2D Seismic data interpretation and reservoir evaluation of Missakaswal area using Petrophysics and Rock physics.

By

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BS GEOPHYSICS
2013-2017

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"PAY THANKS TO ALLAH EVERY MOMENT AND GO TO EXPLORE THE HIDDEN TREASURES, ITS ALL FOR YOUR BENEFIT"

(AL-QURAN).

CERTIFICATE

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

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EXTERNAL EXAMINER ____________________

ACKNOLEDGEMENT

In the name of Allah, the most Beneficent, the most Merciful. All praises to Almighty Allah, the creator of universe. I bear witness that there is no God but Allah, and Holy Prophet Hazrat Muhammad (P.B.U.H) is the last messenger of Allah, whose life is a perfect model for the whole mankind till the Day of Judgment. Allah blessed me with knowledge related to Earth. Without the blessing of Allah, I could not be able to complete my work as well as to be at such a place.

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Abdul Basit

BS GEOPHYSICS

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ABSTRACT

Two dimensional seismic interpretation has been carried out in Missakeswal area located in Chakwal district of Punjab province, Pakistan to reveal the subsurface geology. The data used for this study was provided by department of Earth Sciences, the main purpose of this dissertation is the seismic structural interpretation of the Missa Kaswal area in order to demarcate the probable zone for the accumulation of hydrocarbons. Seismic structural interpretation includes marking of reflector with the help of synthetic seismogram, fault picking, generation of polygon and time and depth contour map. To complete this dissertation SMT Kingdom 8.8 were used. The study area is located in Potwar Basin, pop-up anticline is major structure. Five seismic lines GO-994-GNA-09, 994-GNA-09,994-GNA-14,994-GNA-19,994-GNA-20,994-GNA-21 and Qazian Well-01 are used.

For the interpretation of the seismic lines, three reflectors are marked by correlating synthetic seismogram on seismic section.

Prospect evaluation (including gridding, Time and Depth contouring and identification of structural traps) has been carried out using Kingdom suit of Software. Structural interpretation has identified pop-up and snaked head structures favorable for hydrocarbon accumulation and is marked on seismic sections and time contour maps. These structures have been marked at Chorgali, Sakesar and Nammal formations of Eocene level, which are acting as reservoir rocks in the study area. The horizons are identified and named on the basis of well and generalized stratigraphic data.

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CHAPTER NO 01
INTRODUCTION

1.1 Importance of our work.

Hydrocarbons are one of the most essential part of economics of any country. Even on the smaller scale hydrocarbons play a wide role in everyday life. Geoscientists are trying since a long time for the exploration of hydrocarbons and are applying different methods in this regard.

Geophysical methods are the most widely used methods in the exploration of hydrocarbons; especially reflection seismic has a great importance in this regard. Seismic method plays an important role in the search of hydrocarbon. It is the leading exploration technique used now days. This study would highlight the role of seismic method in exploration geophysics. In order to carry out this study, seismic data of Missakaswal Area located in potowar was used.

1.2 SEISMIC.

Seismic methods are based on the laws of elastic wave propagation in the ground. The propagation velocity and characteristic of seismic waves is predominately affected by mechanical properties of the soil (bulk modulus, shear modulus, density). The goal of all seismic methods is to derive the distribution of seismic velocities and thus the ground's structure from the observation and analysis of the seismic wave propagation.

A geophysical prospecting method based on the fact that the speeds of transmission of shock waves through the Earth vary with the elastic constants and the densities of the rocks through which the waves pass. A seismic wave is initiated by firing an explosive charge (or by equivalent artificial sources) at a known point (the shot point); records are made of the travel times taken for selected seismic waves to arrive at sensitive recorders (geophones). There are two main subdivisions of seismic operations: the reflection method and the refraction method. The seismic method has been applied to a lesser extent to elucidate mining problems, partly due to its high cost. It has been used to investigate the base of drift deposits, and drift-filled channels have been successfully outlined.

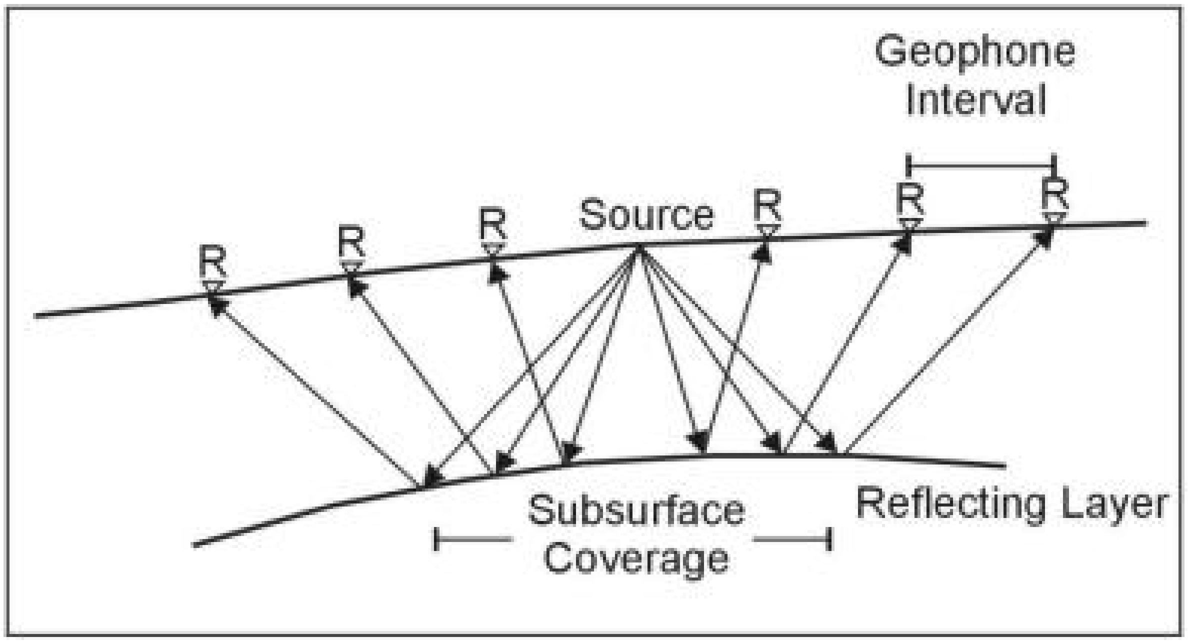


Figure 1.1 Schematic of the seismic reflection method.

1.3 An Introduction to the Study Area.

Missakaswal area is located ten kilometers from Gujar Khan, Rawalpindi district of Punjab. Geographically the study area lies between 33° 11' 06" and 33° 11' 18.24" North and from 73° 20' 42" to 73° 21' 00" East. Stratigraphically, it lies in the Upper Indus which is characterized by large numbers of thrust and normal faults producing asymmetrical structures (anticlines/ synclines). The thesis highlights the 2D structural interpretation and well log integration in order to delineate the subsurface structure and hydrocarbon potential. Two way time structure and depth contour maps have been prepared using Kingdom software. The depth structure map shows high relief anticlinal structure in the subsurface bounded to west and east by reverse faults. According to the petroleum geology, source rock in the study area is Patala Formation of Paleocene age; Chorgali Formation and Sakesar Limestone of Eocene age are acting as reservoir rocks while Murree Formation of Miocene age is acting as a seal.

Geologically, it lies in the Upper Indus Basin of Pakistan. Structurally, Potwar Sub-basin is a highly complex area and mostly surface features do not reflect subsurface structures due to presence of decollement at different levels. The Potwar area is one of the oldest regions of oil production in Pakistan. The first commercial discovery, made in Potwar sub-basin in 1914, was the Khaur Field by Attock Oil Company. Since then, this area has been viewed as an area of great interest for hydrocarbon exploration.

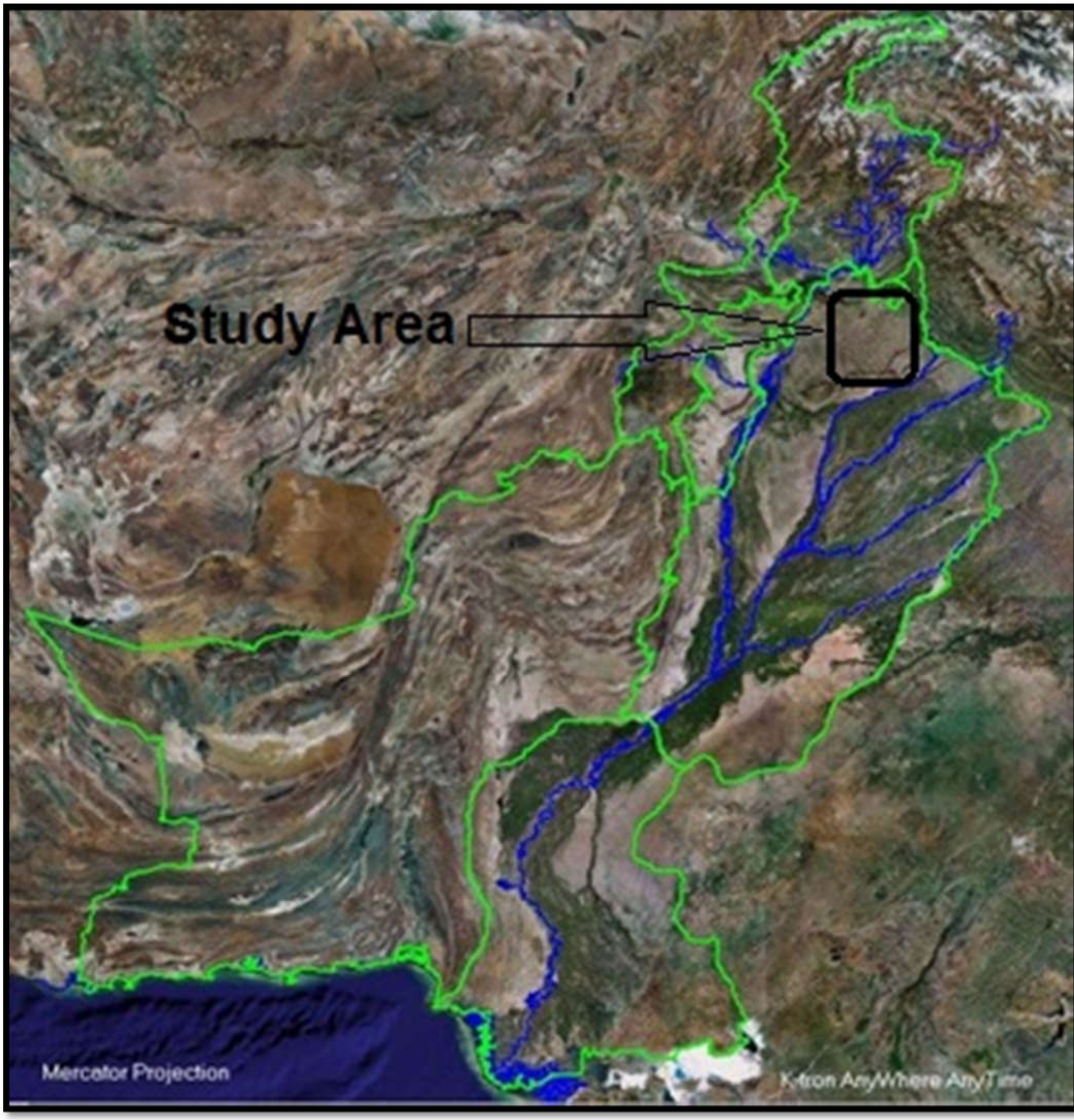


Figure 1.2 Satellite image of Pakistan showing Missakaswal area.

The area under study is Missakaswal oil field which is located ten kilometers from Gujar Khan. Geographically the study area lies between 33° 11' 06" and 33° 11' 18.24" North and from 73° 20' 42" to 73° 21' 00" East (Figure 1.2). Geologically, it lies in the Upper Indus Basin of Pakistan.

Structurally, Potwar Sub-basin is a highly complex area and mostly surface features do not reflect subsurface structures due to presence of decollement at different levels. The Potwar area is one of the oldest regions of oil production in Pakistan. The first commercial discovery, made in Potwar sub-basin in 1914, was the Khaur Field by Attock Oil Company. Since then, this area has been viewed as an area of great interest for hydrocarbon exploration. The main purpose of this study is to understand the tectonic and structural trends present in the subsurface. The structural analysis of the subsurface is done using seismic interpretation, which helped in getting a better understanding of the geological and stratigraphic nature of the area.

Petrophysical analysis has enabled to picture the hydrocarbon potential of the interested reservoir zones. The data provided for study includes a base map, five 2D seismic lines and well log data/well tops of the Qazian well. The well is located at some offset of the strike line GNA-09. The horizons were marked and confirmed through the T-D chart. The geological data was collected from the available literature.

1.4 Geographical Location of Missakaswal Area.

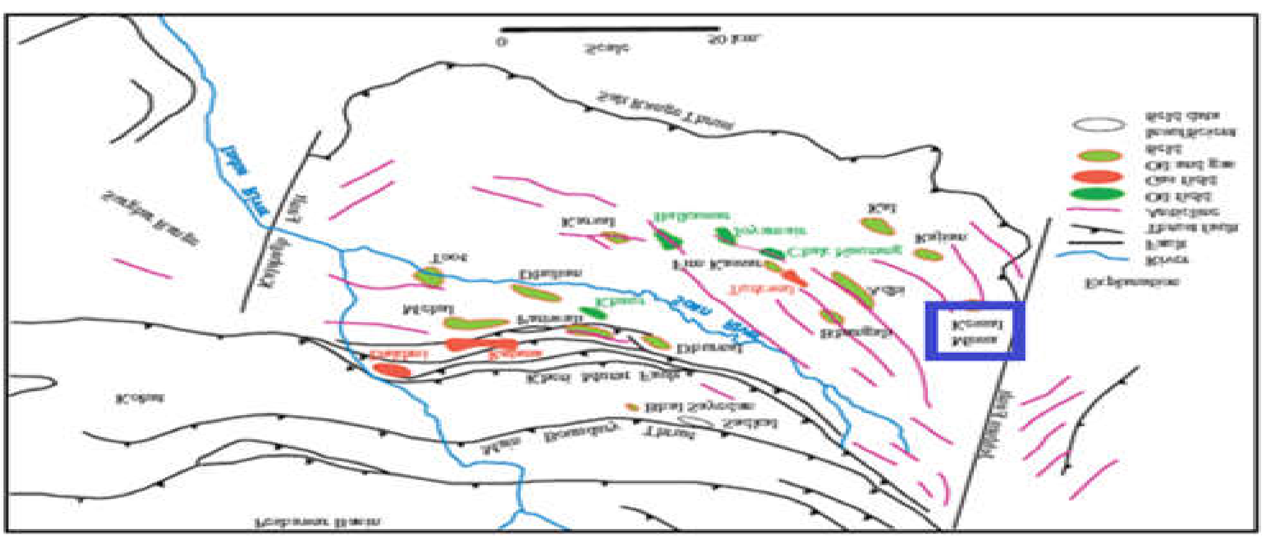


Figure 1.3 Oil and Gas field of Potwar-Sub-Basin. Missakaswal field is also highlighted.

1.4.1 Latitude and longitude of Area.

Latitude

Latitude of area of study is 33° 11' 06”   to   33° 11' 18.24” North.

Longitude

Longitude of the area is 73° 20' 42"   to   73° 21' 00" East.

1.5 DATA USED

To achieve the objectives of the interpretation, seismic and borehole data given below is used is provided by the DGPC to complete the thesis project.

1.5.1 Well data.

WELL NAME : QAZIAN-01X,

TYPE OF WELL : EXPLORATORY.

1.5.2 QAZIAN-01X FORMATION TOP.

FORMATION NAME	***FORMATION TOP (m)***
CHINJI	000000.0
KAMALIAL	001031.7
MURREE	001199.3
BHADRAR/CHORGALI	002062.5
SAKESAR	002107.6
NAMMAL	002182.0
PATALA	002196.0
DANDOT-TOBRA	002225.5
BAGHANWALA-JUTANA-KUSSAK	002258.5
KHEWRA SANDSTONE	002343.8
SALT RANGE	002457.8

1.5.3 SEISMIC LINES USED.

1) GO-994-GNA-09 DIP LINE
2) GO-994-GNA-14 DIP LINE
3) GO-994-GNA-19 DIP LINE
4) GO-994-GNA-20 STRIKE LINE
5) GO-994-GNA-21 STRIKE LINE

1.5.4 SOFTWARE USED.

SMT KINGDOM 8.6

SMT KINGDOM 8.8

1.6 Base Map of the Study Area.

A base map is a map on which primary data and interpretation can be plotted. A base map typically includes location of concession boundaries, wells, seismic survey points and length of seismic spread, longitude and latitude of the study area. Following 2-D reflection seismic lines are used to construct the Base map of 2-D seismic survey for given study area. Base map of the study area shown in figures 1.4 and 1.5.

Base map of the following lines are shown in figure 1.4

- 905-QZN-03
- 905-QZN-08
- 926-GJN-15
- 926-GJN-16
- 926-GJN-17
- 932-GJN-26
- 932-GJN-32

- 994-GNA-09
- 994-GNA-10
- 994-GNA-11
- 994-GNA-14
- 994-GNA-15
- 994-GNA-19
- 994-GNA-20
- 994-GNA-21

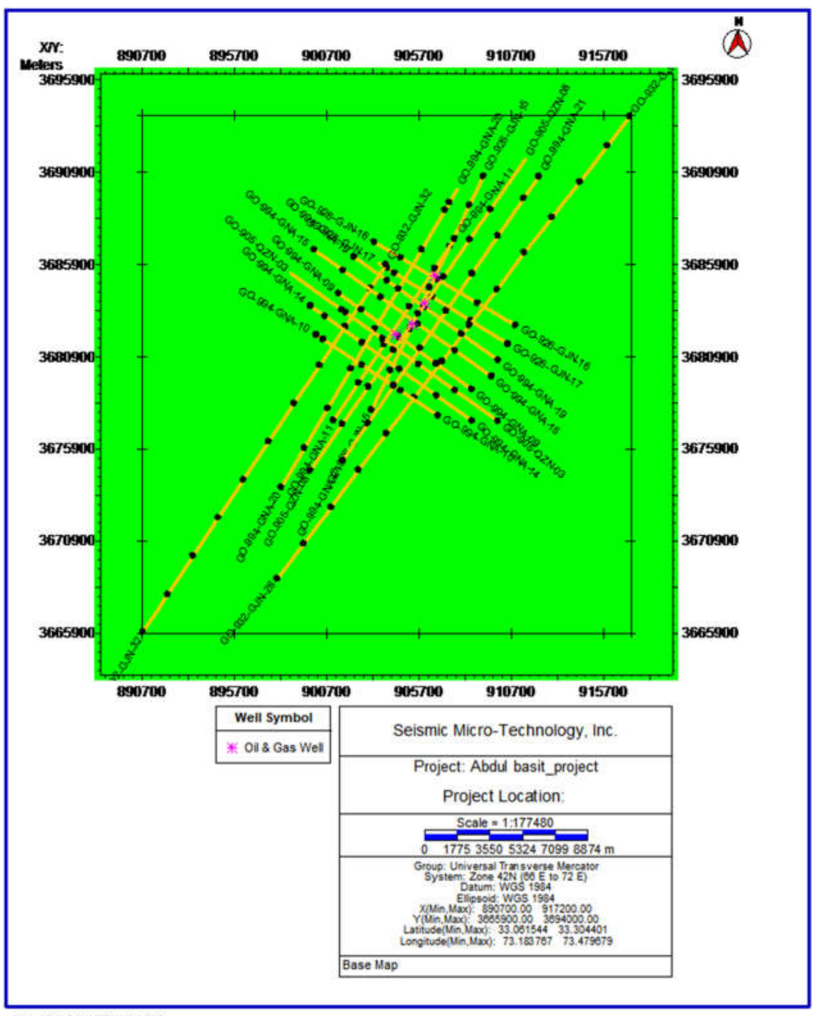


Figure 1.4 Base map of the whole data of Missakaswal.

Base map of the following lines are shown in figure 1.5

- 994-GNA-09
- 994-GNA-14
- 994-GNA-19
- 994-GNA-20
- 994-GNA-21

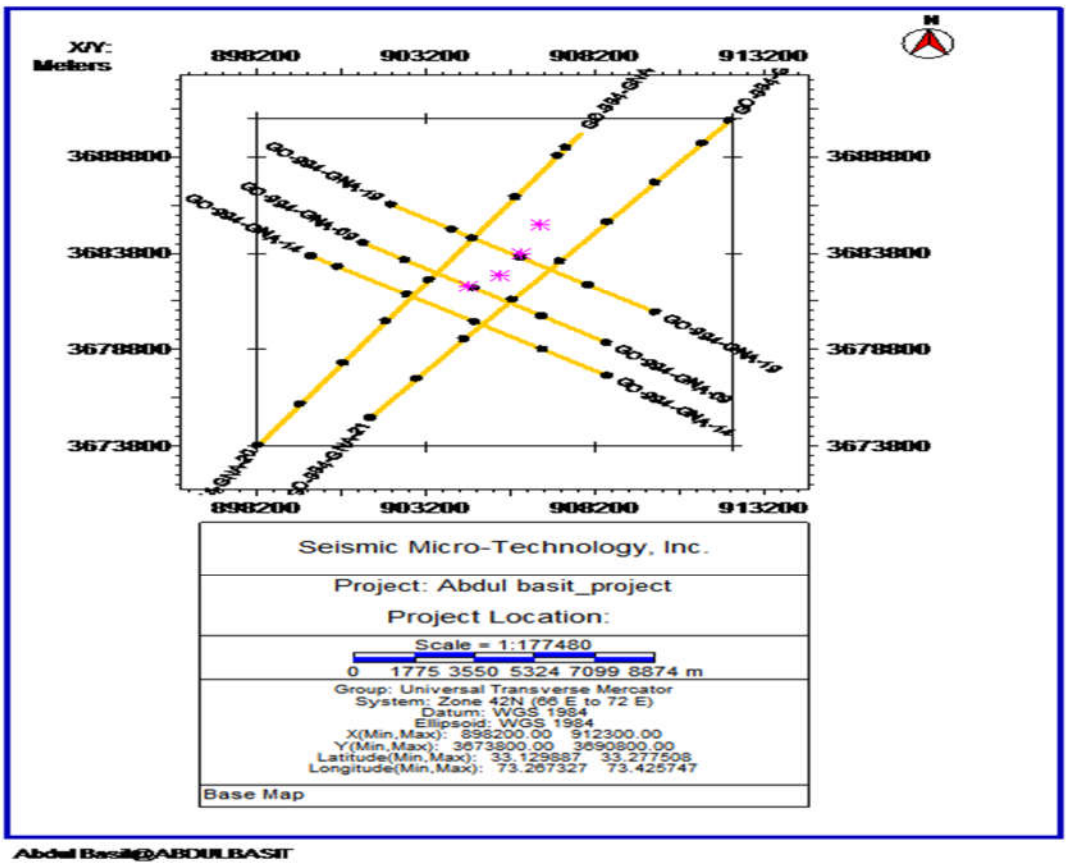


Figure 1.5 Base map of the lines used in the project.

1.7 Objectives.

- The primary objective of the thesis work is the 2-Dimensional Structural interpretation using Seismic data of the lines provided.
- Picking of prominent reflectors on the seismic section.
- Identification of faults on seismic sections.
- Preparation of Time and Depth structure map.
- Petrophysical analysis in order to delineate the reservoir characteristics of the study area.
- Prediction of variation in acoustic properties at reservoir level.
- Facies analysis at the Qazian Well.

CHAPTER NO 02

GENERAL GEOLOGY AND STRATIGRAPHY.

2.1 Regional Geology of Pakistan

Pakistan is covered of the three broad geological subdivisions that, from North to South, may be referred to as the Laurasian, Tethyan and Gondwanaland domains. Their origin may be traced back to Late Paleozoic. In late Paleozoic all the continent had drifted to form a continuous landmass, the super continent of Pangaea. By late Triassic, Pangaea had split into two super continent, Laurasian to the north and Gondwanaland to the south separated by the Tethys seaway. Pakistan is located at the junction of Gondwanaland and Tethyan domain. Pakistan is unique in as much as it is located at the junction of these two diverse domains. The Southern part of Pakistan belongs to Gondwanaland Domain and is sustained by the Indo-Pakistan Crustal Plate. The Northern most and Western region of Pakistan fall in Tethyan Domain and Present a complex geology.

2.2 Sedimentary Basins:

The basin is an area characterized by regional subsidence and in which sediments are preserved for longer periods of time. In a basin a receptacle or container, which is the basin's substratum is called the Basement. The container is filled or content, which is the accumulation of sediments resting on the basement, is called a Sedimentary cover. The gradual settling of the basin is called Subsidence. Pakistan comprises following three sedimentary basins.

- Indus Basin
  - Upper Indus Basin
  - Lower Indus Basin
  - Central Indus Basin
  - Southern Indus Basin
- Baluchistan Basin .
- KakarKhorasaan Basin or Pishin Basin

2.3 Indus Basin:

Indus Basin includes the 25000 square Km of South-East of Pakistan. It includes the Thar-Cholistan desert and Indus Plain. It has 80% of Pakistan population. Tectonically it is much stable area as compare to other tectonic zone of Pakistan. It comprises of buried ridges, platform slop, zone of up warp and dawn warp. Structurally Indus Basin divided into two main parts;

1)Upper Indus Basin (in north)

2)Lower Indus Basin (in south)

Upper Indus Basin is further divided into two sub basin.

- Potwar sub-Basin.
- Kohat sub-Basin.

Lower Indus Basin is also divided into two Basin.

- Central Indus Basin (in north)
- Southern Indus Basin (in south)

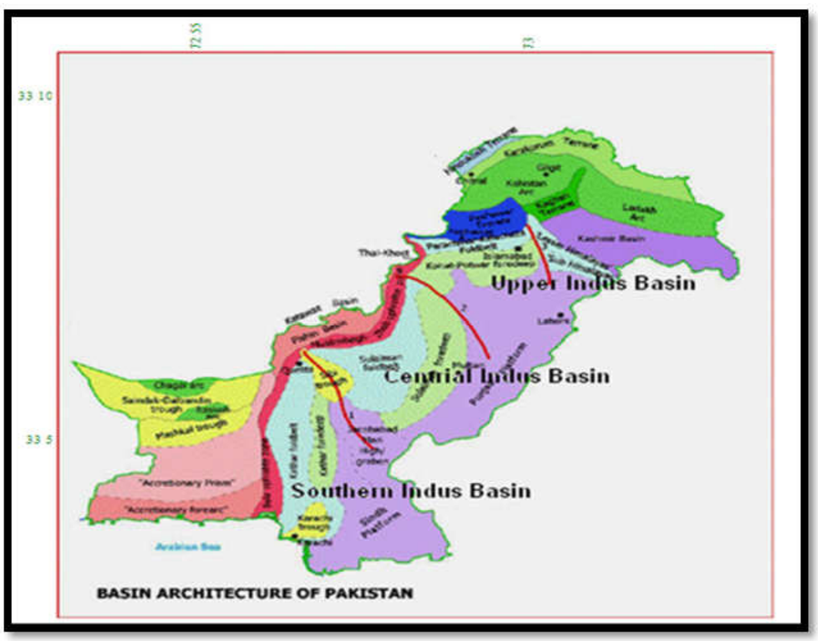


Figure 2.1 Showing Basin Architecture of Pakistan.

2.3.1 Upper Indus Basin:

It is located in the northern Pakistan and separated from the lower Indus Basin by the Sargodha High. In its north MBT, while in east and west strike slip faults Jhelum and Kalabaugh is located, Upper Indus basin is subdivided into Potwar and Kohat Basins along the Indus River. (Kazmi&Jan1997)In the Upper Indus Basin Deposition started From Pre-Cambrian. It is only on basin in Pakistan which receive the deposition from Pre-Cambrian time. The general Stratigraphy of Upper Indus Basin is shown in the stratigraphic column, which shows two main unconformities and some small unconformities.

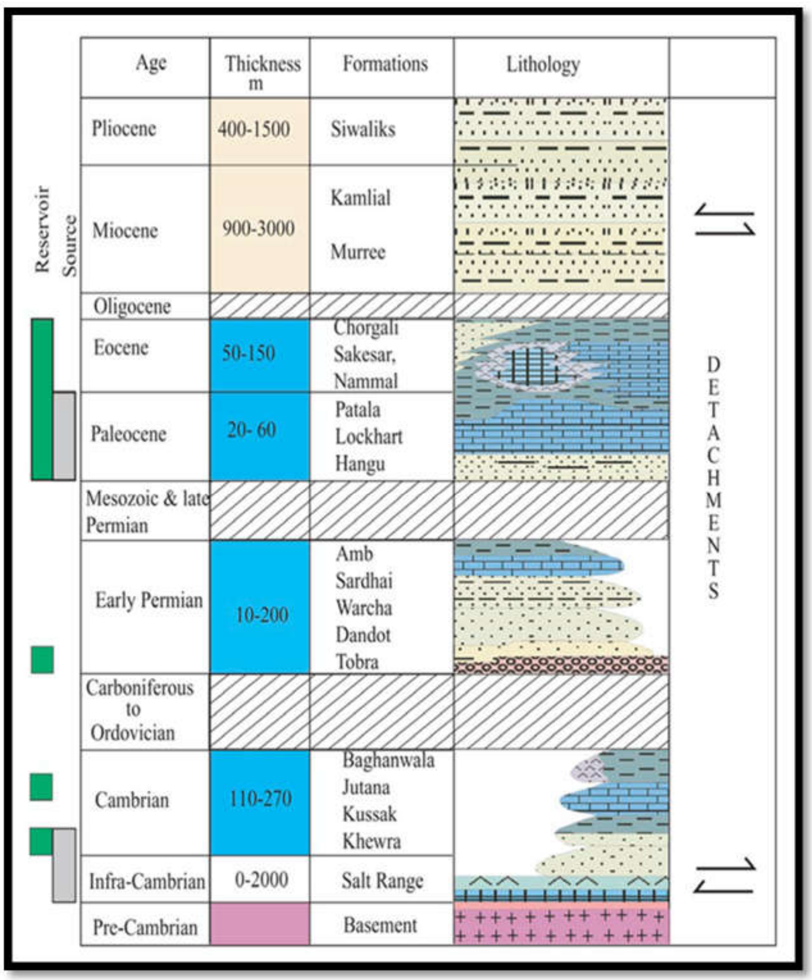
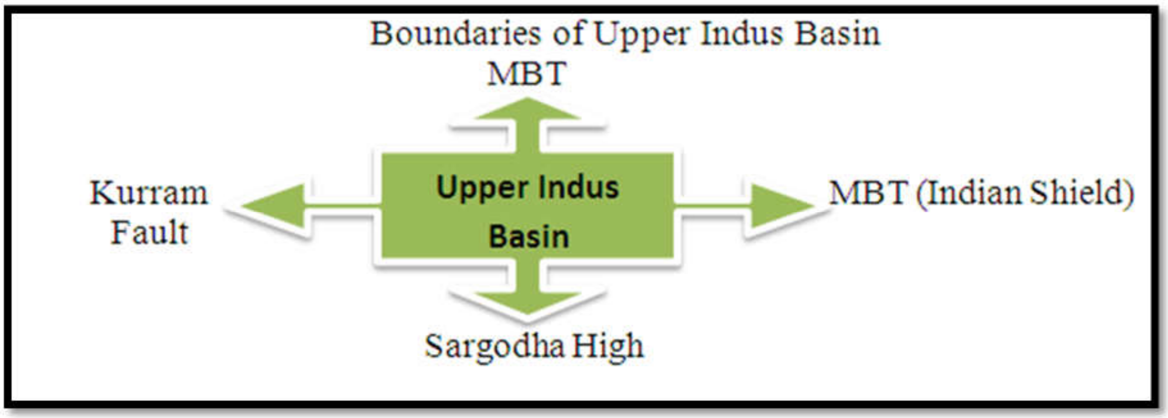


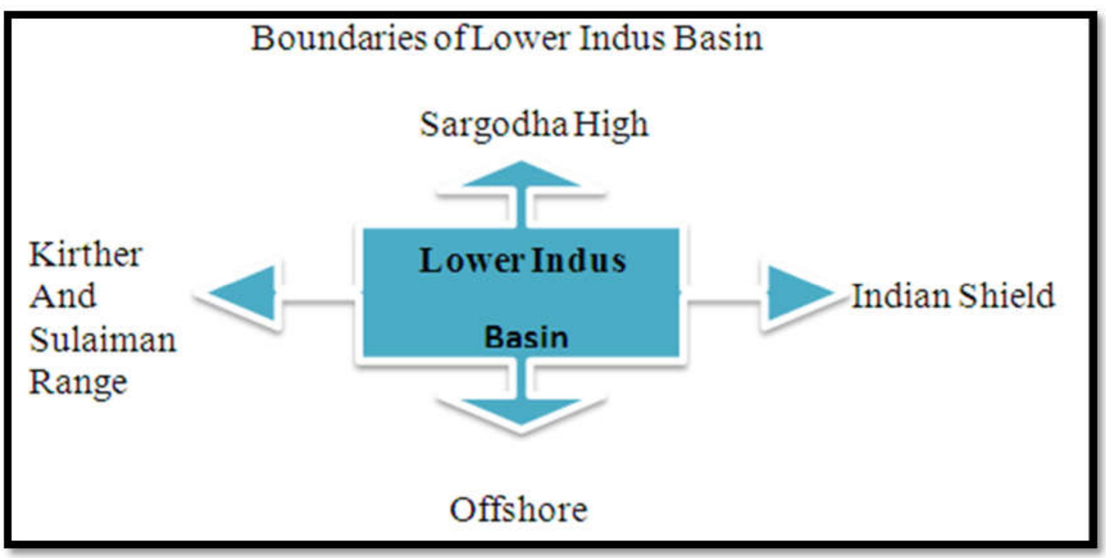
Figure 2.2: General Stratigraphy of Upper Indus Basin

2.4 GEOLOGICAL BOUNDRIES:

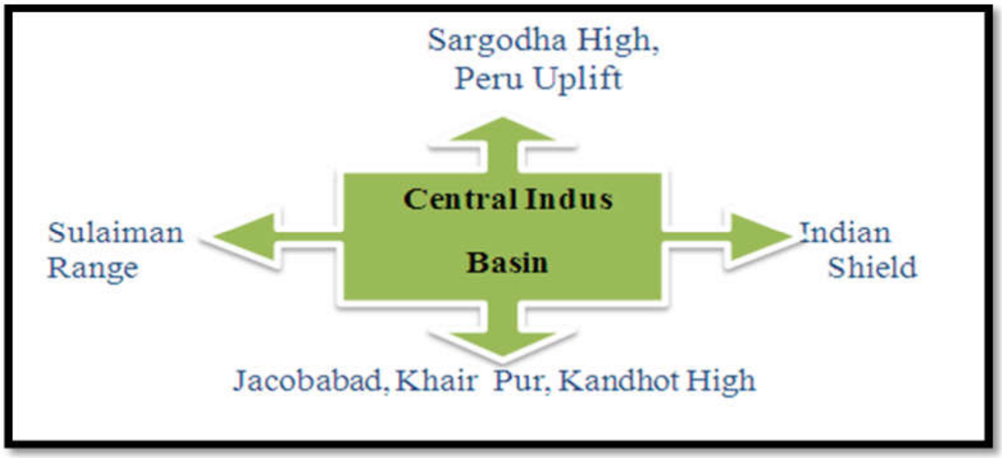
2.4.1 Geological boundaries of Upper Indus Basin.



2.4.2 Lower Indus Basin:



2.4.3 Geological boundaries of Central Indus Basin:



2.5 Central Indus Basin:

The Central and Southern Indus Basins are separated by Jacobabad and Mari Kandhkot highs together termed as the Sukhur Rift. The basin is separated form upper Indus Basin by the Sargodha high and Pezu uplift in the north. It is bounded by Indian Shield in the east, marginal zone of Indian Plate in the West, and Sukhur Rift in the Plate in the west. The oldest rocks exposed in this basin are of Triassic age (Wulgai Formation), While the oldest rocks penetrated through drilling are of Precambrian Range Formation on Punjab Platform. The depth to the basement is about 15000 meters in the through area. Pre-Himalayan non-Orogeny movements resulted in prolonged sea regression causing unconformities which have large gaps in secessions.

Precambrian rocks are largely missing from the basin although. Precambrian shield rocks are evident along the rim of the Indian Plate. Cambrian aged shallow marine rocks are recorded in Karampur well. The basin comprises of three main units on the basis of the topography of Indian Shields and later development. From west to east these are Punjab Platforms, Sulaiman Depression and Sulaiman Fold Belt.

2.6 Potowar Basin:

Geological Boundaries & Structure Styles:-

Potwar is a Fore-land fold and Thrust belt of Himalaya Orogeny that is bounded by Kala-Chitta and Margallla Hills to the north, Indus River and Kohat Plateau in the west, Jhelum River and Hazara Kashmir Syntaxis in the east and Salt Range Formation in the south. Potwar Plateau has undulating topography. It is characterized by a series of parallel ridges and valleys, generally trend in the E-W direction. Geologically, it forms part of the foreland zone of the NW Himalayan Fold-and-Thrust belt. Structurally Potwar Basin is divided into North Potwar Deform Zone (NPDZ) in the north, Soan Syncline and Southern Potwar Deformed Zone (SPDZ) in the south. Potwar basin is covered by the molasse sediments ranging in age from Miocene to Pleistocene. Precambrian to Quaternary sequence is exposed along the ranges in south.

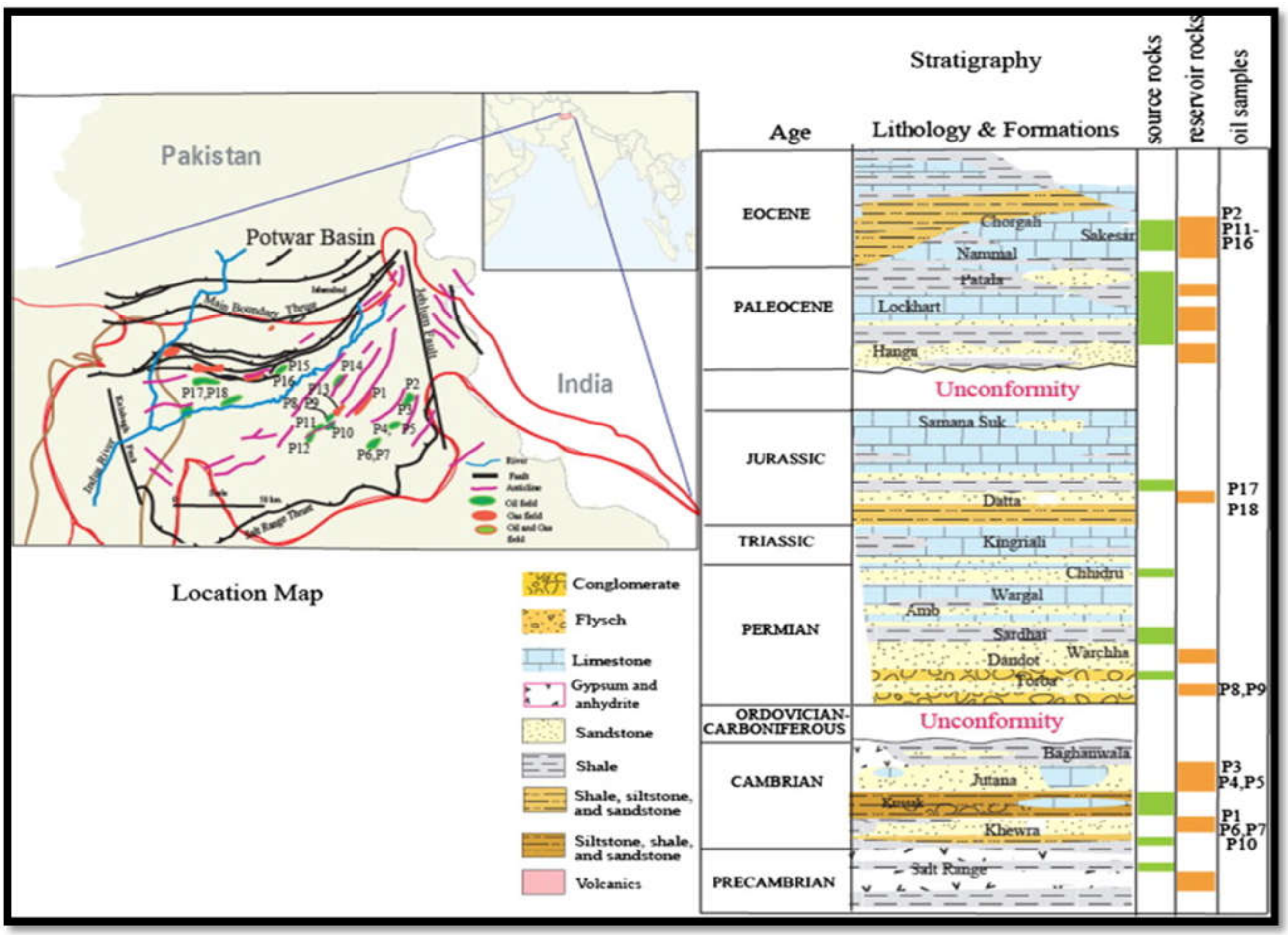


Figure 2.3:Stratigraphy of the Potwar Basin.

2.7 Geology of the Missakaswal area.

Figure 2.4 Basinal Map of Pakistan.

The studied area is a part of the Potwar plateau where the topography is undulating and characterized by a series of parallel ridges and valleys. Generally, they trend in E-W direction. Geo-logically it forms part of the foreland zone of the NW Himalayan fold and thrust belt. This fore-land zone, comprising of Salt range, Potwar plateau/Kohat plateau and Hazara ranges, is an area bounded by the Salt range thrust in the south and the Panjal-Khairabad fault in the north. At its eastern end is the nearly N-S running left lateral Jhelum fault. Kohat-Potwar region situated in

Sub- Himalayan domain contains significant quantity of hydrocarbons trapped in post Himalayan orogeny related compressional/transgressional subsurface structures.

The Potwar sub-basin which includes the Potwar Plateau, the Salt Range and the Jhelum plain is located in northern Pakistan at the western foothills of Himalayas. The sub basin is bounded by Margalla hills, Kala Chitta Range and Main Boundary Thrust (MBT) in the North and Salt Range Thrust in the South whereas Jhelum Strike Slip Fault is present in the East and Kalabagh strike slip fault and Indus River in the West.

The Missakaswal oil and gas field area is located in the Upper Indus basin about 70 kilometers SSE of Islamabad in the eastern Potwar basin. On the surface, it is a thrust bounded anticline striking SW-NE. The first seismic investigation was carried out in 1980 followed by drilling of an unsuccessful well. Another well was drilled after an improved seismic program; which resulted in the discovery of oil and gas in seven different reservoir units i.e. Cambrian, Permian, Paleocene, Eocene and Miocene age. Previous study by OGDCL had revealed that strata of platform sequence display a duplex geometry overlain by a passive roof complex of siwaliks sequence as against earlier interpretation of a pop up structure. The objective of this study is to map the primary and secondary structures, and reservoir formations of the area.

The Missakaswal structure is bounded by a main thrust fault in the strike direction. Few orthogonal faults exist which may provide lateral barriers to the flow during production. The upward migration of oil from the under thrusted block of the duplex has probably contributed to the occurrence of a multi-reservoir system in the upper block. The fractured carbonates within the Eocene (Bhadrar, Sakesar) and Paleocene (Lockhart and Patala) Formations are most productive reservoirs in the Potwar basin. The Patala Shales of Paleocene age and Salt Range Formation of Infra Cambrian age are known source rocks, whereas Murree, Dandot and Kussak Formations are the major cap rocks of the area.

At the regional level, Potwar subbasin is part of active foreland fold and thrust belt of the Himalayas. The structures are bounded by foreland verging thrusts.

Hazara Range has greatest elevation in Potwar area with elevations exceeding 1200 meters above sea level whereas Indus and Jhelum river plains have lowest elevations. Local open folds paralleling the trend of Salt Range and northward dipping strata are the characteristics of southern

Potwar Plateau. The hydrocarbon traps of Potwar Plateau are structurally controlled but local stratigraphic traps have also been reported. Rocks of Cambrian, Permian to Middle Cretaceous, Paleogene and Neogene age overly the rocks of Precambrian age. In the Attock-Cherat Range, limestones and shales of Silurian and Devonian age are exposed. In the Potwar Plateau Limestones and Evaporites of Eocene, fluvial sediments of Miocene to Pleistocene and alluvium of Holocene age are the exposed rocks.

2.8 Stratigraphy of the area.

Subsurface geological data from wells drilled in Missakaswal area indicates presence of Precambrian-Eo-Cambrian, Cambrian-Permian, Permian-Paleocene and Eocene-Miocene breaks in deposition. Eo-Cambrian Salt Range Formation unconformably overlies the basement rocks, composed of metamorphic and volcanic rocks of Indian Shield and is overlain unconformably by Early Cambrian Khewra Sandstone. Contrary to well data obtained in Rajian, Missakaswal and Adhi Kussak (sandstone) Jutana (dolomite) of early Cambrian age and Baghanwala (shale) of middle Cambrian lies conformably over Khewra sandstone. While Dandot mainly composed of sandstone of early Permian lies over Tobra formation (conglomerates). Warcha and Sardhai formations are not present in the study area. The area remains exposed from upper Permian through lower Paleocene. Paleocene sequence comprising of Hangu, Lockhart and Patala formations are well developed. Nammal, Sakesar and Chorgali formations of lower and middle Eocene age conformably overlies Paleocene strata. Rawalpindi Group (Murree and Kamlial formations) with Himalayan provenance was deposited unconformably over middle Eocene Chorgali Formation. Chinji formation is present at the top of Miocene molasses sequence in Missakaswal 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. These unconformities are not easily identified in the seismic profiles due to complex thrusting. 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 molasse deposits. This whole section has been severely deformed by intense tectonic activity during the Himalayan Orogeny in Pliocene to middle Pleistocene time.

The oldest formation penetrated in this area is the Infra- Cambrian Salt Range Formation, which is dominantly composed of halite with subordinate marl, dolomite, and shales. The Salt Range Formation is best developed in the eastern salt range. The salt lies unconformable on the Precambrian basement. The overlying platform sequence consists of Cambrian to Eocene shallow water sediments with major unconformities at the base of Permian and Paleocene. The Potwar Basin was uplifted during Ordovician to Carboniferous; therefore no sediments of this time interval were deposited in the basin.

The second abrupt change to the sedimentary regime is represented by the complete absence of the Mesozoic sedimentary succession, including late Permian to Cretaceous, throughout the eastern Potwar area. In Mesozoic time the depocenter was located in central Potwar, where a thick Mesozoic sedimentary section is present.

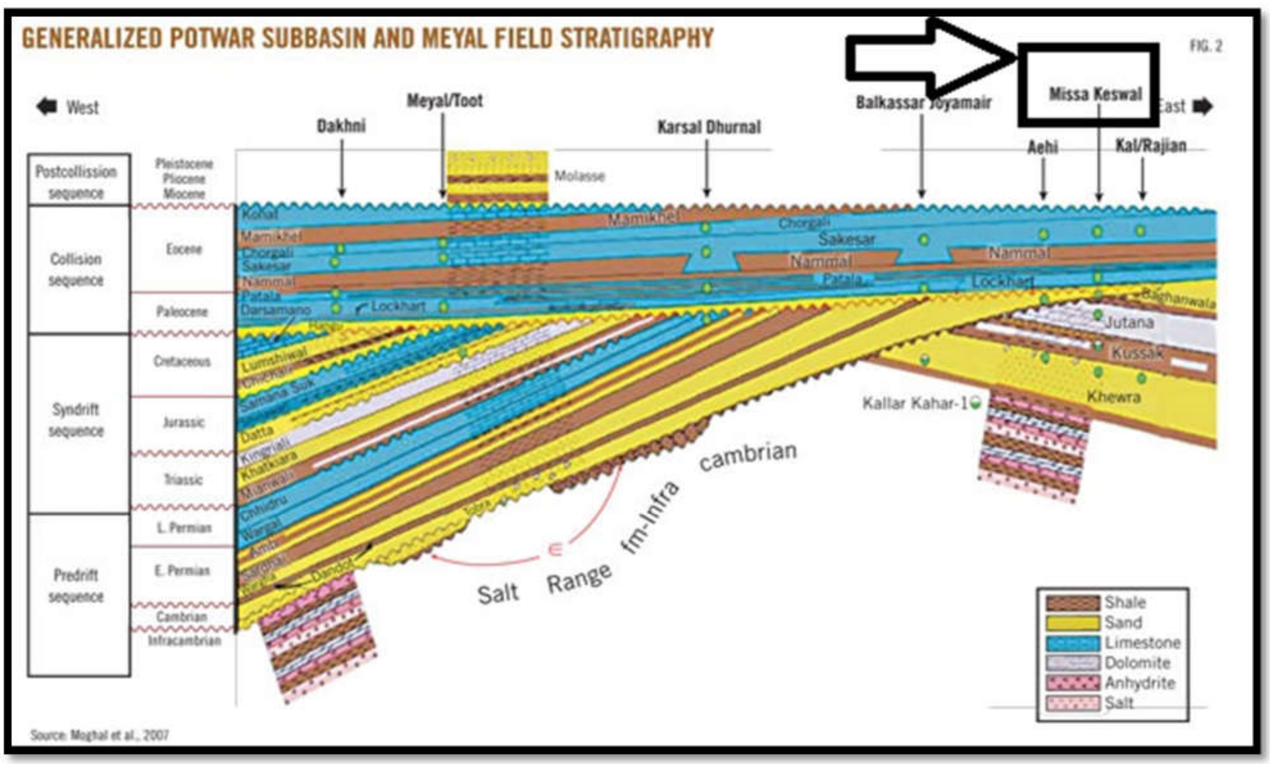


Figure 2.5 Generalized Potwar Sub basin Stratigraphy.

2.9 Reservoir character and production history of study area

Fractured limestones of the Chorgali and Sakesar formations are developed throughout the Surghar Range. These are the primary reservoirs in the Potwar basin. The Sakesar Formation is primarily represented by foraminiferal micritic facies whereas Chorgali Formation comprises thin interbedded shales, limestone and anhydrites. Limestone of both Chorgali and Sakesar formations generally considered to be tight (average primary porosity of 2 - 4 % and permeability 2 - 5 mD), but the fractures in the folded and faulted structures provide sufficient secondary porosity. Its outcrops are densely jointed and fractured. Evidence from the cores taken from wells at Dhulian field indicates that Sakesar reservoir is highly fractured with very low matrix porosity. Very few samples showed porosities greater than 5 % and most samples averaging less than 3 % porosity.

2.9.1 Petroleum Play of Study Area

Potwar marine facies has great potential of hydrocarbon. Previous drilling was restricted up to Eocene carbonate. Recent discoveries in Potwar basin result in delineation of deep subsurface crest.

2.9.2 Reservoir Rocks of Potwar Basin

Although the effective reservoir at Missakaswal lies within the Sakesar and Chorgali formations, the Nammal and Kuldana formations are also worth mentioning in this area because these four formations (Nammal, Sakesar, Chorgali and Kuldana) are part of the same depositional sequence. The Nammal, Sakesar, Chorgali and Kuldana Sequence were deposited on a ramp which fits the classic models for Tertiary low latitude carbonate ramps. These are characterized by slope gradients of less than degree and extend 10 to 100 of kilometers along strike. Hence Paleozoic-Tertiary dominantly marine sedimentary rocks form petroleum systems in Potwar basin and are exposed in Salt Range along the frontal thrust and the fractured carbonates of Sakesar and Chorgali formations are the major producing reservoirs in the study area. Reservoir formations are explained below.

a. Chorgali Formation

The Chorgali formation is named following Chorgali Pass that transects the Khair-e-Murat ridge near the village, Pind Fateh. The formation consists of massive dolostones, marls, nodular, extremely fissile varicolored shales, and evaporite collapse breccia. It is 80 to 90 m thick and is early middle Eocene in age. There is very slight primary porosity and appears as vugs in certain layers and the process of dolomitization has produced porosities up to 25 % .

b. Sakesar Formation

The Sakesar formation is named following Sakesar town in the Salt Range where it is well exposed. It is major formation, acting as reservoir producing both Oil and Gas in Fimkassar area. It is a fractured reservoir, having negligible porosity (matrix). It is about 70 to 300 m thick and is early to middle Eocene in age. The production from Sakesar commenced in 1980, and this formation is encountered in all the wells, used in research. Fimkassar-01, drilled at the apex, encountered Eocene more than 100 m shallower compared to Turkwal-01 and Turkwal Deep-01, while in Turkwal Deep-X2, it'is more than 1,000 m shallower.

c. Nammal Formation

The Nammal formation gets its name from the Nammal Gorge in the western Salt Range. It is 34 to 130 m thick and is early Eocene in age. The lower sections of this formation are shale prone, whereas higher up in section limestones are more prominent.

2.9.3 Source Rocks of Study Area

Hydrocarbon Development Institute of Pakistan (HDIP), in collaboration with Federal Institute for Geosciences and Natural Resources Hanover, Germany have identified a number of source rock horizons through Infra-Cambrian to Eocene in the Potwar basin and surrounding areas. These investigations imply that the organic rich shales of the Paleocene (Patala formation) can be considered as the main formation which is acting as source to the Potwar basin.

2.9.4 Traps/Seal rock of Study Area

Both structural and stratigraphic traps are possible in the Potwar basin. Eastern Potwar represents, thrusted and salt cored anticlines and local pop ups. Northern Potwar represents Passive Roof Duplex geometry, where thrusted anticlines are the potential targets. Traps have been developed due to thin-skinned tectonics, which has produced faulted anticlines, pop-up and positive flower structures above Pre-Cambrian salt (Porth and Raza, 1990).

CHAPTER NO 03

SEISMIC DATA INTERPRETATION.

3.1 Data Processing

Once seismic data has been acquired on field, the second step is the processing data. Data Processing involves sequence of operations, which are carried out according to a pre-defined program to extract useful information from a set of raw data. The main purpose of processing is to convert seismic data recorded in the field into a coherent cross section, indicating significant geological horizons into the earth subsurface, related to hydrocarbon detection and seismic Stratigraphy.

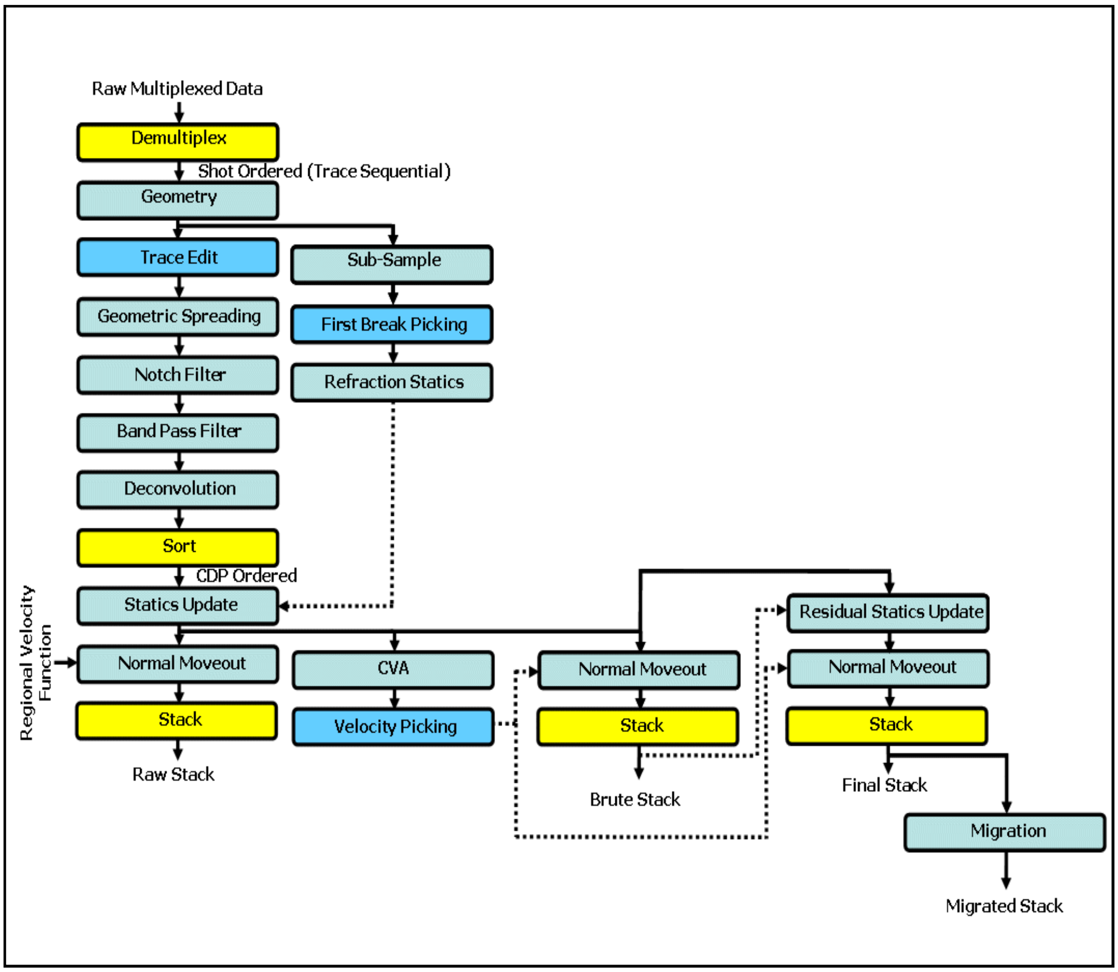


Figure 3.1 Seismic Data Processing Flow Chart (Khan et al., 2009)

i. Demultiplexing

It is the unscrambling of the multiplexed field data to trace sequential form.

ii. **Geometric Correction**

In order to compensate for the geometric effects, we have to apply certain corrections on the recorded data. These corrections are called as geometric corrections. These corrections are applied on the traces gathered during trace editing and muting .

iii. **Static Correction.**

Static correction compensates the effect of weathered layer and elevation effect due to unleveled surface. Static correction is of two types.

- Elevation correction
- Weathering correction

For land data, elevation corrections are applied at the stage of development of field geometry to reduce the travel times to a common datum level.

iv. **Dynamic Correction**

Dynamic correction compensates the effect of offset of receiver from the source .It is also related to the shape of the subsurface interfaces .It is also of two types.

- Normal Move Out Correction (NMO)
- Dip Move Out Correction

Normal move out correction is related more to the non-dipping interfaces. On the other hand dip move out correction is related to the dipping reflectors. It accounts for the effect of dip of the subsurface interface along with the effect of offset distance of receivers.

v. **Filtering**

Filters are used for enhancement of signal. Thus filtering, "Is a process of spectrum modification which involves suppression of certain frequencies”. The most common types of filters used are as follows,

- Low pass frequency filter
- High pass frequency filter

- Band Pass frequency filter
- Notch filter

vi. Deconvolution

Deconvolution is a filtering process designed to improve resolution and supress multiple reflections.

Application of deconvolution

A step in seismic signal processing to recover high frequencies, attenuate multiples, equalize amplitudes, produce a zero-phase wavelet or for other purposes that generally affect the wave shape. Deconvolution, or inverse filtering, can improve seismic data that were adversely affected by filtering, or convolution that occurs naturally as seismic energy is filtered by the Earth. Deconvolution can also be performed on other types of data, such as gravity, magnetic or well log data.

vii. Stacking

In the common depth point (CDP) method ,the geometry is such that the sub surface coverage overlaps .when the data are stacked the traces will be summed together to form one stacked trace .this technique is used for data enhancement .

viii. Migration

Migration moves dipping reflectors in to their true subsurface positions, and collapse diffractions, there by shows detailed sub surface features, such as fault planes.

The process of shifting the reflection points to the positions that correctly image the reflector and remove diffraction images, so that we may get an accurate picture of underground layers.

- **Types of Migration**

There are two important types of migration:

- **Pre-Stack Migration:**

This type of migration is applied to data before the stacking process.

Pre-stack is conceptually the same as post-stack migration but must account for the fact that the data are in finite offset form, so the travel time curves of the arrivals are different than for the equivalent zero-offset data. A major disadvantage of pre-stack migration is that the data volumes are much larger because it precedes the combining of multiple traces into one equivalent zero offset trace. That is, the data volume is larger by a factor equal to the fold of the stack. Migration is a computationally intense process so this is a significant disadvantage.

- **Post-Stack Migration**:

This type of migration is applied to data after the stacking process.

3.2 Interpretation Process

3.2.1: Introduction.

We have to process the data to ready for the interpretation. Seismic interpretation is the transformation of seismic reflection data into a structural picture by the application of correlation of seismic reflectors with geological boundaries and their time-depth conversion. The Seismic data interpretation is the method of determining information about the subsurface of 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. Reflections and unconformities are to be mapped on seismic section, which fully describe the geology and hydrocarbon potential of the area. If the horizon of interest is not prominent and it is difficult in tracing it over the whole area, it is advisable to pick additional horizons above and/or below the target horizon. This helps in understanding the trend and behavior of the target horizon in the zones where its quality is not good enough to be picked with confidence. Final objective of interpretation is conversion of seismic section into a geological section which provides a somewhat realistic subsurface picture of that area, both structurally as well as stratigraphically.

Conventional seismic interpretation implies picking and tracking laterally consistent seismic reflectors for the purpose of mapping geologic structures, stratigraphy and reservoir architecture. The main goal is to detect hydrocarbon accumulations, delineate their extent and to calculate their volumes. Conventional seismic interpretation is an art that requires skill and thorough experience in geology and geophysics. The seismic method has thus, evolved into a computationally complex science.

To get the complete interpretation requires gathering all the relevant data which would be helpful in providing the accurate results. The basic study of reservoir characterization which would be determined step by step starting with the seismic interpretation. The base map of the Missakaswal area with imposed well location is shown in the fig 1.4. By seismic interpretation, we pick reflector from the time section. The reflector on the time section are marked by using well tops and confirm with the generation of synthetic seismogram and its correlation with the time section GO-994-GNA-09 (STRIKE LINE). The rest of dip line reflectors are marked with the help of synthetic correlated seismic section. Therefore, the picking of the reflector of our interest on time section gives the accurate result of our interpretation. In horizons section, the recognition of the main sequence boundaries and introduction of well data, allowed calibration of seismic times to a common datum and resolved the potential stratigraphic problem.

The first step in the interpretation process is to judge the reflections and faults. If existing on seismic time section. Those reflections are selected which are real, show not good character and even continuity of reflectors was not so good.

3.2.2 Interpretation Workflow

Navigations and SEG-Y of given thirteen seismic lines of Missakaswal area are loaded in software (Kingdom Suit) and following procedure is adopted.

Interpretation flow chart.

a. Preparation of base map.

b. Marking of seismic horizons.

c. Fault identification and marking the faults.

d. Fault polygons generation.

e. Contour maps generation (Time & Depth).

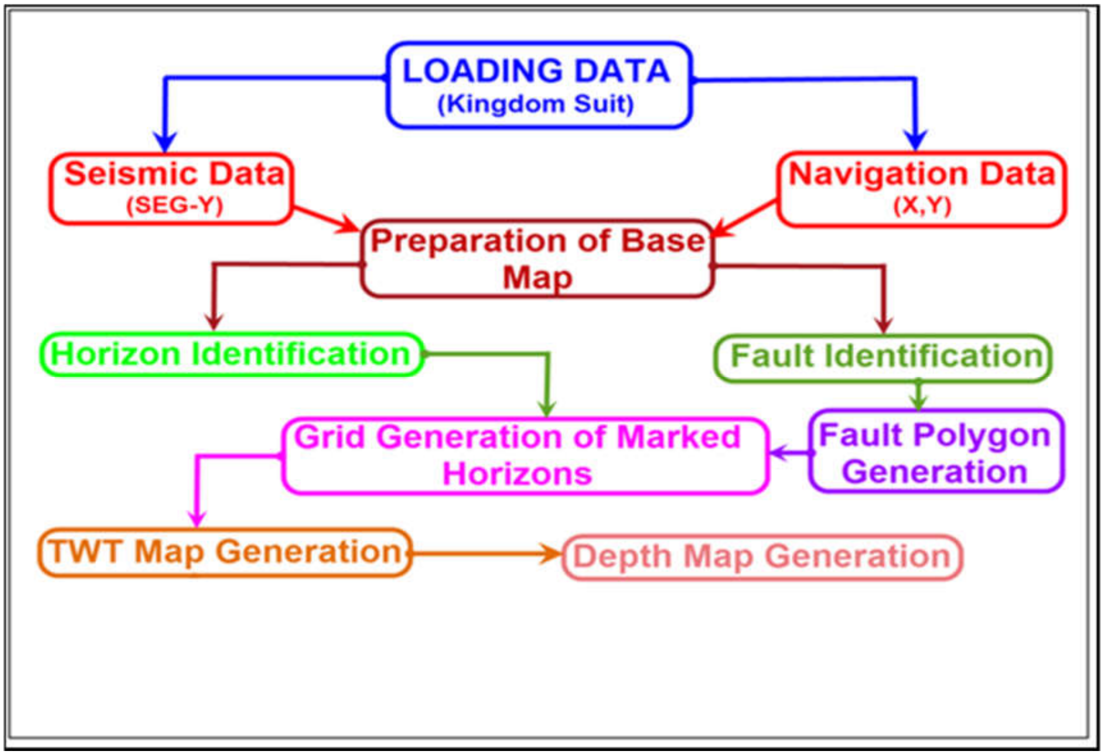


Figure 3.2 Interpretation flow chart.

3.3 Structural Interpretation

Interpretation is the transformation of seismic reflected data into a structural image through the application of corrections, migration and time-depth conversion. Seismic data interpretation is mainly done on the basis of available information and stratigraphy of the area. Seismic is correlated with the formation tops penetrated in the wells using well tops if available. In this study, seismic interpretation is done by picking horizons in Kingdom suit and reflector is continued in all other seismic lines. Major faults are picked on the dip lines and their parts are correlated across the strike lines to map the structures throughout the area. Two-way time (TWT) maps are generated using fault polygons in order to describe the structural inclination at different levels.

3.4 Synthetic Seismogram.

Synthetic seismogram was generated by convolution of Sonic, density curve with the source wavelet of the well Qazian- 01x. The source wavelet used was extracted wavelet.

The calculation of a synthetic seismogram generally follows these steps:

- The sonic and density curves are digitized at a sample interval of 0.5 to 1 ft. (If the density curve is not available, the sonic alone may be used.)
- A computer program computes the acoustic impedance log from the sonic velocities and the density data. The data are often averaged or "blocked" to larger sample intervals to reduce computation time and to smooth them without aliasing the log values.
- The resulting acoustic impedance curve is then used by the program to compute reflection coefficients at each interface between contrasting velocities.
- A wavelet is chosen that has a frequency response and band width similar to that of the nearby seismic data. The synthetic wavelet is convolved with the reflection series for the entire well survey and generates a synthetic seismic trace. A potential pitfall in synthetic generation is using a wavelet of fixed frequency over the entire survey. Care should be taken to choose a wavelet whose frequency is similar to a key interval of the seismic data to which it will be compared.

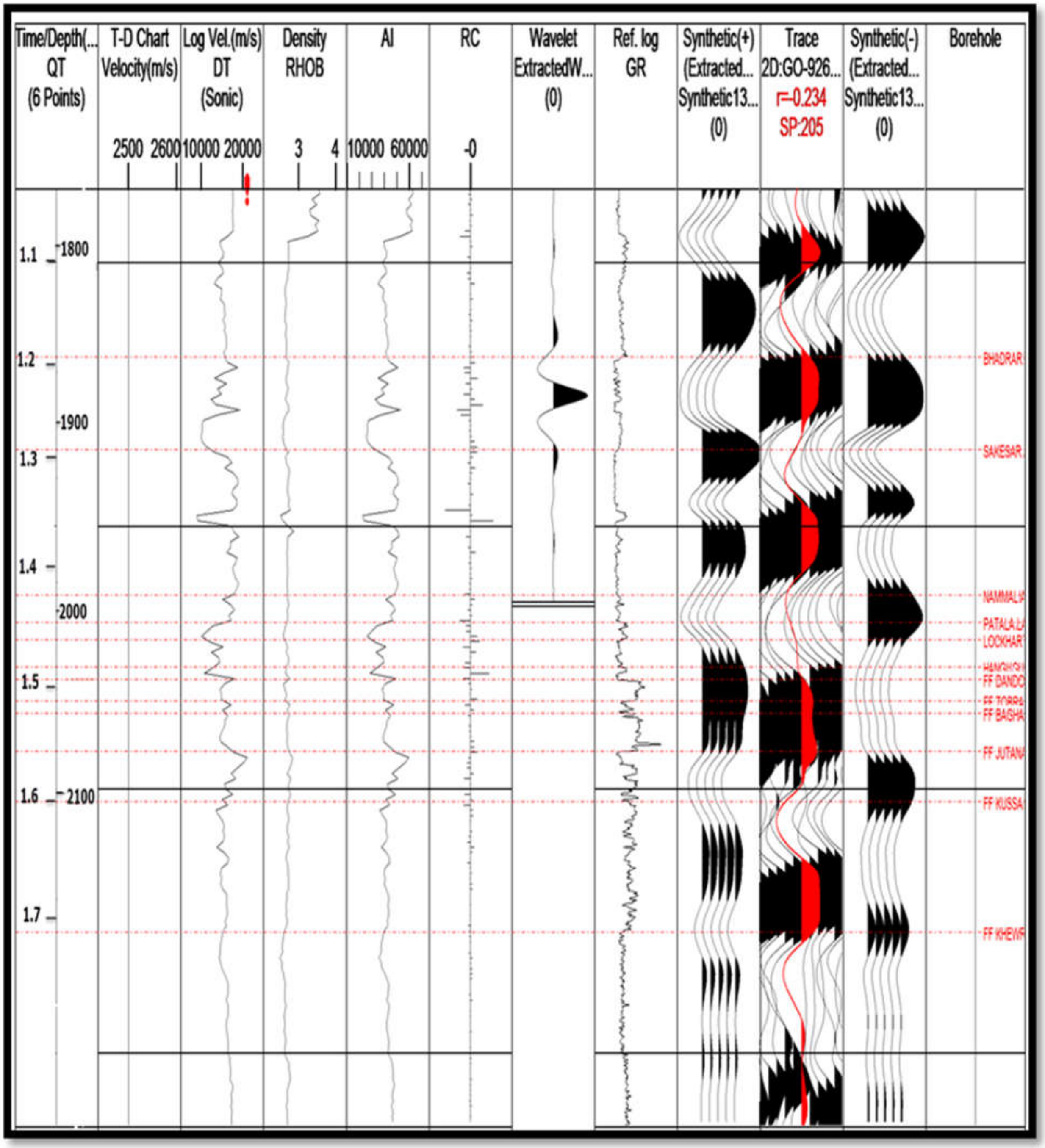


Fig 3.3 Synthetic Seismogram.

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Velocity data from the sonic log (and the density log, if available) are used to create a synthetic seismic trace. This trace closely approximates a trace from a seismic line that passes close to the well in which the logs were acquired. The synthetic then correlates with both the seismic data and the well log from which it was generated.

Well tops were also imposed on the respective synthetic seismogram showing chorgali, Sakesar, Hangu, patella, Lockhart, nammal, Tobra, Dandot, Bangawala and Khewra sandstone Formation respectively.

3.5 Structural Interpretation of Missakaswal Area.

Seismic survey is conducted to acquire data for subsurface analysis, to know structural patterns in the subsurface. Seismic Interpretation of Missakaswal area involves 5 Seismic Lines. While interpreting these seismic lines, it is observed that these seismic lines showing structural changes. These structures are results of compression forces as it falls in the compressional regime or due to Salt diaprism. Mostly the structures present in this area are folds and thrust faults along with triangular zones, pop-up and snake head structures. Below are the interpreted seismic sections showing variation in sub-surface structures.

Methodology of Interpretation:

- Marking of seismic horizons.
- Fault identification and marking.
- Fault polygons generation.
- Contour maps generation (Time & Depth).

3.6 Seismic Horizons

The main task of interpretation is to identify various reflectors or horizons as interfaces between geological formations. This requires good structural and stratigraphic knowledge of the area. Thus, interpretation involves marking of horizons and faults on the seismic section. The seismic data was provided in digital SEG-Y format. Three horizons are marked on the basis of available information. The horizons are named on basis of well tops of the well Qazian well. The Chorgali and Sakesar formations are of Eocene age. Figure 3.4 which are showing strong reflections on a seismic section making it easier to be picked. The seismic data is interpreted by information las file information of Qazian well and then from line to line at their tie points. Well tops are used in order to identify and name the horizons.

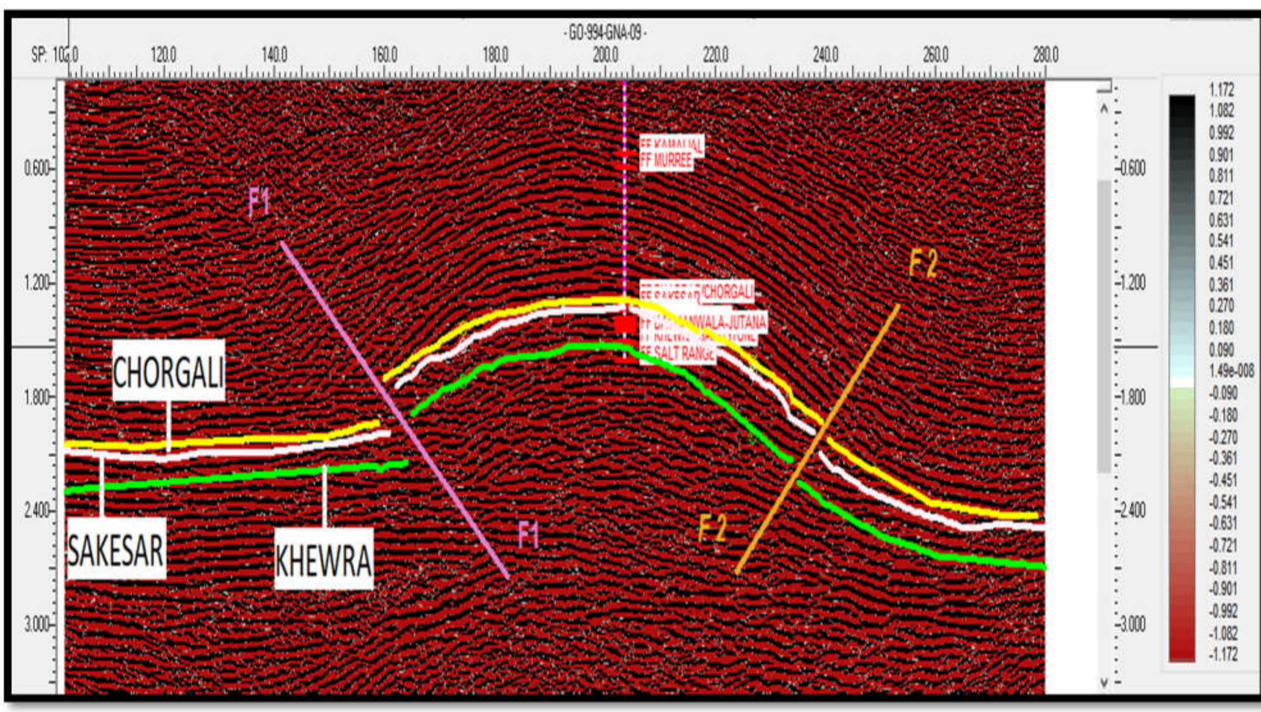

Figure 3.4 Faults and horizon marked on dip line GO-994-GNA-09.

In the figure 3.4 the faults, F1 and F2 are marked on the line GO-994-GNA-09. The horizons which are marked are the Chorgali, Sakesar and the Khewra sandstone. , The Chorgali formation is shown with the yellow color horizon. The Sakesar formation horizon is shown with the lavender blush while the khewra sand stone is shown with the green color horizon line. The discontinuity in the reflector represents the faults. The main faults F1 and F2 are marked on the seismic sections which are detachment faults starting from Salt range Formation of Precambrian age and truncating in to Murree Formation of Miocene age. The scanned seismic sections of Missakaswal along with the marked horizons and faults are shown in figure 3.4.

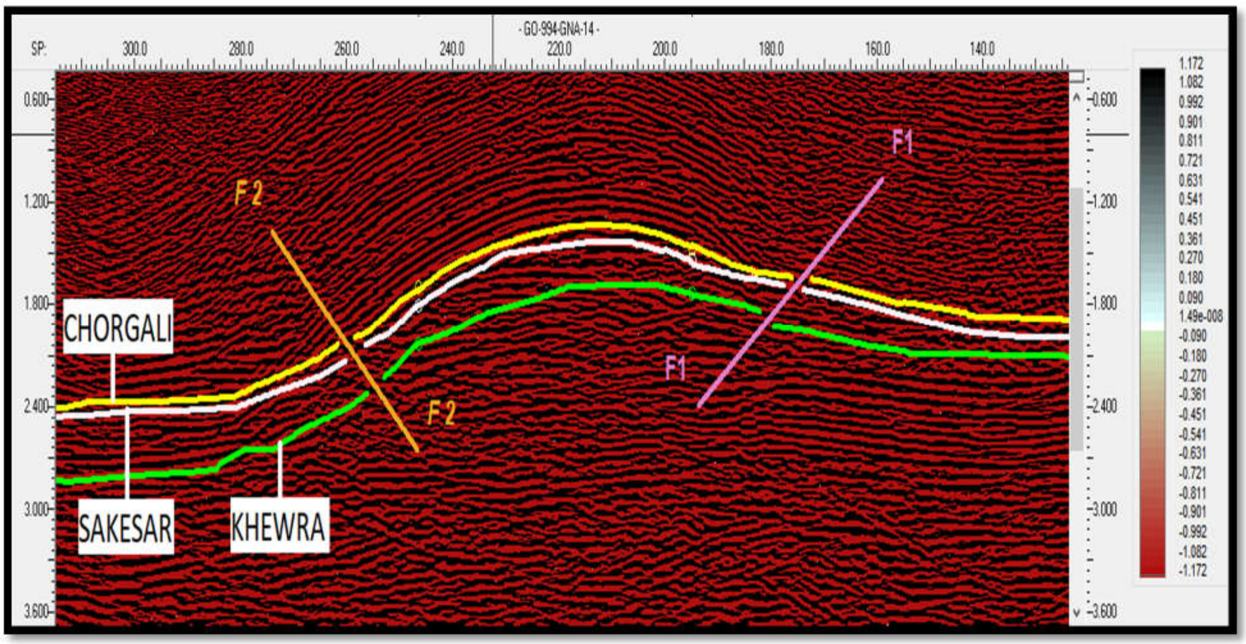

Figure 3.5 Faults and horizons marked on the line GO-994-GNA-14

In the figure 3.5, the Chorgali formation is shown with the yellow color horizon. The Sakesar formation horizon is shown with the lavender blush while the khewra sand stone is shown with the green color horizon line. The interpretation of the map suggests that there is an anticlinal pop-up structure at Center and as we move towards periphery, the depth values increase progressively. The anticlinal structure is bounded by two main faults F1 and F2. These are reverse faults that are dipping towards each other from east and west. This dipping of the faults towards each other while bounding the anticlinal structure is the reason why our area of interest is called a 2-way fault bounded Anticlinal pop-up structure.

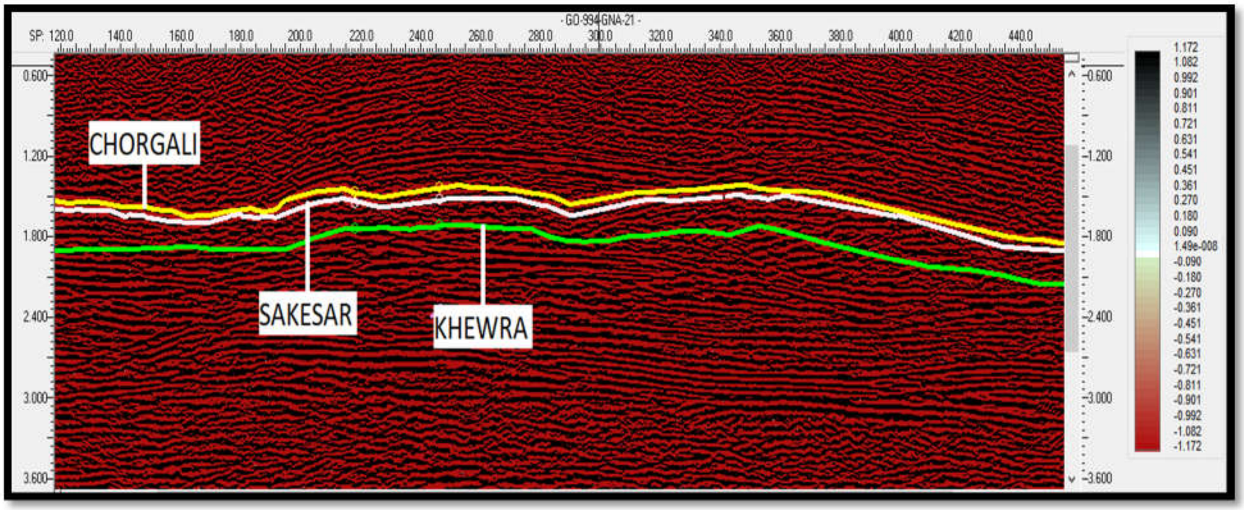

Figure 3.6 Horizons marked on the line GO-994-GNA-21.

In the figure 3.6, the Chorgali formation is shown with the yellow color horizon. The Sakesar formation horizon is shown with the lavender blush while the Khewra sand stone is shown with the green color horizon line. Missakaswal area lies in the thrust regime with faulted anticlinal structure. The area is important because of its structural style. It has repeated packages of Eocene strata in the sub surface which is acting as a potential reservoir. The horizons which are marked are the Chorgali, Sakesar and the Khewra sandstone. , The Chorgali formation is shown with the yellow color horizon. The Sakesar formation horizon is shown with the lavender blush while the khewra sand stone is shown with the green color horizon line.

3.7: Contour Maps

Contour maps that are constructed are the results of seismic interpretation. Mapping is part of the interpretation of the data. The contours are the lines of equal time or depth wandering around the map as dictated by the data. In constructing a subsurface map from seismic data, a reference datum must first be selected. The datum may be sea level or any other depth above or below sea level. Frequently, another datum above sea level is selected in order to image a shallow marker on the seismic cross- section, which may have a great impact on the interpretation of the zone of interest. Contouring represents the 3D earth on a 2D surface. The spacing of the contour lines is a measure of the steepness of the slope i.e. closer the spacing, 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 (TWT) from the surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip, and any faulting or folding. The results of seismic interpretation are usually displayed in map form which shows the time or depth contours.

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. In constructing a subsurface map from seismic data, a reference datum must first be selected. The datum may be sea level or any other depth above or below sea level. Frequently, another datum above sea level is selected in order to image a shallow marker on the seismic cross-section, which may have a great impact on the interpretation of the zone of interest. 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. The interpreted seismic data is contoured for producing seismic maps which provide a three-dimensional picture of the various layers within an area which is circumscribed by intersecting shooting lines. The picked times for each reflector are exported along with the navigation data in the form of an XYZ file to be used for contouring. The Kingdom software is used to generate the contour maps.

3.7.1 Fault Polygon.

Before generation of fault polygons it is necessary to identify the faults and their lateral extent by looking at the available seismic data. If one finds that the same fault is present on all the dip lines, then all points (represented by a “x” sign by Kingdom software) can be manually joined to make a polygon. Construction of fault polygons are very important as far as time and depth contouring of a particular horizon is concerned. Any mapping software needs all faults to be converted in to polygons prior to contouring.

The reason is that if a fault is not converted into a polygon, the software doesn't recognize it as a barrier or discontinuities, thus making any possible closures against faults represent a false picture of the subsurface.

Figure 3.7 formed at Chorgali level shows that after construction of fault polygons, the high and low areas on a particular horizon become obvious. Fault polygons are constructed for all marked horizons and these are oriented in NE-SW'direction.

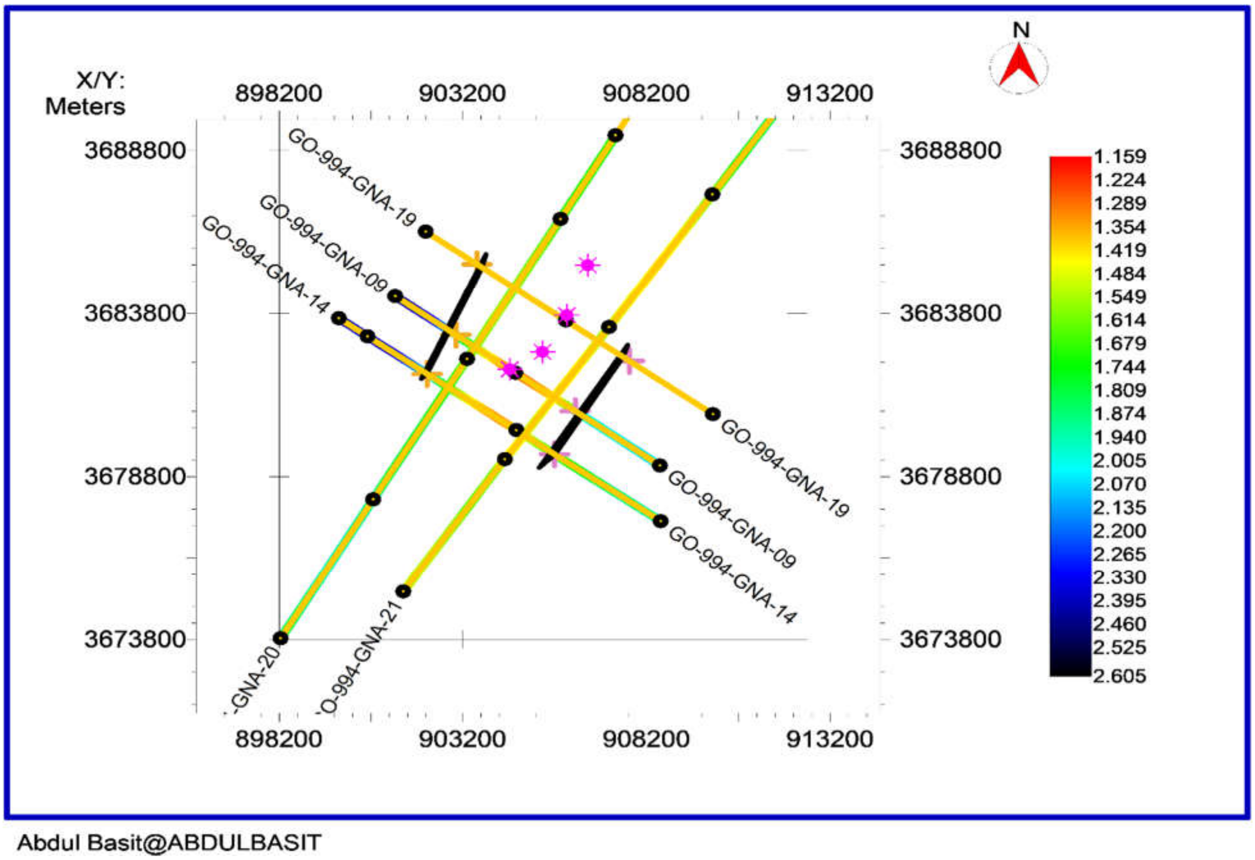

Figure 3.7 Fault Polygon of Chorgali formation.

3.7.2: Time and Depth Contour Maps of Chorgali Formation

Chorgali formation is the first zone of interest. It produced both Oil & Gas and is mainly composed of limestone with some shaly content. Chorgali time & depth contours maps shown in Figures (3.8 & 3.9) are plotted on the seismic base map along with well locations and fault polygons. Here fault polygons making the areas of interest more prominent by providing structural traps for hydrocarbon accumulation in the form of pop-up structure.

Depth contour map of Chorgali formation is shown in figure 3.8. Depth variation is mentioned through the color bar template from shallowest to deepest.

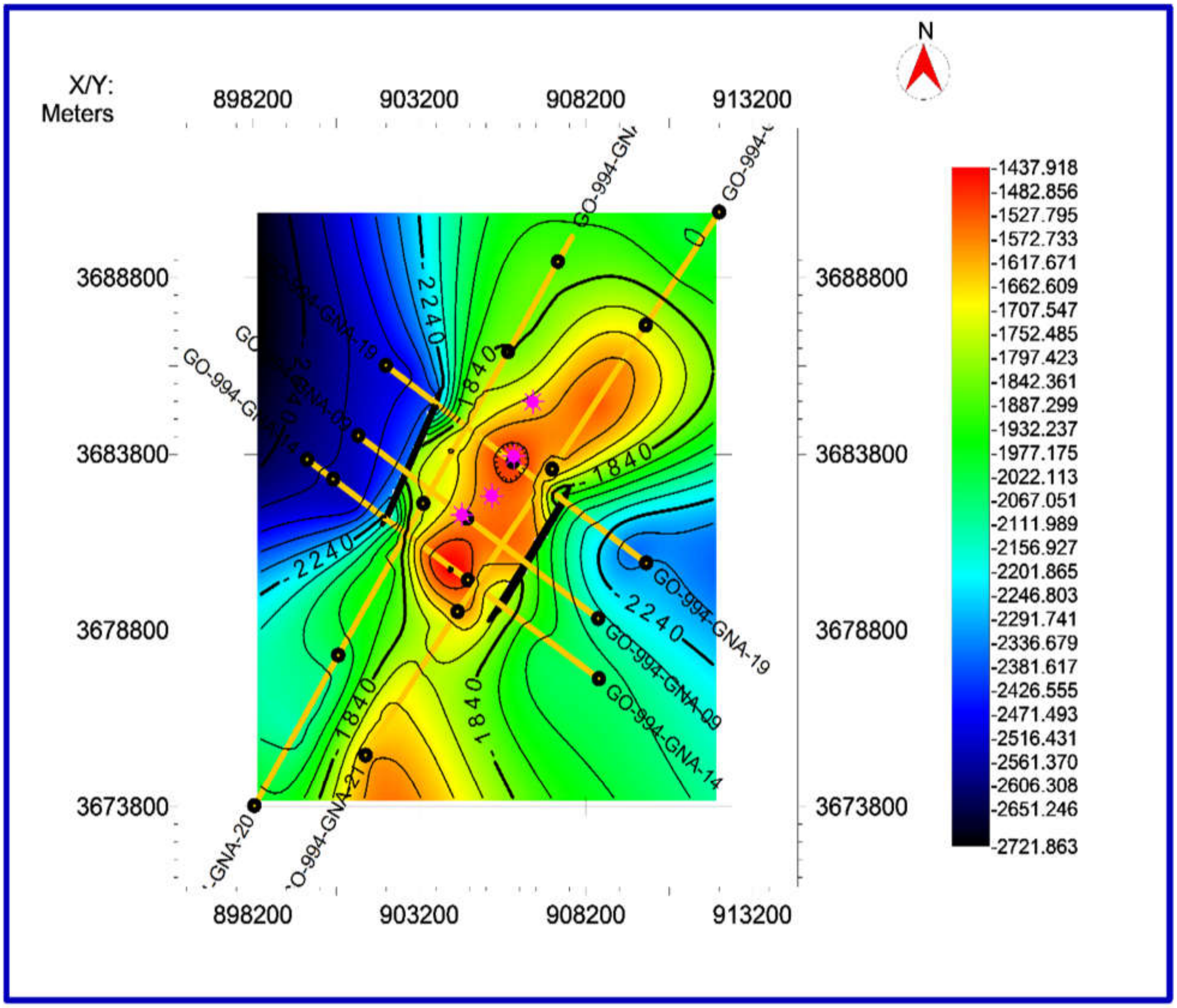

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Figure 3.8 Depth contour map of Chorgali formation

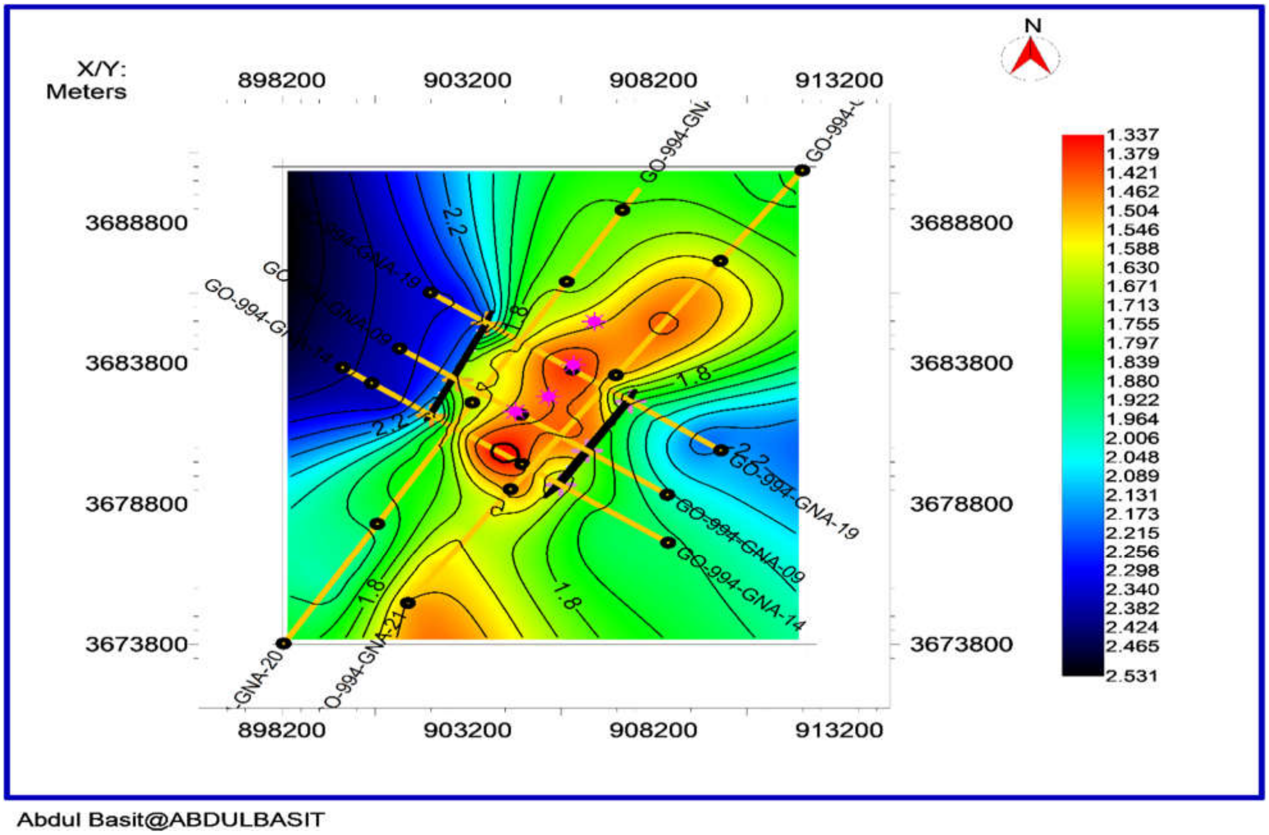

Figure 3.9 Time contour map of Chorgali formation.

3.7.3: Time and Depth Contour Maps of Sakesar Formation.

Sakesar formation is the second zone of interest and potential reservoir rock in Fimkassar area. The contour interval in time & depth contour maps is set as 30 m sec and 30 m respectively. Sakesar time & depth contours maps shown in figure (3.10 & 3.11) are plotted on the seismic base map along with well locations and fault polygons. This level is deeper than previous level i.e. Chorgali formation. Here at this level similar fault polygons are observed which indicates the presence of same faults on both formations. Two Way Time (TWT) contour map of Sakesar formation is shown in Fig 3.11. Time variation is mentioned through the color bar. Depth contour map of Sakesar formation is shown in Fig 3.10. Depth variation is mentioned through the color bar.

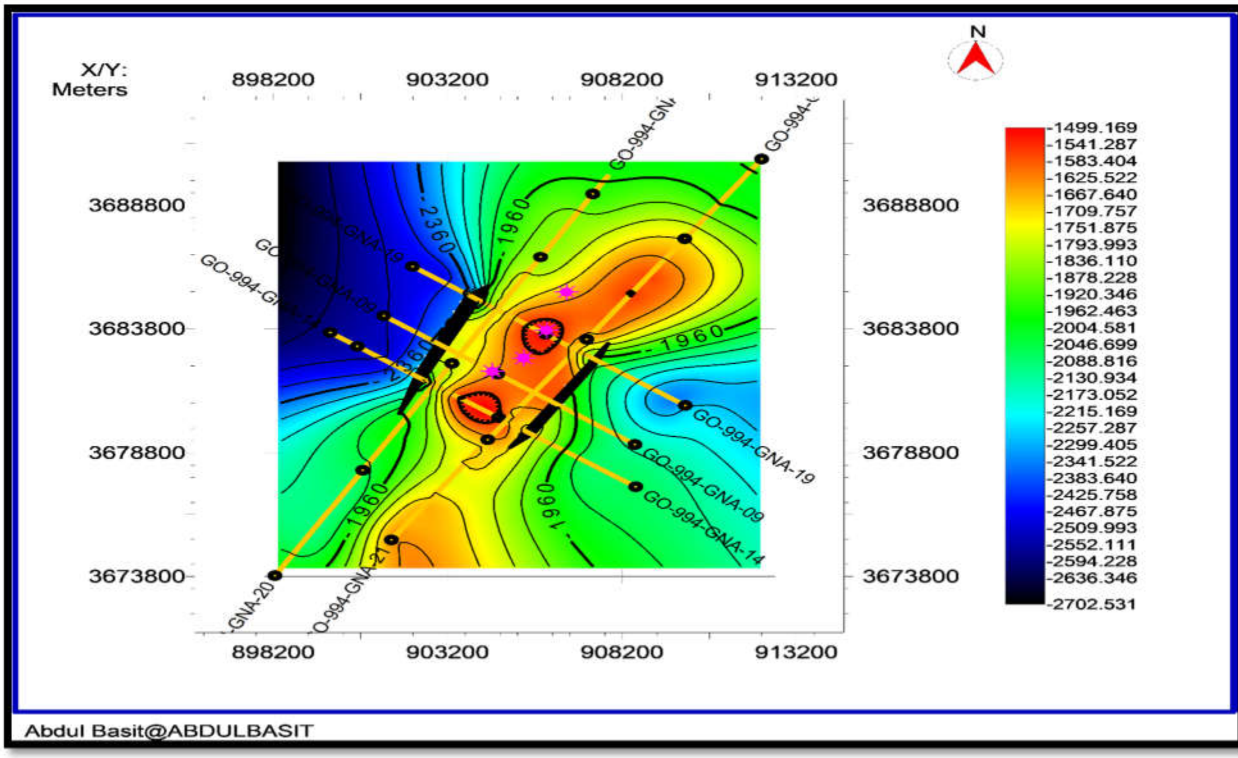

Figure 3.10 Depth contour map of Sakesar formation.

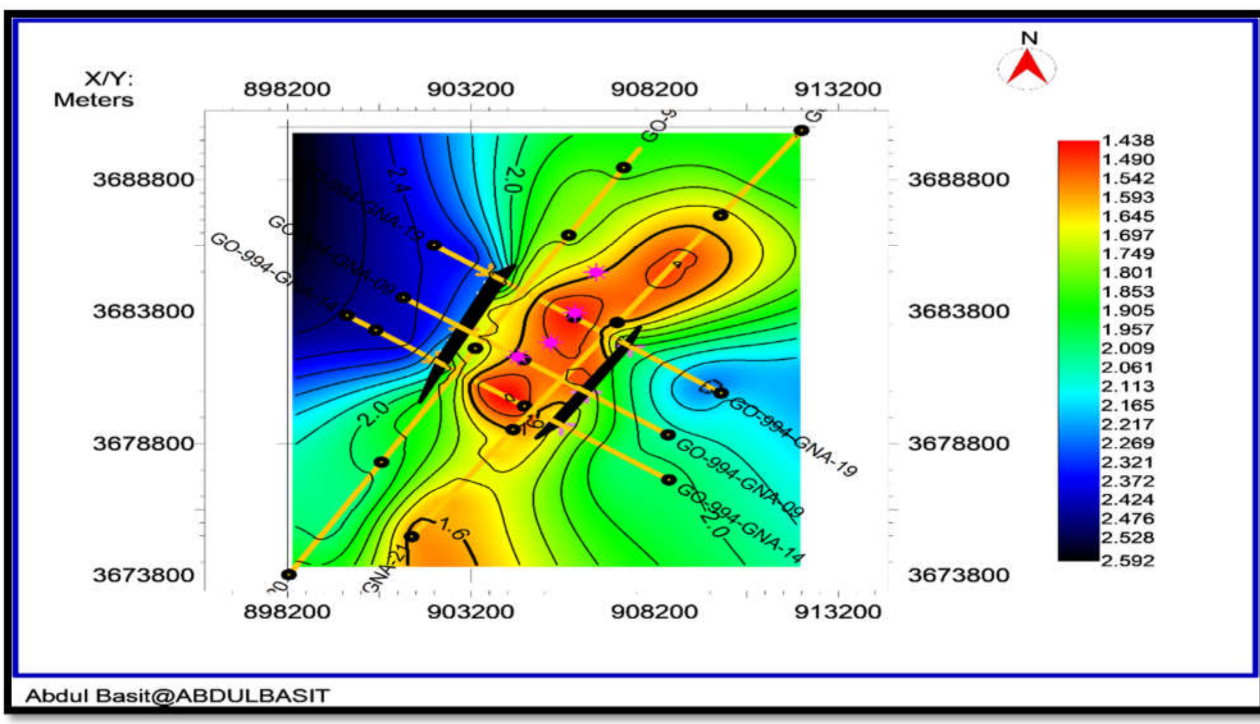

Figure 3.11 Time contour map of Sakesar formation.

3.7.4 Depth and time contour map of Khewra Formation.

Various names for the dominantly shale and sandstone strata exposed immediately above the Salt Range Formation have been proposed so far. These included, as also mentioned by Shah (1977, page 6), 'Purple sandstone series' by Wynne (1878) and 'Khewra group' by Noetling (1894). The Stratigraphic Committee of Pakistan has formalized the name of these strata as 'Khewra Sandstone' (Shah, 1977). Nevertheless, the problem is technically unsolved due to contravention of the established international codes of stratigraphic nomenclature in naming these strata. Therefore the name for these strata needs to be deformalized in order to be compatible with the internationally accepted nomenclature.

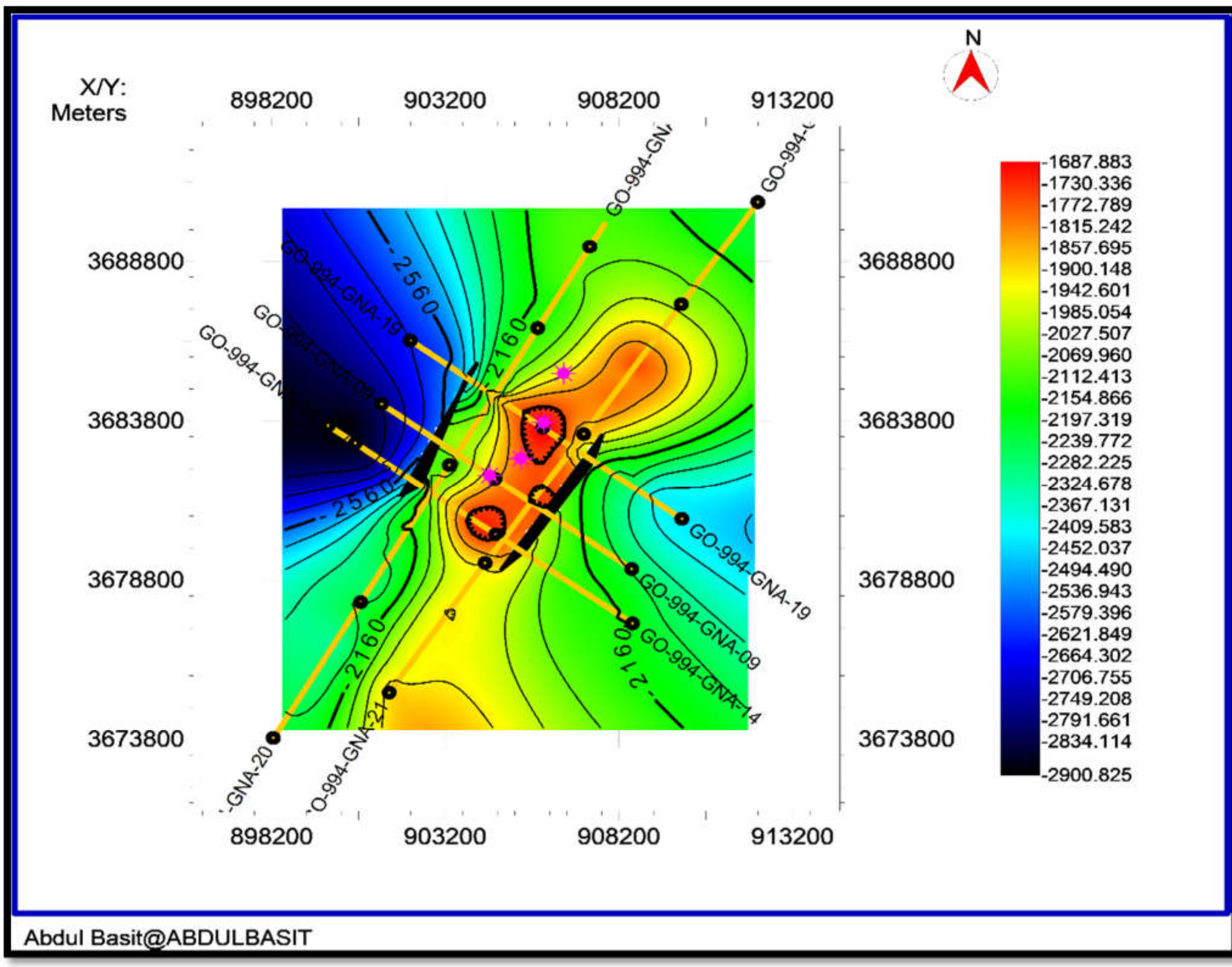

Figure 3.12 Depth contour map of Khewra formation.

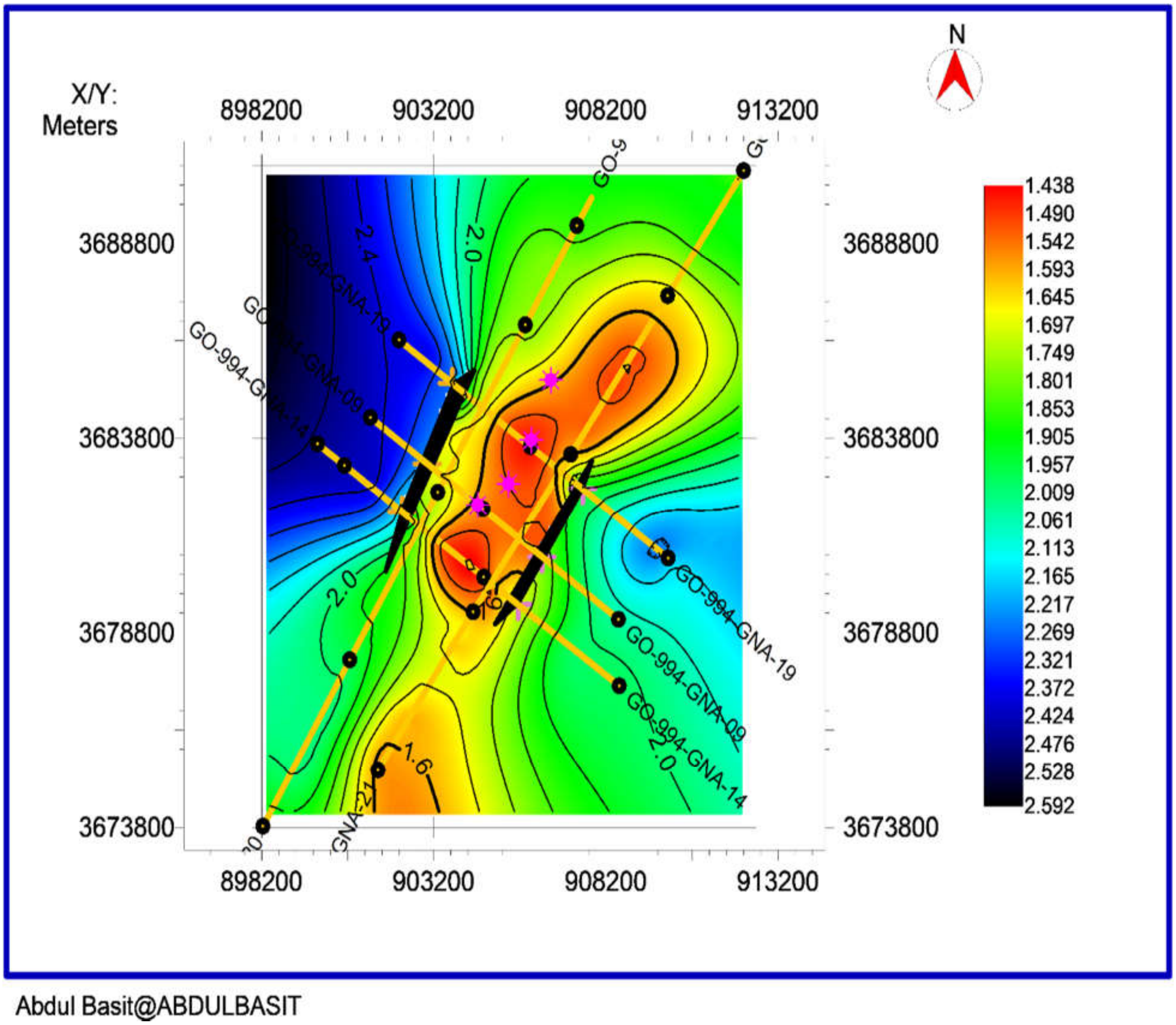

Figure 3.13 Time contour map of Khewra formation.

CHAPTER NO 04

PETROPHYSICAL ANALYSIS.

4.1 PETROPHYSICAL ANALYSIS

Petrophysics is the study of rock properties and their interactions with fluids (gases, liquid, hydrocarbons and aqueous solutions). Because petroleum reservoir rocks must have porosity and permeability, we are most interested in the properties of porous and permeable rocks**.**

Electrical well logging might have been acquainted of the oil also gas industry through half a century back and since then, many logging tools have been used. The interpretation skills have been improved along with Petrophysics. Nowadays, the systematic analysis of logs gives the values of hydrocarbon saturation, water saturation and porosities (Schlumberger, 1998).

Petrophysics use different types of log to locate a probable zone for hydrocarbon accumulation. Seismic interpretation gives us a structural trap by using Petrophysics we have locate the productive zone in reservoir. We run logs in three tracks first track (SP,GR,CALIPER) for lithology identification, second track(MSFL,LLS,LLD) for hydrocarbon versus water bearing zone and third track for (DT,RHOB,NPHI) for porosity. After we run these logs by using formulation we calculate different properties essential for reservoir evaluation.

The key parameters which we calculate in Petrophysics are given below.

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

4.1.1 Classification of geophysical well logs:

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

a) Lithology track

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

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

b) Gamma ray log.

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

c) Spontaneous potential log.

SP log measures the naturally occurring potential of geological formations no artificial currents are injected. It gives deflection opposite to permeable beds since shale is impermeable so it gives straight line opposite to shale known as shale base line. It is used

- To indicate permeable zone
- Identify bed boundaries
- To calculate volume of shale.
- To calculate resistivity of formation water

d) Caliper log.

Caliper log use to measure the borehole size. This log give us help to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. Because if any where there is say wash out then in front of the wash out the porosity and resistivity log will not give the correct reading. Hence caliper log is very important in Petrophysical logs.

e) Porosity log.

DT, RHOB, and NPHI are porosity logs which are used to calculate pore volume of formations. With the combination of resistivity logs they are used to calculate water saturation of formations.

Porosity log contains

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

f) Sonic log.

Sonic log produce compressional waves and measure the transient travel time of waves. Where travel time is higher it is indication of porous media because wave is name of progressive disturbance of media if media is porous travel time is higher. It is used

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

g) Density log.

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

h) Neutron log.

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

i) Electrical resistivity log

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

- Laterelog Deep (LLD)
- Laterelog Shallow (LLS)

j) Laterelog deep.

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

k) Laterelog shallow.

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

The following wire-line logs of QAZIAN-01 allotted by DGPC was used for petrophysical analysis.

QAZIAN -01 allotted by DGPC:

- Gamma Ray log
- Density log
- Resistivity log
- Neutron log
- Sp log (spontaneous log)
- Sonic log

Logs used

- Density log
- Sonic log/porosity log
- Gamma ray log
- Caliper Log
- Spontaneous Potential log
- Resistivity log
- Neutron log
- LLD and LLS

Log curves

The log information of QAZIAN -1x was accessible in Logging ASCII Standard (LAS) format. All the parameters (hydrocarbon saturation, water saturation, volume of shale and porosities) are calculated by using information given in header and LAS file. The method used is given in (figure 4.1) the procedures of each analysis is discussed step by step (Figure 4.2) shows the different log curves.

If we have to choose two or three logs to give the results, then we will use the Gr log, LLD and LLS logs. The GR log will give us the indication about the presence of the shale. It also us the indication where the clean formations are present. Gr log will be the best indicator of the potential reservoir position. The crossover of the LLD and LLS will further confirm over result. The Nphi and Rhob cross over will further confirm our result and give us indication about the density and the porosity values.

4.1.2 SCALE USED FR THE DIFFERENT LOGS TRACK.

The scales used for different logs track area explained in the below table 4.1

No	Log Name	Abbreviation	Scale	Unit
1	Gamma Ray	GR	0-200	API
2	Sonic Log	DT	140-40	µsec/ft
3	Caliper Log	Cali	6-16	Inches
4	Density Log	Rhob	1.95-2.95	Gm/cm^3
5	Neutron Log	Nphi	0.45- (-0.15)	PU
6	Later Log Deep	LLd	0.20-2000	Ώm
7	Later Log Shallow	LLs	0.20-2000	Ώm

Table 4.1 Scale used for the different logs track in SMT kingdom for petrophysical logs.

4.2 WORK FLOW FOR PETROPHYSICAL ANALYSIS

Petrophysical interpretation is carried out using the kingdom software. First of all the raw log curves are loaded step by step and different log properties are calculated. Different mathematical equations and the schlumberger charts are used in order for the calculation of the different log properties. Work flow is given in figure 4.1

The zones of interest are also identified on the basis of the petrophysical interpretation where there is chance of the presence of the hydrocarbon. The raw logs curves which are used are shown in the above interpretation workflow

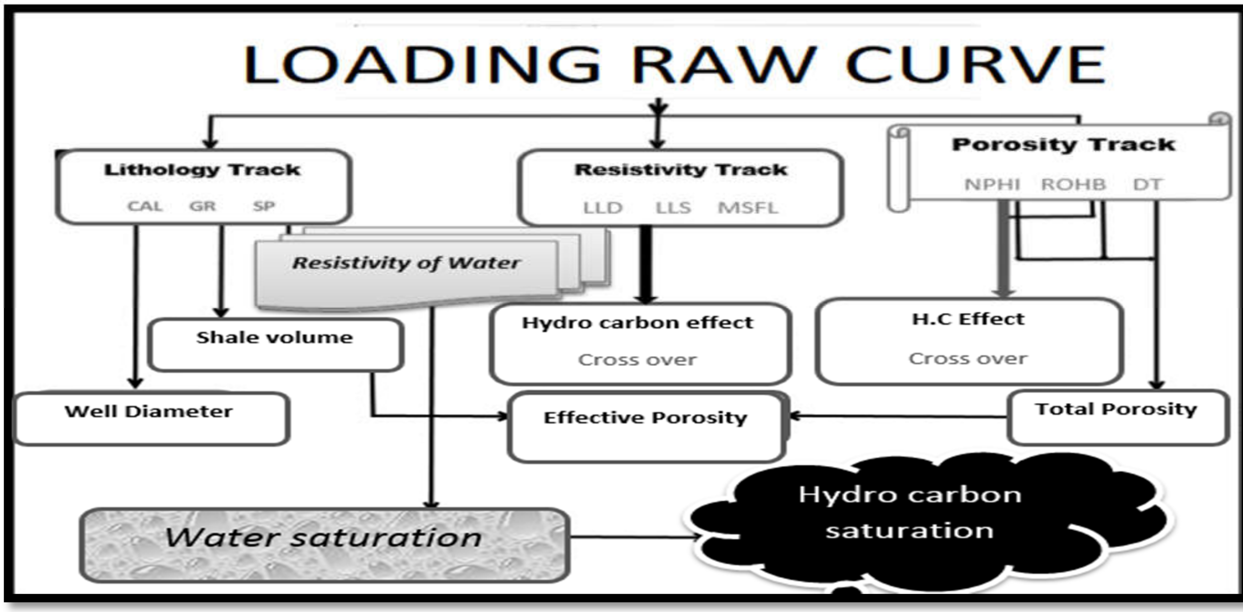

Figure 4.1 Petrophysical interpretation workflow.

I. INTERPRETATION OF ZONE OF INTEREST.

Only one main zone of interest is marked. Depth range of Zone of interest varies from 2088-2110 m in well Qazian-01x. Shale volume of the whole depth range is 43 %. Effective porosity is about 14% and potential of the hydrocarbon is 60%. This is only one pay zone in which high net pay is expected. This zones bear low value of the GR, high porosity and the greater value of the resistivity. Petrophysical properties of this zone is given in the Table 4.3.

II. ZONE OF INTEREST.

On the basis of the single log we cannot give the information about the productive zone we correlate the different logs and get the results. We marked the zone of interest from 2088-2110 m. Because there was low value of Gr which is clear cut condition that it is reservoir zone. Now in 2nd track we run the LLD, LLS, these are resistivity log now there cross over is also the clear cut indication of the formation contain some high resistivity fluid i.e. hydrocarbon. Similarly in the track three the crossover of density and neutron logs is also showing that this is hydro carbon bearing zone. Also calculated effective and average porosity are greater than other zone and hydrocarbon saturation is greater than water saturation.

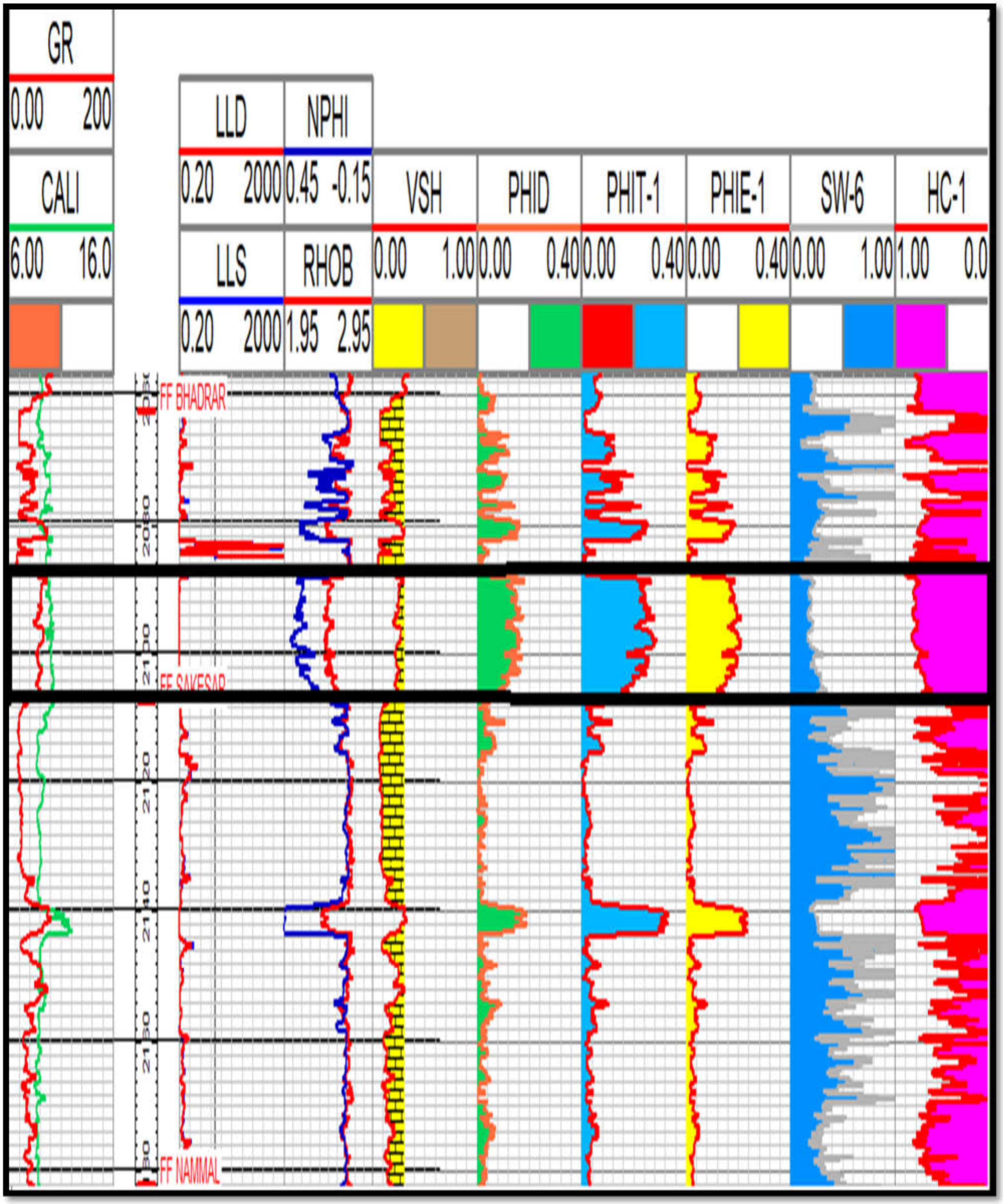

Figure (4.2) Well log interpretation of Qazian-01 by IHS kingdom.

4.3 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 4.2

NO	PROPERTIES	MATHMATICAL FORMULAS
1	Volume of shale (VSH)	VSH=(GR-GRCLN)(GRSHL-GRCLN
2	Density of 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 spontaneous potential (SSP)	SSP=SP(CLEAN)-SP(SHALE)
7	Resistivity of mud filtrate	$R_{mf2} = \frac{(ST+6.77)\times R_{MF1}}{(FT+6.77)}$
8	Formation Temperature (FT)	$\frac{(BHT - SST)}{TD} \times FD$
9	Saturation of Water (S_w)	$S_w = \frac{\sqrt{F \times R_w}}{\sqrt{R_t}}$
10	Hydrocarbon Saturation(HS)	HS=1-Sw

Table 4.2 Different equations for calculating rock properties (Asquith et al., 2004)

a) 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.

b) Calculation of Porosity.

Porosity is one of the most important property in order to understand the petroleum system. 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.

c) Average Porosity

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

d) Effective Porosity.

The effective porosity is the ratio between the pores volume of the rock and the total volume of the rock calculated after removing the effect of the shale. The effective porosity is used to estimate the water saturation. The effective porosity is calculated using the mathematical equation of the (Schlumberger, 1989).

e) Resistivity of formation water (Rw)

When the volume of the shale, effective total and sonic porosity has been calculated the next step is the calculation formation of the water. Computing the resistivity of the water is the initial step in finding the saturation of the water. The following steps has been carried out in order to calculate the resistivity of the water.

Step 1: The values of the surface temperature (ST), maximum recorded temperature (BHT), and the resistivity of the mud filtrate (RMF1) from the well headers, the very first step is to find the (SSP) static spontaneous potential from the relation given in the table 4.3 from (Rider, 1996).

Step 2: Formation temperature is calculated using the using the relation which is given in the table 5.3 by (Rider, 1996).

Step 3: In this step the resistivity of the mud filtrate is calculated using the relation given in the table5.3.

Step 4: In step 4 the resistivity of the mud equivalent (Rmfeq) is calculated by the equation given in the table 5.3.

Step 5: Rweq (Water equivalent resistivity) is determined from the Essp (Static spontaneous potential)

Step 6: This is the last step in this step the value of the resistivity of the water (Rw) is obtained against the value of the Rweq (Resistivity of the water equivalent) and formation temperature. Now when the resistivity of the water is determined the next step is to compute the saturation of the water by using the famous Archie equation.

4.4 PETROPHYSICAL INTERPRETATION OF QAZIAN-01X.

Petrophysical analysis of the well Qazian-01x is carried out on the basics of the different logs curves. The first indicator is Gamma ray which is very useful to differentiate between shaly and sandy portion in Messakaswal area. So on the basics of the gamma ray the clean and shaly zones are marked to make the further interpretation 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 principal use of the resistivity log is to detect the hydrocarbon zone. With the help of the resistivity log volume of the oil and gas can be founded in the particular zone of the reservoir. In petrophysical term the hydrocarbon saturation can be defined as, that when in the porous formation the water saturation is not 100% then the hydrocarbon will be present there. Density in the study area mainly varies between 2 to 2.7 gm/cm^3, because in the study area there is variation of the shale and limestone. The other main result which is observed that very high density corresponding to low resistivity is noted, it may be due to presence of the some heavy minerals Gluconate, Chlorite, Chamosite, Siderite etc. (Fareed et al.,2003).

The other main important result is obtained when Neutron and density logs are combined, because there crossover possibly gives the best clue of the presence of the hydrocarbon (Rider, 1996).After considering all the above explained results and logs response the reservoirs is interpreted and some important petrophysical properties are quantified which are given in the below table 4.3.

Serial NO	Calculation Parameter	Percentage % (2060-2180)m	Percentage % (2088-2110)m
1	Average Volume of Shale VSH_{avg}	15.37	21.40
2	Average Effective Porosity PHI-E	6.60	15.14
3	Average Total Porosity PHI-T	8.39	19.76
4	Average Density Porosity PHI-D	5.44	11.82
5	Average Water Saturation Sw_{avg}	74.20	31.05
6	Average HC in percentage	26.11	68.94

Table 4.3 Average Rock Properties in the different zones.

Typical ranges of porosity of source rocks for petroleum drilling are between 5% and 25%. A porosity of about 25% is a typical 'excellent' value, and one that reservoir engineers will look to obtain before setting up the well site. If porosity is around the lower range and below (less than or equal to 5%) then oil production for conventional oil reserves is usually not economically viable because the rock is not conducive to flow due to the relatively low permeability that is associated with low porosity, and in these cases the engineer must reevaluate the site to determine if economically extraction exists elsewhere in the region.

Shale volume for the total depth range in the reservoir formations is 21.40% and water saturation is the 31.05%. A prominent zone is marked through the well section in Figure 4.2 where high net pay is expected .In this zone also the clear separation of the LLD and LLS is observed.

This zone bears relatively low value of the GR and the high resistivity and high porosity. The detail of this zone is explained below. The zone which is generally called the limestone is main productive zone in Messakeswal field. We calculated the petrophysical properties of this entire zone and then zone of interest which lies in the zone of limestone as shown in the figure 4.2.

Only one main zone of interest is marked. Depth range of Zone of interest varies from 2088-2110 m in well Qazian-01x. Shale volume of the whole depth range is 43 %. Effective porosity is about 14% and potential of the hydrocarbon is 60%. This is only one pay zone in which high net pay is expected. This zones bear low value of the GR, high porosity and the greater value of the resistivity. Petrophysical properties of this zone is given in the Table 4.3.

On the basis of the single log we cannot give the information about the productive zone we correlate the different logs and get the results. We marked the zone of interest from 2088-2110 m. Because there was low value of Gr which is clear cut condition that it is reservoir zone. Now in 2nd track we run the LLD, LLS, these are resistivity log now there cross over is also the clear cut indication of the formation contain some high resistivity fluid.

CHAPTER NO 05

FACIES MODELLING.

5.1 INTRODUCTION

Geologically facies is a rock body which having some specific characteristics which distinguish it from the other (Ravia et al., 2010).

Generally the facies is distinctive rock unit that form under certain condition of the sedimentation that reveals the environmental process. The differentiation between the shale and sand has been constantly challenged for the geoscientist. In this process the key challenge is identifying the facies, from logging and core data, and degree to which the shale content effect the reservoir properties

These facies are related to the certain depositional environment. Basically the depositional environment is specific type of place where the facies are deposited. Such as the Glaciers. Lakes, Abyssal plain, Sea bottom. Stream, Delta etc. The different types of the sedimentary environment are shown in the below figure 5.1.

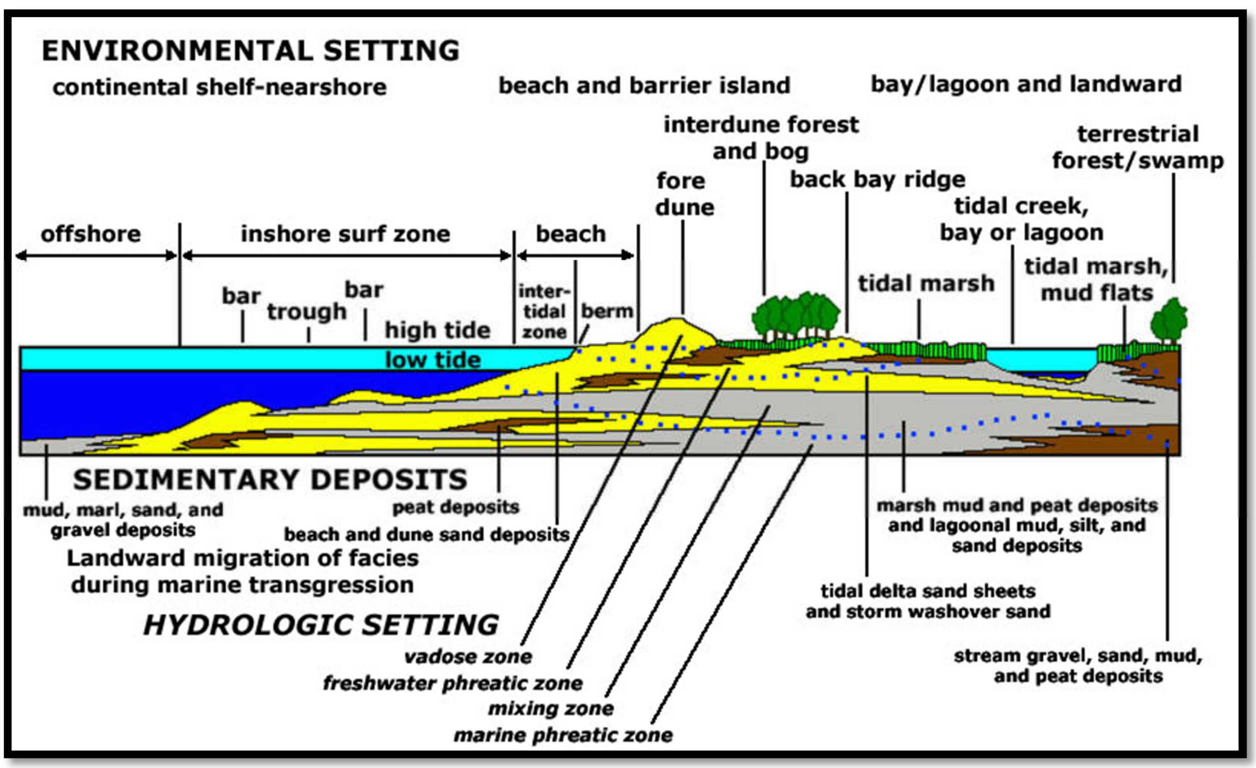

Figure 5.1 Facies deposited in different environment.

5.2 Sedimentary Facies

The sedimentary facies can be differentiated from each other on the basics of the change in the depositional environment.

Sedimentary facies are bodies of sediment recognizably different from adjacent sediment deposited in a different depositional environment, as shown in figure given below. The sedimentary environment is the specific depositional setting of a particular sedimentary rock and is unique in terms of physical, chemical, and biological characteristics. The physical features of a sedimentary environment include water depth and the velocity and persistence of currents.

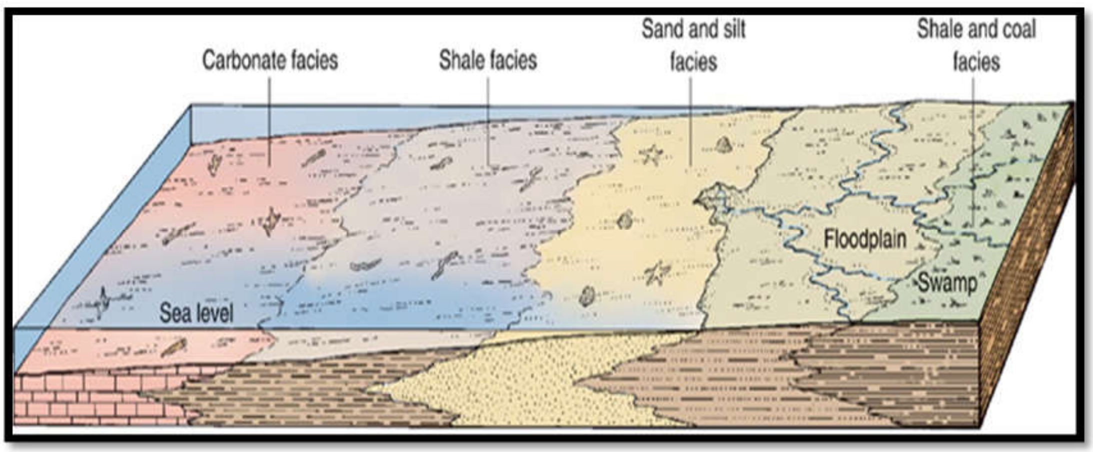

Fig 5.2 Deposition of sedimentary facies.

5.3 Facies analysis of Chorgali and Sakesar limestone:

The facies modeling is performed by plotting different logs .Which log is to be run depend upon objectives of facies modeling.

5.3.1 Cross plot of LLD and RHOB:

The figure 5.3 shows the Cross plot of LLD and RHOB. Since resistivity and density of limestone is higher than shale so limestone facies are marked at higher values as shown in figure 5.4. Since density of shale is highly variable in case concentration of organic contents is lower in shale the density of limestone and shale can overlap so Gamma log is used as reference log for further separation of facies. The light blue color shows the shale while the yellow color shows the limestone.

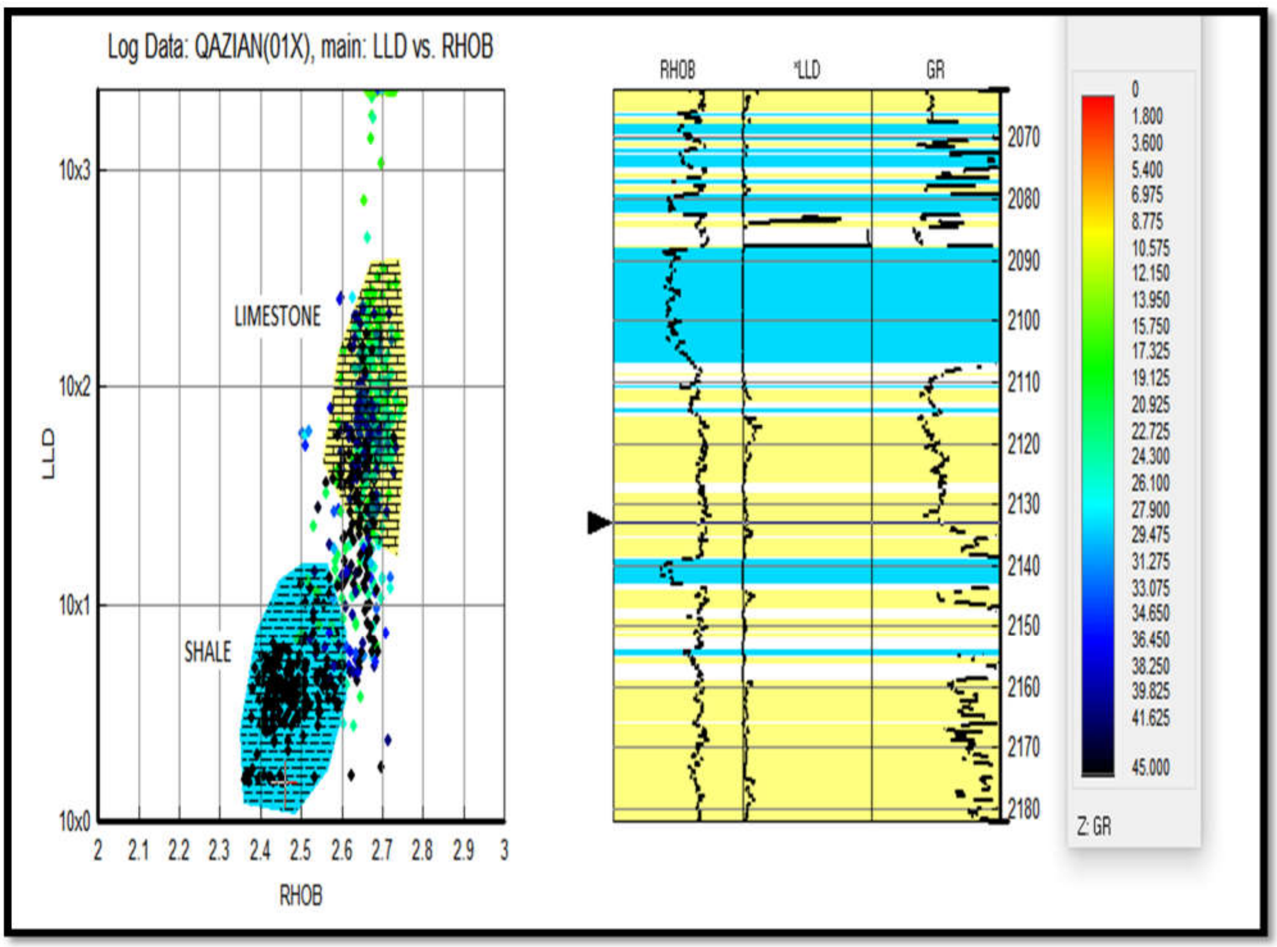

Figure 5.3 Cross plot of LLD and RHOB.

5.3.2 GR, NPHI-E and RHOC cross plot

There is an inverse relation between NPHI and shale. Greater value of shale and low value of NPHI. Limestone has high value of RHOB and NPHI. Shale has low value of RHOB and NPHI. NPHI is plotted along y-axis and RHOB is plotted along x-axis. Red color shows the limestone and yellow color shows the shale. The cross plot of NPHI and RHOB is shown in the figure 5.4.

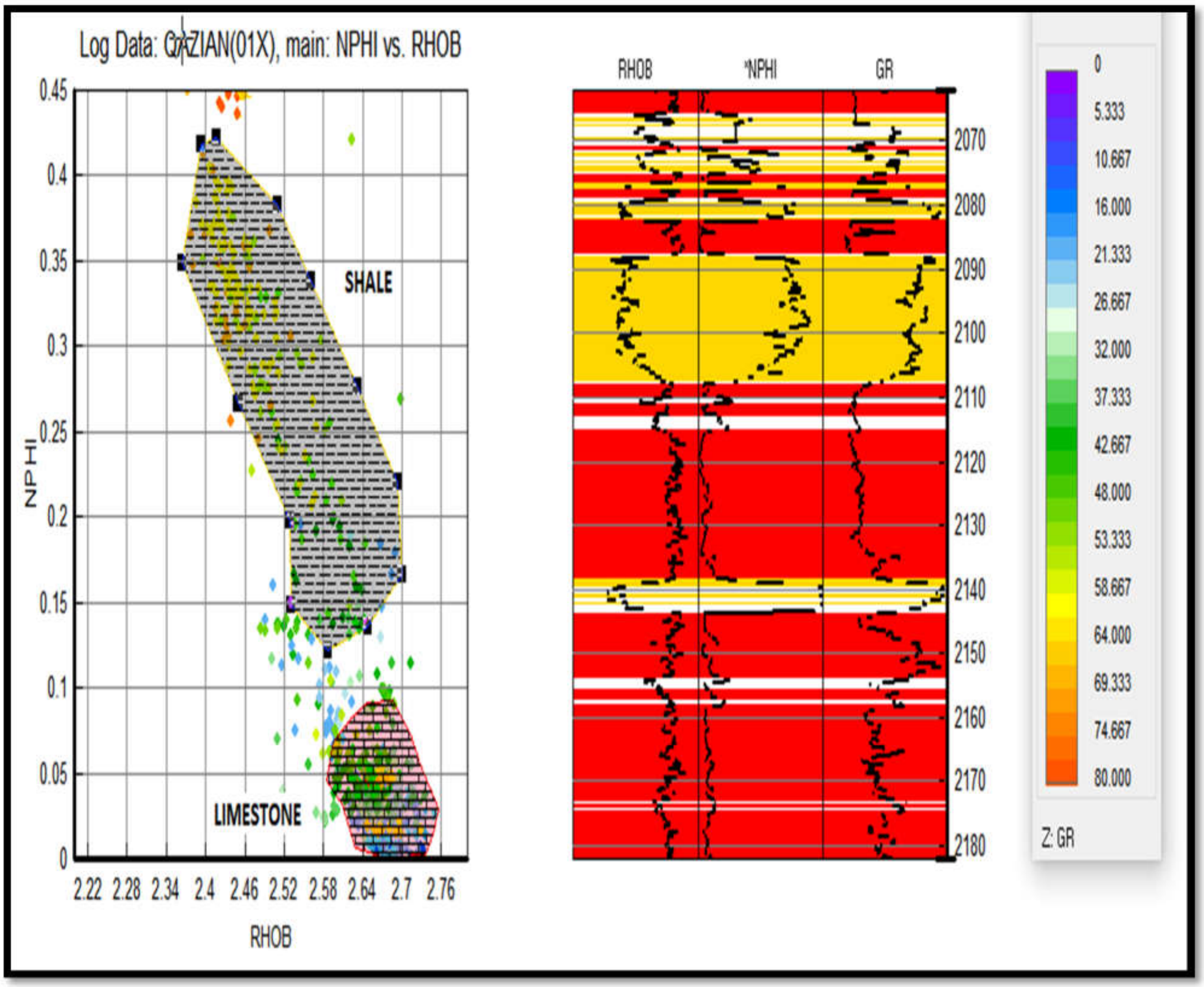

Figure 5.4 NPHI, RHOB cross plot.

CHAPTER NO 06

ROCK PHYSICS.

6.1 INTRODUCTION

Rock physics uses well log data to establish P-wave velocity (Vp), S-wave velocity (Vs), density, and their relationships to elastic moduli (bulk modulus and rigidity modulus), porosity, pore fluid, temperature, pressure, etc. for given lithology and fluid types. Rock physicist may use information provided by the Petro-physicist, such as shale volume, saturation levels, and porosity in establishing relations between rock properties or in performing fluid substitution analysis.

ROCK PHYSICS AND PETROPHYSICS

Petrophysics focuses on interpreting logs for formation evaluation, while rock physics focuses on understanding the relations between geophysical measurements and rock properties. Traditionally, the two disciplines were approached as separate activities since the petro physicist and rock physicist each developing distinct models and setting distinct control parameters. However, the integration approach for imaging subsurface requires a strong link between these two disciplines as well. Therefore, petro physicist should provide primarily input (e.g. clay volume, porosity, Sw) and rock physicist should use them to build and calibrate a valid rock physics model. The input parameters are constantly updated by synchronizing the model and control parameters between two disciplines through several iterations.

The output of this iteration is a calibrated rock physics model and parameters which represent elastic properties changes due to the lithology, fluid, pressure etc. changes at well location. This model represents a relationship which is valid at the well location, and should be calibrated with other information like seismic if we wish to use it in a broader aspect. However, geological information (surface geology, geochemistry etc.) can also be considered as the global or local trend in the rock physics model and make the model more general.

ROCK PHYSICS AND SEISMIC

Reflection seismic helps with creating with 2D or 3D image of the reservoir by providing the subsurface seismic properties. These properties can be used to construct structural frame of the subsurface using different attributes. Further information can be extracted applying different seismic characterization methods such as Amplitude Versus Offset (AVO), inversion etc. However, all of these methods provide an image within elastic properties domain, and a rock physics model is needed to convert them into reservoir properties which are more familiar for the geoscientist and engineers. The calibrated rock physics model from Petrophysics should be used and updated for this purpose. The procedure normally starts from the well tie analysis where well data are used to create a synthetic seismic which should be tied with the measured seismic at the well location. In addition to the wavelet and rock physics parameters, input from Petrophysics (e.g. clay volume, porosity, Sw) also should be considered for updating. Furthermore, this model can be used for velocity modelling, AVO analysis and finally for inversion study.

6.1.1 METHODOLOGY

The log curves of the logs i.e. sonic, density and neutron logs are used here for research purpose. The modeled data has the following parameters i.e. density, porosity and AI (Acoustic Impedance) and having ranges.

6.1.2 MODELED DATA.

At these particular conditions the limestone shows a range in the velocities, porosity, density and impedance (Mavko *et al*., 2009). This data which is acquired at particular conditions is the modeled data and is used to compare with the log data.

6.1.3 LOG DATA.

The log data of one well, Qazian 01x is used here only for zone of interest i.e. for Sakesar and chorgali formation which is acting as major reservoir rock in the study area. Different parameters i.e. density, porosity and impedance are calculated only for zone of interest. These parameters are calculated by using different logs i.e. sonic log (for, and porosity calculation), density log (for density and porosity calculation) and neutron log (for porosity calculation). The data set which is calculated from different logs is termed as log data.

6.1.4 BODY WAVE VELOCITIES

$$Vp= \frac{\sqrt{k+(4/3)\mu}}{\sqrt{\rho}} \text{ ....} (1)$$

$$VS=\frac{\sqrt{\mu}}{\sqrt{\rho}} \text{.......................................} (2)$$

6.2 GRAPHICAL REPRESENTATION OF ELASTIC MODULUS

a) Vs and depth

The S waves do not pass through fluid since fluid don't have shear components. So in reservoir rocks since pores are filled with fluid so s waves velocity decrease exponentially. S waves will only pass through rock matrix so their velocity will be low. The plot of Vs and depth is shown in figure 6.1 and Vs can be calculated by the following formulae.

$$V_S = (0.58321 \times V_P) - (0.07775)$$

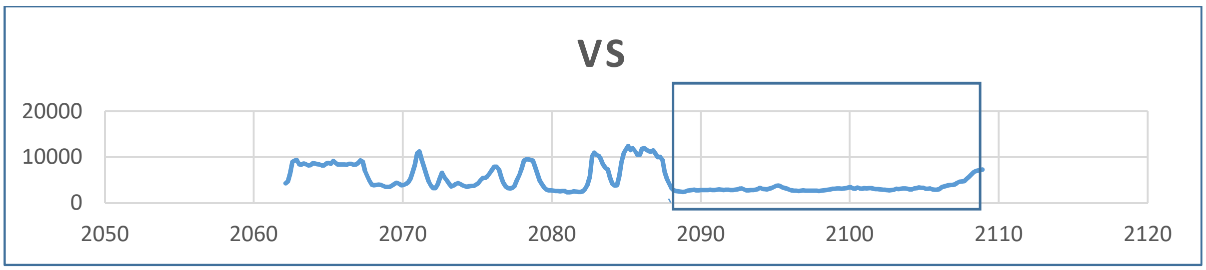

Figure 6.1 Depth vs Vs .

b) Vp and depth

Since if a rock is acting as a reservoir it must be porous and permeable. But seismic waves are pulses of energy whose propagation through a material depends upon contact of particles of material. But reservoir rocks are porous and pores are filled with fluid so P wave velocity is low in reservoir rocks. The plot of Vp and depth of reservoir is shown in figure 6.2, and Vp can be calculated by the following formulae.

$$V_P = \frac{1 \times 1000000}{Sonic \log(DT) \times 3.28} \left(\frac{m}{s}\right)$$

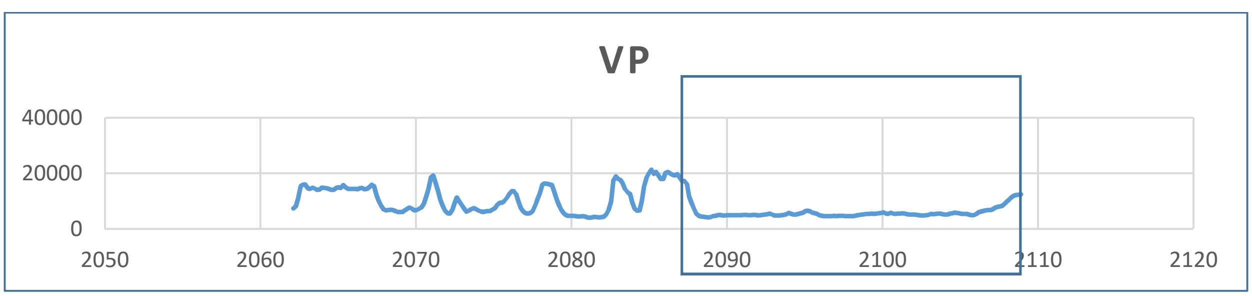

Figure 6.2 Depth vs Vp.

In figure 6.2 we plot the depth along x-axis and p wave along y-axis. In interested zone P wave velocity less because in reservoir due to porosity wave travel slowly and take time. P wave velocities are low in the reservoir rocks.

In fig 6.1 and 6.2, as we describe the behavior of P and S wave is slow. Ratio of P and S wave P/S give Poisson ratio if ratio equal to 0.2 then there is good indication of hydrocarbon.

c) Shear modulus and depth

Shear modulus is defined as ratio of shear stress and shear strain. Since rock pores are filled with fluid so there is no shear stress and shear strain. Hence the shear modulus of reservoir rock is very low. Plot of shear modulus and depth of reservoir is shown in figure 6.3 and can be calculated by the following formulae.

$$\mu = \left(\rho \times V_s^{\,2}\right)$$

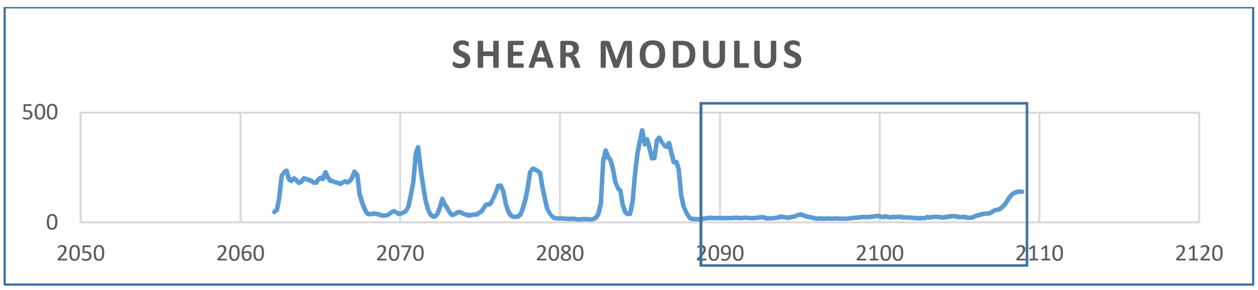

Figure 6.3 Depth vs Shear modulus.

d) Bulk modulus and depth

Bulk modulus is defined as ratio of volumetric stress and volumetric strain. Since reservoir rocks are porous so volumetric strain is higher in reservoir rocks. Since volumetric strain is inversely related to bulk modulus hence bulk modulus of reservoir rock is low. Formulae for bulk modulus is given below.

$$K = \left(\rho \times V_P^{\,2}\right) - \frac{4}{3}\left(\rho \times V_S^{\,2}\right)$$

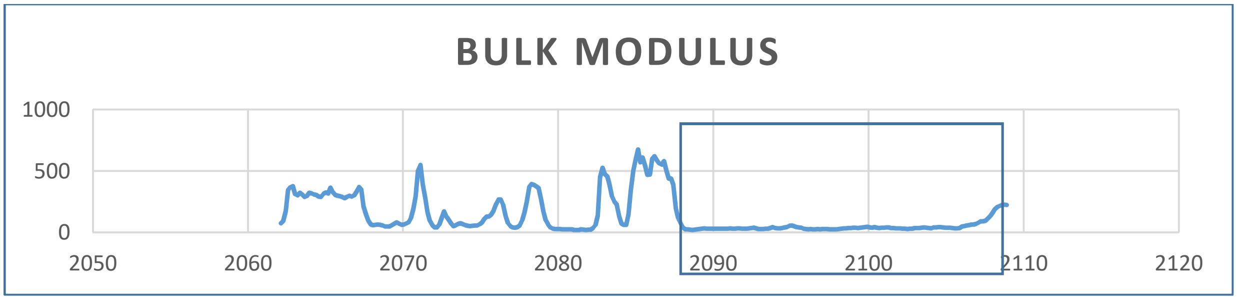

Figure 6.4 Depth vs K.

e) Young modulus and depth

Young's modulus or elastic modulus is ratio of tensile stress and tensile strain. It measures tensile elasticity of an object. It measure deformation along one dimension. The bulk modulus is simply extension of elastic modulus to 3D.Since as discussed above the bulk modulus of reservoir rocks is low because they are porous hence elastic modulus is also low in reservoir rocks. Plot of elastic modulus and depth is shown in figure (6.5). Formulae is given below

$$E = \frac{9 \times K \times \mu}{3K + \mu}$$

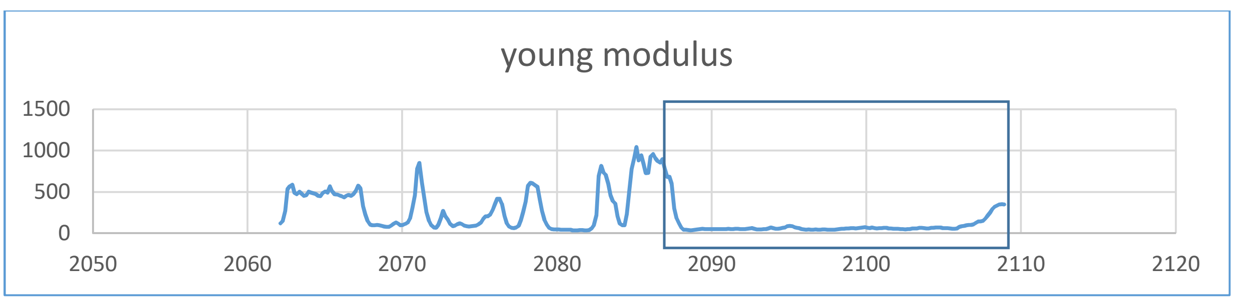

Figure 6.5 Depth vs Young Modulus.

f) Poisson ratio and depth

Poisson ratio is ratio of longitudinal strain and transverse strain. It is more diagnostic lithological indicator because it is independent of density. Since VP and Vs are low in reservoir rocks hence Poisson ratio is also very low. Plot of Poisson ratio and depth is shown in figure 6.6. The poisson's ratio is calculated by the following formula:

$$\sigma = \frac{\frac{1}{2} \times (\frac{V_P}{V_S})^2 - 1}{(\frac{V_P}{V_S})^2 - 1}$$

The value of poison's ratio is determined by above formula which is 0.24 and it is lies within the range of limestone.

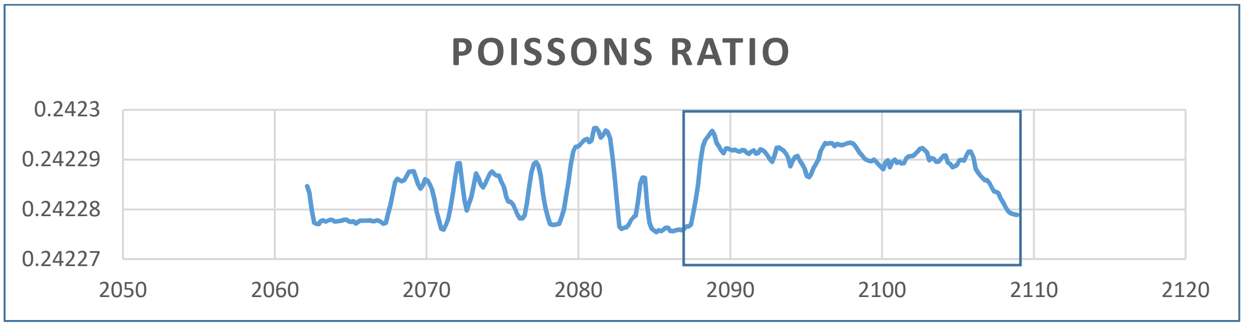

Figure 6.6 Plot of Poisson ratio and depth

In fig (6.1, 6.2, 6.3, 6.4, 6.5, 6.6) shows that rock physics analysis is applied to intervals where we can find fairly universal relations of acoustic properties fluid, lithology, rock texture, porosity

Conclusion

- Missakaswal area lies in a compressional regime characterized by thrust faulting and anticline structures.
- There is repetition of Eocene strata in Missakaswal area due to over thrusting. This is also evident on the seismic section. However due to unavailability of complete log data and lack of control on the seismic data, the repeated portion of Eocene age is not marked and confirmed.
- An anticlinal pop up structure is marked on the seismic sections with two thrust faults F1 and F2 dipping towards each other from east and west.
- Two way fault bounded closure is clearly observed on the depth Contour maps which confirms the presence of pop up structure in the study area
- The pertrophysical analysis shows Chorgali Formation a potential hydrocarbon producing zone.
- Seismic interpretation results have identified pop-up anticline structures in the area of study which are favorable structures for the accumulation of hydrocarbons.
- Reflectors of two formations Chorgali and Sakesar were marked on seismic section, with the help of synthetic seismogram of Qazian-01 well.
- The Khewra formation is also marked with the help of the synthetic seismogram of the Qazia- 01 well.
- Time and depth contour maps show the presence of pop-up anticline structures in study area.
- The pop up structure formed can be a good reservoir if the source formations are present.
- Due to limitation of data control seismic attribute analysis only confirm the interpretation at some locations but not give any reliable location to identify hydrocarbons.
- The Chorgali and the Sakesar formation marked on the seismic section are proved to be the good reservoirs.

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