2D SEISMIC DATA INTERPRETATION INTEGRATED WELL DATA ,CHARACTERIZATION OF JOYA MAIR AND SEISMIC ATTRIBTES OF UPPER INDUS BASIN, PAKISTAN

BY : MUHAMMAD USMAN EJAZ

BS (GEOPHYSICS) 2016-2020

DEPARTMENT OF EARTH SCIENCE.

QUAID-I-AZAM UNIVERSTY ISLAMABAD, PAKISTAN.

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِيْمِ

I commence with the Name of Allah – in whom all excellences are combined and who is free from all defects. The Compassionate One whose blessings are extensive and unlimited. The Merciful One whose blessings are inherent and eternal

CERTIFICATE

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

RECOMMENDED BY

Dr. Abbas Ali Naseem _____________________

(Supervisor)

Dr. Aamir Ali _____________________

(Chairperson Department of Earth Sciences)

EXTERNAL EXAMINER _____________________

ACKNOWLEDGEMENT

Firstly, all praises to **Allah Almighty**, the most Beneficent and the most Merciful. Secondly, my humblest gratitude to the **Holy Prophet Muhammad** (PBUH) whose way of life is a complete guidance and knowledge of humanity for me. This thesis appears in its current form due to the assistance and guidance of several people. It gives me great pleasure to express my gratitude to all those who supported me and have contributed in making this manuscript possible. I express my profound sense of reverence to **Dr. ABBAS ALI NASEEM** who gave me the opportunity to work under her supervision. Her motivation and untiring guidance have made this research work possible. Also, I am immensely pleased to place on record my deep gratitude and heartfelt thanks to those who helped me in the completion of the current research work. I am forever grateful to my fellows for their help and suggestions for completion of this dissertation. Finally, I would like to acknowledge my family especially my mother for her constant support, unceasing prayers and best wishes. Her motivation uplifted my morale whenever I needed. I do thank all those who have helped me directly or indirectly in the successful completion of my thesis.

MUHAMMAD USMAN EJAZ

BS GEOPHYSICS

2016-2020

ABSTRACT

This dissertation is based on structural and stratigraphic interpretation of SEG-Y data format using seismic techniques and well log analysis. The Joya Mir area lies in the upper Indus Basin in south east of Salt Range-Potwar Foreland Basin. It has hydrocarbon potential due to its anticlinal structures. For Seismic structural interpretation three horizons and two reverse faults were marked by using IHS Kingdom 8.8 version and construction of fault polygon, time contours and depth contours takes place. The marked horizons were recognized using formation tops from wells and their depths were confirmed through correlation with synthetic seismogram. The purpose of time and depth contour maps was to understand the spatial geometry of the structures and the nature of geological structures as identified by the seismic section of the area. Seismic interpretation of the 2D data reveals that the study area has undergone severe deformation illustrated by the development of thrusts and back thrusts forming a triangle zone in the subsurface.The general trend of these structures is northwest- southeast which indicated that the area lies in compressional regime. The reservoirs of Eocene occurs at depth of about 2020.48 m from well tops. The interpreted horizons are Chorgali Formation and Sakesar Formation, which has the major petroleum potential in the study area. Petrophysical analysis of Minwal X-1 well indicated the hydrocarbon potential in marked reservoirs and gave approximately 70% of hydrocarbon saturation. Seismic attributes are applied that also confirm the reservoir prospect zone.

TABLE OF CONTENT

CHAPTER 1

INTRODUCTION

CHAPTER 2

REGIONAL TECTONICS AND STRATIGRAPHY

CHAPTER 3 SEISMIC INTERPRETATION

CHAPTER NO 4
PETROPHYSICAL ANLAYSIS

CHAPTER NO 5 SEISMIC ATTRIBUTES

CHAPTER NO 1
INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Introduction to Hydrocarbon exploration

The exploration of hydrocarbon in Pakistan initiated in 1868 at Kundal near Mianwalli, that continue till present day. Most of the Rocks in Pakistan are sedimentary and quite rich in petroliferous material. The exploration companies search for structural and stratigraphic traps where most of the hydrocarbons accumulate. Most of such structures are present in areas where there is intense folding and faulting i-e Potwar area. The possibility of major discoveries, either in on-shore or off-shore areas, is considered quite bright (Sroor, 2010).

Geophysicists have been trying for hydrocarbon exploration since a long time ago and developed many techniques in this regard. Seismic reflection method is used for deep hydrocarbon exploration in petroleum geology. Petroleum geology refers to the specific set of geological disciplines that are used for hydrocarbons exploration. Investigation of the earth's interior using geophysical methods, involves taking measurements at or near the surface of the earth for analysis that can expose both vertical and lateral variations of the physical properties of the earth's subsurface, logs ranging from electrical, nuclear and acoustic have been in use for deriving these parameters (Bust et al., 2013).

1.2 Introduction to the Study Area

The Joya Mir Oilfield lies in the south-southeast of the Salt Range-Potwar foreland basin (SRPFB). It is the result of Tertiary Himalayan collision between the Indian Plate and Eurasian plate in late Eocene and characterized by number of Reverse and Thrust Faults which formed the structural hydrocarbon traps. Joya Mir structure is the combination of thrust and back-thrust, forming a triangle zone at subsurface. The triangle zone is the result of two phases of Himalayan thrusting. Stratigraphically it comprises of a petroleum play in which Patala Formation of Paleocene age act as a source rock while Chorgali and Sakesar Formation of Eocene age are two major reservoirs and Murree Formation of Miocene age is acting as a seal in the study area.

1.3 Location of the study area

The study area lies in Chakwal district in the South-west of Capital Islamabad city located 105 km away from Islamabad. The area lies in UTM (Universal Transverse Mercator) zone 43° N in the world Geodetic System. The coordinates in degrees, minutes and seconds are **Latitude 32º 59′ 52″ N** and **Longitude 72º 8′ 31″E.**

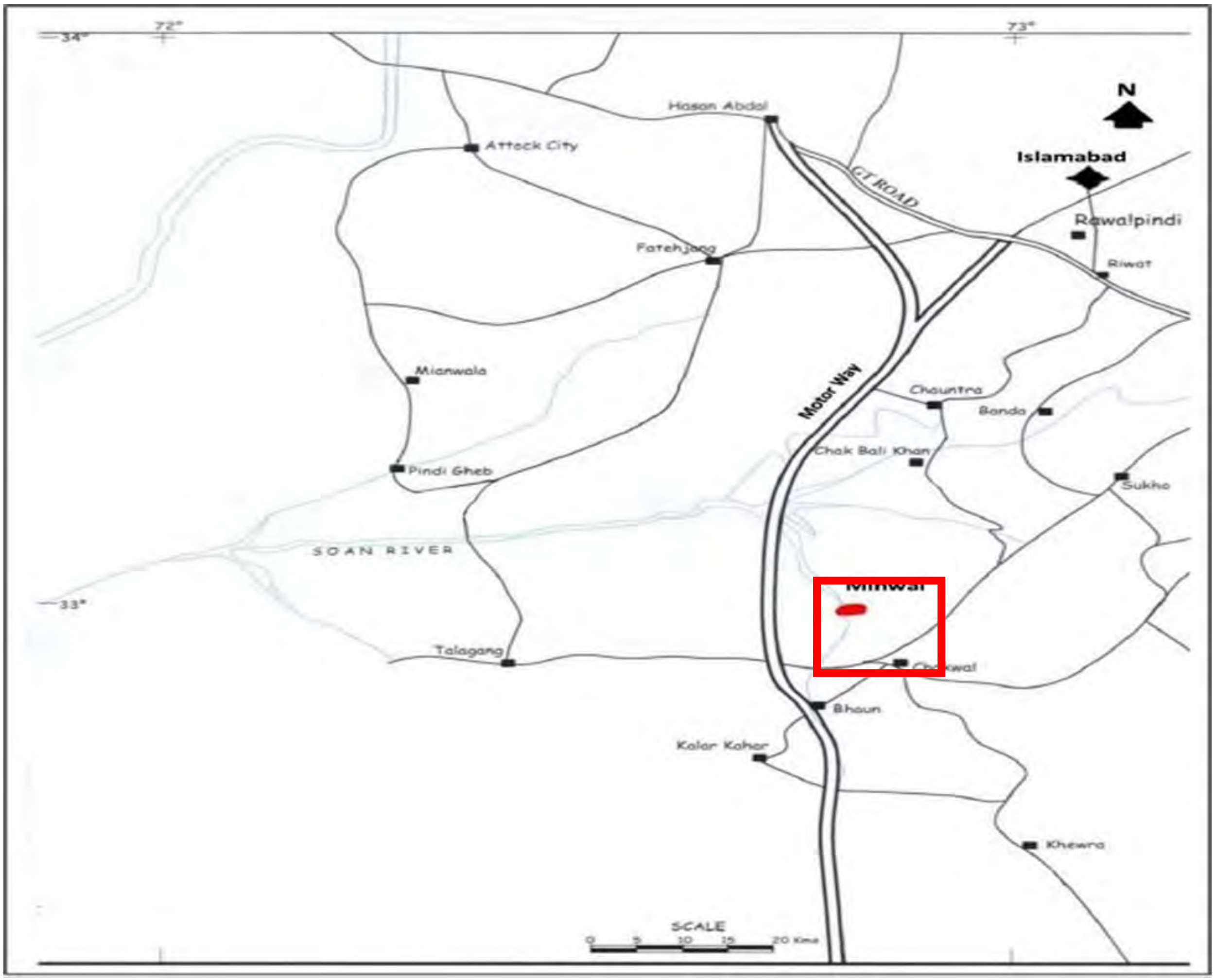


Figure 1.3 Location map of study area

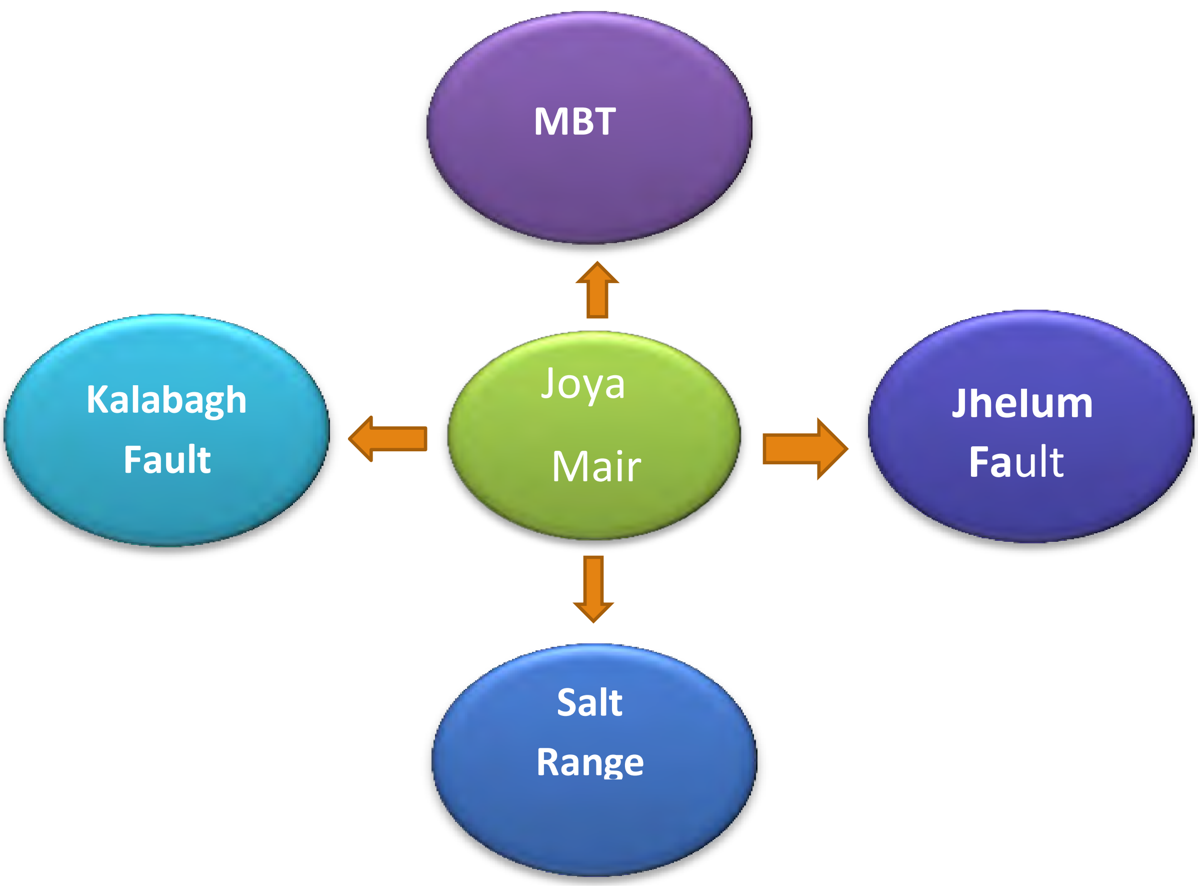
1.4 Geographical Boundaries

Geographically Joya Mair shares borders with KalarKahar to the south and east with the town of Chakwal and to the west lies the town of Talagang. The area is now easily accessible due to the construction of Lahore Islamabad Highway (M-2). The Kohat-Potwar (study area) belongs to the category of extra continental watersheds, which account for 48% of the world's known oil resources (Hasany&Saleem, 2001).The study area is shown in figure 1.3.

1.5 Geological Boundaries of Potwar Basin

The left lateral fault of Jhelum (submitted by Mukherjee) marks the eastern boundary of the plateau. The western margins are delimited by the Kalabagh fault (Gee, 1989). In the south, the plateau is delimited by the thrust of the salt range, while the northern boundary is marked by the main boundary thrust (Rana and Asrarullah, 1982, Jaswal et al., 1997, Kazmi and January 1997).

Geological Boundaries of Joya Mir Area



1.6 Prospectivity Zonation of Pakistan

The country has been divided into zones based on their relative prospectively and geological risk. Onshore areas are sub-divided in three zones;

- **ZONE-I**: high risk - high cost areas
- **ZONE-II**: medium risk - high to medium cost areas
- **ZONE-III**: low risk-low cost areas.

Offshore areas are also sub-divided in three zones; Shallow, Deep and Ultra Deep. Separate incentives have now been provided for the onshore and offshore areas of the country. Joya Mir area lies in zone-II which is medium risk - high to medium cost areas.

1.7 Previous work history

First commercial oil in the Potwar area was produced from the Miocene (Murree Formation) at Khaur in 1915 (Kazmi and Jan 1995) .At the time of independence (1947), Pakistan inherited four productive fields, Khaur, Dhullian, JoyaMair and Balkassar. Traces of hydrocarbons occur in several other localities, and exploration continues in Punjab, Sindh and Baluchistan by arrangement between various foreign companies and the Oil and Gas Development Corporation (OGDC).

Joya Mair field was discovered in 1946 by Attock Oil Company, establishing the potential of fractured Eocene limestone. The Chorgali (Bhadrar) and Sakesar formations are the main reservoirs of oil production in the field. In total, 15 wells were drilled in the D & P Lease Joya Mair, one of which was off-structure, two wells could not reach T.D and 12 wells cut the tank. Some wells were abandoned prematurely and some were plugged due to mechanical problems after a small production, whereas only six wells (A-3, A-5, A-7, P-2, POL-1, A-6 And MinwalX-01) currently produce. Wells A-3, A-5, A-7 and B-2 (P-2) are in regular production while A-6, POL-1 and Minwal X-1 are intermittent producers. All regular producers and A-6 are located in the northwestern compartment of the field, while POL-1 is located in the southeast compartment.

The maximum output was about 3700 BOPD in 1965 which has since dropped to about 420 BOPD and 0.05 MMSCFD of gas. The field produced on natural reservoir pressures until 1961, and then it was converted to the gas lift and produced until 1974. The average depth of the wells targeting the Eocene reservoir is about 9000 ft. Most wells are drilled in the western compartment which is structurally lower than east. While three wells are in the eastern compartments that are all non-producing, only POL-1 contributes with minor rates.

The fractured carbonates of the Sakesar and Chorgali formations of the Eocene age are the main producing reservoirs of Joya Mir. Minor oil production comes from Paleocene Lockhart Formation.

1.8 Exploration and production Information:

Following is the production and exploration information of Joya Mir oil fields.

Production information of Joya Mir oil field

Recoverable reserves	Oil=38.37 MMstb , Gas =234.86 MMscfd
PPL working interest	100 percent
Operator	POL
Peak production	3700 BOPD in 1965
License Area	149.13 Sq Km

1.9 Data set used in current study

The well data used in current study is Minwal X-1 along with the five Seismic lines, including three dip lines and two strike lines mentioned below in Table 1.9. The data has been acquired from the Directorate general of petroleum concession (DGPC). The trend of the seismic dip and strike lines in SE-NW and SW-NE respectively.

Table 1.9 Data Set

LINE NUMBER	LINE TYPE	LINE DIRECTION	WELL
POL93 MN 08	Dip Line	NW-SE	Minwal X1

POL93 MN 06	Dip Line	NW-SE	
POL93 MN 05	Dip Line	NW-SE	
POL93 MN 10	Strike Line	NE-SW	
POL93 MN 11	Strike Line	NE-SW	

The lines written in colours are assigned to me.

1.10 Well Data Type

The well data includes the following files:

- LAS files
- Well tops

These files store all the information about the logs run in the well and well tops. Following is brief details of well Joya Mair Minwal X-01.

1.11 Well Tops Information.

Table 1.11

Formation Top	Formation Top Age	Formation Top Value	Thickness (m)
Nagri	Pliocene	0.0	231.74
Chinji	Miocene	231.74	680.87
Kamlial	Miocene	912.61	87.5
Murree	Miocene	1000.11	1020.37
Chorgali	Eocene	2020.48	33.76
Sakesar	Eocene	2054.24	121.995

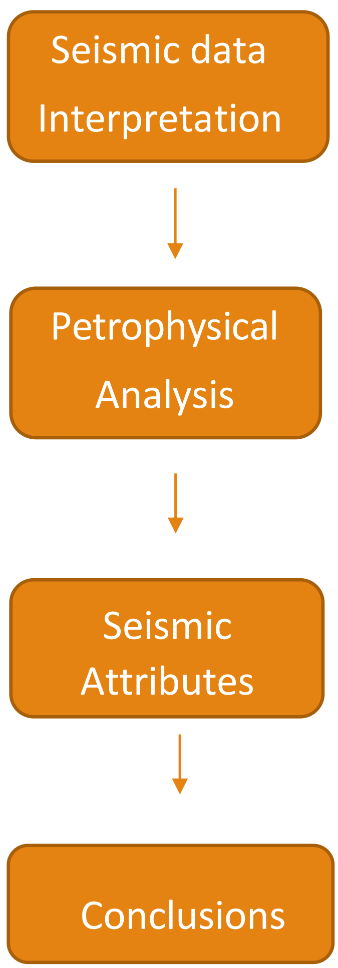
1.12 Aims and objectives

The main objective of research was to reveal the structure of the area and hydrocarbon prospect with the help of available 2D seismic data.

The main objectives of the current study are the following

- Detailed seismic interpretation for identification of structures favorable for hydrocarbon accumulation, which mainly includes:
  - To construct the Base map of Study area.
  - To construct the synthetic seismogram.
  - To mark the Horizons and Structure on the seismic Section by using well data.
  - Generation of time and depth contour maps
- Petro physical analysis to infer the reservoir properties.
- Analyzing seismic attributes.

1.13 Work Flow adopted:



CHAPTER NO 2

GEOLOGY

CHAPTER 2

REGIONAL TECTONICS AND STRATIGRAPHY

2.1 Regional Tectonics

The Himalayan Orogenic belt is the youngest mountain belt in the world which came into existence as a result of collision between the Indian plate in the south and Eurasian plate in the north. The site of collision is considered to be a broader zone and marked by the Himalayan- Kurrakuram-Hindukush ranges in northwestern Pakistan (McDougal and Hussain, 1991). The Himalayan along with associated mountain chain trend east-west, switching to a more north- south trend in the west. Beginning about 55 Ma ago, collision of the Indo-Pak sub-continent with Eurasia plate produced the Himalayan Orogenic belt which is considered to be a broader zone. They include Meta sedimentary and igneous rock of the southern Asian plate emplaced over the rock of Kohistan Island arc along main Kurrakuram Thrust (MKT) during late cretaceous (Butler et al. 1985). Kohistan island arc terrain is composed of metamorphic and basic to ultra-basic rocks which are thrusted over northern margin of Indian plate along Main Mantle Thrust (Tahir kheli et al. 1979). The foreland consisting of telescoped igneous, sedimentary and metamorphic rocks of the northern Indian cratonic foreland basin is marked by Main Boundary Thrust (MBT) in the south. The MBT extends westward from the front of main Himalayan range around Hazara Kashmir syntaxes and thrust the hill ranges over the Kohat-Potwar foreland basin. The main boundary thrust system contains highly deformed Pre-Cambrian-Cenozoic sedimentary rocks which progressively become younger southward. The Kohat- Potwar foreland basin contains deformed Paleocene-Pleistocene sedimentary sequence bounded by the Salt Range Thrust (SRT) in Potwar plateau and the southern boundary of Trans Indus Range and the unreformed Bannu basin in Kohat plateau. The un-deformed foreland or indo-gigantic plain lies south of the Salt Range and Trans-Indus ranges and is the present day depocenter for the Himalayan shed.

The northwest Himalayas in Pakistan can be divided into four tectonomorphic terrain which is separated by major fault systems. These four tectonomorphic terrains are from north to south which is as under

- Main Karakoram Thrust (MKT).
- Main Mantle Thrust (MMT).
- Main Boundary Thrust (MBT).
- Salt Range and Trans Indus Ranges Thrust.

2.2 Sedimentary Basins of Pakistan:

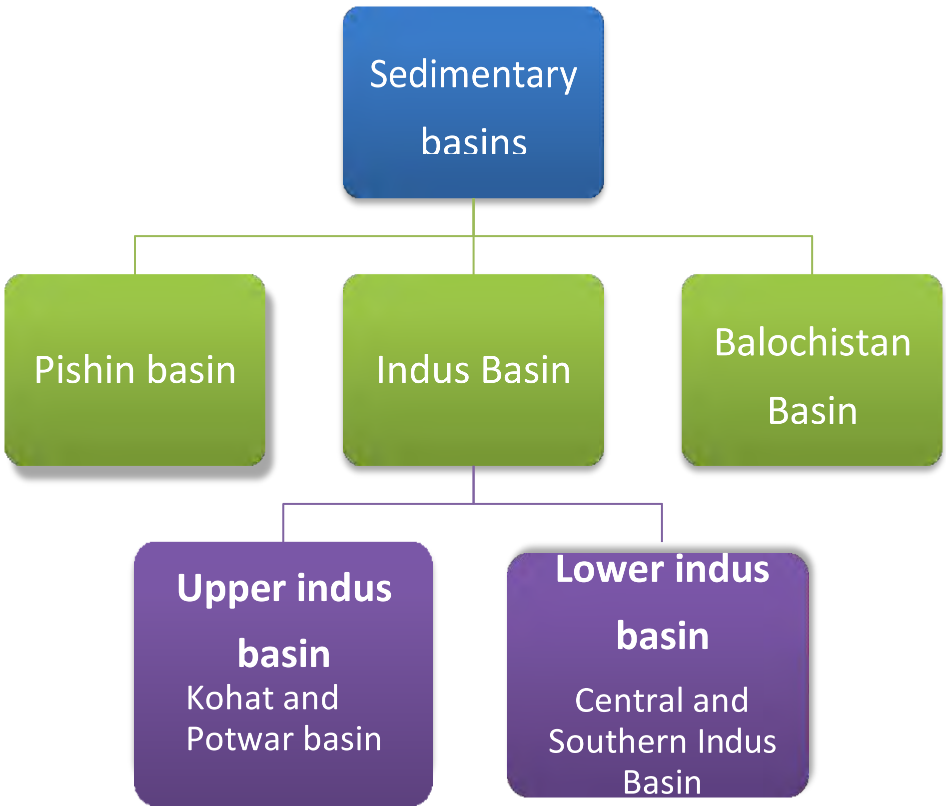


Figure 2.2 : Sedimentary basins of Pakistan.

2.3 Local Tectonic of Study area

The Potwar Plateau is comprises of less internally deformed fold and thrust belt having a width of approximately 150 km in N–S direction. The Potwar Plateau comprises of undulated terrains and topography. The Potwar sub basin is tectonically situated directly below the western foothills of Himalayas and falls in Potwar Plateau. It is bounded in the north by Main Boundary Thrust (MBT) and to the east by Jhelum left lateral strike slip fault and to the south by Salt Range Thrust and to the west it is bounded by Kalabagh right lateral strike slip fault. (Aamir and Siddiqui, 2006).

2.4 Tectonic boundary of Potwar Plateau

The Potwar is bounded by the following two strike-slips and two thrust faults which are as under.

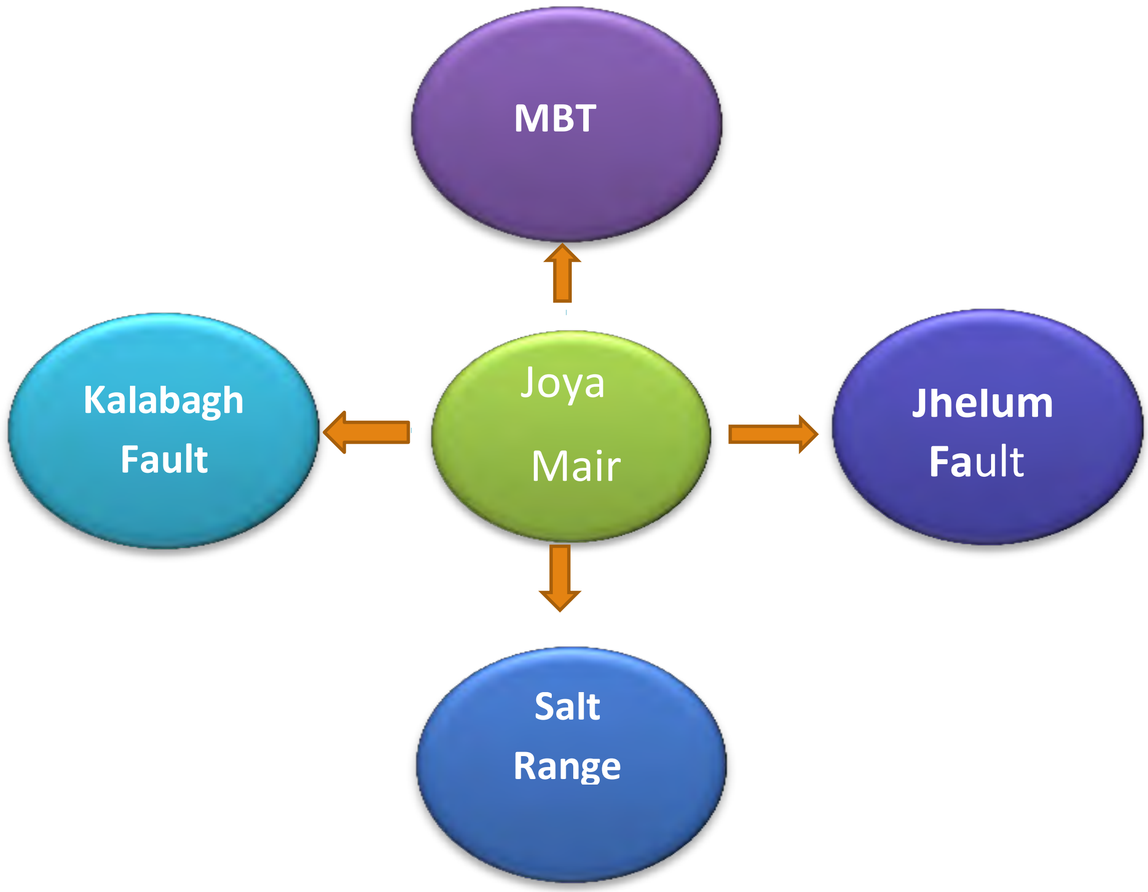


Figure 2.4 Tectonic boundary of potwar plateau

Kalabagh fault

It is right lateral strike-slip fault and its direction is from north to west 150 km which can be seen as faulted block. It lies in the north of the Kalabagh City, Mianwali and is the Trans-Indus extention of Western Salt Range (McDougal & Khan, 1990)

Jhelum Fault

Extending from Kohala to Azad Pattan the Murree is hanging while Kamlial, Chingi and Nagri formations are on the footwall. Starting from the Indus-Kohistan to Ravi it is the active aspect of the Indian Shield. It is seen in the map that MBT, Panjal Thrust and HFT cut shortened by left-lateral reverse Jhelum Fault in west (Baig, Lawrence, 1987).

Salt Range Thrust

It is also known as Himalayan Frontal Thrust. Salt range and Trans-Indus Himalayan ranges are the Foothills.

Main Boundary Thrust

The MBT which lies in the north of the Islamabad is called as Murree fault. The western part of this fault is orienting to north east forming non-striking fault in its western part i.e. Hazara Kashmir-Syntexis (Latif, 1970; Yeats and Lawrence, 1984: Greco, 1991) also this fault strike the in the direction of east moving in the direction of Southern side of Kala chitta Range and North of Kohat plateau (Meissner et at, 1974).

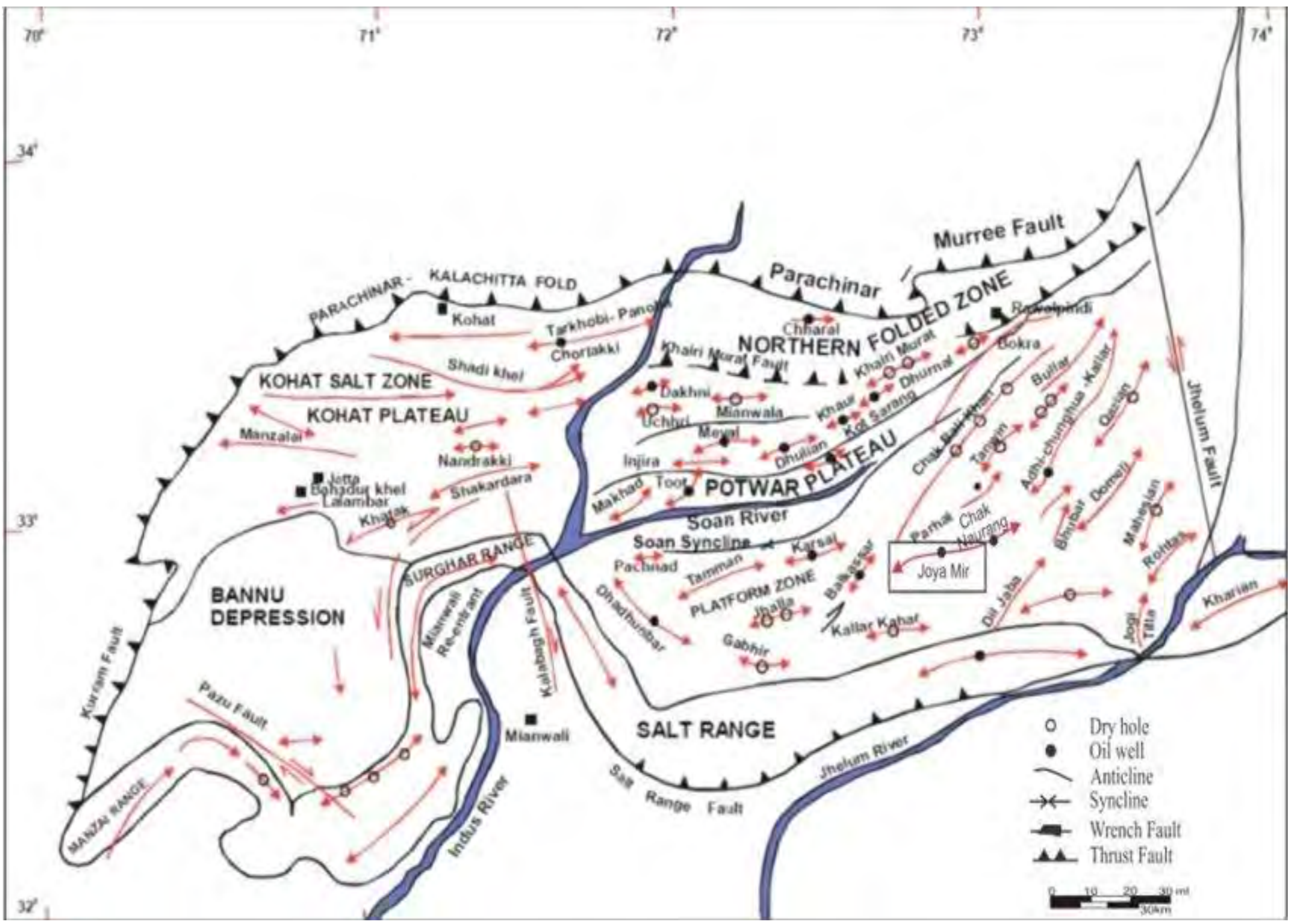


Figure 2.4: Tectonic map of Pakistan (after Shami,1998)

According to the seismic interpretation subsurface geological structures found in Potwar region may be classified into.

1. Pop-up anticlines
2. Snake head anticlines
3. Salt cored anticlines
4. Triangle zone

Minwal X-1 lies in near Joya Mir. This region is active area for oil and gas exploration and production. This Well is drilled by POL drill on the Joya Mir in North Eastern limits of the structure. The location of the well was at SP Seismic Line No: 93-MN-08. The Eocene Chorgali and Sakesar formations were the primary objective. The well is located in the high fractures reservoir which could contribute in an excellent well productivity. Structurally it is a broad anticline with its axis running SW-NE direction. The limbs of the anticline are in the SW. direction. The Northern limb showing dips which are steeper as compared to the Southern limb, which are slightly gentler.The dips of the Northern limb are in between 50° - 60° while that of Southern limb shows 55° - 75°dips. On the NE side, the anticline is separated by Chak Naurang-Wari fault which is a major fault in the area.

2.5 Stratigraphy of study area

The stratigraphic column is divided into three unconformity-bounded sequences. These unconformities in the study area are Ordovician to Carboniferous, Mesozoic to Late Permian, and Oligocene in age. The Potwar sub-basin is filled with thick infra-Cambrian evaporite deposits overlain by relatively thin Cambrian to Eocene age platform deposits followed by thick Miocene-Pliocene molasses deposits. This whole section has been severely deformed by intense tectonic activity during the Himalayan orogeny in Pliocene to middle Pleistocene time.

2.5.1 Paleocene Patala Formation

The Patala Formation overlies the Lockhart Formation conformably and its type section is in the Patala Nala in the Western Salt Range (Davies and Pinfold, 1937). It is acting as a source rock in the study area. It consists largely of shale with sub-ordinate marl, limestone and sandstone. Marcasite nodules are found in the shale. The formation also contains coal, and its thickness ranges from 27m to over 200m (Warwick, 1990). It contains abundant foraminifera mollusks and ostracods (Davies & Pinfold, 1937, Eames, 1952, and Latif,1970). The age of the Patala Formation is Late Paleocene.

2.5.2 Eocene Namal Formation

It comprises grey to olive green shale, light grey to bluish grey marl and argillaceous limestone. In Salt Range, these rocks occur as alteration. In Surghar Range the lower part composed of bluish grey marl with interbedded calcareous shale and minor limestone while upper part consists of bluish grey to dark grey limestone with intercalation of marl and shale. It type locality is Nammal Gorge Salt Range, Punjab and thickness of thisformation is 100m at type locality. Its age is early Eocene.

2.5.3 Eocene Sakesar Formation

With increase in limestone beds, the Nammal Formation transitionally passes into the overlying Sakesar Formation, the type locality of which is the Sakesar Peak (Gee, 1935 and Fatmi, 1973). It is acting as reservoir rock in Joya Mir area. It consists of grey, nodular to massive limestone, which is cherty in the upper part. Near Daudkhel, the Sakesar Formation laterally grades into massive gypsum. Its thickness ranges from 70m to about 450m. Its age is early Eocene.

2.5.4 Eocene Chorgali Formation

The Chorgali Formation rests conformably over the Sakesar Formation (type locality Chorgali Pass) (Pascoe, 1920 and Fatmi, 1973). It consists largely in the lower part, of thin-bedded grey, partly dolomitized and argillaceous limestone with bituminous odor, and in the upper part, of greenish, soft calcareous shale with interbreeds of limestone. Its thickness ranges from 30m to 140m.It contains molluscs, ostracods and foraminifera.The age of the Chorgali Formation is Early Eocene. It is overlain unconformably by the Neogene sequence.

2.5.5 Miocene Succession Murree Formation

The type section of Murree Formation is in north of Dhol Maiki. Murree Formation is composed of thick monotonous sequence of red and purple clay and interbedded greenish sandstone with sub-ordinate intra-formational conglomerate (Wynne, 1873). The thickness of the formation increases from180m to 600m in the Salt Range to 3,030m in the northern Potwar area.

It is poorly fossiliferous though plant remains and some vertebrate bones have been found. This fauna indicates early Miocene age of the Murree Formation.

2.5.6 Miocene Kamlial Formation

The type section of Kamlial Formation is in the southwest of Kamlial, the formation overlies the Murree formation conformably and transitionally at some localities lies unconformably on the Eocene Sakesar Formation (Pinfold, 1918, Lewis, 1937, Fatmi, 1973 and Cheema et al., 1977). The formation consists mainly of grey to brick red, medium to coarse grained sandstone interbedded with purple shale and intraformationalconglomerate. A number of mammalian fossils have been found .The age of the Kamlial Formation is middle to late Miocene.

2.5.7 Pliocene Succession (Siwalik Group)

Chinji formation

The type locality of Chinji formation is South of Chinji, Campbellpur, Punjab, and its lithology comprises of Clay, sandstone with minor siltstone. According to Shami and Baig thickness of this formation is 750m at type locality. The age of Chinji formation is Late Miocene to early Pliocene.

Nagri Formation

Nagri village, Campbellpur District, Punjab is the type section of the Nagri Formation. Its lithology comprises of salt, conglomerate, clay. Thickness of this Formation ranges from 200m- 3000m. Its age is early Pliocene.

Table 2.5 : Generalized stratigraphy of Joya Mir field

AGE	FORMATION	ENVIRONMENT
Pliocene	Nagri	Fluvial Channel
	Chinji	Fluvial Stream Channels
Miocene	Kamlial	Fluvial

	Murree	Fluvial
Oligocene	Unconformity	
Eocene	Chorgali	Shallow Marine Supra tidal Lagoonal
	Sakessar	Shallow Marine Supratidal Lagoonal
	Nammal	Shallow Marine Restricted Anoxic
Paleocene	Patala	Shallow Marine
	Lockhart	Shallow Marine (Distal to Proximal)
	Hangu	Shallow Marine (Littoral to Paludal)
Cretaceous	Unconformity	
Jurassic		
Triassic Late Permian		
Early Permian	Sardhai	Very Shallow Marine to Estuarine
	Warcha	Fluvial Sub Aerial PaludalLagoonal
	Dandot	Shallow Marine Lagoonal
	Tobra	Glacial to Fluvial
Late Cambrian	Unconformity	
Cambrian	Khewra	Shallow Marine Sub Littoral to Littoral
Pre-Cambrian	Basement	Restricted Marine Hyper saline

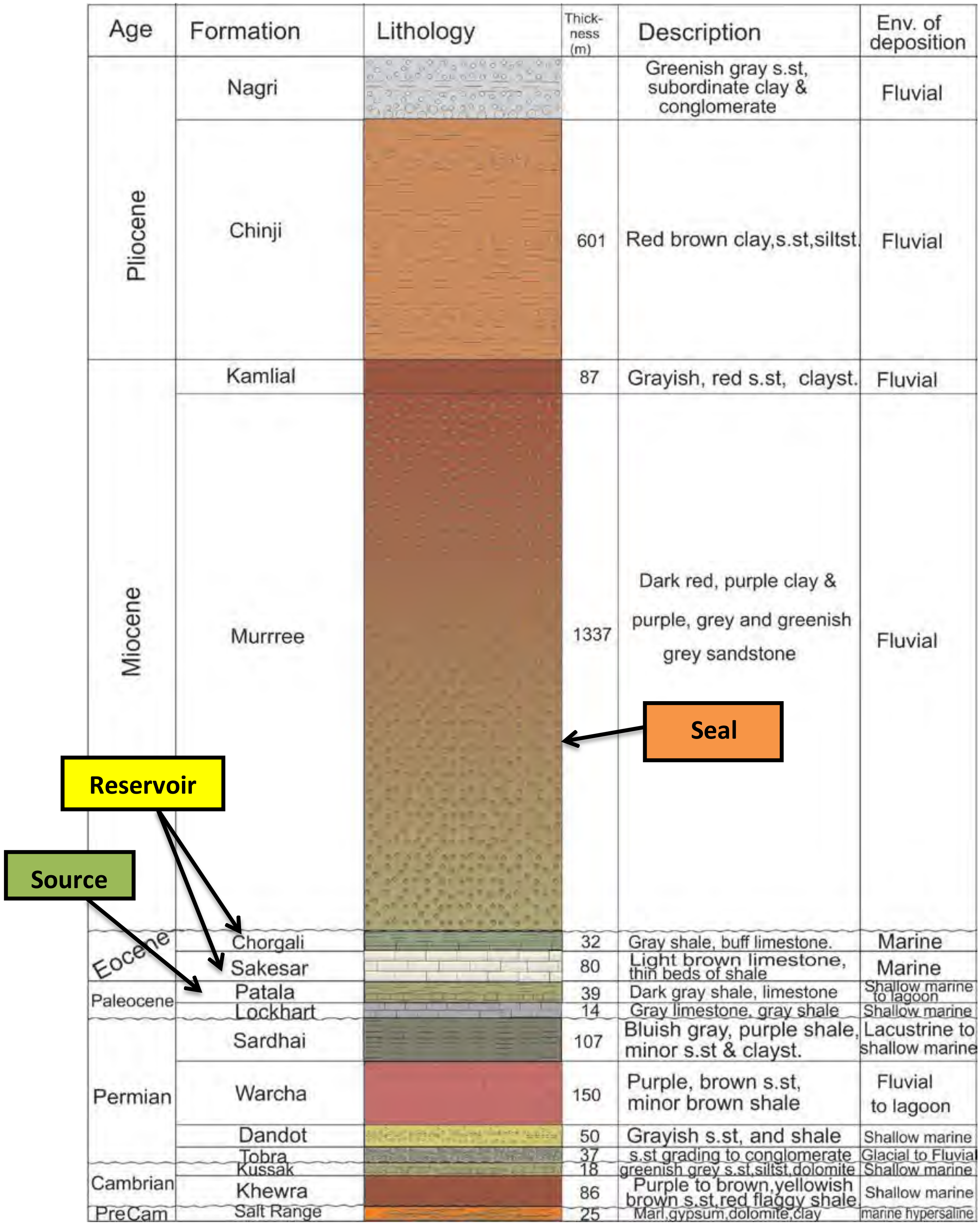


Fig. 3. Stratigraphic column of the Joya Mair area (after Shami, 1998).

2.6 Petroleum geology of the area.

The geological history of this basin begins from Precambrian age. East of Potwar Plateau is salt-cored anticlines which are separated by the wide synclines. Tanwin-Bains-Buttar and Joya Mir-Chak Naurang-Adhi-GungrillaKallar are such major Anticlines of Potwar Plateau. The cores of these salt anticlines are thrusted and originated due to the compression of Himalayan orogeny in Miocene-Pliocene age. The oil and gas in the area has been produced from the fractured carbonates of Paleocene and Eocene age but Mesozoic sandstone and Paleozoic carbonates has produced additional oil (Ahmed, 1995) in the area.

2.6.1 Petroleum system

- **Reservoir**

The main oil producing reserviors in Minwal are the Cambrian, Permian, Jurassic, Paleocene and Eocene age successions. Primary porosity is lower in these reservoirs as compare to the secondary porosity. The main oil producing reservoirs in Minwal area are fractured carbonates which are of Sakesar and Chorgali Formations. The massive light yellow gray and partly dolomitized of Sakesar limestone contain chert. The Chorgali Formation is creamy yellow to yellow gray, silty, partly dolomitic and thin bedded limestone.It was deposited in intratidal conditions dominated environment. (Shami and Baig, 2002).

- **Source Rock**

The potential source rock in Minwal is the grey shales of Mianwali Formation, Datta Formation and Patala Formation. The Eo-cambrian Salt Range Formation contains oil shales with 27%-36% TOC in isolated pocket of shales are the source rock in the Salt Range Potwar Foreland Basin (Shami and Baig, 2002).In Potwar, the TOC 1.57 and hydrogen Index of 2.68 in shales have been observed (Porth and Raza, 1990). Patala formation is the key source rock of oil production in Potwar sub-basin according to the oil to source correlation.

- **Cap Rock**

The thin-skinned tectonics has developed the traps creating the faulted anticlines, pop-up and positive flower structures above Pre-Cambrian salt. The lateral and vertical seal to Eocene reservoir is provided by the Murree Formation’s clays and shales (Shami and Baig, 2002).

- **Maturation**

The thermal maturities of the Kohat-Potwar rocks range from 0.3 to more than 1.6 percent. A basin profile indicates maturities equivalent to vitrinite reflectance of 0.62 to 1.0 percent for tertiary rocks in the productive part of the Potwar Basin. Fluid inclusion data, with vitrinite reflectance data used for calibration, shows calculated and measured Ro samples between 0.6 and 1.1 percent for Cretaceous, 0.5 to 0.9 percent for Jurassic, and 0.65 to 0.95 percent for Permian rocks .North of the main boundary thrust fault, maturities are higher. In the northern and probably central basin, Cretaceous rocks are in the 1.0 to 1.6 percent Ro range. Dry gas generation begins near at 1.3 percent Ro.

- **Generation and Migration**

Generation of hydrocarbons most likely began in Late Cretaceous time for Cambrian through Lower Cretaceous source rocks and again from Pliocene time to the present for younger source rocks (OGDC, 1996). Burial-history plots by Law and others (1998) start at about 30 Ma and therefore show only a late or second period of generation beginning 20 to 15 Ma and continuing to the present. The burial-history plots of Law and others (1998) also indicate that maximum burial was reached approximately 2 million years ago. Migration is primarily over short distances up dip and vertically into adjacent reservoirs and through faults and fractures associated with plate collision and thrusting.

Table 2.6.1: Generalized Petroleum System

Formation	**Rock type**
Murree	Seal
Chorgali	Reservoir
Sakesar	Reservoir
Patala shales	Source

CHAPTER N0 3

INTERPRETATION

CHAPTER 3

SEISMIC DATA INTERPRETATION

3.1 Seismic data interpretation

The final step in seismic study of an area is to interpret the processed seismic section so that a geological model of sub-surface can be developed. The objective of seismic reflection interpretation is to study the subsurface structures that help in discovering the hydrocarbon accumulation. As science has not yet discovered the direct method of finding the oil and gas, or of assessing the quantities of hydrocarbons in the subsurface, so the seismic reflection method only indicates the geological situations where the hydrocarbons can accumulate.

Seismic interpretation is the transformation of seismic reflection data into a structural picture, contouring of subsurface horizons and further depth conversion by applying some suitable velocities. The ultimate goal is to detect the accumulations of hydrocarbons delineate their extent, and calculate their volumes.

3.2 Methods for the Interpretation:

The main methods for the interpretation of the seismic section are.

1. Structural Analysis
2. Stratigraphic Analysis

3.2.1 Structural analysis

It is the study of reflector geometry on the basis of reflection time. The key use of the structural analysis of seismic section is in the search for structural traps containing hydrocarbons. Most structural interpretation uses two-way reflection times rather depth. And time structural maps are constructed to display the geometry of selected reflection events. Some seismic sections contain images that can be interpreted without difficulty. Discontinues reflections clearly indicate faults and undulating reflections reveal folded beds.

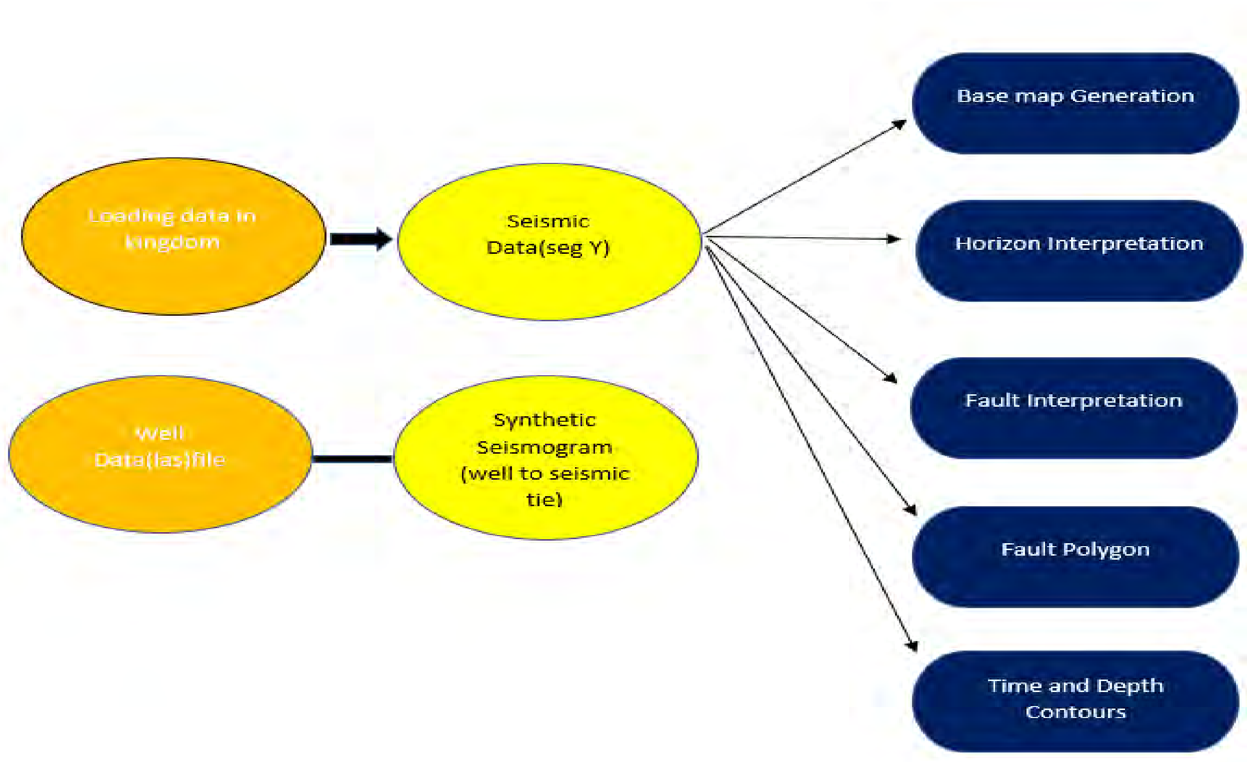
3.2.2 Stratigraphic analysis:

Stratigraphy analysis involves the delineating the seismic sequences which present the different depositional units recognizing the seismic facies characteristic with suggest depositional environment and analysing the reflection characteristic variation to locate the stratigraphic change and hydrocarbon depositional environment. The amplitude velocity and frequency or the change in the wave shape are the indicative of the hydrocarbon accumulation. Variation of the amplitude with the offset is also important hydrocarbon indicator. Unconformities are mark by the change in the drainage basin but that helps developed the depositional environment. Reef, lenses, unconformities are the example of the stratigraphic (Sheriff, 1999**).** .

3.3 Interpretation workflow

This interpretation was performed using different techniques and steps with each step include various processes performed with the use of software tools. Simplified workflow used in the thesis given in figure 3.3

Figure 3.3: Work flow adopted for the seismic data interpretation



3.4 Structural Interpretation of Joya Mair Area

Seismic interpretation of Joya Mair area involves six seismic lines.While interpreting these seismic lines, structural changes is observed.Mainly indicating thrust and reverse faults. These structures are results of compressional forces as it falls in the compressional regime. Mostly the structures present in this area are anticlines folds and thrust faults along with triangular zones and pop-up structures.

3.5 Data assigned for interpretation

Data contain following lines.

LINE NUMBER	LINE TYPE	LINE DIRECTION	WELL
POL93 MN 08	Dip Line	NW-SE	Minwal X1
POL93 MN 06	Dip Line	NW-SE	
POL93 MN 05	Dip Line	NW-SE	
POL93 MN 10	Strike Line	NE-SW	
POL93 MN 11	Strike Line	NE-SW	
POL93 MN 09	Dip line	NW-SE	

- The lines written in colours are assigned to me

3.6 Base Map Generation

The base map is an important component of interpretation. For a geophysicist a base map shows the orientations of the seismic lines and specifies the points where the seismic data were acquired or simply a map that consists of number of dip and strike lines on which seismic prospecting is carried out.

A base map generally includes the location of concession and concession boundaries, wells, seismic survey points, and other cultural data such as buildings and roads with geological reference such as latitude and longitude.

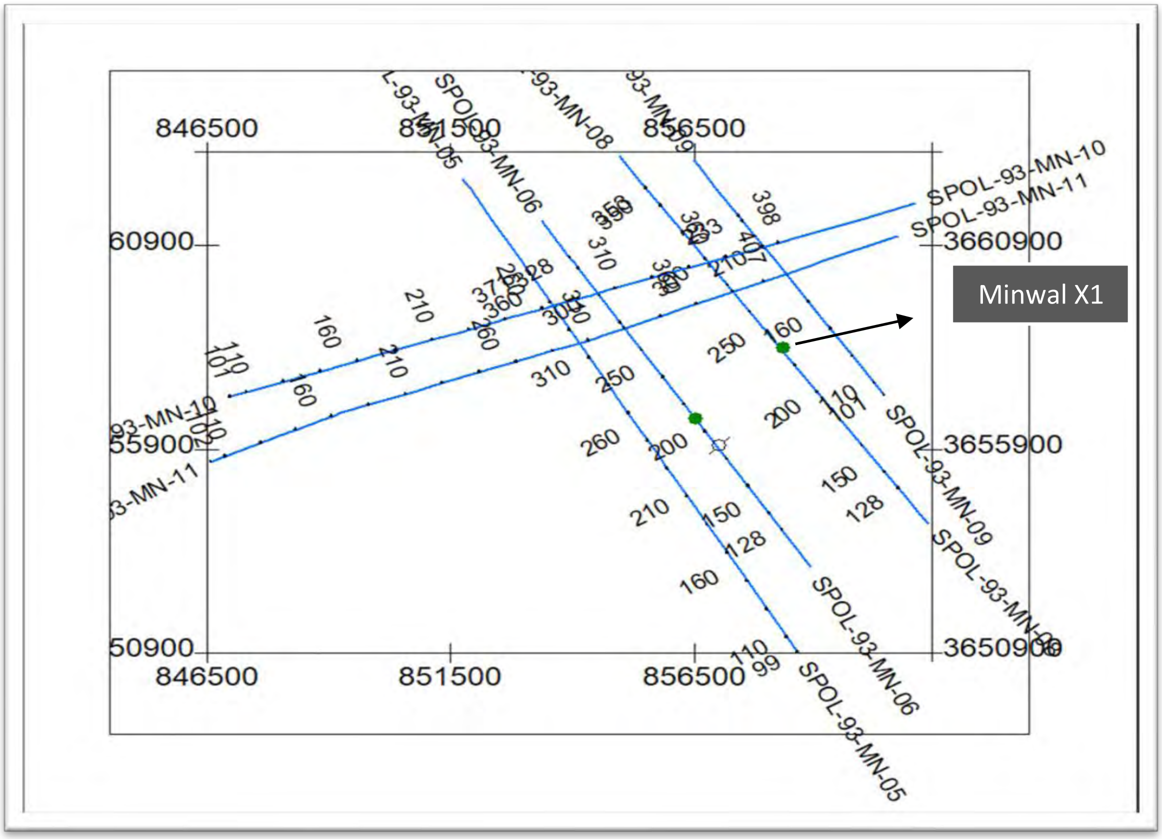


Figure 3.6: Base map of Joya Mir

3.7 Generation of Synthetic Seismogram:

Synthetic seismogram is convolution of reflection coefficient from well data and the source wavelet. The purpose of generating the synthetic is to tie the synthetic seismogram with the Seismic line, on which well is located **(Line POL-MN-93-08)**. 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 synthetic seismogram three horizon were marked on the line. Then by tie marked seismic line with other lines and horizons are marked on these lines. Well to seismic tie is an efficient way to mark the prospect zone. The time section gives the position and configuration of the reflectors in the time domain. However, the objective is to target the rock formations of the reservoir .

STEPS:

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

1. Load the Las file of the well in the software.
2. Open 1D forward modeling Project and select the well logs.
3. Integrate the sonic log to rescale from depth in meters to two-way travel time in seconds.
4. Compute velocity and density from sonic and density logs.
5. Create a TD chart for the well from the velocity logs.
6. Compute Acoustic impedance log using velocity and density log.
7. Compute the reflection coefficients from the time-scaled velocity log.
8. Two-way travel time; using extracted wavelet.
9. Convolve the reflection coefficient log with the wavelet to generate the amplitudes of the synthetic seismogram

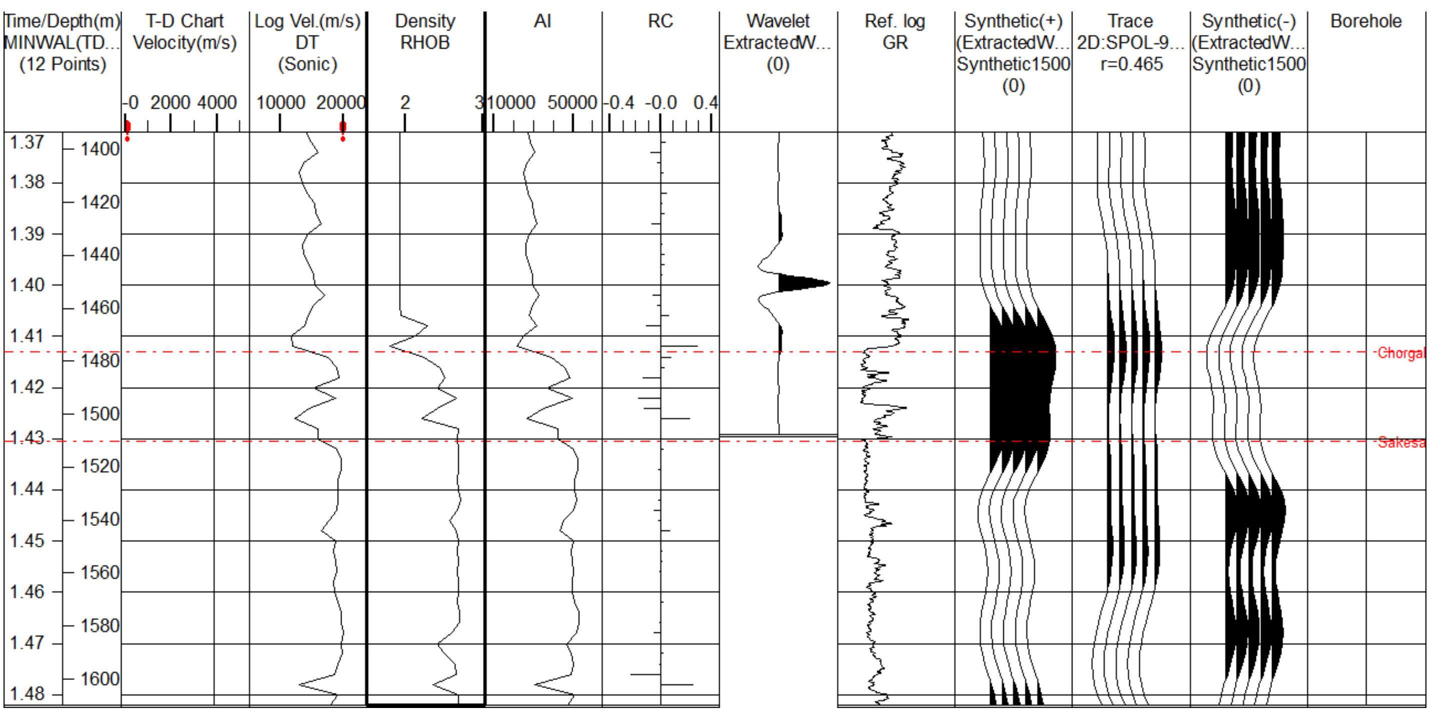


Figure 3.7: Shows the Synthetic Seismogram (Minwal Well X-01)

3.8 Horizon marking and interpretation:

The seismic section gives the position of the horizons in time domain. Two major reflectors are marked on seismic lines. Each reflector is marked with different colors so that they can be easily distinguished. However, the main goal is to target the rock formations of the reservoir which are Chorgali and Sakesar.

Seismic lines POL-MN-93-08, POL-MN-93-06 and POL-MN-93-05 oriented towards NW-SE, showing different horizons (Basement, Sakesar and Chorgali) terminated by forethrust and backthrust reverse faults structure which is an identification of Triangle zone in this area.

The Joya Mair triangle zone is limited by a fore thrust (Fault-1) on the SE side and a back thrust in the NW (Fault-2) side, the pop-up structures form a saddle-type structure, which may be the result of an increased effect of strike slip fault behavior near the Jhelum fault and may be the result of the diapirism of salt.

3.9 Marked horizons

Horizon can be interpreted on basis of synthetic seismogram , generated from well.In this project, four horizons were being marked.

- Chorgali Formation (Reservoir)
- Sakesar Formation (Reservoir)
- Salt Range Thrust
- Basement rock

3.10 Fault interpretation and marking

The study area lies in the southern part of the Potwar Plateau which is characterized by northward-dipping strata and local open folds of low structural relief and axes. The area is under compressional regime and having fore thrust and back thrust fault system. Therefore , two reverse faults are marked on assigned lines.

- F1 Reverse Fault
- F2 Reverse Fault

- Joya Mir structure is the combination of thrust and back-thrust, forming a triangle zone at subsurface. The triangle zone is the result of two phases of Himalayan thrusting. Stratigraphically it comprises of a petroleum play in which Patala Formation of Paleocene age act as a source rock while Chorgali and Sakesar Formation of Eocene age are two major reservoirs and Murree Formation of Miocene age is acting as a seal in the study area.

The interpreted marked horizons and faults on seismic lines are illustrated in below figures .

3.11 Interpretation of POL-MN-93-08 (dip line)

The line 93-MN-8 is north-west oriented line and is perpendicular to the axis of the structure present in the area and parallel to the dip of the major faults present. Here the reservoir rocks of Cambrian to Eocene are Chorgali and Sakesar present at depth of 2020.48 m and 2054.24 m respectively.Below the depth of 2176.235m the salt range formations start. Basement rock is also marked on the section (Fig.3.11).Minwal X-1 well is drilled on the respective line .

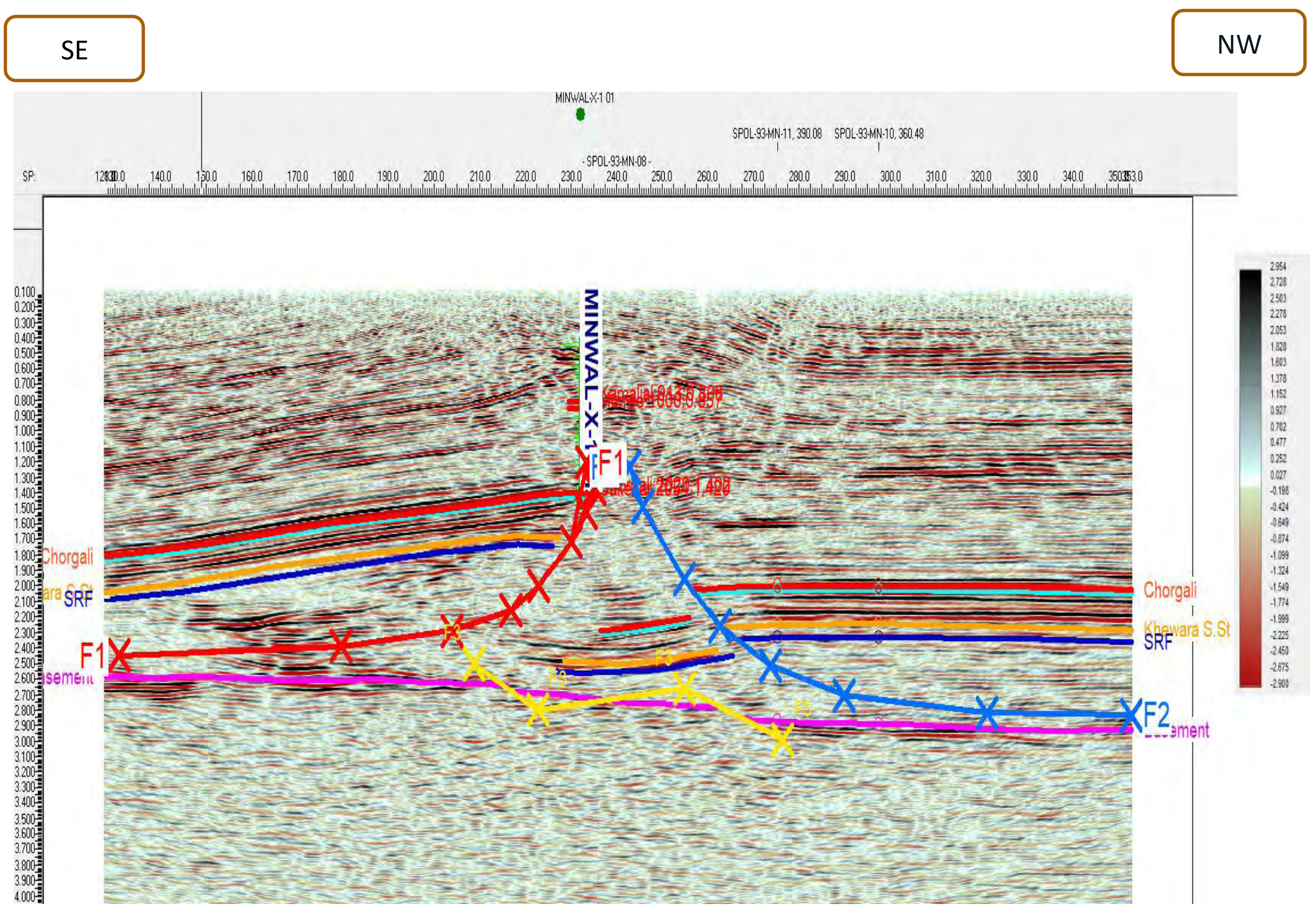


Figure : 3.11 (POL-MN-93-08) Dip line

3.12 Interpretation of POL-MN-93-05 dip line

SE-NW dipping seismic line 5, showing different horizons (Sakessar and Chorgali). Horizons are forming an asymmetric anticline whose limbs are gentle in the SW side and somewhat steep in the NE side. This triangle structure probably is the result of salt tectonics. Joyamair triangle zone is doubly plunging in the NE and SW. The basement exists at a TWT of 2.6 sec Figure 3.13. The decollement is provided by the Salt Range Formation above the basement. Two major blind thrusts originating from the basal decollement are visible in line 93-MN-5. No well has been drilled on this line. The arrangement of structures show that the forethrust is southeast verging while the backthrust is northwest verging forming a triangle zone.

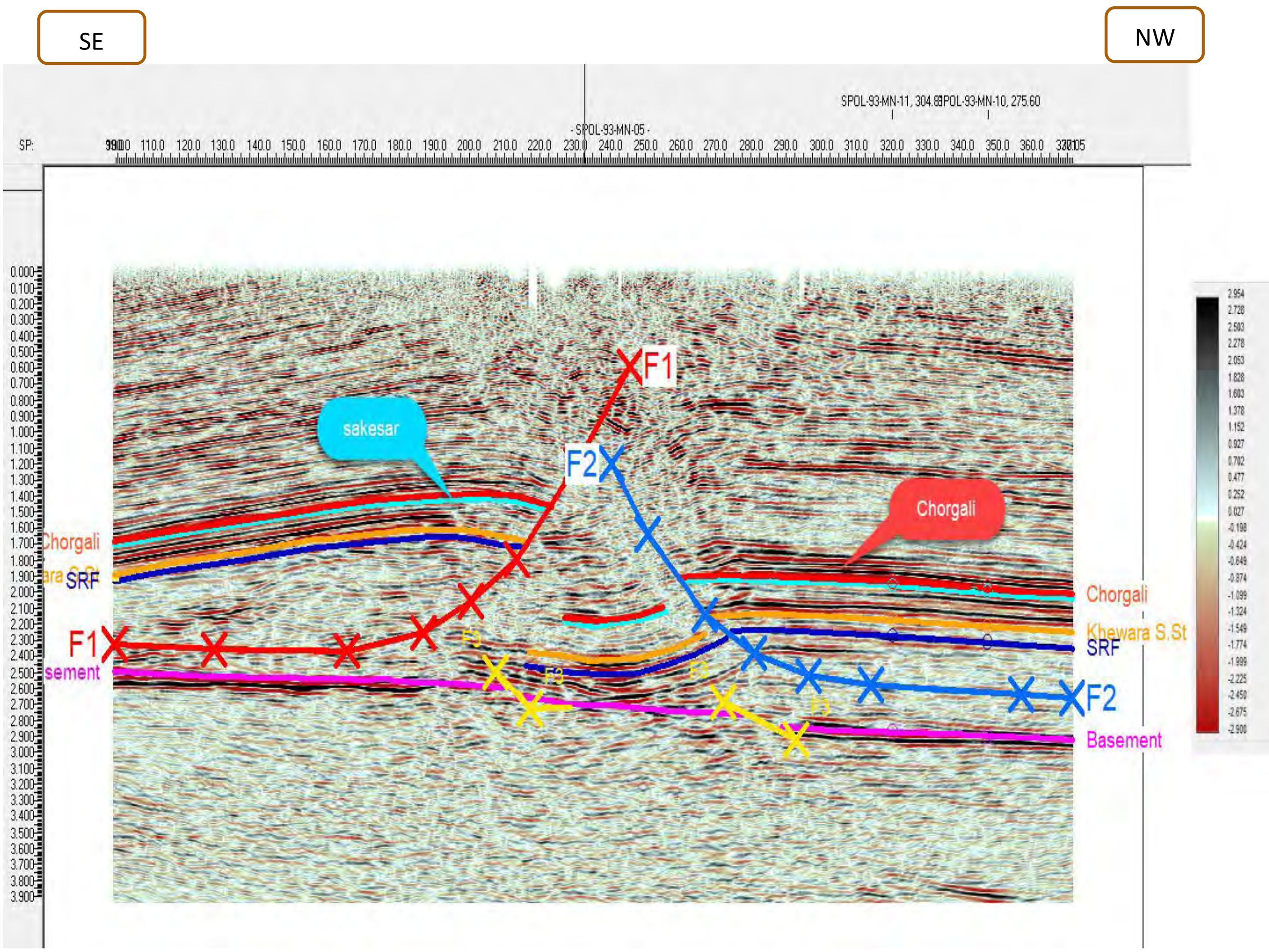


Figure 3.13 (POL-MN-93-05)Dip line

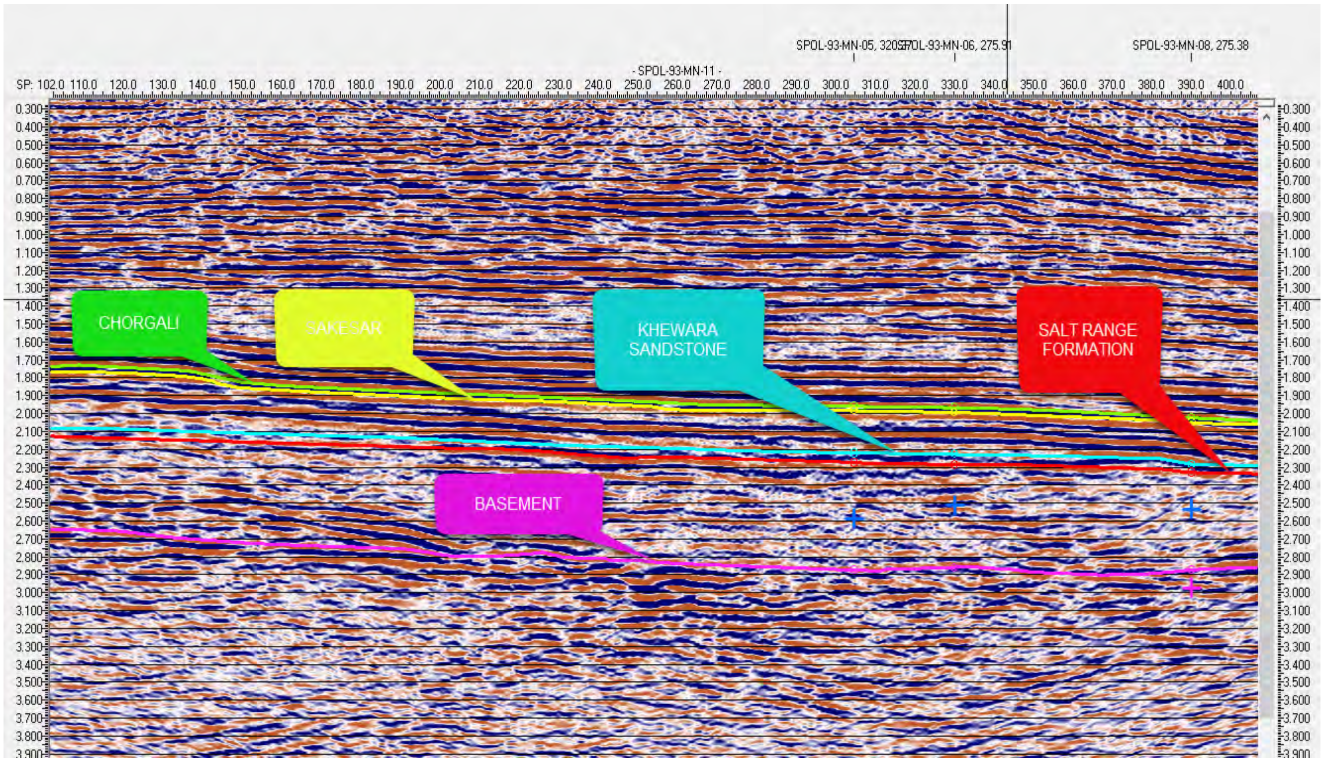


Figure 3.13 a (POL-MN-93-11) Strike line

- **Fault polygon generation**:

Before generation of fault polygons it is necessary to mark and identify the faults by analyzing seismic data. If one finds that the same fault is present on all the dip lines, then all points 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 making any possible closures against faults represent a false picture of the subsurface.So in order to accurately interpret the subsurface , conversion of fault into polygon is must. Figure 3.9 indicates the fault polygon for the sakesar reservoir .The pointed marks on the fault are indicating thrusting

3.13 Contour Map :

A line that connects the line of equal values is called a contour line. Such maps show us steepness of slopes, elevation top of the subsurface of the sedimentary rock layer and also the two way travel time of the horizon in millisecond (Norman, 2001).

- Time Contouring
- Depth Contouring

3.14 Time contour map

Now the next step is to compute time contour map. For contouring time map, Firstly we have to create grids.The time contour maps of reservoir rocks Chorgali and Sakesar formations are given below in figure 3.14 a and 3.14 b .The blue color is indicating the deepest parts between the thrusting and red is indicating shallower regions.

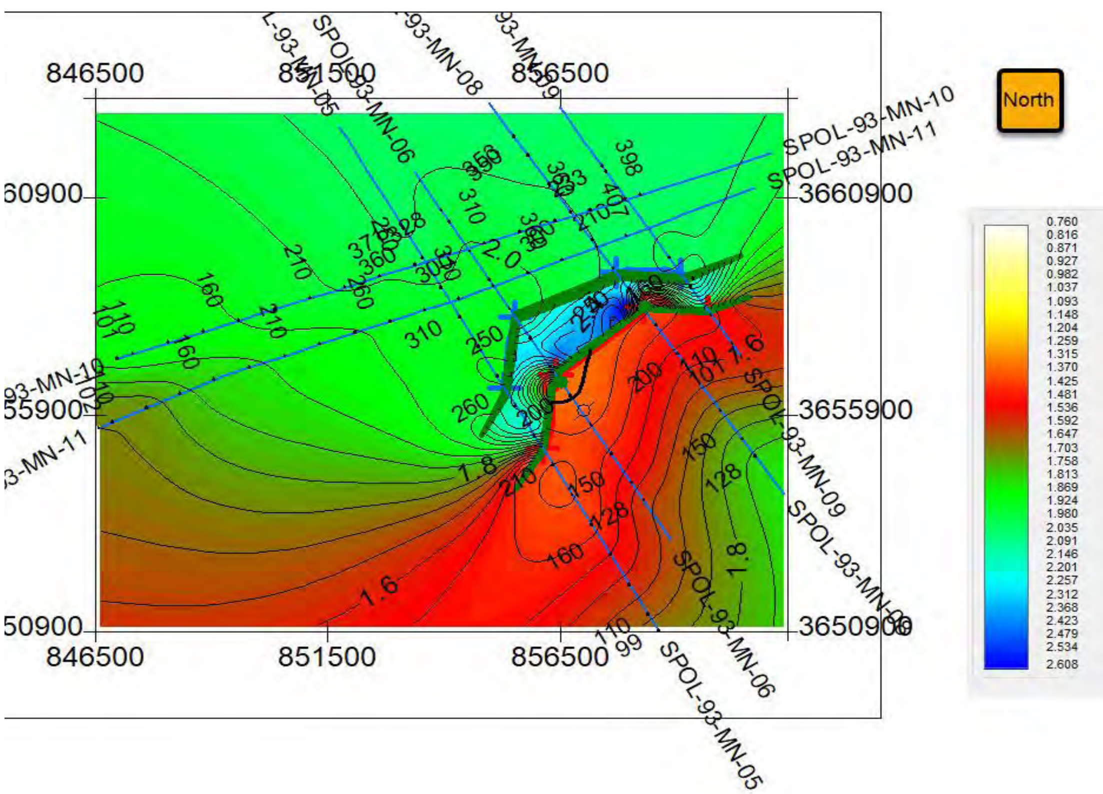


Figure : 3.14 a Time contour map for Chorgali

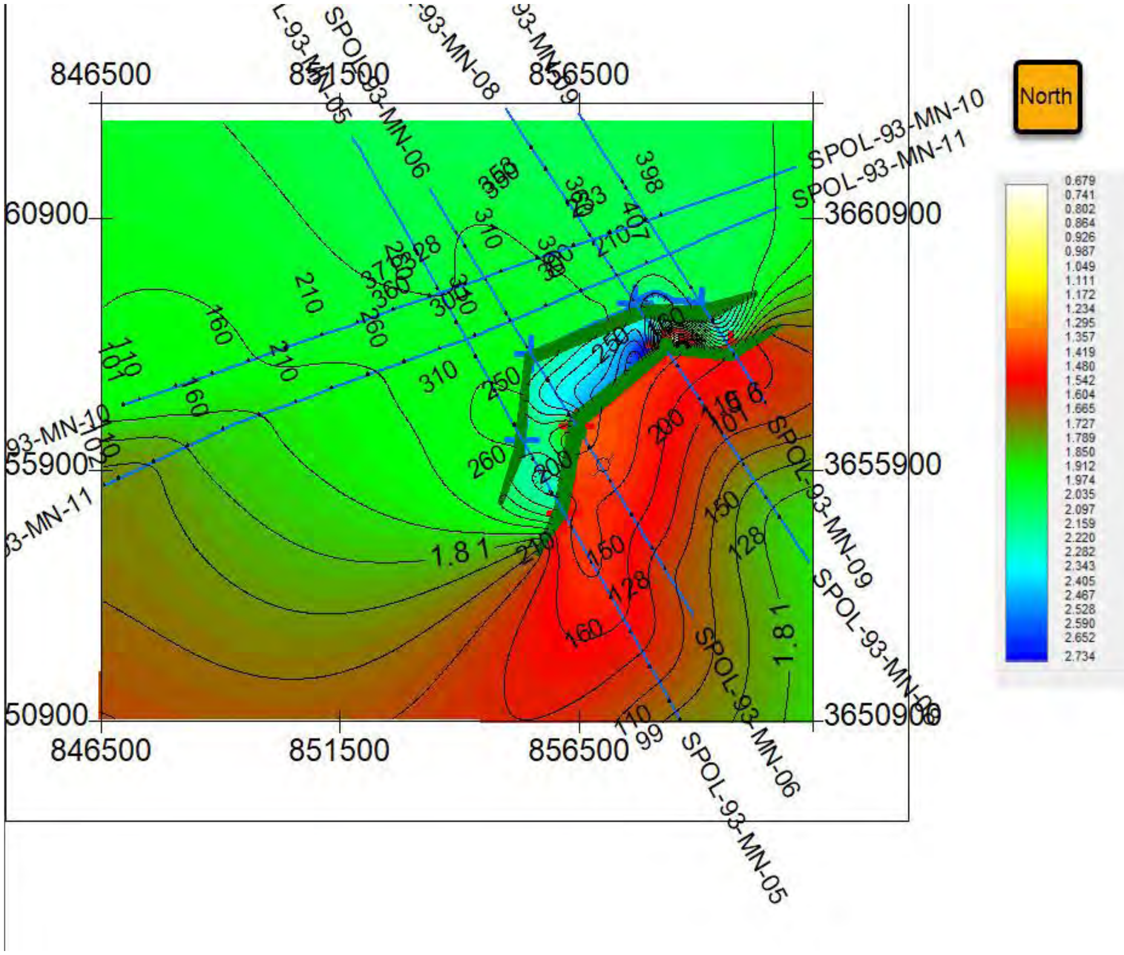


Figure 3.14.1b Time contour map for Sakesar

1. Depth Contour Map

The depth contour map marks the depth of structure. The depth contour map in the subsurface mainly shows the faults, anticlines and folds. From the scale the central portion between fault polygons is deepest in depth than the surrounding area So after marking the time contour map the depth contour map is being generated in the area of the Eocene top by using the following formula in the software.

S=V*T/2

Where,

T = Two way reflection time (sec)

V =Average velocity (m/sec)

S=Depth in meters

We have the time and depth of the given formation (Chorgali and Sakesar formations). Firstly calculate velocity of each formation by using the formula.

$$V=2*S/T$$

Then by multiplying the value of velocity with time, we can calculate the depth of each formation and hence we will compute depth contour map. The depth values have assign a color bar which can be used as a guide for interpretation. On basis of color bar orange color shows the deepest point which also give us information about the probable well location while the blue color represents shallowest point as shown in figure 3.15a and figure 3.15b.

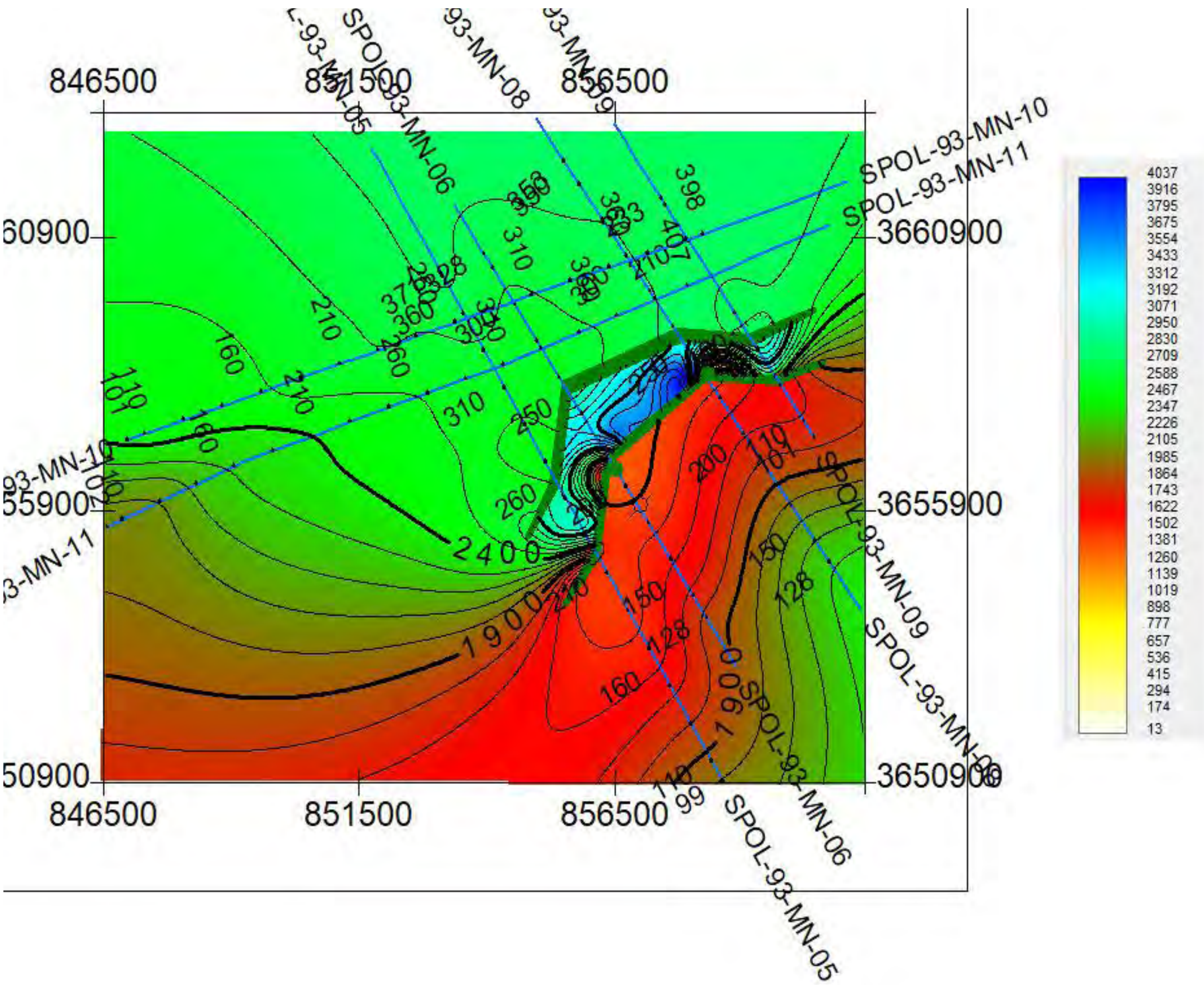


Figure 3.15.2 a Depth contour map of Chorgali

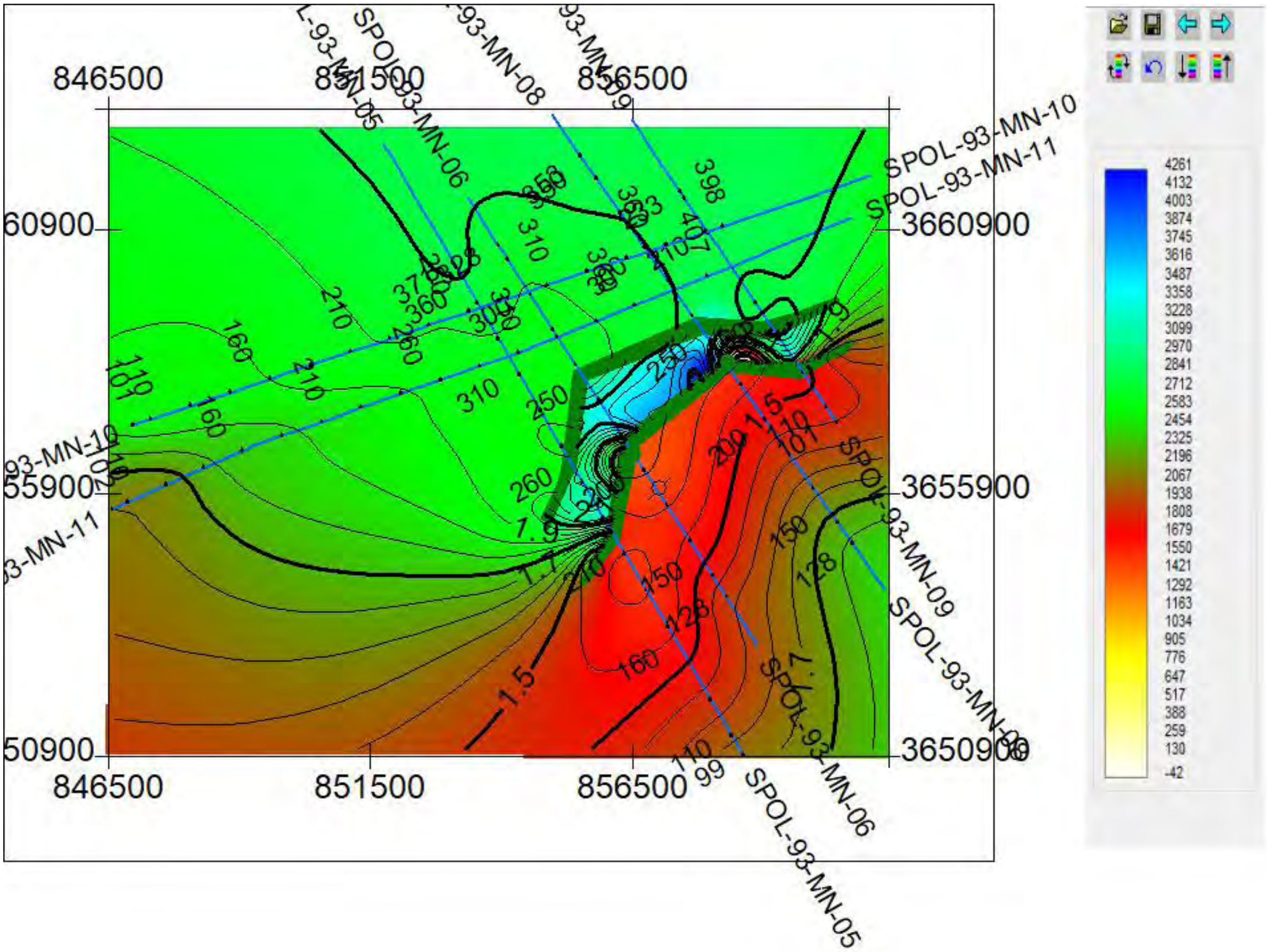


Figure 3.15 b Depth contour map of Sakesar.

CHAPTER NO 4

PETROPHYSICS

CHAPTER 4
PETROPHYSICS

4.1 Introduction:

Petrophysics is study of the physical properties relating the incidences, behavior of the rocks and fluids inside the rocks Reservoir characterization is the key step in oil and gas industry as it helps in defining the well and field potential so identify the zones within the reservoir which bears the hydrocarbons and can be recovered (Cosgrove et al., 1998).

Petrophysics is one technique used for the reservoir characterization. This study facilitates in identification and quantification of fluid in a reservoir. Knowledge of reservoir physical properties like volume of shale, porosity, water and hydrocarbon saturation is needed to define accurately probable zones of hydrocarbons. The integration of petrophysics along with the rock physics enables the geologists and geophysicists to understand the risks and opportunities in the area. Petrophysics is apprehensive with using well measurements to subsidize reservoir depiction (Daniel, 2003).

The continuous recording of a geophysical parameters along a borehole produces a geophysical well log. It involves measuring the physical properties of s rock surrounding rock layers with a sensor located in a borehole. The record of the measurements as a function of depth is called a well log. (Telford, 1990)

Geophysical well logging has become a standard operation in petroleum exploration, identification of geological formations, formation fluids, correlation between wells and evolution of the productive capabilities of reservoir formations are usually the principle objectives. (Telford, 1990)

The instrumentation necessary for borehole logging is located in a cylindrical metal tube known as Snode. There are many types of well logs, depending upon characteristics of the rock properties being measured.

4.2 Log Interpretation Objectives:

Quantitative analysis of well logs provides the analyst with values for a variety of primary parameters such as:

- Its storage capacity (Porosity)
- Water saturation , fluid type (oil, gas, water)
- Type of reservoir (Lithology)
- Its productivity

(Permeability) The main

objectives of logging are:

- To provide data for evaluating petroleum reservoir.
- To aid in testing, completion and repairing of the well.

To calculate the oil reserves in an oil pool we must have the knowledge of following:

- Thickness of the oil bearing formation.
- Porosity of formation.
- Oil saturation.
- Lateral extent of the oil bearing strata.

The petrophysical analysis through wireline logs (Density, Neutron, Self-potential and Resistivity) for the Sakesar Formation of Eocene age in Minwal X-1 well is conducted. The analyses are made to calculate porosity, determine formation water resistivity, water saturation and oil saturation. These findings are very useful in investigating the hydrocarbon potential of the reservoir.This reservoir characterization is the key step in the oil and gas industry as it defines the potential of the well and identify areas of the reservoir that can be recovered.

4.3: Types of logs used

In petrophysics, there are three main tracks. The lithogical track , porosity track and resistivity track. Following are the various type of logs used for petrophysical analysis:

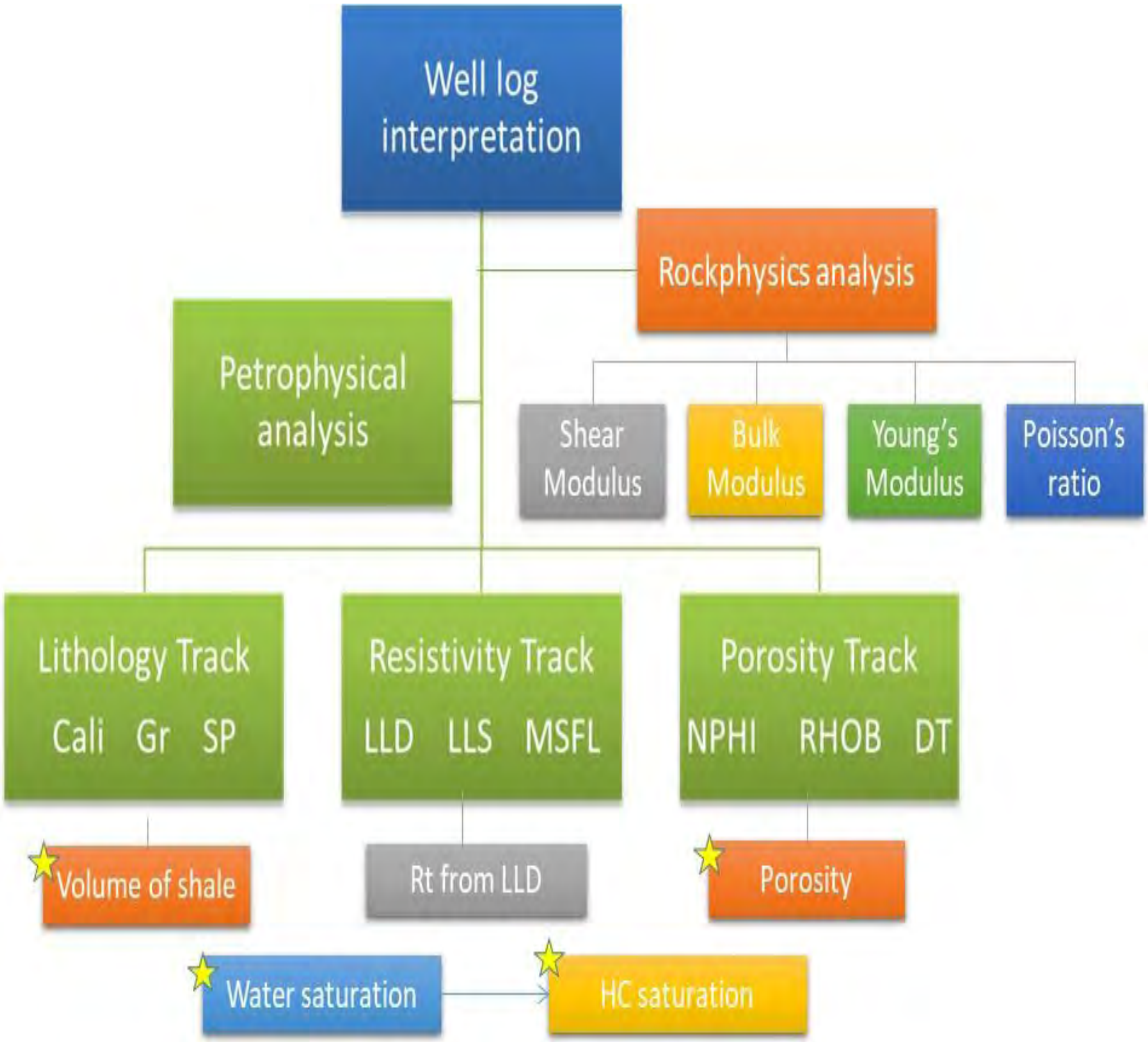
Table 4.3

Lithological Logs	Porosity logs	Fluid Dynamic logs
Gamma ray Log (Gr)	Sonic Log(DT)	Resistivity Logs (LLD, LLS)
Spontaneous potential Log (SP)	Density log (Rhob)	Induction log
Neutron-density log	Neutron porosity log (NPHi)	
Litho-density log		

For the analysis of petrophysical activity, the following parameters are determined on the basis of the logarithmic curves.

- Volume of shale
- Water saturation
- Hydrocarbon saturation
- Porosity

The above mentioned parameters will help in characterization of reservoir rocks i.e Chorgali and Sakesar formation rocks.



Petrophysical analysis workflow

4.4:Interest Zones

The zones of interest are defined on the basis of source, reservoir and seal rock formations given in well tops of Minwal-01 well. The zones of interest which are marked are listed in the Table

Table 4.4

Prospect Zones	**Start Depth (m)**	**End Depth (m)**
Chorgali	2020.48	2054.24
Sakesar	2054.24	2176.235

4.5: Log Data

The Joya Mair Minwal X-01 log data was available in Log ASCII Standard (LAS) format. The logarithmic curves as well as some parameters given in the header of the LAS file are used to calculate all the basic and advance parameters.

Table 4.5: Scale used for the different logs

SR NO.	**TYPE OF LOG**	**ACRONYM**	**SCALE**	**UNIT**
1	Gamma ray Log	GR	0---------150	API
2	SP Log	SP	120-------(-20)	mV
3	Density Log	RHOB	1.50----3.00	gm/cm3
4	Sonic Log	DT	140-------40	µsec/ft
5	Neutron Log	NPHI	0.60---(-0.15)	PU
6	Caliper Log	CALI	6----------16	Inches
7	Laterolog Deep	LLD	1--------2000	Ωm
8	Laterolog Shallow	LLS	1--------2000	Ωm

4.6 Lithology Track

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

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

4.6.1 Gamma Ray (GR):

This log is actually a measurement of the natural radioactivity of the formation. Gamma radiations are emitted in the form of electromagnetic energy called photon. When photon collides with electrons, some energy is transferred to electron called Compton scattering. These scattered radiations reached the detector and are counted after absorption of gamma rays from natural radioactive source present within the layer. These emissions are counted and displayed as count per second which is termed as gamma ray log. This log is very important and used for various purposes however, its basic purpose is to differentiate between sand and shale (Asquith and Gibson, 2004).

4.6.2 Spontaneous Potential Log (SP):

The "SP" log is a record of the naturally occurring potential in the well bore. This log utilizes a single moving electrode in the bore hole and a reference electrode at the surface, located in the mud pit. The "SP" curve therefore is a record of the potential difference, which exists between the surface electrode and the moving electrode in the bore hole (Asquith and Gibson, 2004). This log can be used for the following purposes (Daniel, 2003).

- To identify the permeable and impermeable zone.
- To detect the boundaries of bed.
- To determine the volume of shale.
- To determine the resistivity of formation water.
- Qualitative measure of permeability

4.6.3 Caliper Log:

Caliper log is used to measure the borehole size. This log helps us to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. Because if there is any 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 pertophysical logs.

4.7 Porosity Logs Track:

Porosity logs measure the percentage of pore volume in a bulk volume of rock. These logs are also helpful to provide data to distinguish between oil and gas and, in combination with resistivity measurements and calculate water saturation.

Porosity log include.

- Sonic log (DT)
- Density log (RHOB)
- Neutron Porosity log(NPHI)

4.8 Sonic Log:

Sonic log device consists of a transmitter that emit sound waves and a receiver that picks and record the compressional waves as it reach the receiver. This log is a recording verses depth of time (t) which is required by a compressional wave to go across 1 feet of formation, called interval transient time Δt, while it is the reciprocal of the velocity of sound wave. This time (Δt) is depended upon lithology and porosity of the formation (Asquith and Gibson, 2004).

4.9 Density Log:

Gamma rays collide with electrons in formation and scattered gamma rays (Compton scattering) received at detector and counted as indicator of formation density. An increase in counting rate causes a decrease in bulk density of formation and vice versa.

Bulk density from the density log is considered to be sum of density of fluid times its relative volume plus density of matrix time its relative volume. However, density log separately and also along with other logs used to achieve various goals (Tittman and Wahal, 1965).

4.10 Neutron Log (NPHI):

This is the porosity log which measure concentration of hydrogen ions in the formation. Neutron is continuously emitted from a chemical source in neutron logging tool. When these neutron collide with nuclei in the formation and results in loss of some energy. Hydrogen atom has same mass as that of neutron, maximum loss of energy occurs when neutron collide with hydrogen atom. Hydrogen is usually indication of presence of fluids in pores, so energy loss is related to the formation porosity.

In shale free formation (clean formation), this log measures the liquid filled porosity where the porosity is filled by water or oil. Neutron porosity will be very low when pores in the formation are filled with gas instead of oil or water. This occurs because there is less concentration of ions (hydrogen) in the gas as compared to water and oil. This decreasing of neutron porosity due to presences of gas called as gas effect (Asquith and Gibson, 2004).

4.11 Electrical Resistivity Logs Track:

Basically there are different types of electrical Resistivity logs, which measures the subsurface electrical resistivity. This helps to differentiate between formations filled with salty waters and those filled with hydrocarbons. Resistivity and porosity measurements are used to calculate water saturation.

Resistivity logs includes

- Lateral log Deep (LLD)
- Lateral log Shallow (LLS)
- Micro- Spherically Focused Log (MSFL), But MSFL was not present in my Data of Miano-09.

Laterolog Deep (LLD):

Lateral log is used for deep investigation of the undisturbed zone (Uninvaded zone) and it is called Lateral log 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. LLD having deep penetration as compared to the (LLS).

Laterolog Shallow (LLS):

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

4.12 Calculation of Rock Properties:

Many of the rock properties can be derived using geophysical well logs. We have calculated the following properties using the different equations which are given in below Table 4.12.

	PROPERTIES	***MATHMATICAL FORMULAS***
1.	VOLEUME OF SHALE (Vsh)	VSH=(GR-GRCLN)/(GRSHL- GRCLN)
2.	DENSITY POROSITY (PHID)	PHID=(RHOMA-RHOB)/(RHOMA- RHOF)
3.	SONIC POROSITY(PORS)	PORS=(DLT-DLTM)/(DLTF-DLTM)
4.	TOTAL POROSITY (PHIT)	PHIT=(DPHI+NPHI)/2.0
5.	EFFECTIVE POROSITY (PHIE)	PHIE=((DPHI+NPHI)/2.0)*(1-VSH)
6.	STATIC SPOTANIOUS POTENTIAL (SSP)	SSP=SP(CLEAN)-SP(SHALE)
7.	RESISTIVITY OF MUD FILTRATE(Rmf2)	$R_{Mf}2$=(ST+6.67)*Rfm1/(FT+6.67)
8.	FORMATION TEMPRATURE (FT)	$FT=\frac{(BHT-ST)}{TD} \times FD$
9.	SATURATION OF WATER (Sw)	$SW=[\ ((a/\Phi^{m}) \times Rw)/\ Rt]^{1/2}$
10.	HYDRO CARBON SATURATION (HS)	$HS= 1-S_W$

(TABLE 4.12)

4.13 Volume of Shale:

The volume of shale is calculated using the Gamma ray (GR) log. This log is used to measure the natural radio activity of the formation. Hence it provides the concentration of the radioactive material present in the formation, hence it is very useful in order to identify the lithology. The value of the gamma ray is low in the carbonate and in sandstone while it having higher value in the shale. The reason is that the concentration of the radioactive material is larger in the shale as compared to sand and the carbonates.

This will lead us to distinguish between reservoir and the non-reservoir rocks (Acquith and Gibson, 2004).The volume of the shale is estimated by using the following equations given in table 4.3 by (Rider, 1996).

4.14 Calculation of Porosity:

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

4.15 Average Porosity:

Average porosity is the sum of all porosities logs divided by number of logs used for calculating porosity. Its mathematical equation (Schlumberger, 1989) is given in Table 4.1.

4.16 Effective Porosity:

Effective porosity is the ratio of linked pore volume to the total volume, calculated after removing the effect of shale.

Effective porosity is used for the estimation of water saturation. It can be calculated using the mathematical relation (Schlumberger, 1989) given in the Table 4.1.

Now to calculate the Water saturation required the Resistivity of the water of formation.

4.17 Water Saturation (Sw) Determination

Water saturation has been calculated with help of the Archie's Equation:

$$Sw = [((a/\Phi^m) \times Rw)/ Rt]^{1/2}$$

Where,

Sw= water saturation

Rw=water resistivity (formation) Φ

= effective porosity m(cementation

factor) =1.95

a(constant) = 1

Rt= log response (LLD)

Rw has been calculated with help of the following formula:

Rw= 0.1

Φ = porosity in clean zone

Rt =Observed LLD curve in clean zone.

N= saturation exponent and its value varies from 1.8 to 2.5 and it is taken as 2.05

4.18 Calculation of Hydrocarbon Saturation (S_h)

The fraction of pore spaces containing hydrocarbons is known as hydrocarbon saturation and is calculated by relation given in equation (13)

$$S_h = 1 - S_w,$$

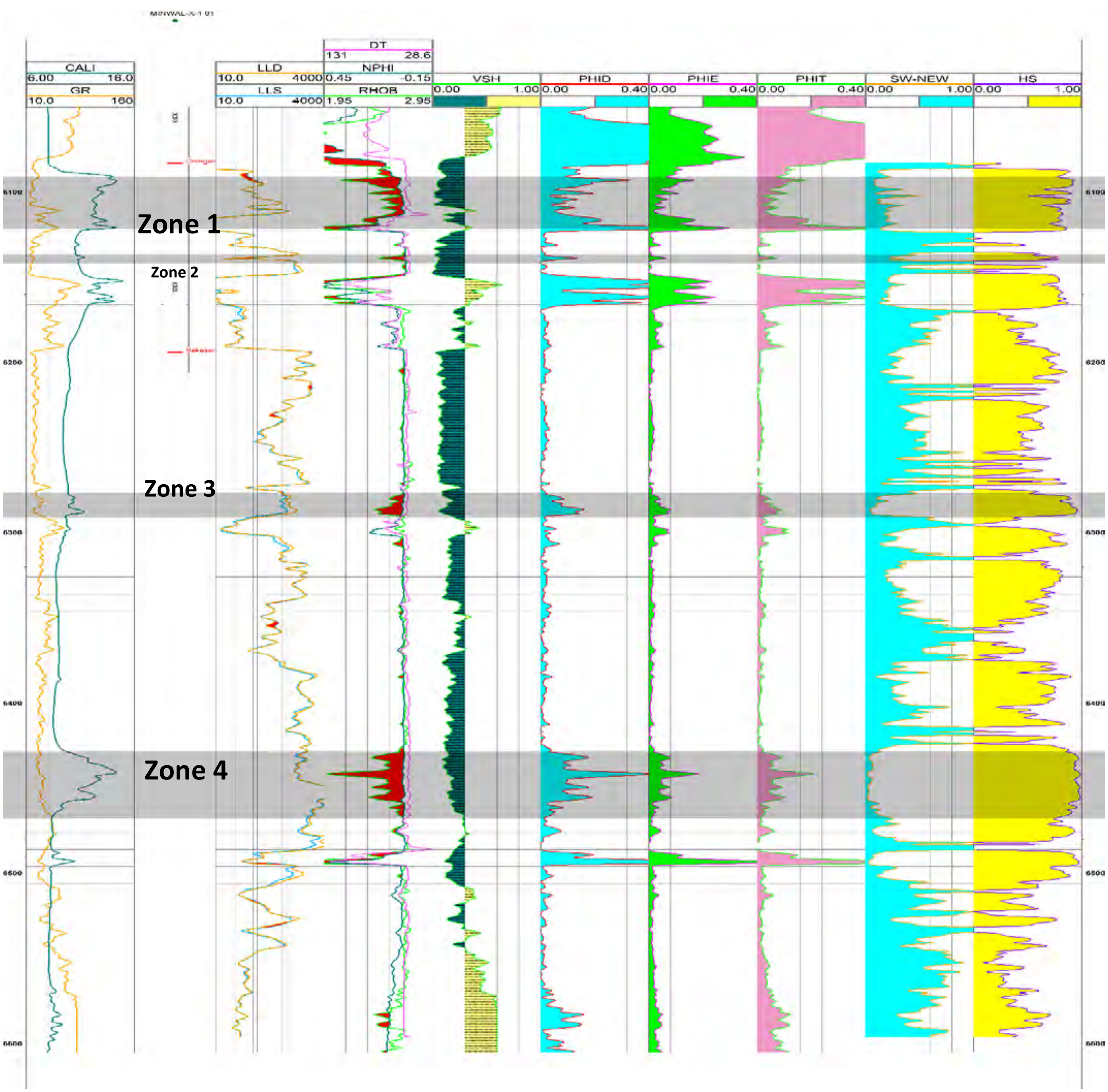
where,

S_h= Hydrocarbon saturation,

S_w= Water saturation.

As the S_h is the remaining percentage pore volume other than the percentage of pore volume occupied by water, hence this method is an indirect method which quantitatively estimate hydrocarbon saturation.

4.19 Result of Petrophysical Evaluation



4.20 Zone Marked:

Zones marked in above image indicates the prospect zone. The zone is marked on basis of log curve responses. In this particular zone, the response of caliper s bit disturbed due to presence of fracturing, But the value of Gr log is low indicating non shaly (limestone) lithology, where resisitivity log indicate high responses while MSFL is low. The density and NPHI has a very prominent crossovers indicating prospect zone. Whereas the values of porosity are relatively high due to presence of secondary porosity along with primary porosity.Moreover, water saturation percentage is lower than that of hydrocarbon saturation.

Results of petrophysical analysis.

ZONE/ROCK PROPERTIES		CHORGALI(6635-6665FT) ZONE-1	CHORGALI(6680-6685FT) ZONE-2
1	Average volume of the shale (VOS)	13.2%	4.75%
2	Average Porosity (PHIT)	11.38%	2.36%
3	Average Density Porosity	16.29%	4.78%
4	Average, Effective Porosity (PHIE)	9.35%	2.22%
5	Average,Saturation of Water (Sw)	19.17%	94.21%
1.	Average,Saturation of Hydrocarbon (Sh)	80.82%	5.78%

CHORGALI FORMATION ZONE

ZONE/ROCK PROPERTIES		SAKESAR(6820-6834FT) ZONE-1	SAKESAR(6970-7010FT) ZONE-2
1.	Average volume of the shale (VOS)	12.39%	16.3%
2.	Average Porosity (PHIT)	4.72%	6.26%
3.	Average Density Porosity	8.08%	11.56%
4.	Average, Effective Porosity (PHIE)	4.17%	5.29%
5.	Average,Saturation of Water (Sw)	16.63%	6.29%

6.	Average,Saturation of Hydrocarbon (Sh)	83.36%	93.70%

SAKESAR FORMATION ZONE

Petrophysical analysis of Joya Mair Minwal X-01 is concluded on the basis of behavior of different log curves. As a first indicator of lithology, GR log is very useful as it suggests where shale may be predictable. For the higher values of GR, higher will be the percentage of shale. So due to this reason, clean zone or shale free zone is defined easily.

Where there is low value of the shale we can say that this is the zone in the reservoir where the hydrocarbon can be present, but not confirm. Basically to confirm the types and amount of hydrocarbon we go towards the integrative results of other logs that give a comprehensive report about the hydrocarbon and water present in that zone.

The resistivity log such as LLD and LLS are run in track 2. LLD measure the resistivity of deeper uninvaded zone where hydrocarbons are present whereas the LLS measure the resistivity of shallow invaded zone adjacent to the borehole.The resistivity logs measure same value in this case because of the high saturation of water in the abandoned well.The principal use of resistivity logs is to detect and quantify hydrocarbon. That is, resistivity logs are used to give the volume of oil/gas in a particular reservoir, or, in petrophysical terms, to define the water saturation (Sw). When Sw is not 100%, then hydrocarbons are present there. Higher values of resistivity usually indicate the presence of hydrocarbons or fresh water. If separation between LLD and LLS is reported, that is quite possibly a hydrocarbon zone as value of LLD is much higher in case of oil or gas. Density in the study field mainly varies from 2.55 to 2.99 g/cm3. But somewhere at the reservoir level, very high density corresponding to low resistivity is noted. It may be due to the presence of some heavy minerals like gluconate, Chlorite, Chamosite Siderite etc. (Farid et al 1993).

Chorgalli formation starts at a depth of 2020.48 m(6627ft) to 2054.24m(6738ft) having a total or gross thickness of 33.76 m .

Calliper log measure the continuous record of size and shape of borehole.The greater value of caliper log curve in track-1 indicates fracturing due to limestone where the borehole diameter is increased then the normal diameter.

Also the low value of SP log is observed in case of carbonates because of low permeability and low ions exchange in carbonates. The hydrocarbon zone also show low SP response because the interstacial water contact with the borehole fluid is reduced. The SP curve is flat opposite Shale formation because of low permeability and porosity .This creates a straight line known as shale base line. The maximum deflection in clean formations i-e Sand is called SSP (Static Spontaneous Potential).

Density log is used for porosity calculation and it is run in track-3 which measures the formation bulk density along with neutron porosity log. Both the logs measure the porosity of the formation and forming a crossover at the reservoir

On basis of the above mentioned figure the logs result is divided into four prospect zones. All the four zones are marked on basis of log response, as value of GR log reduces and caliper is straightened, it is indicative of favourable hydrocarbon conditions.Similarly the value of resistivity logs are high , porosity is low , dominant lithology of limestone is present. This all is indicative of favourable reservoir conditions in both reservoirs Chorgali and Sakesar formation.

CHAPTER NO 5

SEISMIC ATTRIBUTES

CHAPTER 5

SEISMIC ATTRIBUTES

Introduction:

Seismic attributes can be conveniently defined as "the quantities that are measured, computed or implied from the seismic data".

From the time of their introduction in early 1970's seismic attributes gone a long way and they became aid for geoscientists for reservoir characterization and also as a tool for quality control. Different authors introduced different kinds of attributes and their uses. With the introduction of 3D seismic techniques and associated technologies and introduction of seismic sequence attributes, coherence technology in mid 1990's, and spectral decomposition in late 1990's has changed the seismic interpretation techniques and provided essential tools that were not available for geoscientists earlier. With the introduction of 3D visualization techniques, use of seismic attributes has attained a new dimension. Development of a wide variety of seismic attributes warrants a systematic classification. Also a systematic approach is needed to understand the use of each of these attributes and also their limitations under different circumstances.

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 Classification of Seismic Attributes:

Though the purpose of this paper is to understand the purpose of different attributes that can be used as tools in interpretation, it is useful to understand the classification of different attributes at this stage. The following classification is taken from the paper "Seismic Trace Attributes And Their Projected Use In Prediction of Rock Properties And Seismic Facies" by Rock Solid Images.

The Seismic Attributes are classified basically into 2 categories (Taner et al, 1994).

- Physical Attributes
- Geometric Attributes

5.3.1 Physical Attributes:

Physical attributes are defined as those attributes which are directly related to the wave propagation, lithology and other parameters. These physical attributes can be further classified as pre-stack and post-stack attributes. Each of these has sub-classes as instantaneous and wavelet attributes. Instantaneous attributes are computed sample by sample and indicate continuous change of attributes along the time and space axis. The Wavelet attributes, on the other hand represent characteristics of wavelet and their amplitude spectrum.

5.3.2 Geometrical Attributes:

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

5.3 Seismic Attributes:

In my work, I applied following attributes to confirm seismic interpretation.

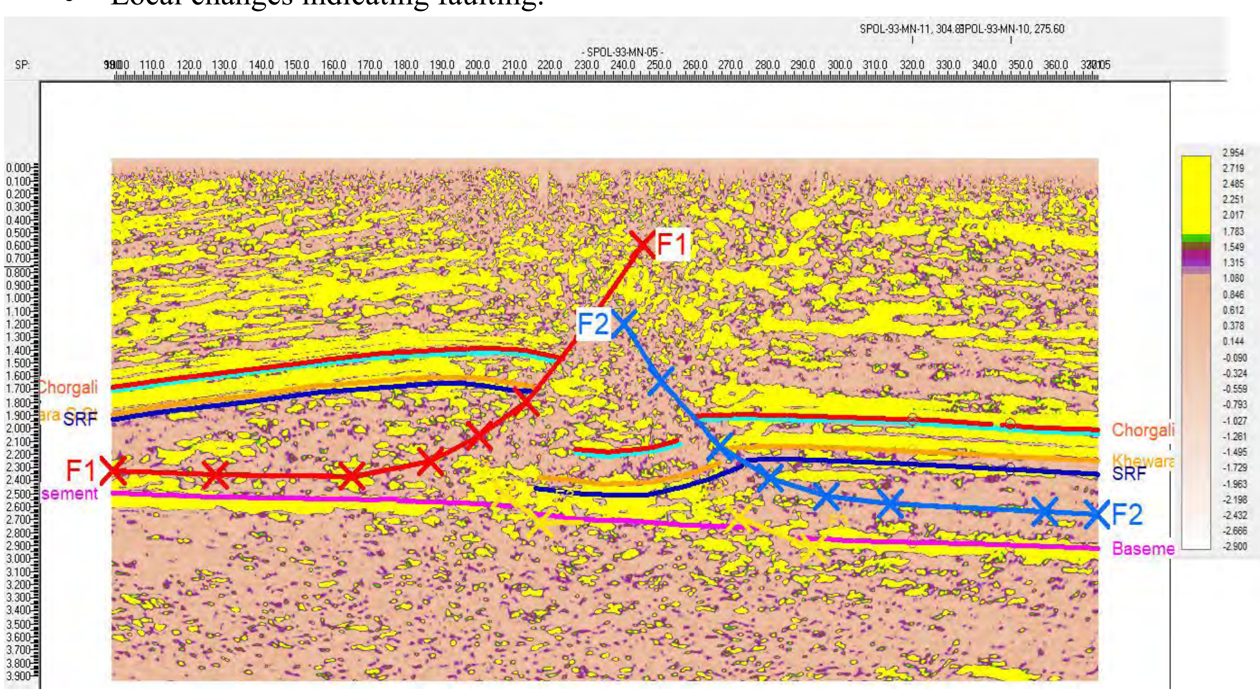
- Envelop of Trace
- Instantaneous Phase
- Average Energy

5.4.1 Envelop of Trace

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

This attribute is mainly useful in identifying:

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



Trace Envelop

Envelope of a trace shows mainly the acoustic impedance contrast, It always remains positive whether the reflection coefficient is positive or negative.

5.4.2 Instantaneous Phase:

Instantaneous phase attribute is given by

$\phi(t)=\text{arc tan} |H(t)/T(t)|$

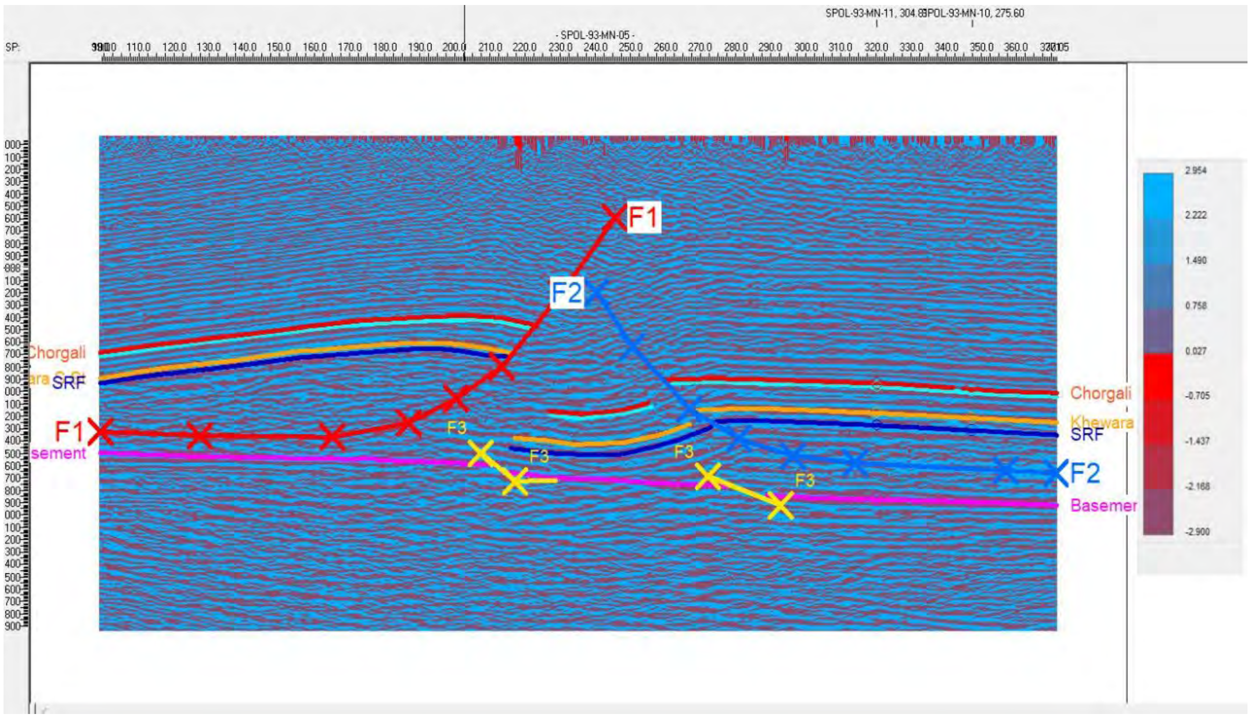
The seismic trace T(t) and its Hilbert transform H(t) are related to the envelope E(t) and the phase $\phi(t)$ by the following relation:

$T(t)=E(t)\cos(\phi(t))$ $H(t)=E(t)\sin(\phi(t))$

Instantaneous phase is measured in degrees ($-\pi$, π). It is independent of amplitude and shows continuity and discontinuity of events. It shows bedding very well. Phase along horizon should not change in principle, changes can arise if there is a picking problem, or if the layer changes laterally due to “sink-holes” or other phenomena.

This attribute is useful as

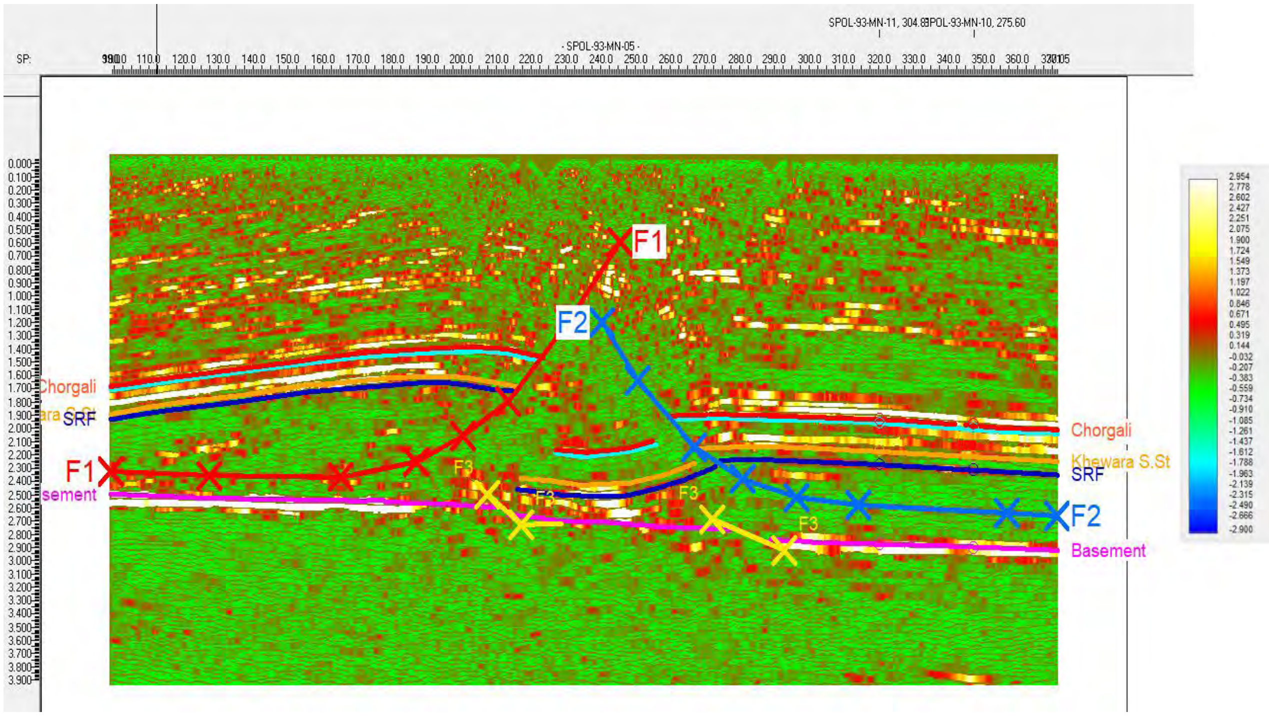
- Best indicator of lateral continuity.
- Relates to the phase component of the wave propagation.
- Can be used to compute the phase velocity.
- Has no amplitude information, hence all events are represented.
- Shows discontinuities, but may not be the best. It is better to show continuities Sequence boundaries.
- Detailed visualization of bedding configurations.
- Used in computation of instantaneous frequency and acceleration.



Phase attribute

5.4.3 Average Energy:

Average energy is a post-stack wavelet attribute, in which, within a specified window the square root of the sum of squared amplitudes is calculated and divided by their number of samples. The wavelet attributes are computed at the peak of the envelope, which represent the attributes of the wavelets within a zone defined by the trace 45 envelope minima. These attributes indicate spatial variation of the wavelets and therefore relate to the response of the composite group of individual interfaces below the seismic resolution. The attribute has a blocky response and individually highlights the seal, reservoir and source rocks as shown in Figure



Average Energy

5.5 Conclusion:

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.

6. Conclusions:

The following conclusions can be drawn from the work carried out in this dissertation.

- Correlation of depth converted sections with formation tops and synthetic seismogram indicate Murree formation as seal ,Chorgali and Sakesar limestone as reservoir and Patala shale as source rocks.
- Two reverse faults F1 and F2 were marked on given sections.
- Time and Depth contour maps of Chorgali and Sakesar help us to confirm the presence of anticlinal structure in the given area.Surface contour map of Chorgali and Sakesar gives the real shape of sub-surface structure, which is a Triangle zone bounded by forethrust and back thrust faults.
- Petro physical analysis of the reservoir zone show the hydrocarbon potential of the well by yielding 20% water saturation and 80% hydrocarbon saturation.
- Seismic attributes also applied on seismic data which confirm the hydrocarbon prospect zone.

7. References:

- Aamir, M., and M., M., Siddiqui, 2006. Interpretation and visualization of thrust sheets in a triangle zone in eastern Potwar, Pakistan. The Leading Edge, p. 24-37.
- Ahmed, Shahid., 1995, Production Of Crude Oils In Pakistan: Outlook For The Future, Ministry of Petroleum and Natural Resources, JOJ9-A, Pak Plaza, Fazal-e-Haq Road, Blue Area, Islamabad, Pakistan, PP-1.
- Asquith, G.B.,and Gibson, C.R., 2004, Basic well log analysis, 2nd edition.
- Baig, M. S. and Lawrence, R. D., 1987. Kashmir J. Geol., 5, PP 1-22
- Bust, V. K., Majid, A. A., Oletu, J. U., & Worthington, P. F. (2013). The petrophysics of shale gas reservoirs: Technical challenges and pragmatic solutions. Petroleum Geoscience, 19(2), 91-103.
- Butler, R.W., Coward, M.P., Harwood, G.M., Knipe, R.J., 1987. Salt control on thrust geometry, structural style and gravitational collapse along the Himalayan mountain front in the Salt Range of northern Pakistan. In: Lerche, I., O'Brien, J.J., (Eds.), Dynamical geology of salt and related structures. Academic Press, 339-418.
- Cheema, M.R., S.M. Raza & H. Ahmed. 1977. Cainozoic. In: Shah, S.M.I. Ed.1977. Stratigraphy of Pakistan. Quetta, Geological Survey of Pakistan(Memoirs 12): PP-56-98
- Davies, L. M. & E. G. Pinfold, 1937: The Eocene beds of the Punjab SaltRange. India Geol. surv., Mem., Palaeont. India, NewSeries, PP-24, 79.
- Doll, H. G., 1948, The SP log, theoretical analysis and principles of interpretation: Trans., AIME, v. 179, p. 146-185
- Fatmi, A.N., 1973, Lithostratigraphic Unit of Kohat Potwar Province,Indus Basin, Pakistan, Pakistan Geol. Surv., Mem., 10., PP-8.
- Gee ER (1989) Overview of the geology and structure of the Salt Range, with observations on related areas of northern Pakistan.In: Malinconico LL, Jr. Lillie RJ, (eds.) Tectonics of the western.Himalayas. GeolSoc Am Spec Pap. 232: 95–111.
- Gee, E.R., 1935, The saline series of north-western India-CurrentScience, Bangalore, vol.

II, PP-460-463.

- Hasany, S.T., and Saleem, U., (2001), An Integrated Subsurface, Geological and Engineering Study of Meyal Field, Potwar Plateau, Pakistan.
- Kazmi, A.H., and Jan, M.Q., 1997, Geology and Tectonic of Pakistan, Graphic publishers, Karachi, Pakistan.
- Kobesh, F. P., and R. B. Blizard, 1959, Geometric factors in sonic logging: Geophysics, v. 24, p. 64-76.
- Krebs, J.R., Anderson, J.E., Hinkley, D., Neelamani, R., Lee, S., Baumstein, A. & Lacasse, M.D., 2009. Fast full-wavefield seismic inversion using encoded sources, Geophysics, 74(6), WB41–WB51.
- Lewis, G. E. 1937, A new Siwalik correlation. Am. J. Sci. 33, PP-191-204.
- McDougal, J. W., and S. H. Khan., 1990, Strike slip faulting in a ForelandFold-Thrust Belt: the Kalabagh Fault and western Salt Range, Pakistan. Tectonics, v. 9, no. 5, PP- 1061-1075.
- Norman, J.H., 2001,2 Nd edt, Nontechnical guide to Petroleum Geology, Exploration, Drilling and Production, Penn, Well Corporation 1421S. Sheridan Road P.O.box 1260 Tusla, Oklahoma 74112,PP-222.
- Pascoe, E. H., 1920, Petroleum in the Punjab and North-West FrontierProvince, India Geol. Surv. Mem. 40, PP-330-489.
- Raza, H.A., R. Ahmed, S. Alam and S.M. Ali, 1989. Petroleum zones of Pakistan. Pak. J. Hydrocarbon Res., v. 1, no. 2,p. 1-19.
- Schlumberger, 1977. Log Interpretation charts: Houston. Schlumberger well services inc.
- Shami, B.A., Baig, M.S., 2002. Geomodeling for the enhancement of hydrocarbon potential of Joya Mair field, Potwar, Pakistan. Pakistan Association of Petroleum Geoscientists-Society of Petroleum Engineers, annual technical conference, Islamabad, 124-145.
- Sheriff R.E., (1999), "Exploration Seismology", (2nd edition), Cambriage University Press, USA.
- Sroor, M. (2010). Geology & Geophysics in Oil Exploration (p. 33).

Tahirkheli, R. A. K., M., Mattauer, F. Proust, and P.Tapponier,1979. The IndiaEurasia suture zone in northern Pakistan:synthesis and interpretation of recent data at plate scale.In Geodynamics of Pakistan (eds. Farah, A. and DeJong,K. A.), Geol. Surv,Pakistan, Quetta, p. 125-130.

- Velzeboer, C.J., 1981. The theoretical seismic reflection response of sedimentary sequences. Geophysics Vol. 46, No. 6, pp843-853
- Walden, A.T., and Hosken, J.W.J., 1985. An investigation of the spectral properties of primary reflection coefficients.Geophysical Prospecting , 33, 400-435
- Wynne A B., 1873, Notes from the progress of report on the geology of parts of upper Punjab, Indian Geol. Surv. Recs 7(3), PP-59-64
- Meissner, C. R., Master, J. M., Rashid, M. A., and Hussain, M., 1974: *Geology of the Kohat quadrangle, West Pakistan*. U.S. Geol. Surv. (IR), PK-28, p.1-75
- Eames, F. E., 1952. A contribution to the study of the Eocene in western Pakistan and Western India, Part a., The geology of the standard sections in the western Punjab and in the Kohat District. Geol. Soc. London. Quart. J., 107: 159-172.