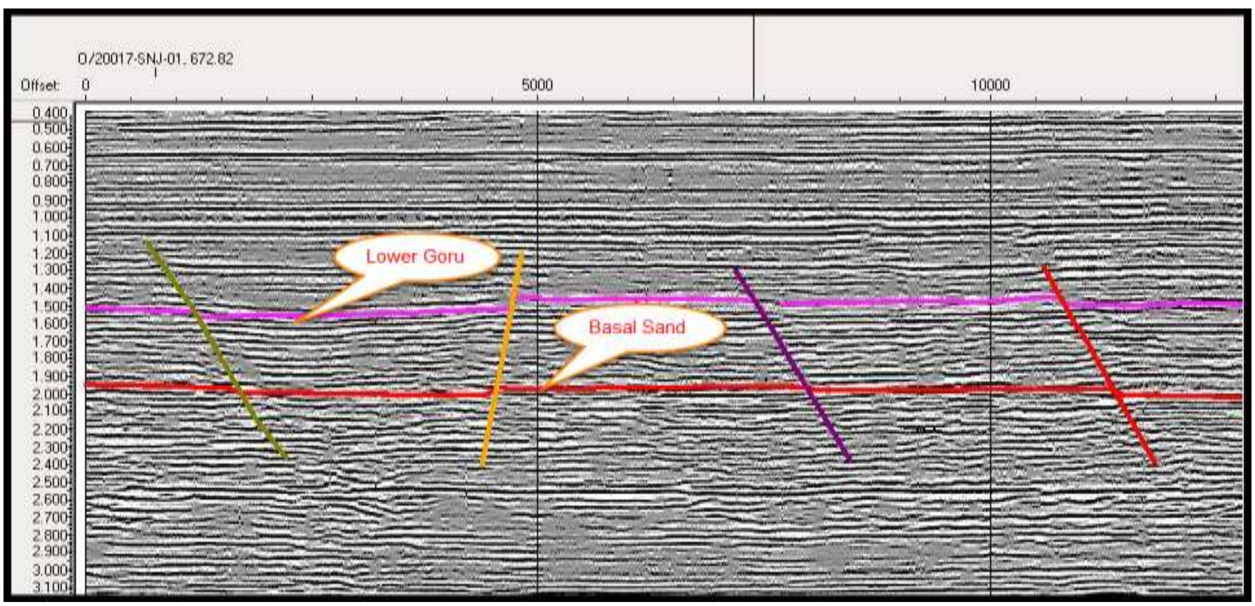


Figure 9 Interpreted seismic section of line 20017SNJ-04

Line 20017SNJ-04 is also dip line.Major faults are marked.Two horizons are marked which are Lower Goru and Basal sand.

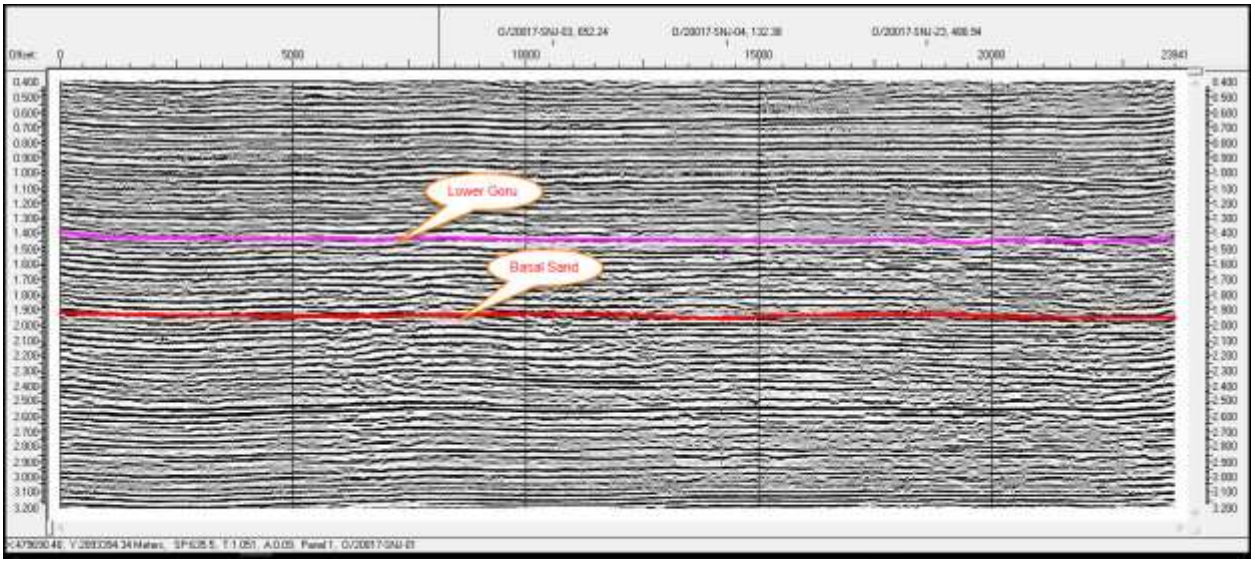


Figure 10 Interpreted seismic section of line 20017SNJ-01

20017SNJ-01 is strike line it gives straight reflectors.Two horizons are marked starting from Lower Goru to Basal Sand.

3.6 CONTOUR MAPS:

The results of seismic interpretation are usually displayed in map form. Mapping is part of the interpretation of the data. The seismic map is usually the final product of seismic exploration, the one on which the entire operation depends for its usefulness. The contours are the lines of equal time or depth wandering around the map as dictated by the data (Coffeen, 1986)

Contouring represents the three-dimensional earth on a two dimensional surface. The spacing of the contour lines is a measure of the steepness of the slope; the closer the spacing, the steeper the slope. A subsurface structural map shows relief on a subsurface horizon with contour lines that represent equal depth below a reference datum or two-way time from the surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip, and any faulting and folding.

3.6.1 TIME CONTOUR MAPS:

Two way time maps are made at different levels which show the position of that formation in time. In this study, time maps are constructed for basal sand. Contour interval is kept to 0.4msec. Low values of time are associated with shallow levels which represent horst block and high values of time are associated with deeper levels which represent graben. All the wells are drilled on horst blocks.Figure 11 shows time contour map of Basal Sand.

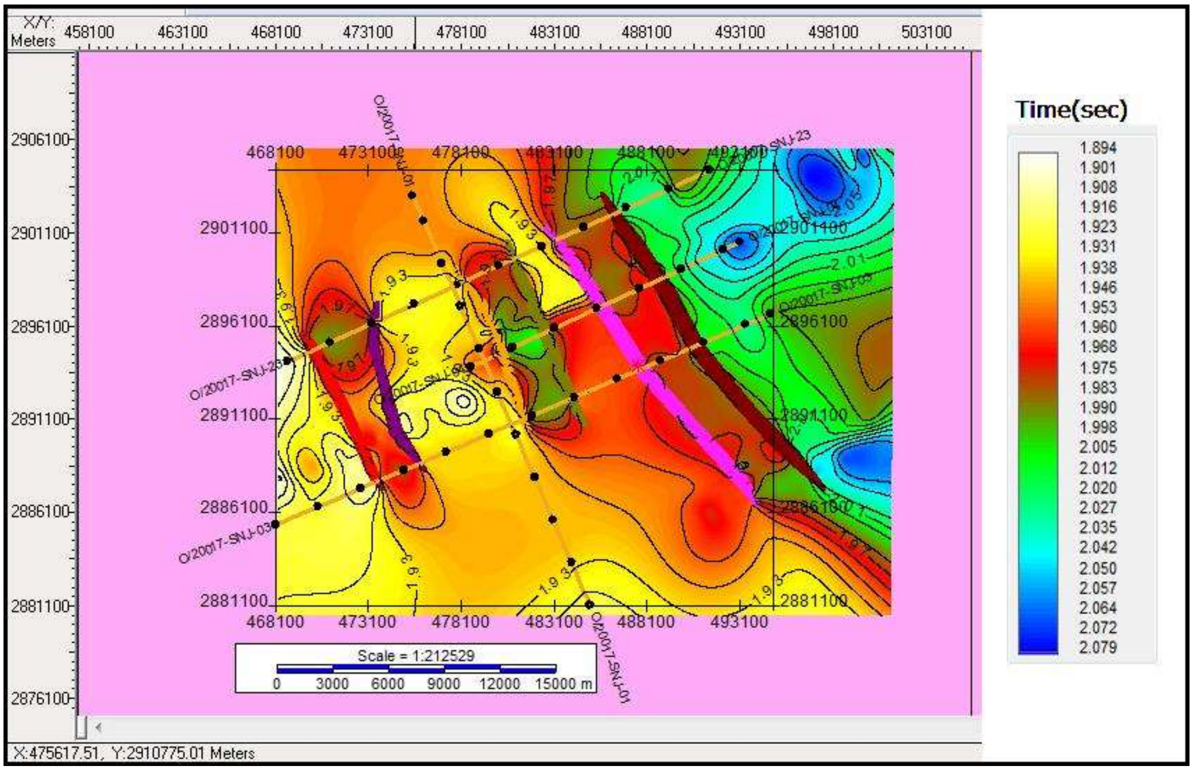


Figure 11 Time contour map of Basal Sand

3.6.2 DEPTH CONTOUR MAP OF BASAL SAND:

A depth contour map at Basal sand has been prepared Figure 12. Depth contour map is plotted with contour interval of 0.4m. These maps show overall horst and graben structure.

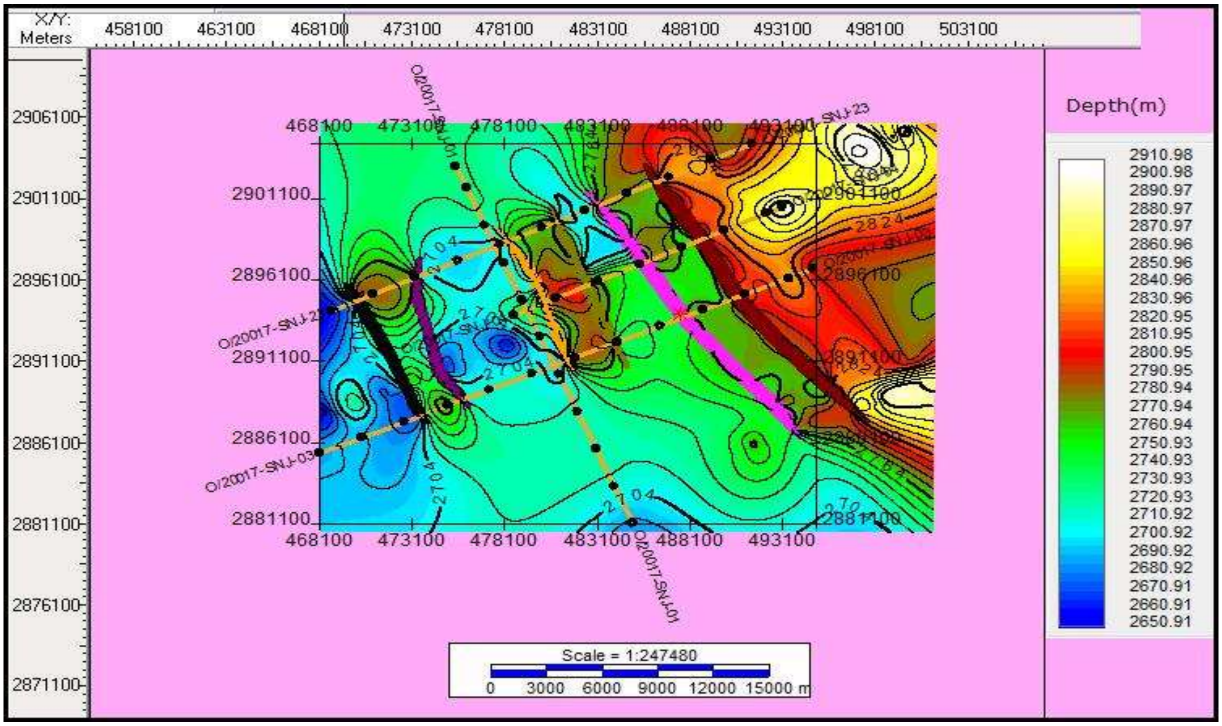


Figure 12 Depth contour map of Basal Sand

CHAPTER# 4

PETROPHYSICS

4.1 INTRODUCTION:

Petrophysics is study of physical and chemical properties define occurrence and behavior of rocks and fluids. To accurately define hydrocarbons in reservoir, measurements such as density, porosity and resistivity are made in drilled wellbore, from which average porosity, volume of shale, water saturation versus hydrocarbon saturation are calculated. Petrophysics is concerned with using well bore measurements to subsidize reservoir description (Daniel, 2003).

4.2 TYPES OF LOGS:

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

4.2.1 SPONTANEOUS POTENTIAL LOG:

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

In shally sections, the maximum Sp response to the right can be used to define a ‘’shale line’’. Deflection of Sp log from this line indicate zone 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, sand stones are tightly cemented or the interval is completely bitumen saturated i.e. oil sands.

4.2.2 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.

4.2.3 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

Types of Resistivity Logs:

- Lateral Log Shallow.
- Lateral Log Deep.
- Micro spherically Focused Log.

4.2.4 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 petro physics. (Schlumberger, 1974)

$$\varphi = \frac{t_{log} - t_{ma}}{t_f - t_{ma}}$$

4.2.5 <u>DENSITY LOG</u>:

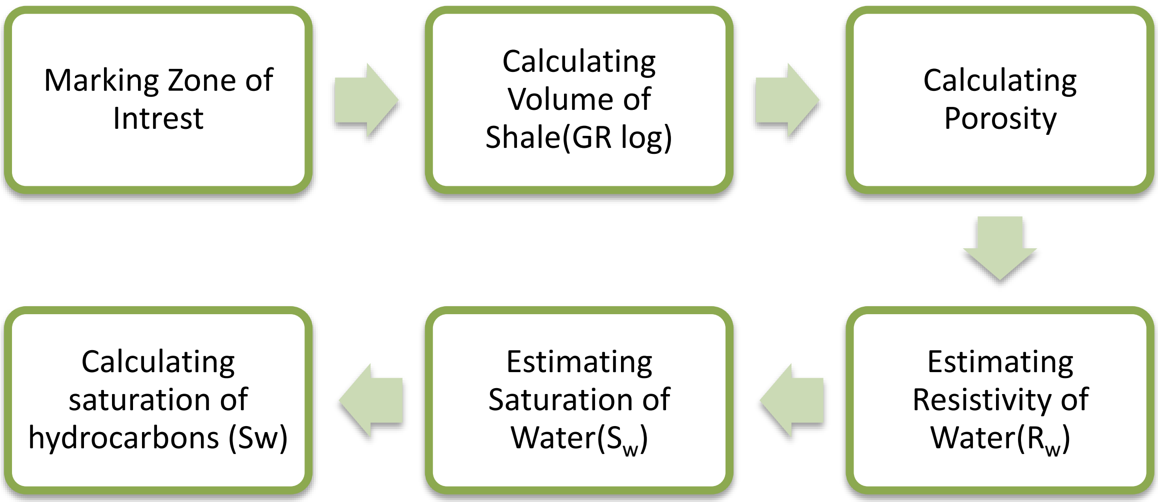
Density logs measure the bulk electron density of the formation, and are measured in kilograms per cubic meter (gm/cm3 or kg/m3). Thus, the density tool emits gamma radiation which is scattered back to a detector in amounts proportional to the electron density of the formation. The higher the gamma ray 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). (Schlumberger, 1974)

$$\emptyset = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

4.2.6 <u>NEUTRON LOG</u>:

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. (Daling, 2005)

WORK FLOW FOR PETROPHYSICS:



4.3 VOLUME OF SHALE:

Shale is more radioactive than carbonate or sand, gamma ray logs can be used to calculate volume of shale in porous reservoirs. The volume of shale can then be applied for analysis of shaly sands.

The following formulae from Schlumberger, 1974

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

Where;

IGR = gamma ray index

GR_{log}= gamma ray reading of the formation

GR_{min} = minimum value of gamma ray (clean sand and carbonate)

GR_{max} =maximum value of gamma ray (shale)

CONSOLIDATED:

$$Vshale = 0.33 * [2^{2*IGR} - 1]$$

UNCONSOLIDATED:

$$Vshale = 0.0883 * [2^{3.7*IGR} - 1]$$

4.4 CALCULATION OF RESISTIVITY OF WATER:

The Resistivity of Mud Filtrate at Zone of Interest (Reservoir Formation) is calculated by the equation given below:

$$R_{mf1} = R_{mf2} * (T_1 + \frac{6.67}{T_2} - 6.67$$

Where:

R_{mf1} = Resistivity of mud filtrate at surface temperature

R_{mf2} = Resistivity of mud filtrate at formation temperature

T_1 = surface temperature

T_2 = formation temperature

4.5 CALCULATION OF WATER SATURATION:

The fraction of pore spaces containing water is termed as Water Saturation (Sw) which is calculated by from the Archie’s formula given by; (Schlumberger, 1974)

$$Sw = \sqrt[n]{\frac{aRw}{\emptyset m R_T}}$$

Where;

R_W = Resistivity of water

R_T = True Resistivity

$\emptyset$ = Porosity

m=Cementation Factor

n=Wet ability factor

a = constant

4.6 CALCULATION OF HYDROCARBON SATURATION:

The fraction of pore spaces containing Hydrocarbons is known as Hydrocarbon Saturation and mathematically given by the following equation;

$$Shc = 1 - Sw$$

Where;

Shc= saturation of hydrocarbon

Sw= saturation of water

4.7 RESULTS OF WELL CHAK66-01:

The well log of the CHAK 66-01 well has been interpreted by using the KINGDOM software (Figure 13). Lower goru is our reservoir which has A, B and C type of sands. Reservoir has Various Zones in the well which have been observed on the basis of logs interpretation. Due to the fact that log data only recorded in depth starting from 2000m to 3000 m but we croped the zone of interest only from 2118m to 2142m. This has done due to fact that there is no major anomaly or difference identified in other logs and behavior of logs is another reason which restrict us from marking other zones. The results shows that also there are clean sand in Zone of interest because of low shale value and high matrix value indicated but water saturation increases in this zone and hydrocarbon is less in this zone (Figure 13), but it has good effective porosity with few amount of hydrocarbons are also present which may be recovered. From all this we can conclude that CHAK 66-01 may be a hydrocarbon producing well. Zone depth ranges from (2118-2142) Meters Lower Goru reservoir. (Table 3)

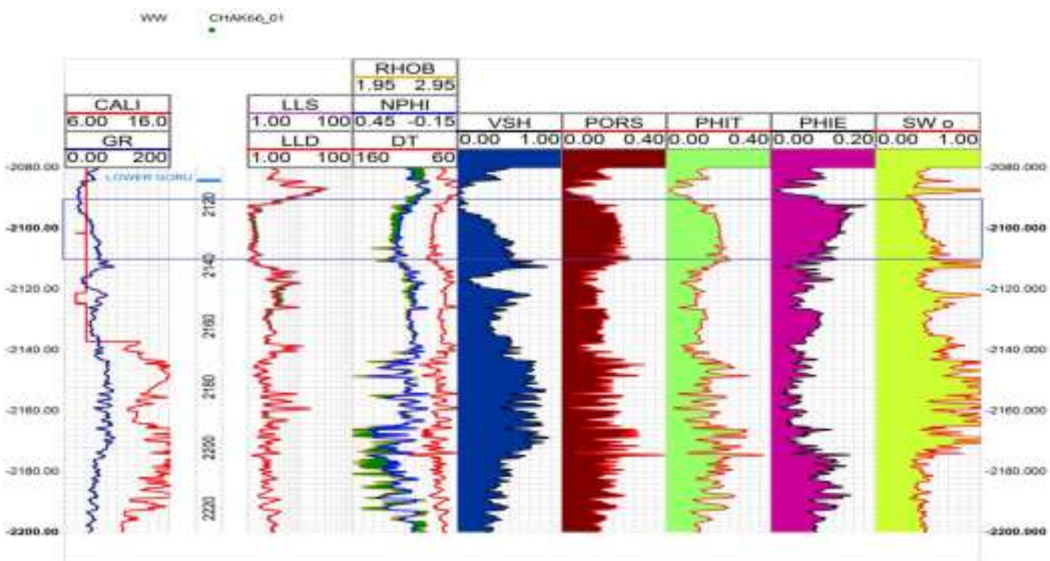


Figure 13 Petrophysical behaviour of potential HC zone of Lower Goru

Serial No	Parameters	Percentage %
1	Average Shale volume(VSH)	31
2	Average Porosity from Density log(RHOB)	16
3	Average Porosity in(PHIT)	17
4	Average Effective Porosity(PHIE)	11.5
5	Average Water saturation(SWo)	43
6	Average Hydrocarbon(Sh)	57

Table 3 Calculation of parameters of CHAK66-01

CHAPTER# 5

COLOURED INVERSION OF POST STACK DATA

5.1 WAVELET AND ACCOUSTIC IMPEDANCE:

For many seismic processing applications, it becomes necessary to derive an estimate of the seismic wavelet. Because the character of wavelet is imprinted on seismic trace, it is important to gunderstand its shape in order to decipher the properties of earth's interior from seismic traces. In spite of the fact the wavelet is time varying and is expected to be spatially varying , an overall knowledge of wavelet is crucial to enhancing resolution for better imaging of structure and predicting lithology and fluid content. The most common practice is to invert the post-stack seismic data for wavelets. A post-stack trace emulates a zero-offset or normal incidence seismogram, which can be simulated using convolution model assuming 1D earth model. Most seismic data contain noise this problem must be compensated.

In frequency domain, the convolution operation is replaced by a multiplication. Three inverse problems are identified:

- Estimation of the wavelet when the reflection coefficient is known.
- Estimation of reflection coefficients or acoustic impedances when the wavelet is known.
- Simultaneous inversion for acoustic impedance of wavelet.

Inversion of seismic data to acoustic impedance is usually seen as a specialist activity, so despite the publicized benefits, inverted data are only used in a minority of cases. To help overcome this obstacle we aimed to develop a new algorithm which would not necessarily be best in class, but would be quick and easy to use and increase the use of inversion products with in BPA. This new technique "Colored Inversion", performs significantly better than the traditional fast-track routes such as recursive inversion, and benchmarks well against unconstrained sparse-spike inversion.
Once the Colored Inversion operator has been derived it can be simply applied to the data on the interpretation workstation as a 'user defined filter'. In this way inversion can be achieved within hours since the volume data do not have to be exported to another package, and no explicit wavelet is required.

5.2 METHODOLOGY:

The well data and information of logs is required for the performing the colored inversion in Kingdom Software

- The velocity is obtained from sonic log and density is obtained from density log and values of densities are obtained from density log by convolving these values.
- We get acoustic impedance by cross-matching these impedance data with the input reflection data.
- We derive a single optimal matching filter Figure20 . Convolving this filter with the input data we see in Figure 19 that the result is very much similar, everywhere.
- This empirical observation indicates that inversion can be approximated with a simple filter and that it may be valid over a sizeable region.

The phase of the operator is constant -90^{o} which is in agreement with the simplistic view of inversion being akin to integration, and concept of a zero-phase reflection spike being transformed to a step AI interface, provided the data are zero-phase.

Walden and Hoskins's (1984) empirical observation tells us that earth reflection coefficient series have spectra that exhibit a similar trend that can be simply described as constant function. The term is a positive constant and is frequency arrives at a similar observation theoretically may vary from one field to another but tends to remain reasonably constant with in any one field (Velzeboer ,1981)

It therefore follows that if our seismic data are inverted correctly they too should show the same spectral trend as logs in the same area.

5.3 NON UNIQUENESS AND CONVOLUTION:

The process of convolution for constructing a seismogram using a wavelet and acoustic impedance is performed to generate an operator. Note that wavelet is smoothly varying function, while the reflectivity is a series of delta functions placed at two-way normal time of each reflector (Cooke and Schneider 1983). The spectra of the wavelet and reflectivity series for synthetic are also shown in figure14. We observe that wavelet is a band-limited, while reflectivity series is a broad-band. Because the convolution is equivalent to multiplication in frequency domain the spectrum of resulting seismogram is band-limited as well. We can imagine the complexity of the problem further we can take into account the loss of high frequencies of wavelet caused by attenuation. In other words series cannot be assumed to be stationary. Even under stationary conditions the data does not contain all the frequencies. The most common approach to deriving the wavelet is based on well-log data that produce a true reflectivity series.

5.4 <u>WAVELET EXTRACTION</u>:

The wavelet is shown in Figure is extracted on the basis of the well log data that provides the true reflectivity series (i.e. compressional wave velocity and density computed into acoustic impedance logs, which are mapped into normal incidence reflectivity series). An initial guess of wavelet is convolved with reflectivity series and synthetic normal incidence trace is generated. The difference between the observed and synthetic traced is minimized using a suitable chosen norm with smoothness constraints (Mrinal K. Sen).

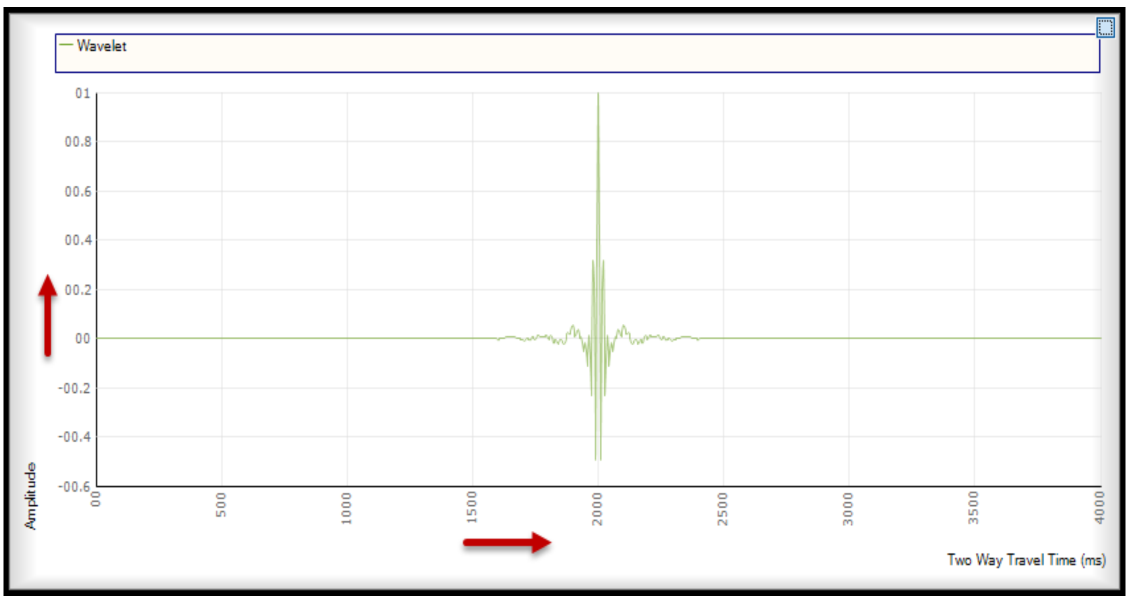


Figure 14 Extracted Wavelet

5.5 <u>IMPEDANCE ESTIMATION</u>:

Now our approach is to convolve this wavelet with acoustic impedance (reflectivity series). The acoustic impedance is also computed from well log data as described previously. The impedance spectrum is shown in Figure 15 is estimated after removing source wavelet; noise must be absent; all multiple reflections must be removed; spherical spreading including all plane reflections (Ghosh ,2000).

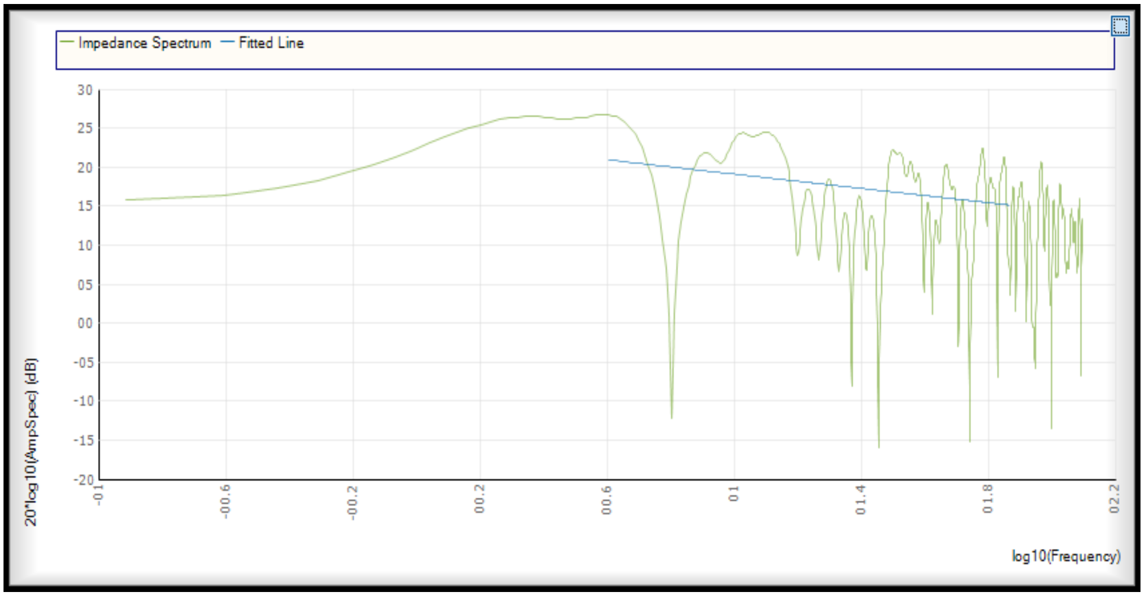


Figure 15 Impedance Spectrum with Fitted Line

5.6 <u>BUTTERWORTH FILTER</u>:

The Butterworth filter is a type of signal processing filter designed to have as flat a frequency response as possible in the pass band. It is also referred to as a maximally flat magnitude filter. It was first described in 1930 by the British engineer and physicist Stephen Butterworth in his paper entitled "On the Theory of Filter Amplifiers. An ideal electrical filter should not only completely reject the unwanted frequencies but should also have uniform sensitivity for the wanted frequencies. This filter is used here for convolution of the wavelet and reflectivity series for formulation of seismogram. The Butterworth filter is shown in Figure16.

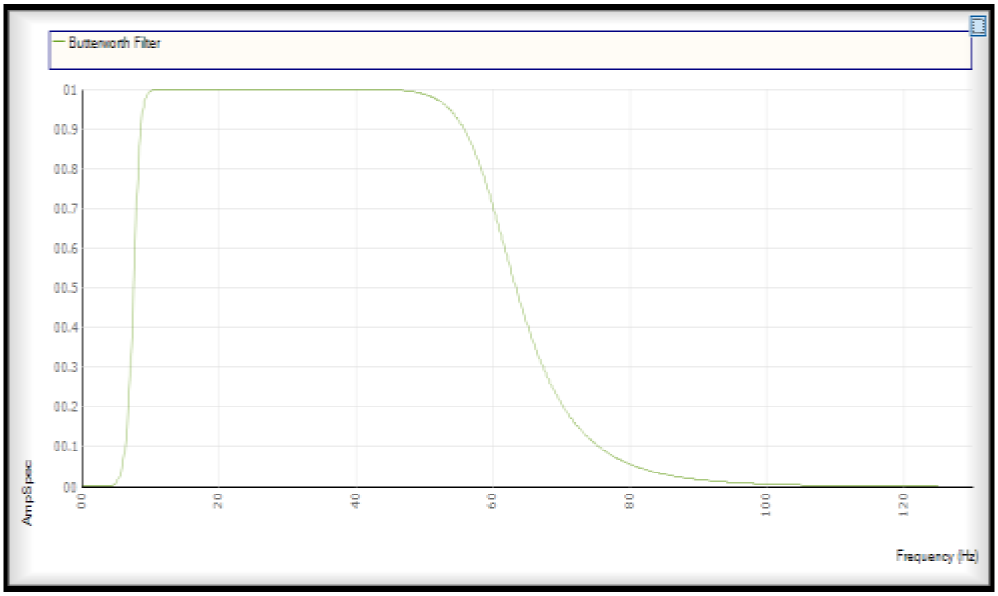


Figure 16 Butterworth Filter

After the process of convolution is performed we get the seismogram (operator). There is a vast difference between the seismogram of our desire and the seismogram we obtained from the convolution

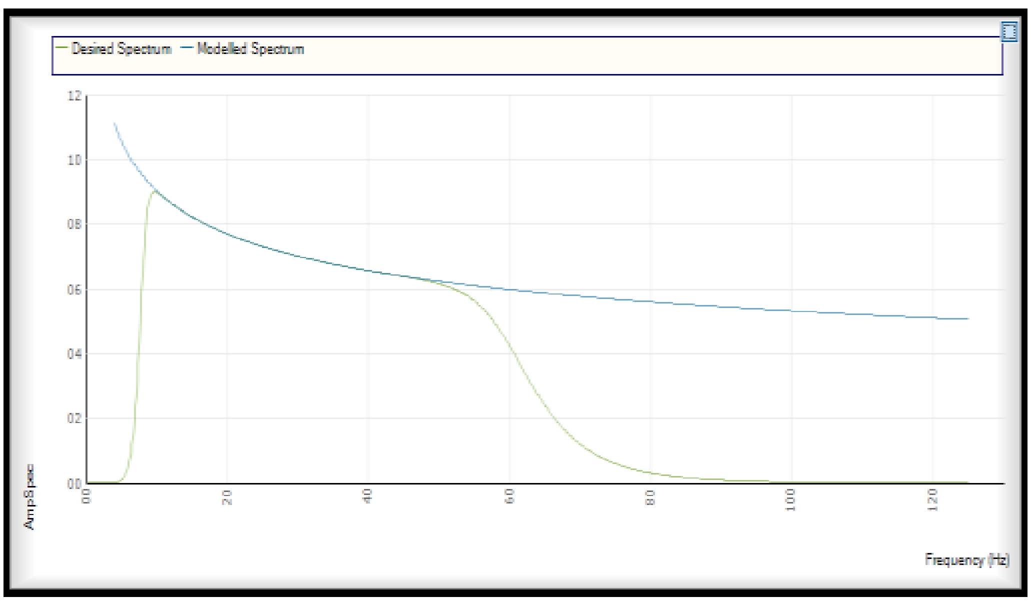


Figure 17 Desired and Modeled spectrum

There are two spectrums shown in Figure 17 both are of different colors. The blue color shows the spectrum obtained from convolution of wavelet and acoustic impedance and the spectrum in blue color shows a desired spectrum. Now we need to obtain a spectrum of our desire for this purpose we have to convolve this spectrum with another spectrum known as shaping spectrum which is obtained by applying Fourier transformation on desired spectrum. The Figure 18 shows us the shaped seismic spectrum and desired seismic spectrum.

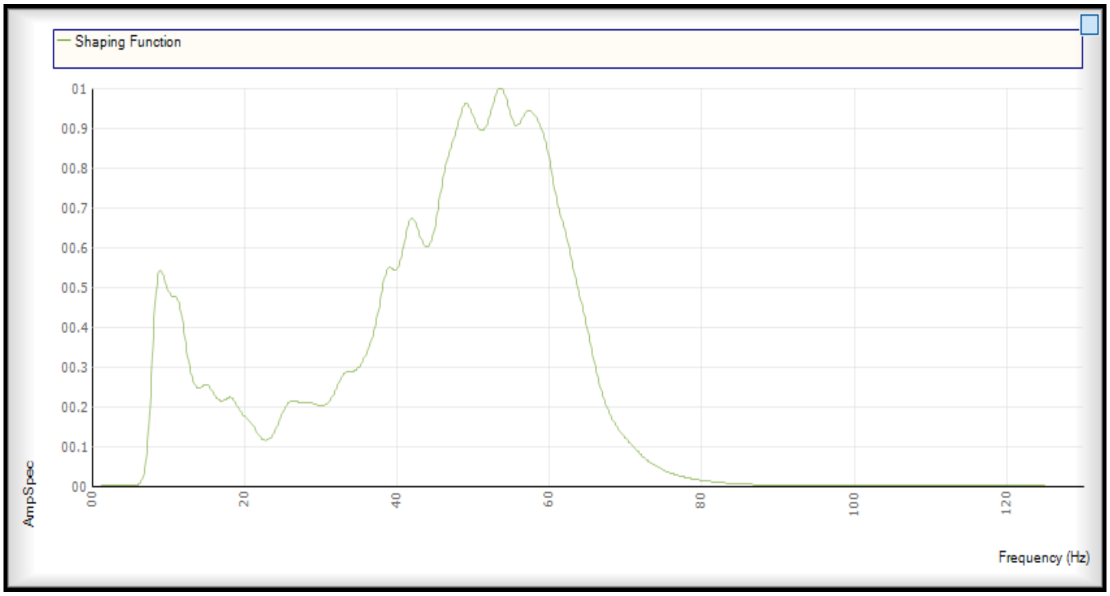


Figure 18 Shaping Spectrum

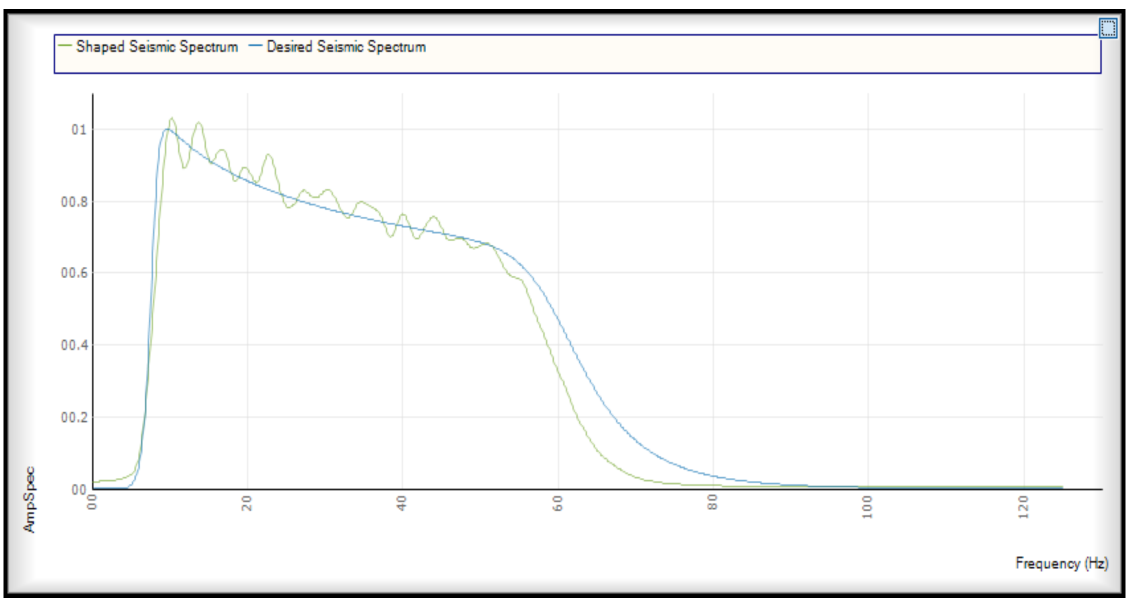


Figure 19 Convolution of shaped seismic spectrum with desired spectrum

A seismogram for specific window (as values of acoustic impedance is obtained from well data) is developed now we develop a seismogram to invert whole section. For this purpose we convolve desired spectrum with seismic mean spectrum. After convolving seismogram with seismic mean spectrum we are able to apply it on whole seismic section. The Figure 20 shows seismic mean spectrum and desired spectrum.

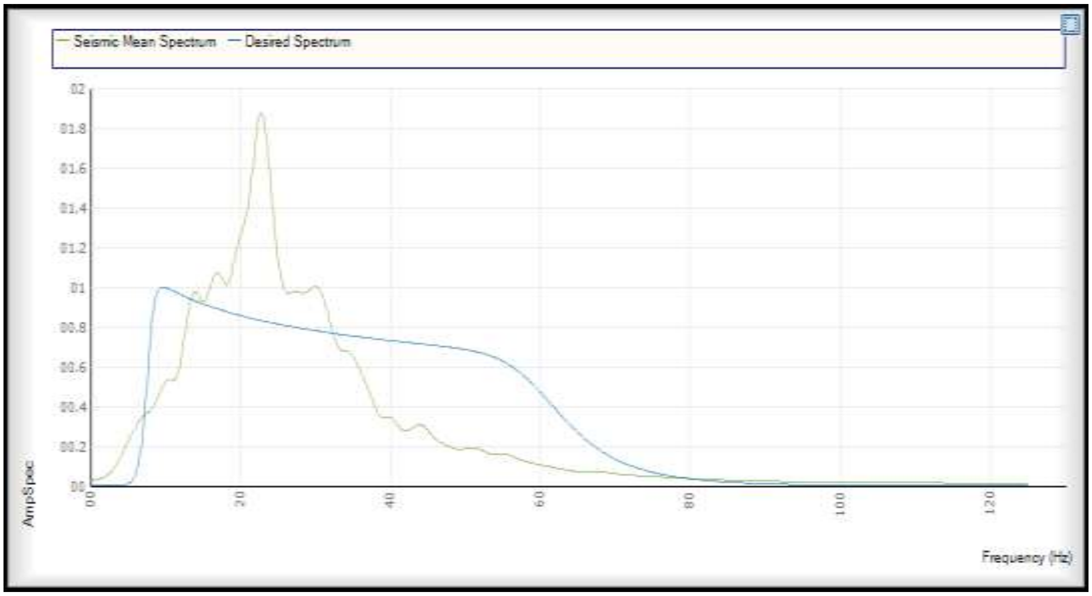


Figure 20 Covolution of seismic mean spectrum with desired spectrum

After completion of the process of generating synthetic seismogram, the section is inverted an acoustic impedance is shown on section instead of amplitude as shown in Figure 21.

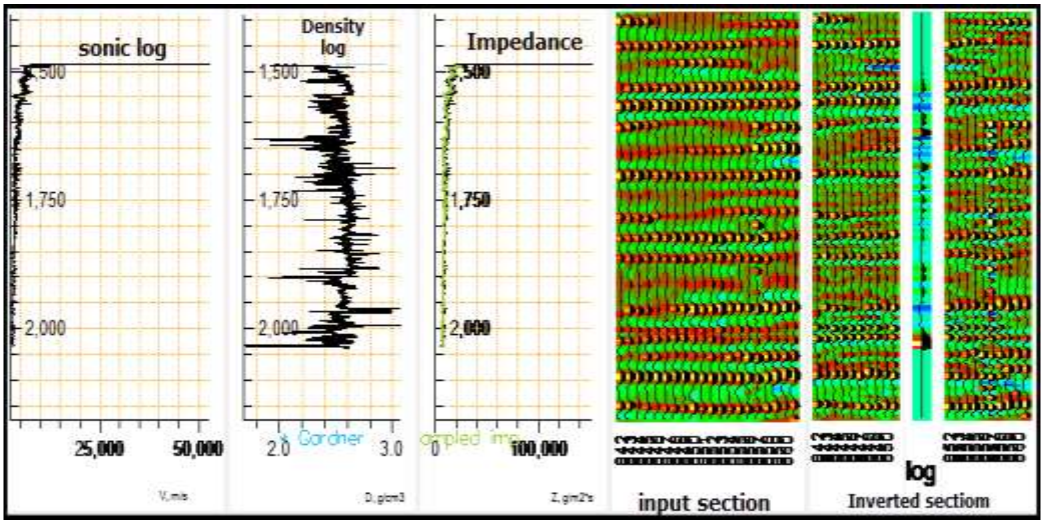


Figure 21 Input seismic section and inverted section along with logs

This window displays sonic log and density logs. These logs are used to compute the acoustic impedance. If values of density log are missing then Gardner equation is used to estimate these densities. This equation is very popular in petroleum exploration because it can provide information about the lithology from interval velocities obtained from data these values are calibrated from sonic and density well log information but in the absence of these, Gardner's constants are a good approximation for density. At the right corner of the window input seismic section is shown on left side and inverted section is shown on the right hand side. The inverted section is shown on the both sides of logs sides of the well the log is inverted to invert the seismicsection.

The zoomed picture of inverted section is given below.

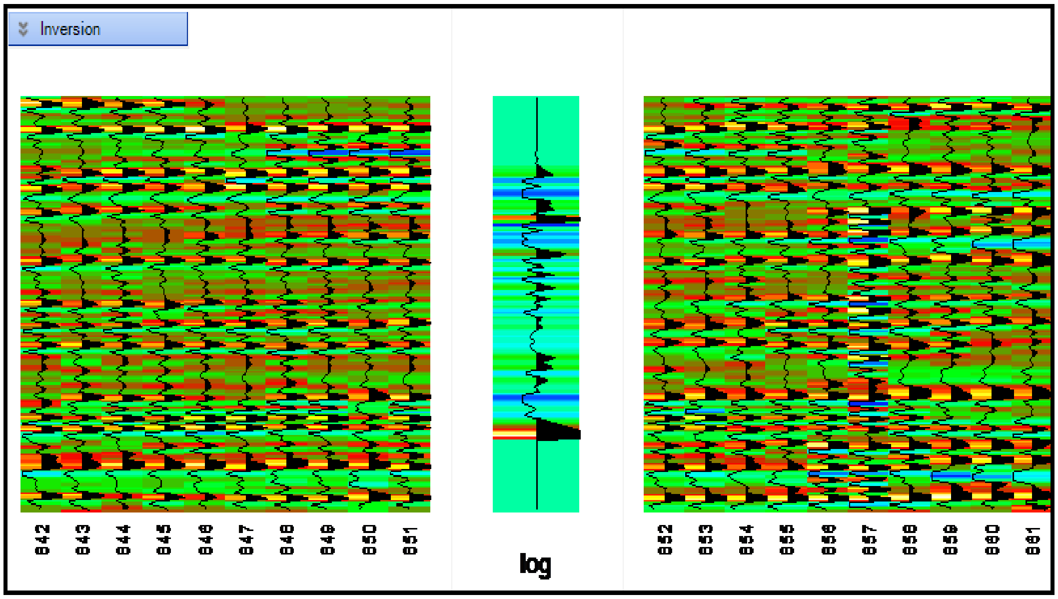


Figure 22 Inverted section with inverted log

Now inversion is applied to the whole section is given below

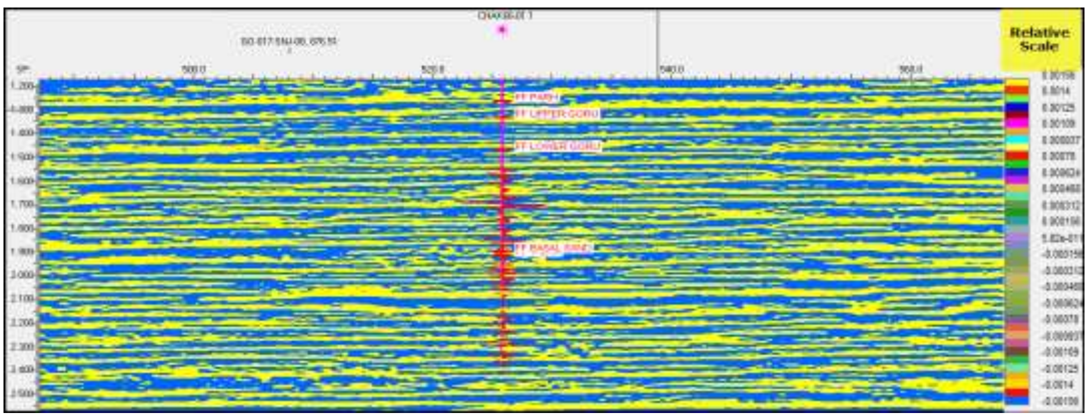


Figure 23 Inverted seismic section

CONCLUSION

Research work was carried out using data of four seismic lines and single well. It is not sufficient data to accurately approve a zone as potential zone for hydrocarbon. The main purpose of this research was to find the structural trap and zones of the reservoir of Sinjhoro field i.e. Lower Goru, Basal sand that has intercalations of shale and siltstone by using seismic and well log data and to propose a new well location on the basis of seismic data interpretation.

Geologically the study area is located in extensional regime. The rifting occurred dunring geological past is responsible for extensional features. Three geological formations have been marked on seismic section, namely Ranikot, Lower Goru and basal sands. Now dew to the extensional regime horst and graben structures are present in the area. The seismic line is showing series of horst and graben structures. The fault cuts are dipping in east and west direction while they are trending in North and south direction. Normal faults have very less throw of approx 5ms. Most of the faulting can be observed at cretaceous level, while the faults die out as we move towards younger formation.

Firstly,these faults are deep-rooted into the Sember source shale, and therefore they can act as conduits to primary hydrocarbon migration.

Secondly, these faults can act as a barrier and thus provide a lateral seal to trap the hydrocarbons within the structure. To evaluate whether these faults are a sealant, a fault seal analysis should be conducted. In one of the above figure, it is clear that the faults near the top of the Lower Goru Formation are predominantly oriented in a NNW to SSE direction. The southern limits of these faults are not obvious due to a lack of seismic data in the study region.

It is concluded from surface Geology of the area that horst and graben structure prevail the whole area. Extension of the structure is in the North-South direction. And clues of horst and graben structure are clear from the normal faulting in the interpreted seismic sections and time, depth sections of Basal Sands. These structures are largely oriented in a NNW to SSE direction and are a part of the regional rift system of the Lower Indus Basin. Following conclusions has been deduced:

- Two horizons on all the sections have been marked along with the faults.
- Major faults are mark in the area and all these faults are normal.
- Time and depth contour maps were prepared to analyze the overall behavior of the structure.
- There are small anticlinal structures bounded shown by these maps bounded by two normal faults which is clue towards either Horst or Graben or negative flower structures to some extent.
- Petrophysical portion of thesis includes the interpretation of well CHAK66-01. From all the results it is concluded that water saturation is decreasing as we move towards the reservoir zone.
- Volume of shale also decreases in the reservoir zone as compared to other lithologies. From petrophysical analysis it has also seen that some lithologies (from Gamma ray log and other characteristics interpreted as sands) have good saturation of hydrocarbons and have good porosity. From this result it can be concluded that these lithologies are may be the part of oil reservoirs.
- Measuring favorable zone on the basis of colored inversion indicate low impedance zone in the reservior. The range of acoustic impedance at the marked horizon Basal Sand is 0.000140 (m/s) (g/cc).

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