Seismic Interpretation and Reservoir Characterization of Missa Keswal Area using 2D Seismic and Well Data

By

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(2013-2017)

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بسم الله الرحمن الرحيم

“In The Name of ALLAH, the Most Merciful & Beneficent”

It is He who made the night and the day alternate for one who desires to take admonition, or desires to give thanks.

Al-Quran (25:62)

Certificate of Approval

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

<u>RECOMMENDED BY</u>

Dr. Mumtaz Muhammad Shah __________________________

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External Examiner __________________________

DEDICATION

This dissertation is dedicated to my Parents who instilled in me the virtues of perseverance and commitment and relentlessly encouraged me to strive for excellence. Their guidance and prays made me able to achieve such success and honor.

ACKNOWLEDGEMENT

First praise is to Allah, the Creator, most Merciful and Almighty, on Whom ultimately, we depend for sustenance and guidance. I bear witness that Holy Prophet Muhammad (S.A.W) is the last messenger, whose life is perfect model for the whole mankind till the Doomsday. I thank Allah for giving me strength and ability to complete this study.

Foremost, I would like to express my sincere gratitude to my Supervisor **Dr. Mumtaz Muhammad Shah** for the continuous support of my dissertation, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this dissertation. Beside my Supervisor, I am thankful to my respectable seniors, my dear sisters my brother Nauman Khan and my friends especially Osman Nadeem, Khizer Ali Khan Jadoon, Hamza Hamid, Tayyab Hamid, Muhammad Usman, Zeenia Hussain and all the clerical staff of the department for their cooperation and guidance during the research work.

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ABSTRACT

The principle reason for this work is the seismic interpretation of the Missa Keswal area, located in Chakwal district of Punjab province, Pakistan with a specific end goal to divide the plausible zone for the accumulation of hydrocarbons. The study area is situated in Potwar sub basin of upper Indus basin 33°11'19''N to 73°21'20''E. Three seismic lines (two dip and one strike) and Qazian Well are chosen. Patala formation acts as a source rock, Chorgali and Sakesar formation acts a reservoir rock whereas Murree formation acts a seal/cap rock. Seismic structural interpretation incorporates marking of reflector with the assistance of synthetic seismogram, fault picking, generation of polygon and time and depth contour map. The seismic interpretation shows anticline structures bounded by thrust faults. Two-way fault bounded closure is clearly observed on the time and depth Contour maps which confirms the presence of pop up structure in the study area. Time sections are converted into the depth sections to view the real picture of the interpreted horizons.

In facies analysis, different cross plots were generated to confirm the dominant lithology of our reservoirs which turn out to be limestone. Volume of shale, porosity, water immersion and hydrocarbon potential are computed by applying petro-physical techniques providing the results with the help of which we distinguished the Zone of interest for a reservoir. SMT Kingdom 8.6, HIS 8.8 are the software used for interpretation of 2D seismic and well data.

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Chapter No. 01

INTRODUCTION

1.1 INTRODUCTION:

Hydrocarbons are of great importance for the economy of any country. Areas thought to contain hydrocarbons are initially subjected to gravity and magnetic survey, and passive seismic or regional seismic reflection surveys to perceive large scale features of the sub-surface geology. In Seismic method, the Reflection seismology (used in present work) is extensively used for hydrocarbon exploration. The potential of hydrocarbon is high in North (potwar, Kohat) and South region of Pakistan (Badin, Mari). The Indus basin also including the Kohat and Potwar (study area) depression contain 48% of the world's known petroleum resources (Riva, 1983). Structural Traps are most dominated in Potwar sub basin and for the delineation of these structures mostly seismic data is incorporated.

Seismic surveys use reflected sound waves to produce a scanning of the Earth's subsurface. Seismic surveys can help locate ground water, are used to investigate locations for landfills, and characterize how an area will shake during an earthquake, but they are primarily used for oil and gas exploration (Seismic acquisition).

Geophysicists have been trying for hydrocarbon exploration since a long time ago and developed many techniques in this regard. Seismic method is direct result evaluating and accurate geophysical method used for structural analysis. Seismic Reflection Method most commonly used in hydrocarbon exploration in petroleum geology. Petroleum system mainly comprises of three constituents that are enlisted below.

- Source rocks (contains organic materials which for responsible for generation of hydrocarbons).
- Reservoir rocks (migration of hydrocarbons takes place from source rock and reservoir rock offers suitable conditions for their accumulation).
- Seal or trap rocks (act as a barrier it stops upward movement of hydrocarbons).

Reservoir characteristics can be calculated using borehole data. Well log is one of the most fundamental methods for reservoir characterization, in oil and gas industry, it is an essential method for geoscientist to acquire more knowledge about the condition below the surface by using physical properties of rocks. This method is very useful to detect hydrocarbon bearing zone, calculate the hydrocarbon volume, and many others.

Facies is a rock body 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. So, the modelling technique used for representing lithofacies is known as facies modelling. (Mutti, 1978). This technique requires different cross plots that help to delineate existence of a specific facies throughout the borehole.

1.2 INTRODUCTION AND LOCATION OF STUDY AREA:

The area under study is Missakeswal oil field which is located ten kilometres from Gujar Khan. 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 (Moghal et al., 2007).

Latitude:

Latitude of the area is 33° 11' 06" to 33° 11' 18.24" North.

Longitude:

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

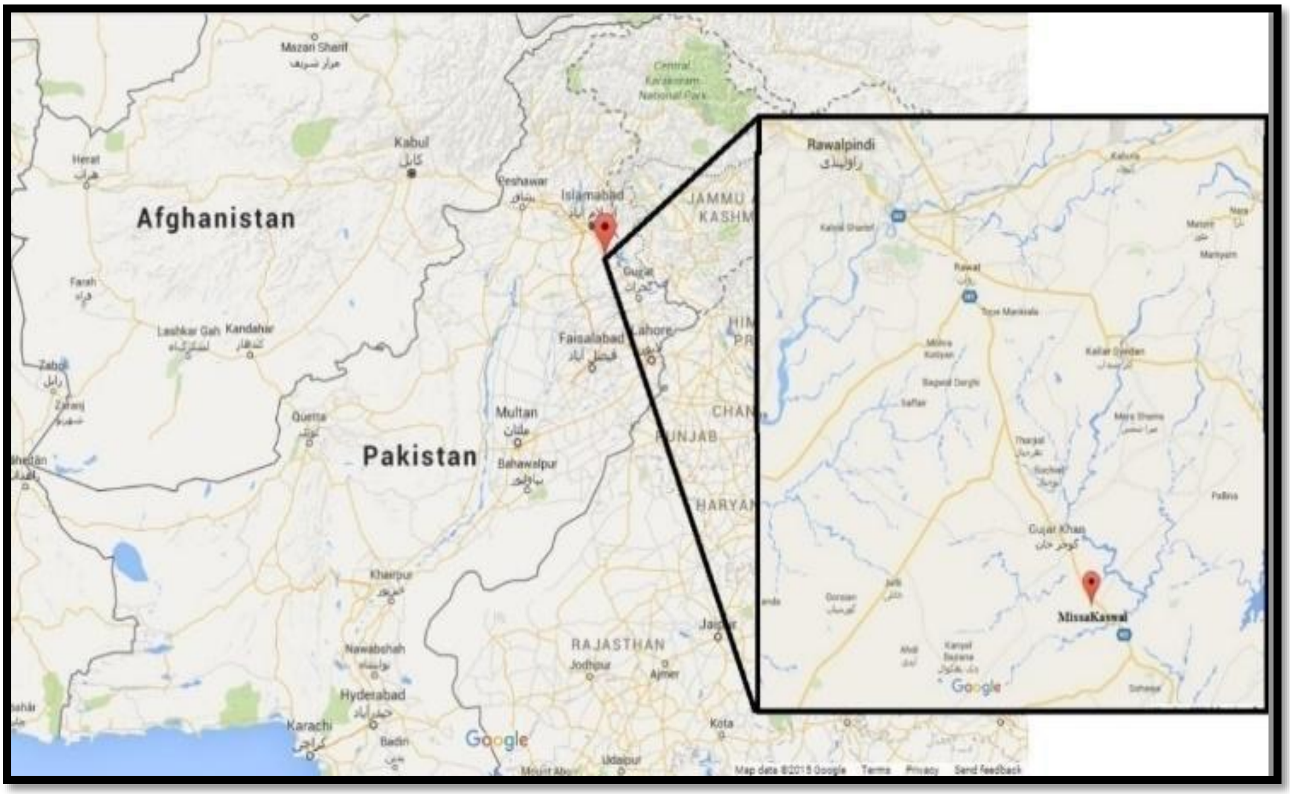


Figure (1.1) location of study area

1.3 EXPLORATION HISTORY OF MISSA KESWAL OIL FIELD:

Missa Keswal oil and gas field is located 70 km SSE of Islamabad in the eastern part of Potwar basin. On surface, it is a thrust bounded anticline striking in SW-NE direction. First seismic work was carried out in 1980, followed by drilling of an unsuccessful well. Another well was drilled after an improved seismic programme which resulted in discovery of oil and gas in seven different reservoir units of Cambrian, Permian, Paleocene, Eocene and Miocene age. Among these, three reservoir units namely Jutana, Baganwala and Kussak of Cambarian age had never produced in the Potwar basin earlier. The field had original, in place, proven reserves of 37.650 MMSTB of oil and 27.900 BSCF of gas. Current production from three wells is around 4500 barrels of oil and 7.3 MMSCFD of gas a day. This production comes from fractured limestone and porous sandstone rocks.

1.4 Objectives

- The main objective of the thesis is to understand subsurface geology and their impact on reservoir properties for hydrocarbon exploration in the study area.
- Picking of prominent reflectors on the seismic section.
- Faults identification on seismic sections.
- Preparation of time and depth structure map.
- Reconstruction of probable geological event to the present day in the study area.
- Petrophysical analysis in order to delineate the reservoir characteristics of the study area.
- Facies analysis to identify dominant lithology of reservoir.

1.5 DATA USED:

This study is based on the seismic reflection data and well log data of Missa Keswal area

1.5.1 SEISMIC DATA DETAILS:

Following are seismic lines selected for study the area. The data was acquired by OGDCL in Sep 1999.

Line Name	Line Type	Line Orientation
,GO-926-GJN-17	Dip Line	NW- SE
GO-994-GNA-09	Dip Line	NW-SE
GO-905-QZN-08	Strike Line	NE-SW

Table (1.1) Seismic Lines

1.5.2 WELL DETAIL:

In the study area, four wells are present namely Missa-01, Missa-02, Missa-03 and Qazian 01X. Following is the detail of assigned well.

Well name / Borehole	Well depth	Status	Coordinates
QAZIAN -01X / Main	2481	Exploratory	X: 904472.94 Y: 3682215.33

Table (1.2) Well Data

1.6 BASE MAP OF 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.

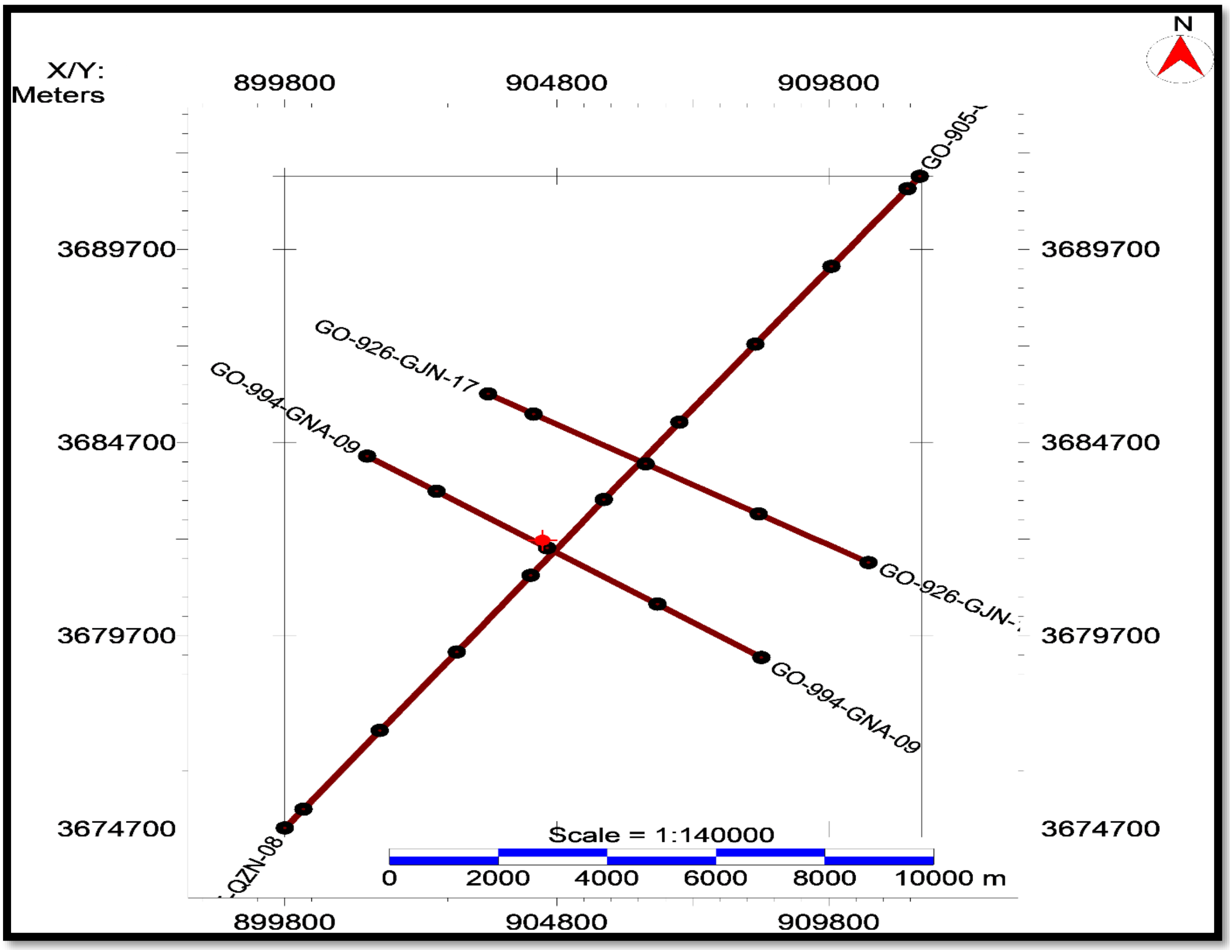


Figure (1.2) Base map of study area

1.7 SOFTWARE USED:

- IHS KINGDOM 8.8
- SMT KINGDOM 8.6
- SNAGIT

1.8 METHODOLOGY:

- Collection of geological & Geophysical data.
- Preparation of base map.
- Marking of faults on seismic sections.
- Marking of interested reflectors on seismic sections.
- Determination of horizons by generating 1-D synthetic seismogram.
- Finding velocity of horizon using well data.
- TWT contour map generation.
- Depth contouring.
- Petrophysical properties of reservoir rock with the help of log data.
- Facies modelling

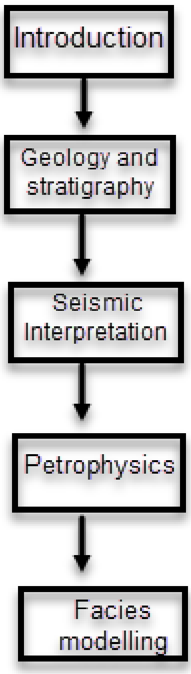


Figure (1.3) Methodology of dissertation

Chapter No. 02

GENERAL GEOLOGY AND STRATIGRAPHY

2.1 GEOLOGY AND TECTONICS:

The Missa Keswal 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 sub-basin is part of active foreland fold and thrust belt of the Himalayas. The structures are bounded by foreland verging thrusts. The geometry of the sub-basin has been influenced by Jhelum fault in the East and Kalabagh fault in the West. Southern 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. Paleo magnetic study carried out by (Johnson et al) indicates that there is an increase from 10 to 50 degrees (western to eastern part) in the counterclockwise thrust related motion of Potwar Plateau. Local open folds paralleling the trend of Salt Range and northward dipping strata are the characteristics of southern Potwar Plateau. According to Kemal (1991), the hydrocarbon traps of Potwar Plateau are structurally controlled but local stratigraphic traps have also been reported.

According to Shah (1977) and Baker (1988), 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.

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/transpressional subsurface structures. Since first discovery of oil in 1914 at Khaur, about 150 wells for exploration of hydrocarbons have been drilled in the Potwar sub-basin.

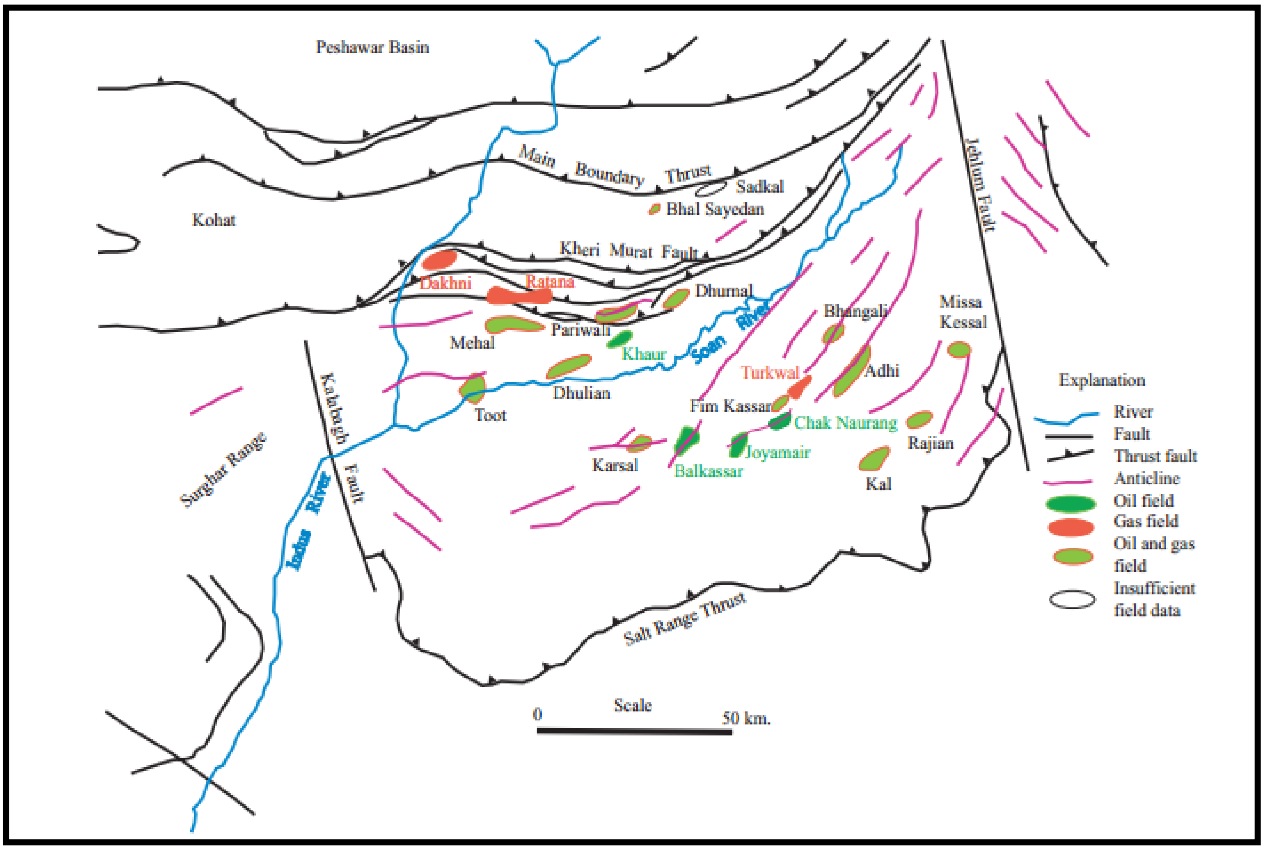


Figure (2.1) Tectonic map of Kohat-Potwar Plateau with highlighted box showing study area. (Kemal, 1992)

2.2 SEDIMENTARY BASINS OF PAKISTAN:

Pakistan comprises of two sedimentary basins Indus basin in the east and Baluchistan basin in the west. These two basins evolved through different episodes and finally these two were welded by collision of Indian-Eurasian plates during Cretaceous-Paleocene along Ornach-Nal and Chaman Strike slip faults. The collision of Indian Plate with Eurasian Plate is oblique along the left lateral

- Indus Basin
- Baluchistan Basin.

2.2.1 INDUS BASIN

The Indus basin belongs to the type extra continental down wrap. The basin has elongated shape and is oriented in Northeast and Southwest direction. The main tectonic features of Indus basin are the platform, the fordeep comprising depressions, inner folded zone and outer folded zone (Kazmi & Jan., 1997). Indus basin is divided into Compression regime in upper Indus basin, Basement uplift in central Indus basin and Extensional regime in lower Indus basin. On the basis of structure Indus basin is subdivided into two parts

- Upper Indus Basin (North)
- Lower Indus Basin (South)

Upper Indus basin is located in Northern Pakistan and separated from lower Indus basin by the Sargodha high. In its North MBT, while in the east and west strike slip faults Jhelum and Kalabagh is located respectively. Upper Indus basin is subdivided into two parts (Kazmi & Jan., 1997).

- Potwar basin
- Kohat basin

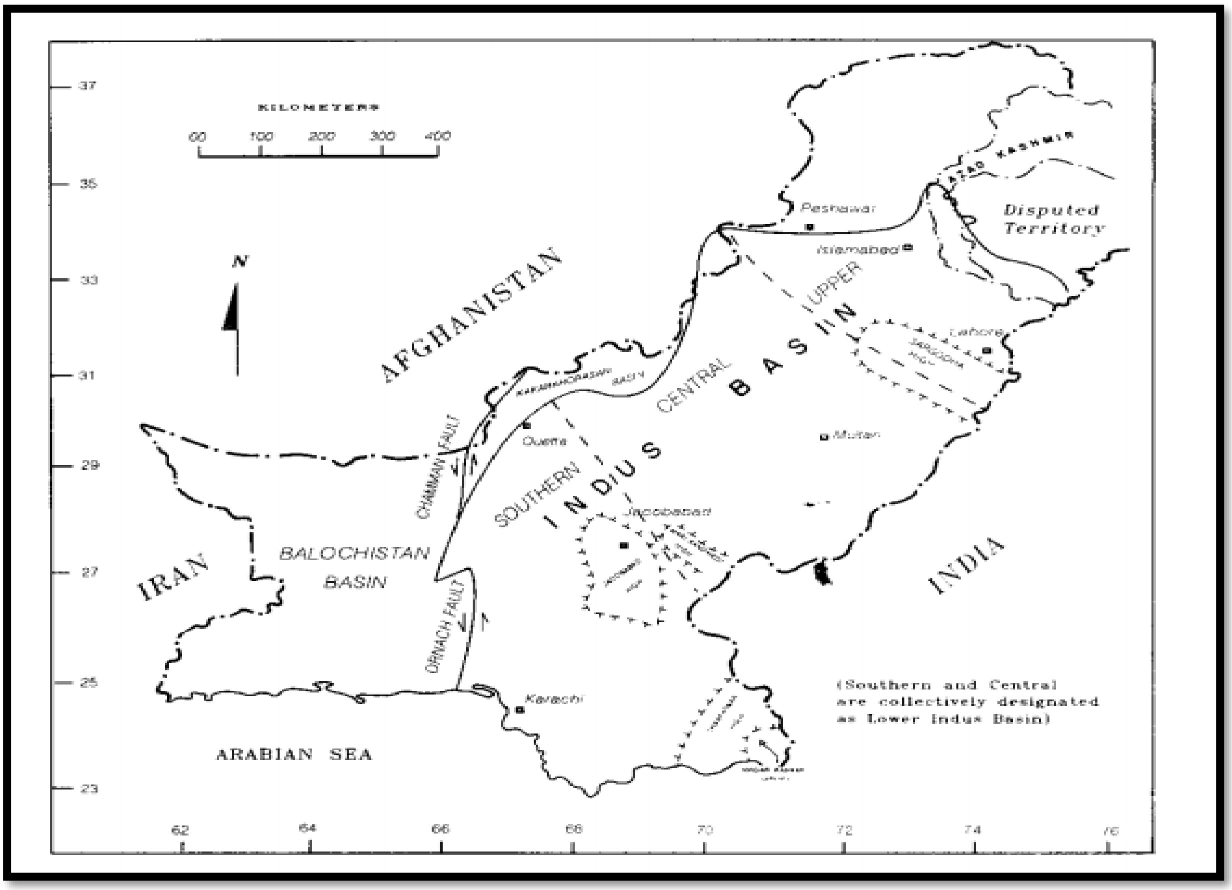


Figure (2.2) Major Sedimentary basins in Pakistan, (after I.B Qadri)

2.3 STRATIGRAPHY OF THE STUDY AREA:

Subsurface geological data from wells drilled in Missakeswal 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.

Stratigraphic succession of the Potwar Basin is characterized by thick Infra-Cambrian evaporite deposits overlain by relatively thin stratigraphic succession of the Eocene to Cambrian. Thick Miocene-Pliocene molasses deposits are related to severe deformation in Late Pliocene to Middle Pleistocene (During Himalayan orogeny).

Well data obtained in Rajian, Missa Keswal 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 Missakeswal area.

The general stratigraphy of Upper Indus basin is shown in stratigraphic column showing two main unconformities and some small unconformities.

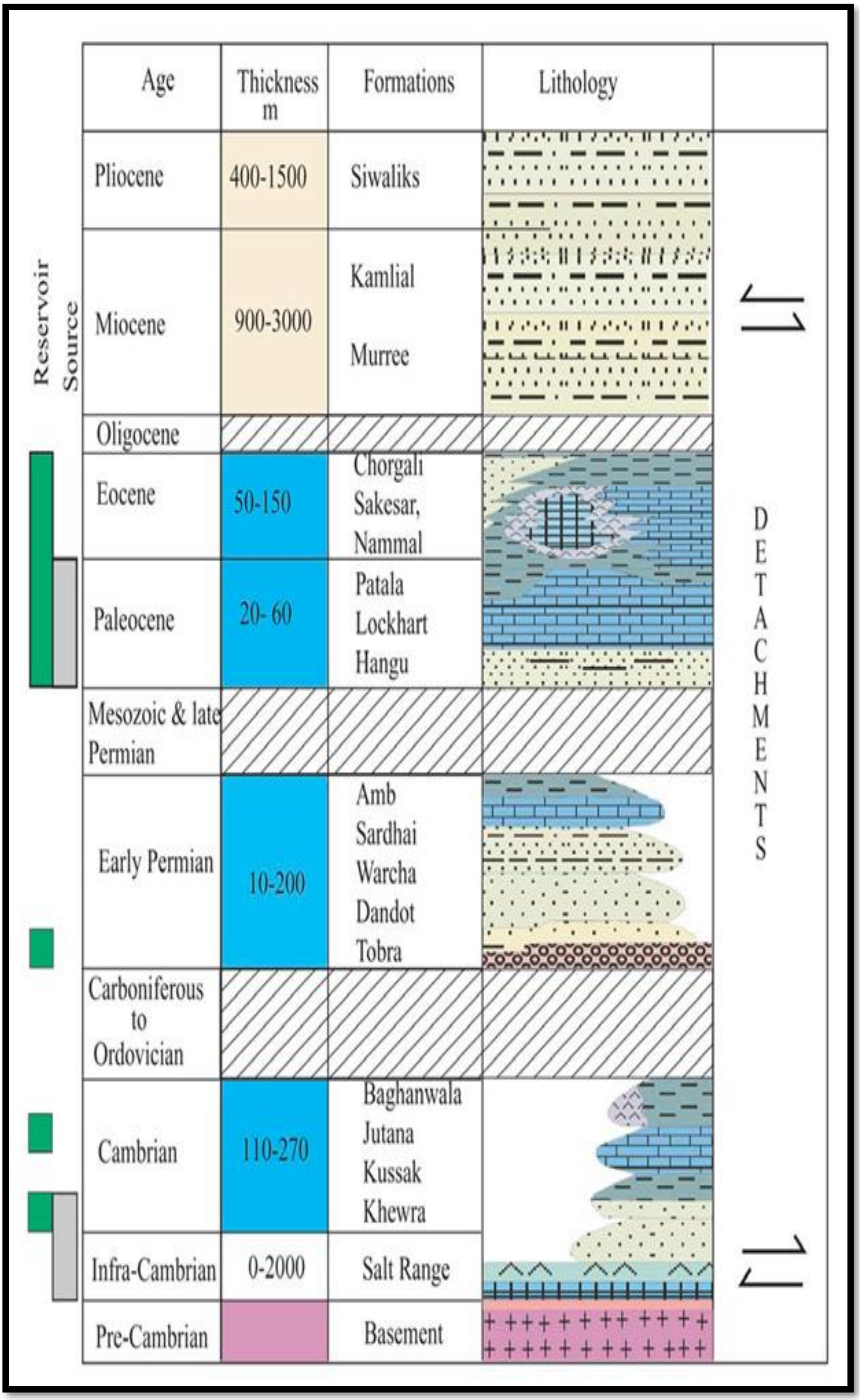


Figure (2.3) General Stratigraphy of Upper Indus Basin (Aamir & Siddiqi, 2006)

2.4 RESERVOIR CHARACTER AND PRODUCTION HISTORY:

Fractured limestones of the Chorgali and Sakesar formations are developed throughout the Salt Range and 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 (Khan, et al., 1998).

2.5 PETROLEUM PLAY:

Petroleum play of an oil field comprises of source rock, reservoir rock, and cap rock. In Missakaswal area Patala formation of Paleocene age is source rock, chorgali and sakesar limestone of Eocene age are acting as reservoir and Muree formation of Miocene age is acting as seal.

2.5.1 SOURCE ROCK (PATALA FORMATION)

Patala formation is widely exposed in kohat-potwar basin, in south in salt range and surger range in west in samana and kohat ranges in north in Hazara Mountains and kala chitta range. This formation contains thick seems of coal and act as a source rock for hydrocarbon exploration in adjacent kohat-potwar area. Patala formation age is Paleocene in salt range and on its top in Nammal Gorge area a break in deposition was observed. This is an important geological event representing gap in deposition between Paleocene and Eocene but this is not yet observed elsewhere kohat-potwar area.

2.5.2 RESERVOIR ROCK (CHORGALI AND SAKESAR LIMESTONE)

The sakesar limestone is grey nodular to massive bedded limestone and it is highly fossiliferous. The sakesar limestone is 70m to 150m thick in study area. The formation has confirmable contact with nammal and chorgali formation in north of gandhala nala while its contact with kamlial formation is unconformable.

Chorgali formation is a potential reservoir in Potwar plateau. The chorgali formation is well exposed in central salt range and in some area of eastern salt range. Chorgali formation contains alternating beds of flaggy limestone and shale capping compact limestone. On its type locality formation shows thickness of 150m.

2.5.3 SEAL ROCK (MUREE FORMATION)

The formation generally consists of clay, siltstone, sandstone and conglomerates. The formation was deposited in fluvial environment. The stacked channelized sand bodies are 5-60m thick at these localities. The formation is acting as seal rock in Missakaswal oil field. The formation is mainly consisting of conglomerates and shale which means it is not permeable and hence is acting as seal rock in this area.

Play Element	Formation	Age
TRAP	Structural Trap	
SEAL	Murree Formation	Miocene
RESERVIOR	Chorgali Formation Sakesar Foramation	Eocence Eocence
SOURCE	Patala Formation	Paleocene

Table (2.1) Petroleum Play of Study Area

Chapter No. 03

SEISMIC DATA INTERPRETATION

3.1 SEISMIC INTERPRETATION:

Seismic interpretation implies picking and tracking seismic reflectors on basis of lateral continuity for the purpose of identifying geologic structures, stratigraphy and petroleum play. The ultimate goal is to portray hydrocarbon accumulation and their extent by keeping economic factor in mind also calculates their volume as well. Conventional seismic interpretation is an art that requires skill and experience in geophysics and geology Badley (1985).

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 (Coffeen, 1986). According to Badley (1985), such 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 strati graphically. (Badley, 1985)

3.2 INTERPRETER'S OBJECTIVES:

An interpreter should clearly understand seismic responses and must be certain about conclusions of seismic data. As sufficient information is available on seismic record, it is compulsory to focus primarily on extracting the data pertinent to task.

3.3 AVAILABLE DATA:

Three seismic lines, base map, and well tops of well Qazian-01x acquired from DGPC for this project.

Available seismic lines are as follows:

- **GO-905-QZN-08**
- **GO-994-GNA-09**
- **GO-926-GJN-17**

3.4 INTERPRETATION WORK FLOW:

The Interpretation was carried forward using different techniques and steps with each step involve different processes, which were performed using the software tools as mentioned above. Below is the flow chart of seismic data interpretation.

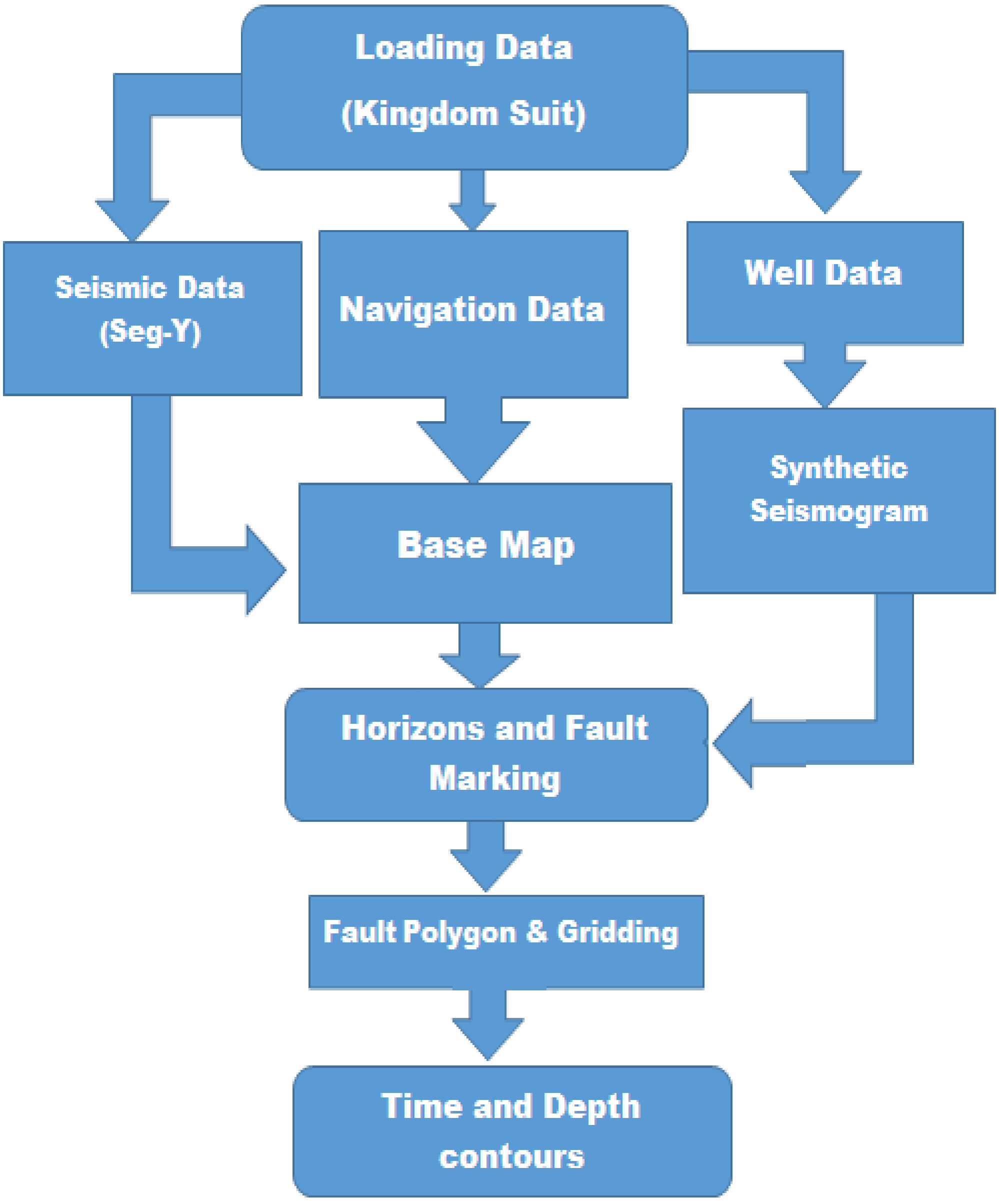


Fig (3.1) Interpretation Flow Chart

3.5 BASE MAP OF STUDY AREA:

Base map is a map which shows orientation and location of the seismic lines and wells. The map consists of dip and strike lines.

Base map of Missa Keswal area showing seismic survey line with well position.

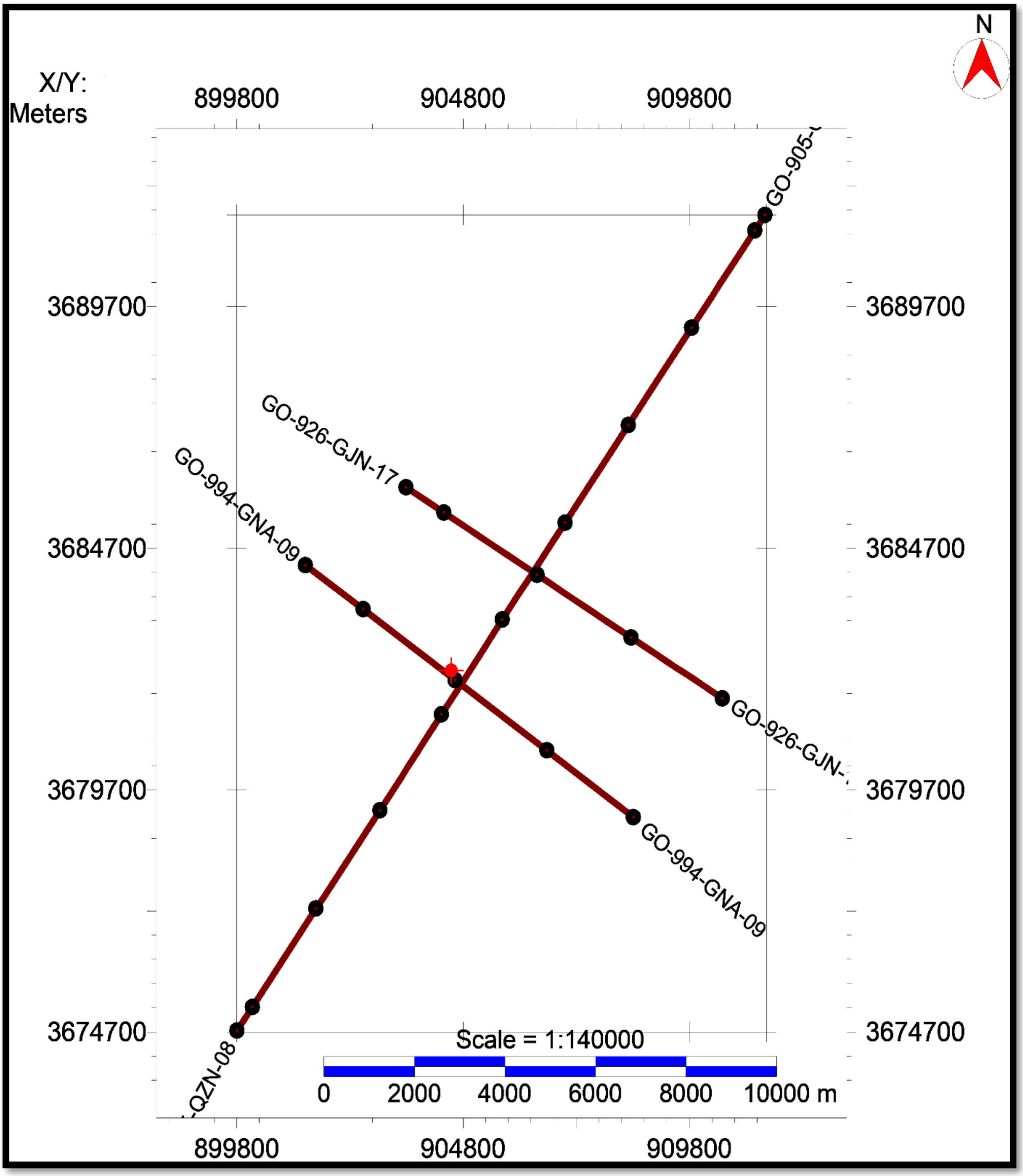


Fig (3.2) Base Map of Missa Keswal with well

3.6 WELL TO SEISMIC TIE:

The aim of well to seismic tie is to compare the seismic data which is obtain in time domain and with the well data which is in depth domain. We perform well-to-seismic tie using a synthetic seismogram. The purpose of well to seismic tie is to match the measurements made through well logs, which are determined in depth domain, to the seismic data which are determined in the time domain.

Well data is needed to form a synthetic seismogram for synthetic seismogram seismic source wavelet is required.

3.6.1 SYNTHETIC SEISMOGRAM AT WELL DATA OF QAZIAN -01X:

Synthetic seismogram is a seismic trace created from sonic and density logs and it is used to compare the original seismic data collected near the well location. 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 shown in fig.3.3.

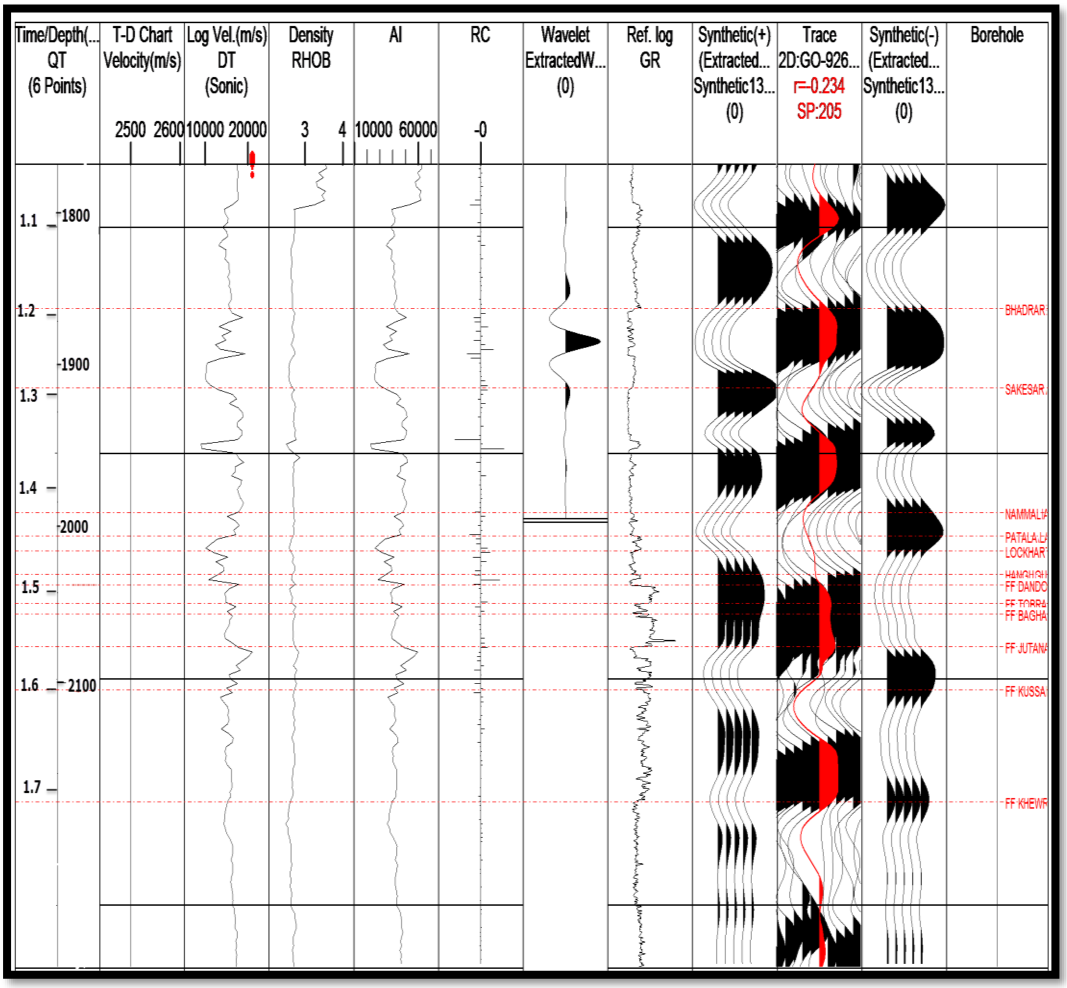


Figure (3.3) Synthetic Seismogram

Well tops are also imposed on the respective synthetic seismogram showing chorgali, Sakesar, Hangu, patella, Lockhart, Nammal, Tobra, Dandot, Bangawala and Khewra sandstone Formation respectively as shown in Figure 3.2.

Ideally, if high impedance rocks lie below the low impedance rocks, then there would be positive phase at sequence boundary and if there are low impedance rocks lying below the high impedance then there would be negative phase at the sequence boundary.

3.7 INTERPRETATION OF SEISMIC LINES:

It includes following steps.

3.7.1 Horizon Picking

The first step in interpretation of a processed seismic section is to pick up the best seismic reflectors from the seismic section. Reflectors are marked on the prominent coherence of reflections visible, which appeal most on the seismic section from the above subsurface interface. Two reflectors were marked in the seismic section of the study area, which are designated as chorgali and Sakesar.

3.7.2 Fault Marking

The following step is the seismic interpretation in identification of faults. Faults are the broken reflectors in seismic section, which continues after slight distortion regime. Major two faults were marked in the seismic section.

3.7.3 Geology of the Area:

On the basis of the geology of the area, it is evident that the area under study lies in compressional regime. This background knowledge helps us to identify that reverse and thrust faults should be marked on the seismic section.

3.8 INTERPRETED SEISMIC SECTIONS:

Interpreted section of Dip Line GO-994-GNA-09 using formation top and synthetic seismogram from Qazian -01 well. Two seismic horizons namely; Chorgali, Sakesar of Eocene age on the basis of well tops and further more confirmed by synthetic seismogram. Along these seismic horizons two faults are also picked.

The interpreted sections are shows in Figure 3.4, 3.5 and 3.6:

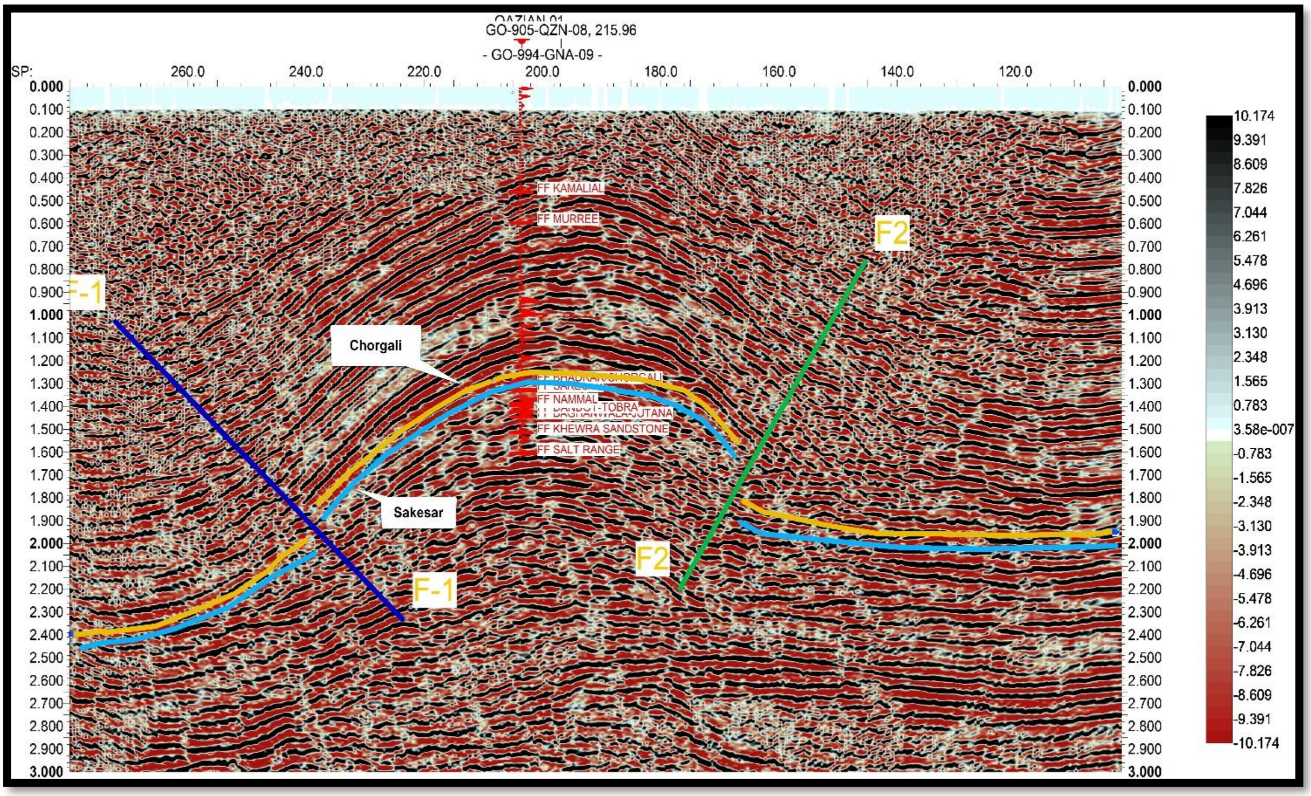


Figure (3.4) interpreted seismic line GO-994-GNA-09

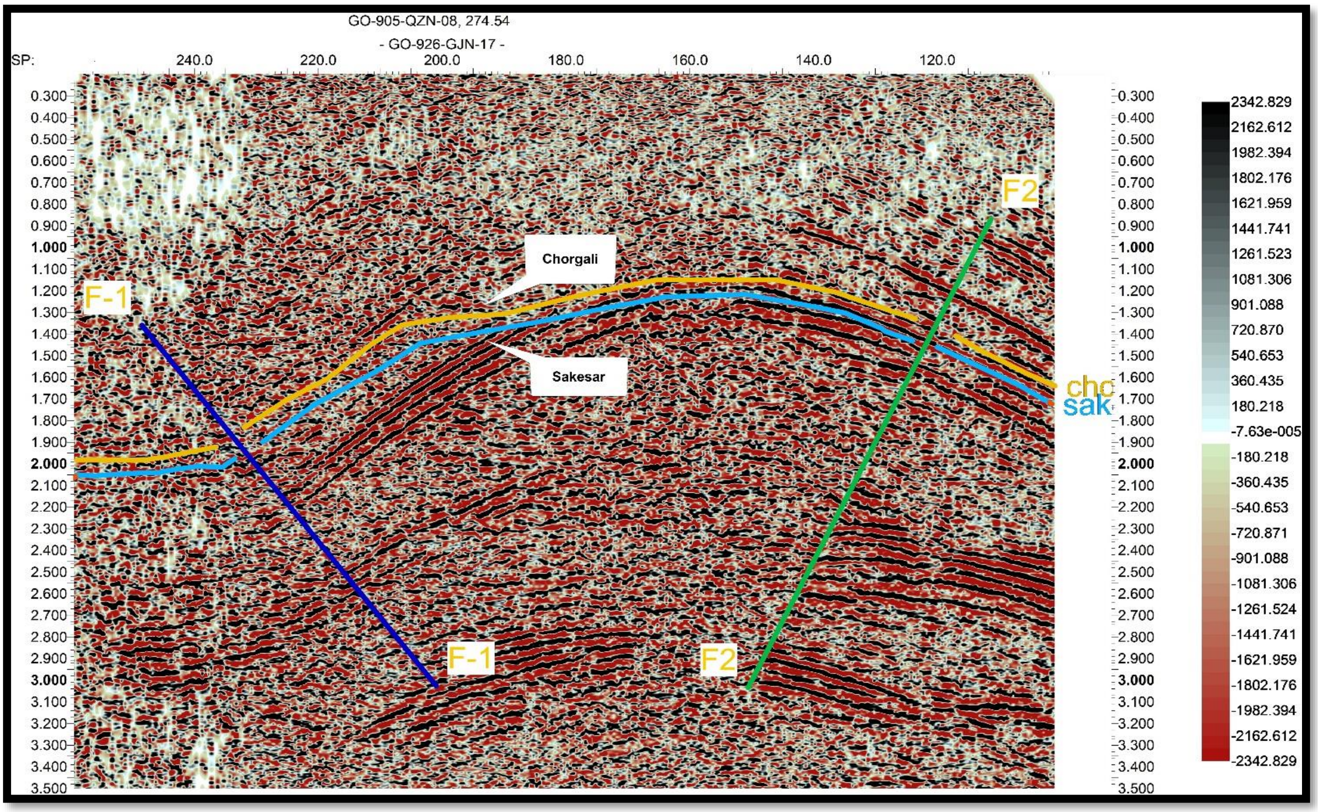


Figure (3.5) interpreted seismic dip line GO-926-GJN-17

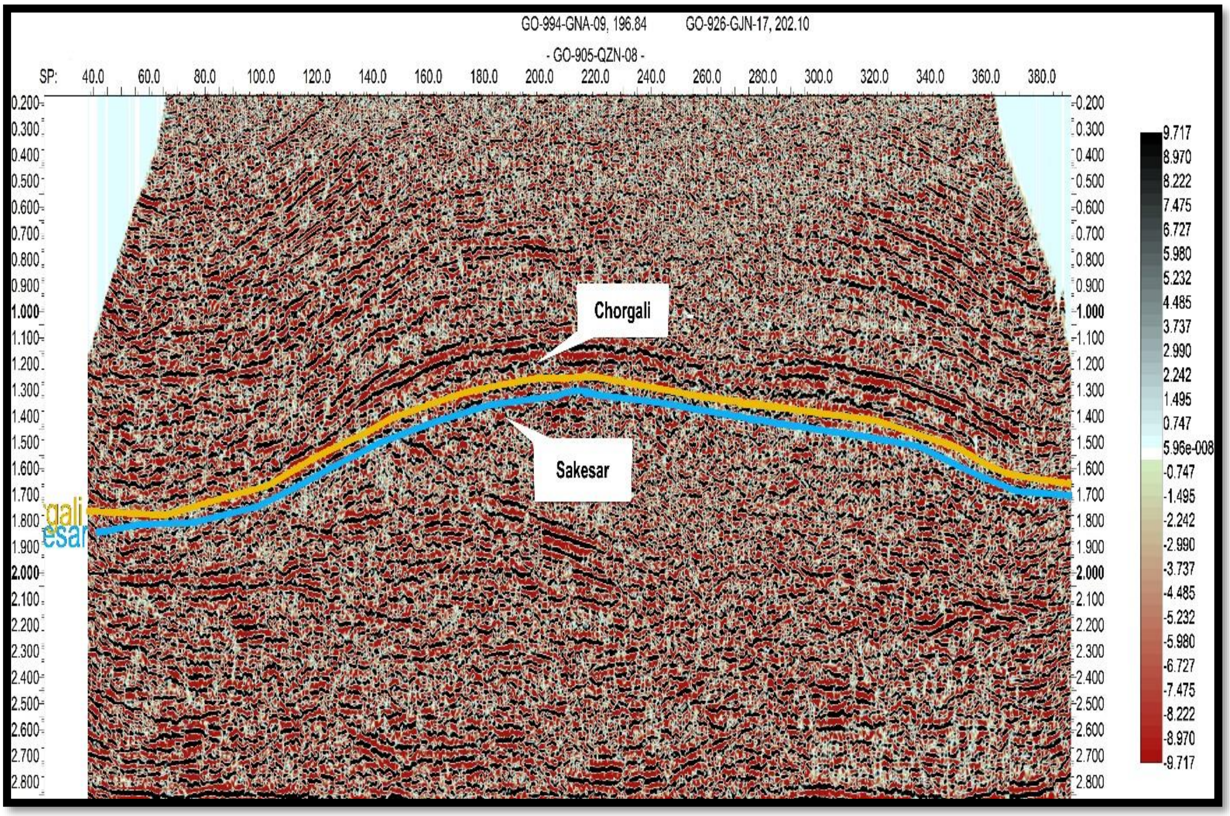


Figure (3.6) interpreted seismic strike line GO-905-QZN-08

3.9 FAULT POLYGON GENERATION:

We mark the fault on seismic section to show the extension and orientation of fault in the entire area. For this, we have to generate the fault polygon, also if we do not generate fault polygon, software doesn't read it as a barrier. After we tie the seismic lines, we construct the fault polygon using kingdom.

The Fault polygon on given seismic lines is shown in figure 3.7.

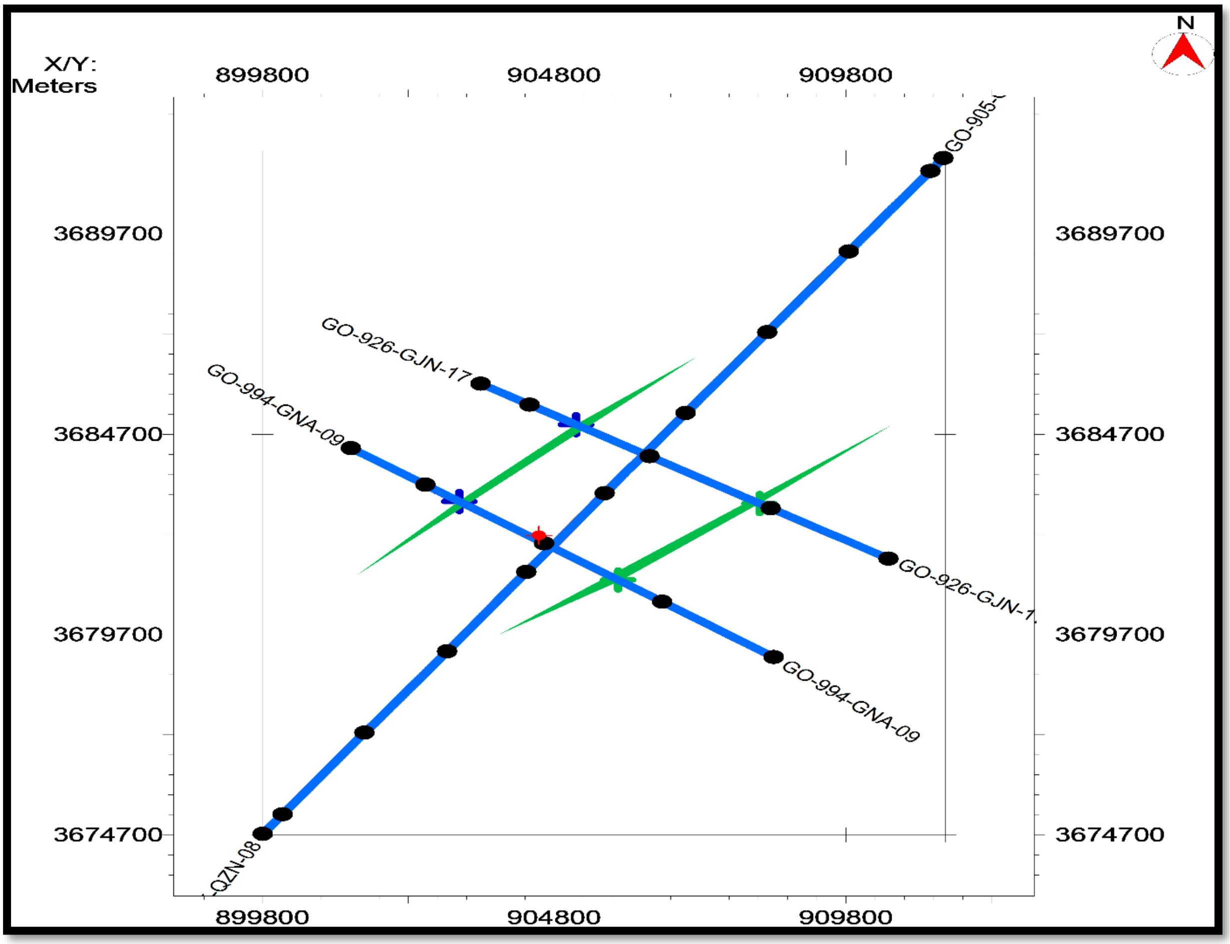


Figure (3.7) Fault polygon

3.10 CONTOUR MAPS:

Contour lines are representative of the same events. The results of seismic interpretation are generally demonstrated in map form. Mapping is part of the interpretation of the data. The seismic map is generally the final product of seismic exploration, the one on which the entire operation depends for its usefulness. The contours are the lines of equal time or depth wandering around the map as dictated by the data (Coffeen, 1984).

The layout 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 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 suit is used to generate all the contour maps.

3.10.1 TIME AND DEPTH AND CONTOUR MAPS OF FORMATIONS:

Chorgali formation is the formation of interest; it is producing both Oil & Gas and is composed of limestone with some amount of shale. On the seismic section, Chorgali reflection is very strong and very easy to locate. A horizon interpolated average velocity contour map for this formation is also generated to understand the spatial variations in velocity. Chorgali time & depth contours are posted on the seismic base map along with well locations and fault polygons.

The Time and Depth Contour Maps of Chorgali Formation are shown in Figure 3.8 (a), (b) and Figure 3.9 (a), (b) respectively. Different seismic lines are used for this contouring. The Chorgali formation acts as a Reservoir in Missa Keswal area.

The Depth contour map represents the horizon in units of depth i.e. meters. This gives a more accurate structure style of the horizon in the subsurface. Figure below shows the depth contour maps for Chorgali Formation and Sakesar Limestone.

The contour interval is set according to scale and the variations in the colour represent changes in the depth. 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.

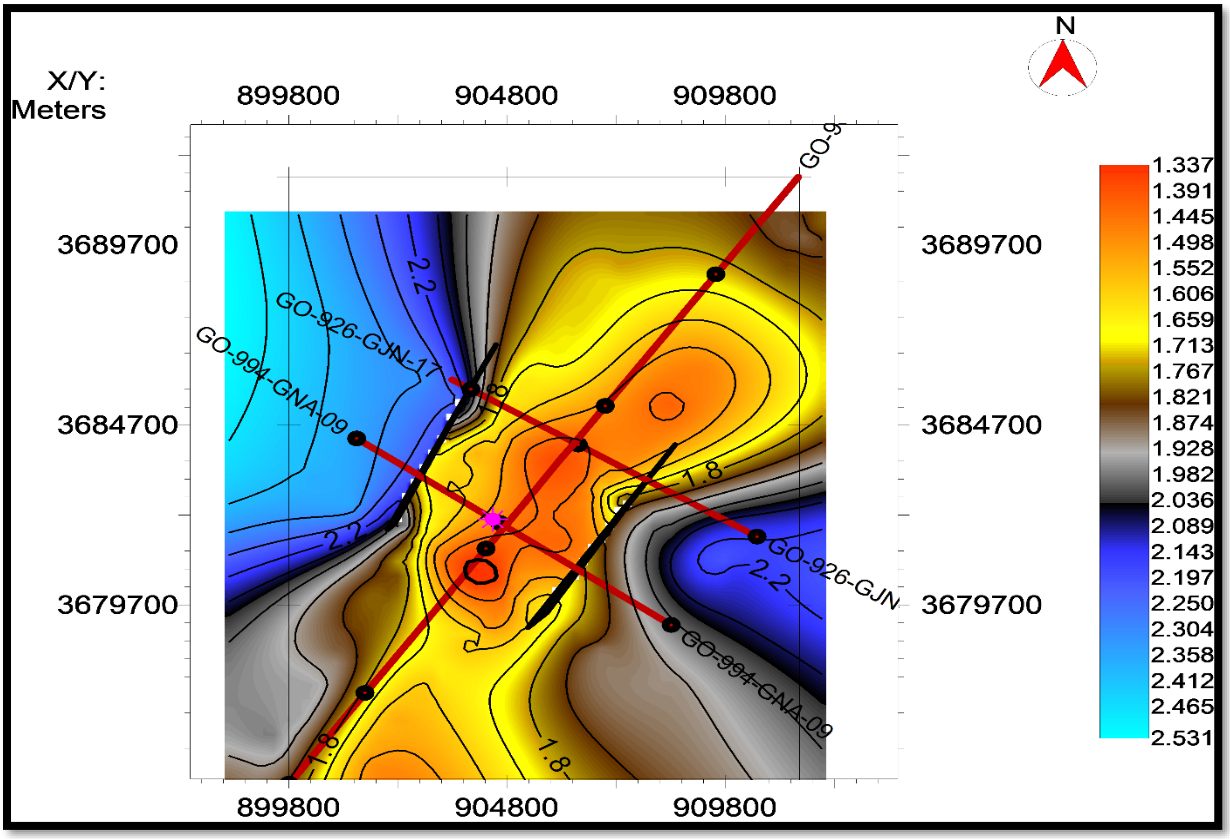


Fig 3.8 (a) Time Contour Map of Chorgali/Bhadrar Formation

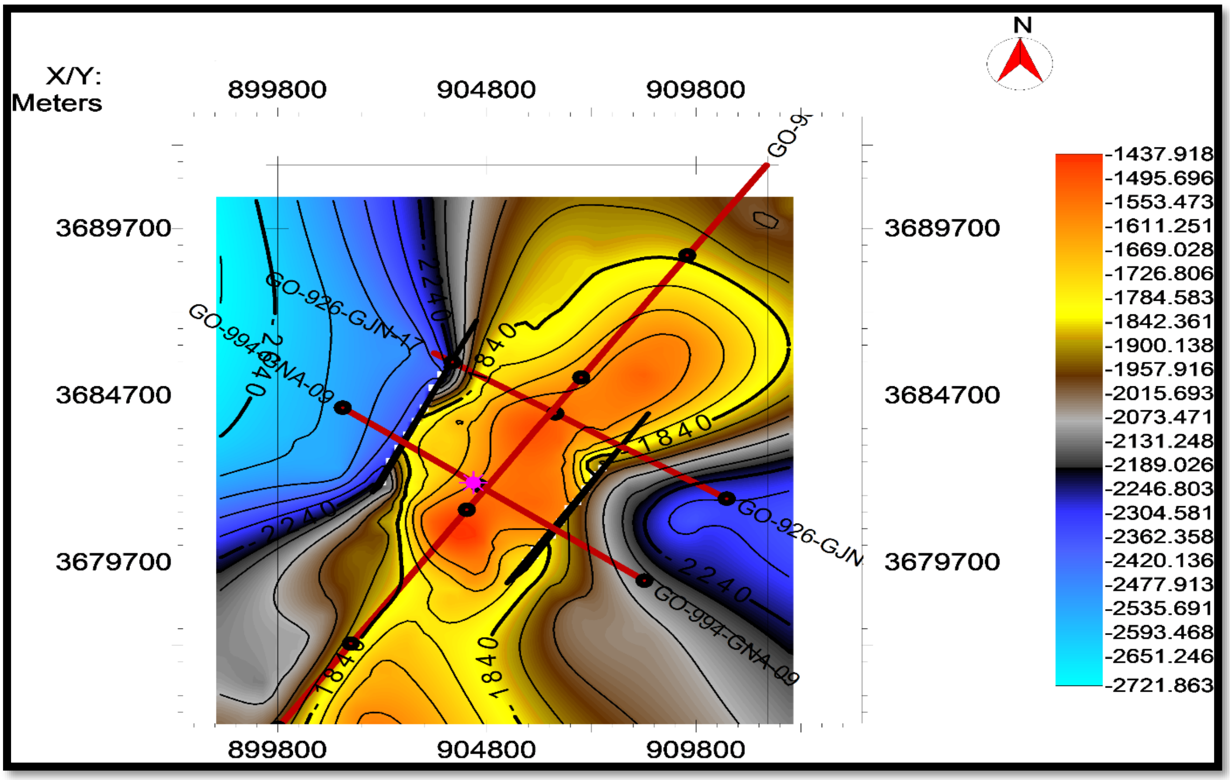


Fig 3.8 (b) Depth Contour Map of Chorgali Formation

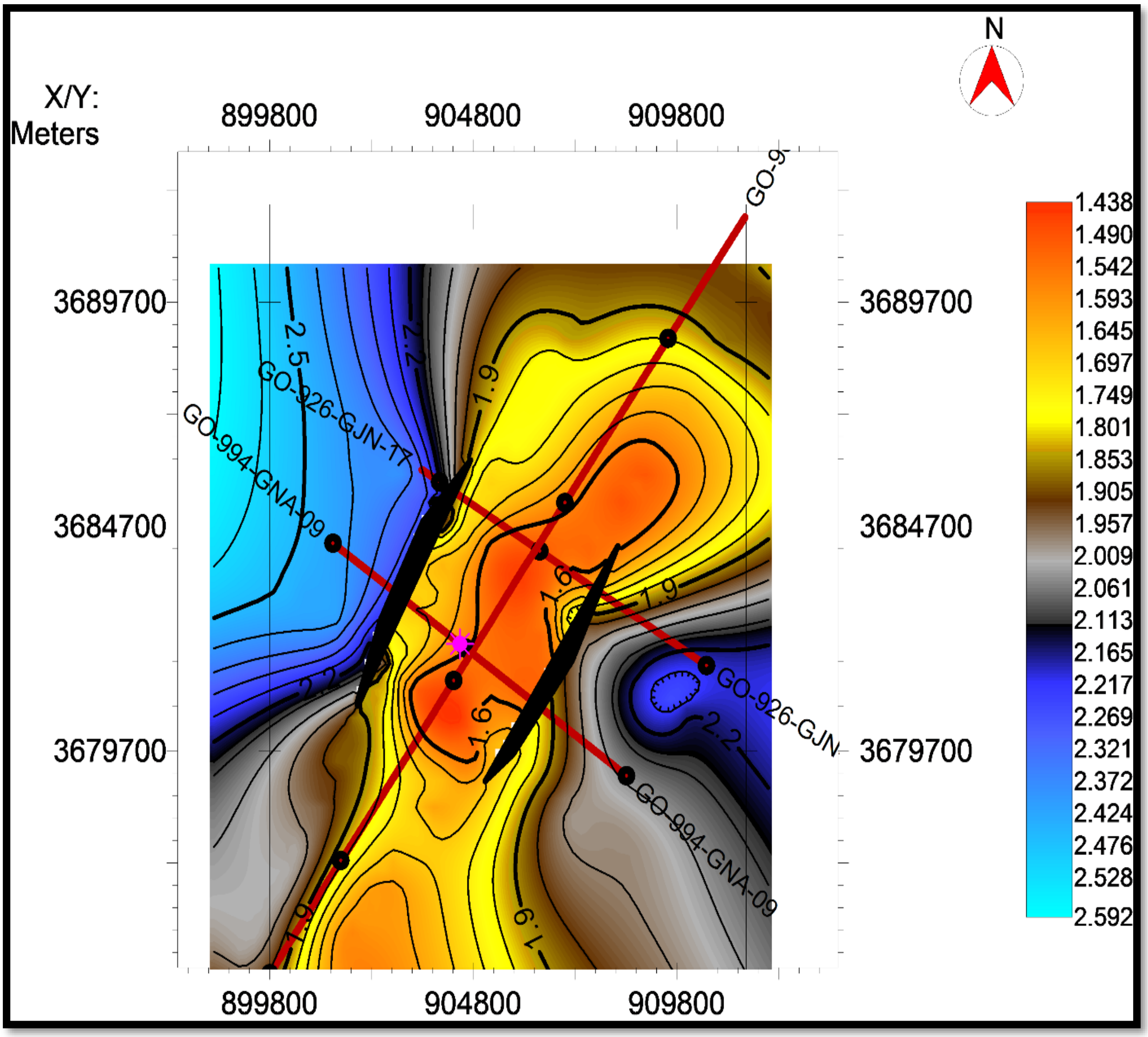


Fig 3.9 (a) Time Contour Map of Sakesar Formation

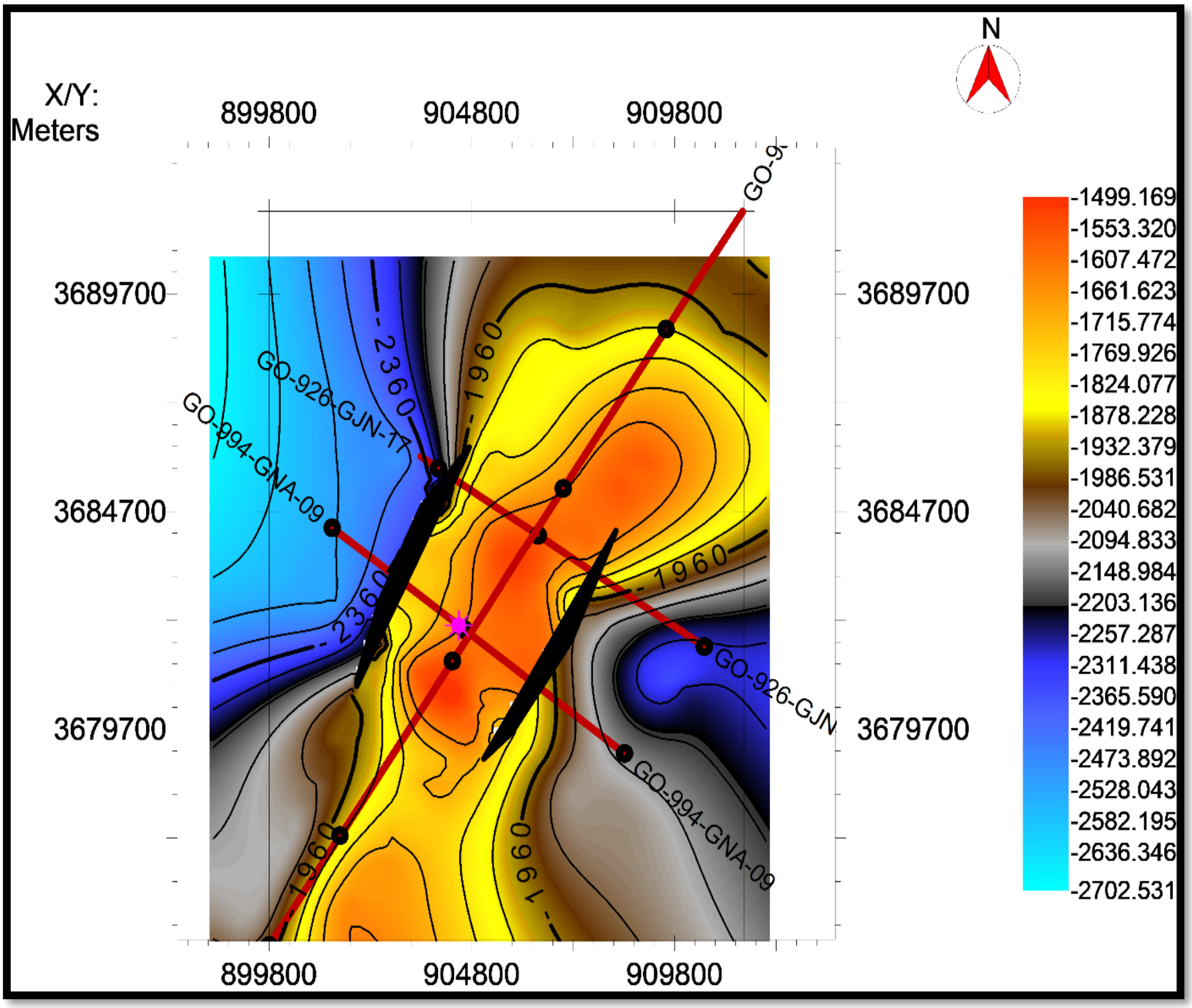


Fig 3.9 (b) Depth Contour Map of Sakesar Formation

Chapter No. 04

Petrophysics

4.1 PETROPHYSICS:

Petrophysics use different types of log to locate a probable zone for hydrocarbon accumulation. We have located 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 (DT, RHOB, NPHI) for porosity. Following are the parameters calculated by performing Petrophysical analysis.

- Raw Log Curves
- Lithology
- Volume of Shale
- Porosity
- Resistivity of Water
- Water Saturation
- Hydrocarbon Saturation

Before going to calculate these parameters, we must have to know about different types of the logs and their characteristics in detail.

4.2 CLASSIFICATION OF GEOPHYSICAL WELL LOGS:

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

4.3 LITHOLOGY TRACKS:

In lithology track the following three logs are displayed;

- Gamma ray (GR)
- Spontaneous Potential log (SP)
- Caliper Log (CALI)

4.4 POROSITY LOGS:

Logs that are used to calculate pore volume of formations with the combination of resistivity logs are termed as Porosity Logs. They are used to calculate water saturation of formations:

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

4.5 ELECTRICAL RESISTIVITY LOGS:

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 Petro physical interpretation.

- Laterolog Deep (LLD)
- Laterolog Shallow (LLS)

4.6 LATEROLOG DEEP

Laterolog is used for deep investigation of the undisturbed zone (Uninvaded zone) and it is called Laterolog 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.

4.7 LATEROLOG SHALLOW

Laterolog shallow (LLS), used for shallow investigation of the transition zone / invaded zone. Because the depth of the investigation is smaller than the LLD. All the above explained track are shown in the below figure 4.1 taken from SMT Kingdom.

NOTE: Remember to choose LOGARITHMIC scale for LLD and LLS logs

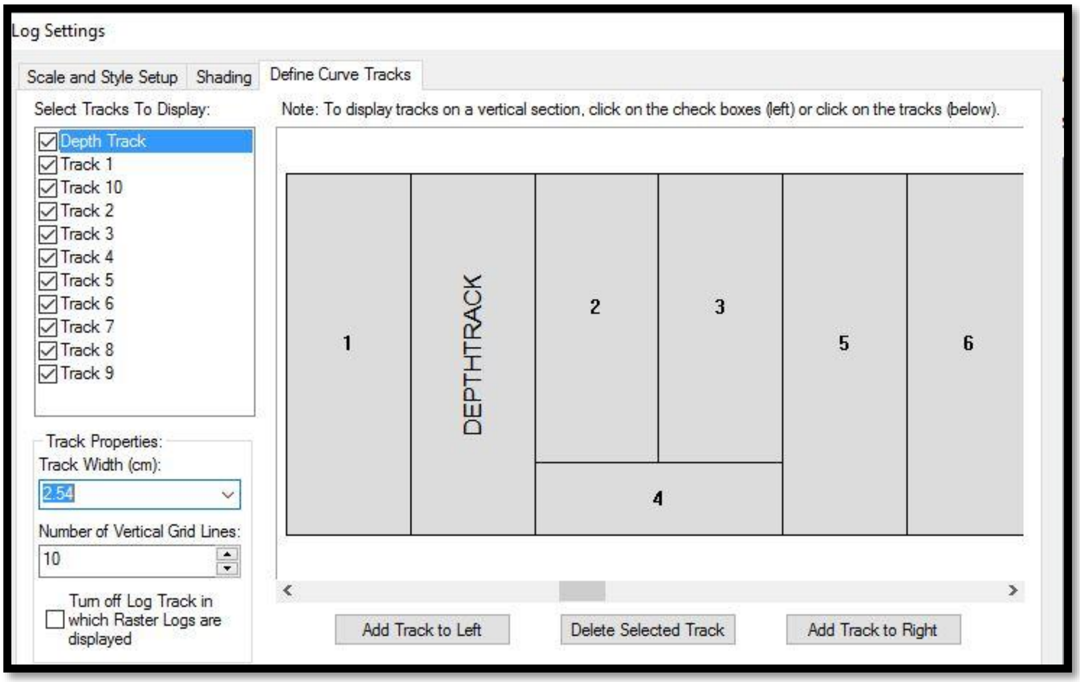


Figure (4.1) Log Tracks in Kingdom Software

4.8 PROPERTIES TO BE CALCULATED:

	PROPERTIES	MATHMATICAL FORMULAS
1.	VOLEUME OF SHALE	VSH=(GR-GRCLN)/(GRSHL-GRCLN)
2.	DENSITY POROSITY	PHID=(RHOMA-RHOB)/(RHOMA-RHOF)
3.	SONIC POROSITY	PORS=(DLT-DLTM)/(DLTF-DLTM)
4.	TOTAL POROSITY	PHIT=(DPHI+NPHI)/2.0
5.	EFFECTIVE POROSITY	PHIE=((DPHI+NPHI)/2.0)*(1-VSH)
6.	STATIC SPOTANIOUS POTENTIAL	SSP=SP(CLEAN)-SP(SHALE)
7.	RESISTIVITY OF MUD FILTRATE	$R_{mf2} = \frac{(ST + 6.77) \times R_{mf1}}{(FT + 6.77)}$,
8.	FORMATION TEMPRATURE	$FT = \frac{(BHT - ST)}{TD} \times FD$
9.	SATURATION OF WATER	$S_w = \sqrt[n]{\frac{F \times R_w}{R_t}}$,
10	HYDRO CARBON SATURATION	HS= 1-S_W

Table (4.1) Formulae to calculate different properties

4.8.1 VOLUME OF SHALE:

The volume of shale can be estimated from the response of Gamma ray log. The response of Gamma ray must be known through different lithologies. The gamma ray log is the passive logging because we measure the Formation properties without using any source. Actually it is the measures the Formation's radioactivity. The gamma ray emits from the Formation in the form of the Formation in the form of the electromagnetic energy which are called the photon. When photon collides with the Formation electron hence they transfer the energy to the Formation electron so the phenomenon of the Compton scattering occurs. Now these emitted Gamma rays reached to the detector of the gamma ray and counted and displayed as count per second which is termed as the Gamma ray. The volume of the shale is calculated by using (Asquith and Gibson, 2004) equation given below.

$$Vsh = \frac{(GR_{log} - GR_{min})}{GR_{max} - GR_{min}}$$

Vsh= Volume of shale

GR_{log} = Gamma ray reading of formation,

GR_{min} = Minimum gamma ray value,

GR_{max} = Maximum gamma ray value.

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

4.8.2 POROSITY

a) DENSITY POROSITY ($\emptyset_D$):

Porosity is estimated using density, sonic and neutron logs. The combined response of these logs estimate the porosity. These logs give following types of porosities.

In the density logging gamma ray collide with the electron in the Formation and scattered gamma ray (Compton scattering) received on the detector which indicate the density of the Formation increase in the bulk density of the Formation causing the decrease in the count rate and vice versa. Bulk density which is obtained from the density log is considered the sum of the density of the fluid density and the matrix density of the Formation.

If rock type is known then porosity is calculated by using (Asquith and Gibson, 2004) equation. The rock lithology is known by using gamma ray log in this case it is limestone. The following relation is used for calculating porosity.

$$\emptyset_D = \frac{(\rho_{mat} - \rho_b)}{(\rho_{mat} - \rho_f)} \quad .$$

ρ_{mat} = Density of matrix,

ρ_b = Bulk density,

ρ_f = Density of fluid.

b) NEUTRON POROSITY:

This is the type of porosity log which measure concentration of Hydrogen ions in the Formation. Neutron is continuously emitted from chemical source in the tool of the neutron logging. When these neutrons 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 electron collides with hydrogen atoms. Hydrogen is an indication of the presence of the fluid in the Formation pores; hence loss of energy is related to the porosity of the Formation.

The neutron porosity is very low when the pores in the Formation are filled with the gas instead of the water and oil; the reason is that gas having les concentration of the hydrogen as compared to water and oil. This less porosity by the neutron PHI due to the presence of the gas called the gas effect (Asquith and Gibson, 2004).

c) AVERAGE POROSITY

Average porosity is simple average of porosities measured by three logs RHOB, DT, and NPHI.

d) EFFECTIVE POROSITY

Effective porosity is measurement of interconnected pores of formation. As shale is impermeable, so this porosity is removed effect of shale.

4.8.3 WATER SATURATION:

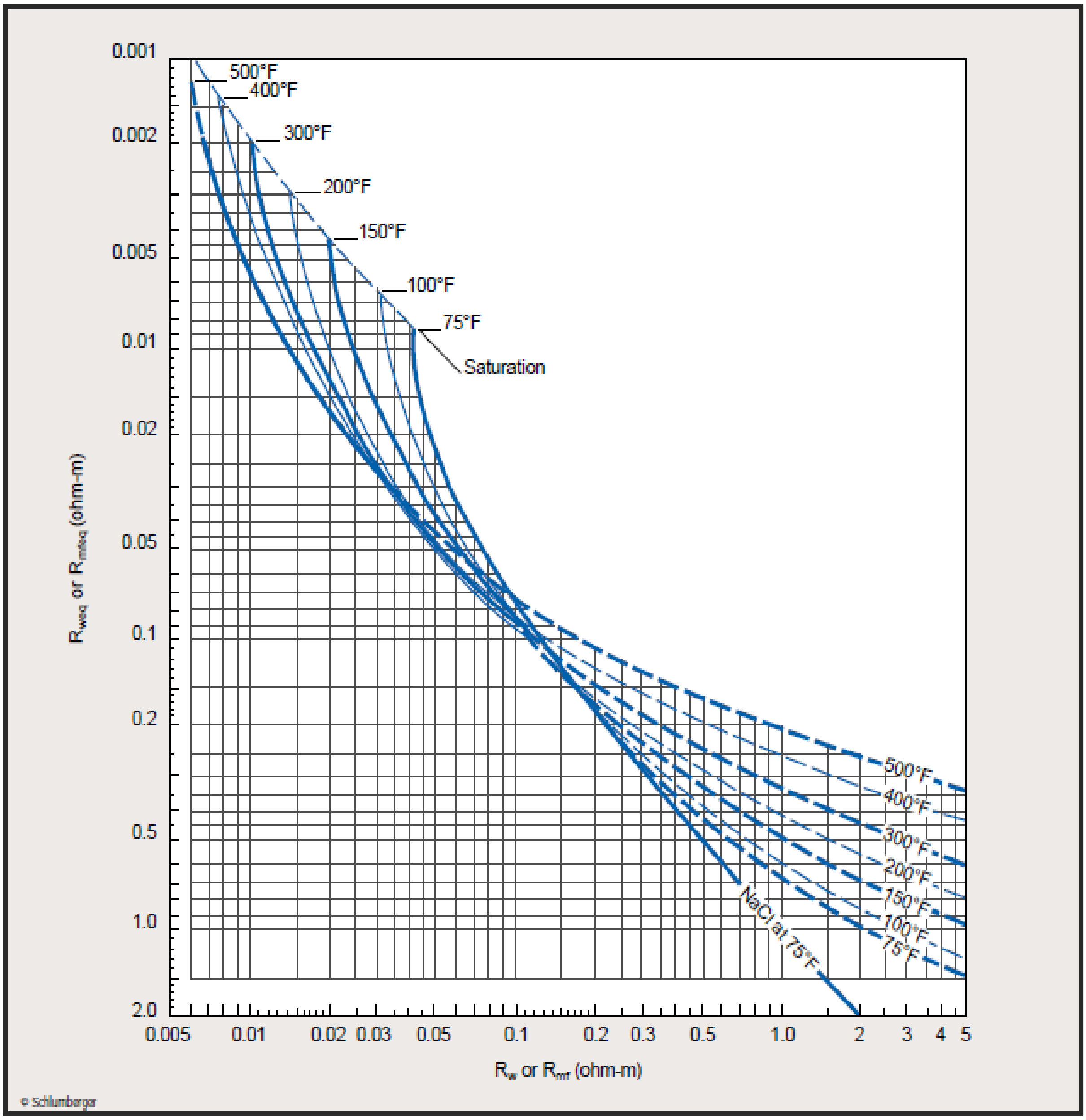
After the calculation of volume of shale, effective, total and sonic porosities, the next step is the calculation of resistivity of water. Computing water resistivity is the vital step in finding the saturation of water. The following steps lead to the calculation of resistivity of water.

Step 1*:* After noting the values of surface temperature (ST), maximum recorded temperature (BHT) and resistivity of the mud filtrate (Rmf1) from well headers, very first step is to find the static spontaneous potential (SSP) from the relation in Table 4.1. (Rider, 1996).

Step 2*:* Formation temperature is calculated by using the relation from Table 4.1. (Rider, 1996).

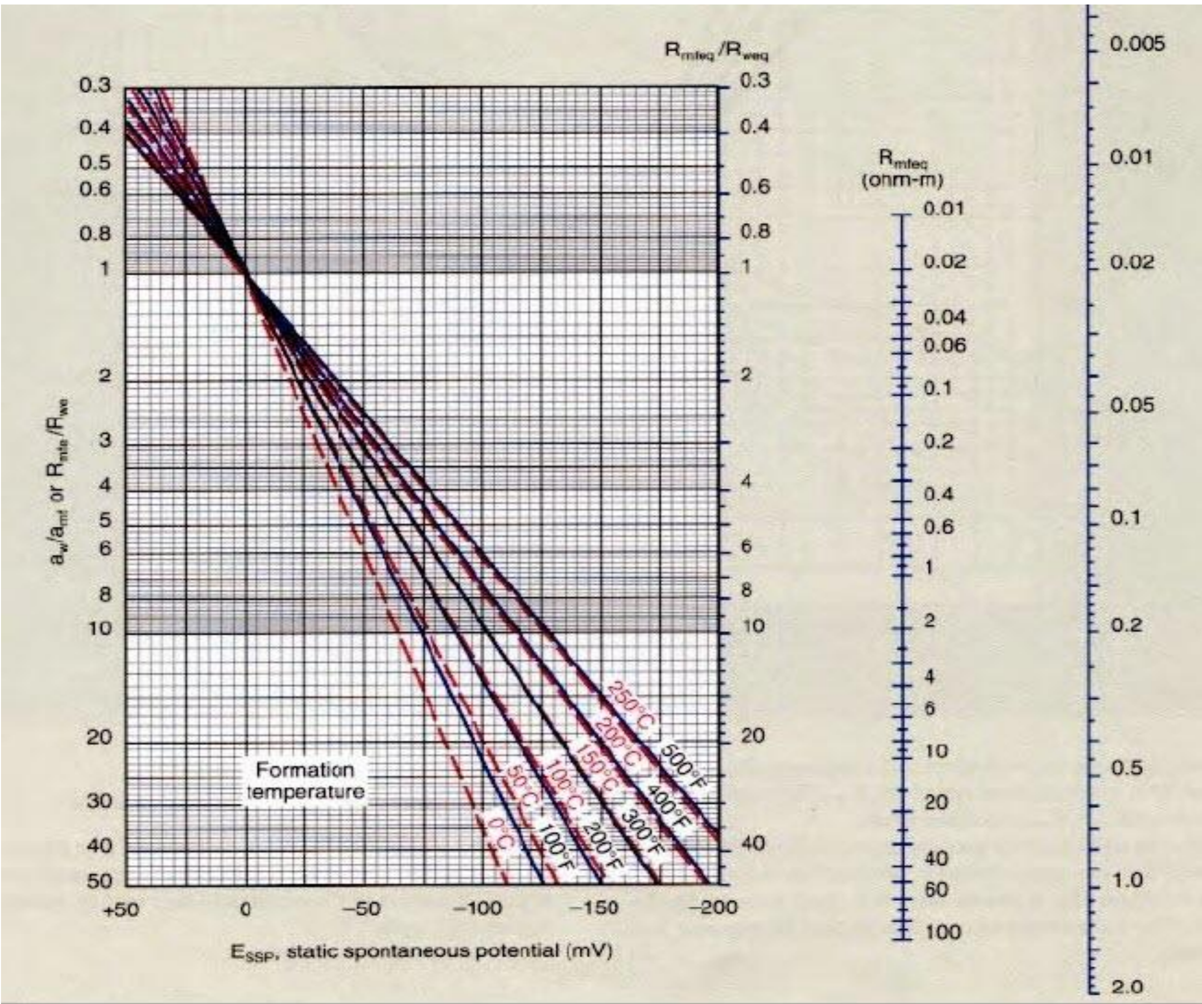
Step 3*:* Finding the resistivity of mud filtrate by using the relation given in Table 4.1.

Step 4*:* Now for finding the resistivity of mud equivalent (Rmfeq), using Schlumberger Chart.



<u>Step 5</u>: After calculating the value of Rmfeq, the next step is to derive the value of resistivity of water equivalent against the value of Rmfeq at SSP value and BHT from the graph.

<u>Step 6</u>: Rw versus Rweq and formation temperature. The value of resistivity of water (Rw) is derived against the values of Rweq and formation temperature (Table 1.2.). After using all the relations of finding the resistivity of water by SP chart method, the next step is the computation of saturation of water by using Archie Generalized Water Saturation equation (Archie, 1942).



"Determining Rweq from SP chart (Schlumberger, 1989)"

4.9 PETROPHYSICAL INTERPRETATION OF QAZIAN WELL-01X:

Petrophysics provides different results in case of different lithologies by running well logs. As a first indicator of lithology, GR log is very useful for the indication of shale. For the higher values of GR, higher will be the percentage of shale. Therefore, due to this reason, clean zone or shale free zone is defined easily. Where there is low value of the GR shows less shale, so its mean that depth may be hydrocarbon-bearing zone.

To detect and quantify hydrocarbon, principally resistivity logs are used. That is, resistivity logs are used to give the volume of oil/gas in a reservoir, or, in Petrophysical terms, to define the water saturation (Sw). When Sw is not 100%, then its shows hydrocarbons are present there. Higher the response of resistivity logs usually determines the presence of hydrocarbons or fresh water.

4.9.1 ZONE OF INTEREST:

By observing the responses of different log curves , we will mark the zone of interest which will provide us accurate details about the quantity and quality of hydrocarbons present in the particular reservoir.

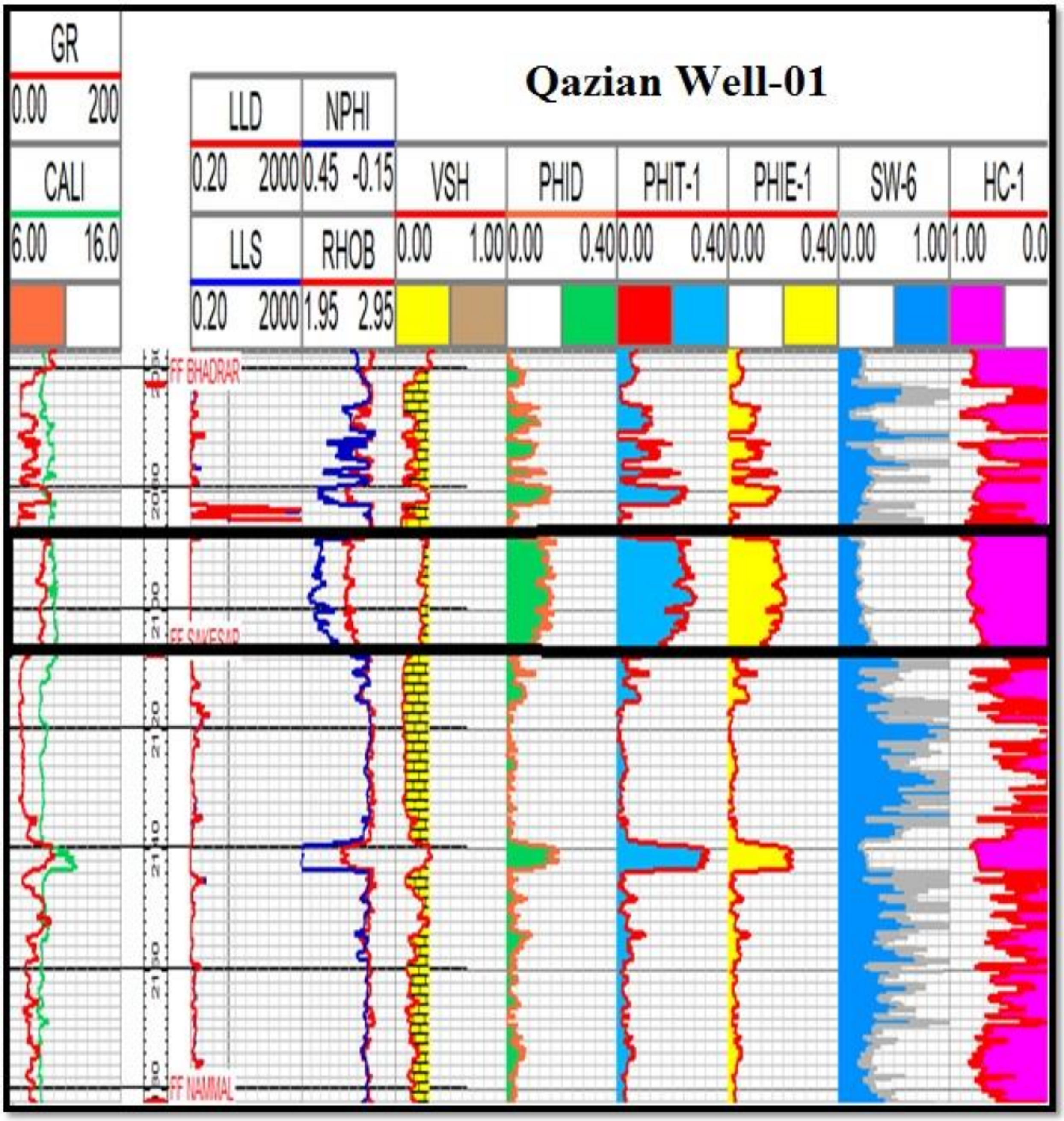


Fig (4.2) Zone for Possible Hydrocarbons

4.10 PETROPHYSICAL ANALYSIS AND RESULTS:

- The crossover of LLS and LLD is indicator of high resistivity values which is indication of presence of hydrocarbon.
- The crossover of NPHI and DT shows high porosity and larger travel time. So the porosity is high in the zone. But the travel time is large which means velocity is low. Though the reservoir is limestone velocity should be high but since it is acting as a reservoir (porous and permeable) so velocity is low in this zone.
- Volume of shale is calculated using the equation given below. Volume of shale is calculated **43%** in the zone

$$V_{sh} = IGR = GR_{log} – GR / GR_{max} – GR_{min}$$

- Average porosity obtained from density log is calculated **31%**. Porosity is calculated using following equation.

$$\Phi = \rho ma – \rho bulk / \rho ma + \rho fl$$

- Total porosity is **29%** in zone of interest calculated using following equation.

Porosity = Pore volume/Total volume

- Average effective porosity is calculated **14%** in zone of interest, which shows that zone is highly porous and permeable and can act as productive reservoir. Effective porosity is calculated using following relation.

$$\emptyset_e = \emptyset_t \times (1 - V_{sh})$$

- Average water saturation is calculated 40% in zone of interest. Water saturation is calculated using following relation.

$$Sw = (F \times Rw/Rt)^{1/n}$$

- Hydrocarbon saturation is **60%** in zone of interest. Hydrocarbon saturation is calculated using following equation.

$$Sh = 1 – Sw$$

Serial NO	Calculation Parameter	Percentage % (1896-1914 meters)	Percentage % (1870-1982 meters)
1	Average Volume of Shale VSH_{avg}	43	29
2	Average Effective Porosity PHI-E	14	6
3	Average Total Porosity PHI-T	29	12
4	Average Density Porosity PHI-D	31	14
5	Average Water Saturation Sw_{avg}	40	56
6	Average HC	60	44

Table (4.2) Petrophysical Analysis

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.

Chapter No. 05

Facies Modeling

5.1 FACIES:

The term “**facies”** was introduced by the Swiss geologist Amanz Gressly in 1838 and was part of his significant contribution to the foundations of modern stratigraphy.

Geologically, facies is a rock body 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. This gives the main indication about the productive zone in the reservoir.

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.

5.2 WALTHER’S LAW OF FACIES:

The Walther's Law of Facies was introduced by the German geologist Johannes Walther (1860-1937) as an important geological principle, after the establishment of the concept of "facies", one of the foundations of modern stratigraphy. Walther's Law states that any vertical progression of facies is the result of a succession of depositional environments that are laterally juxtaposed to each other.

Sedimentary environments that started out side-by-side will end up overlapping one another over time due to sea level change (transgressions and regressions). The result is a vertical sequence of beds. The vertical sequence of facies mirrors the original lateral distribution of sedimentary environments. Walther’s Law is an important principle upon which the origin of vertical rock successions is explained. Sediments are deposited in environments that change over time as a result of relative sea-level fluctuations. As the environments change, so does the nature of the sediments deposited at any one location. The vertical succession thus records the lateral changes in environments over time.

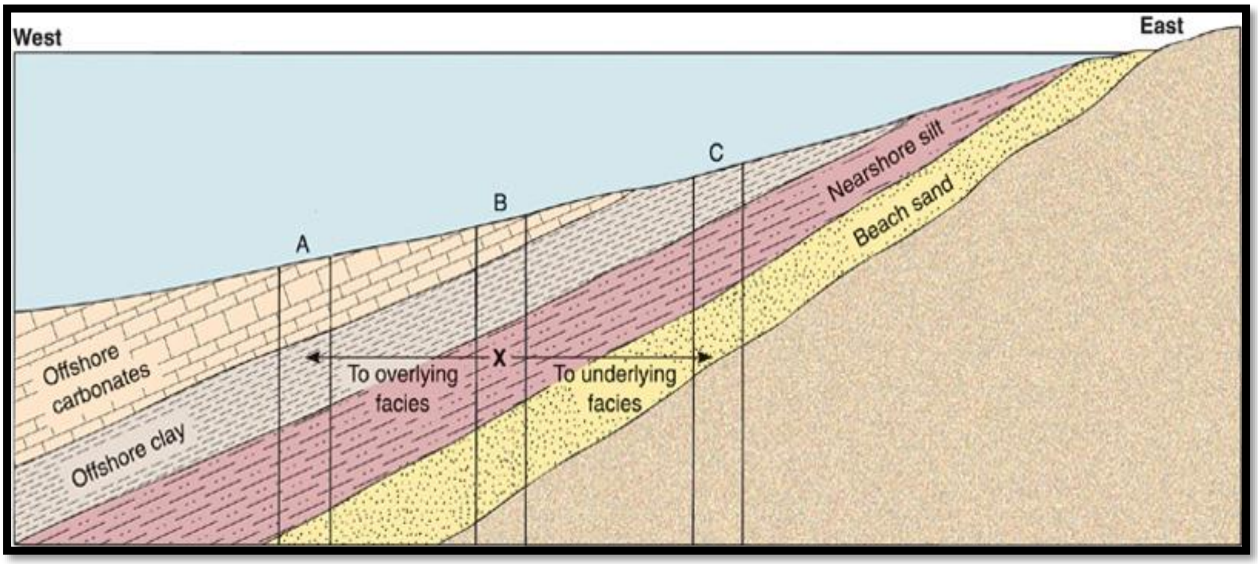


Figure (5.1) Illustration of Walther's Law or Principle, which states that vertical facies changes correspond to lateral facies changes.

A) TRANSGRESSION:

A marine transgression is a geologic event during which sea level rises relative to the land and the shoreline moves toward higher ground, resulting in flooding and produce the fining upward.

B) REGRESSION:

A marine regression is a geologic event during which sea level falls relative to the land and the shoreline moves toward lower ground so it exposes former sea bottom and produce coarsening upward.

5.3 FACIES ANALYSIS:

Fundamental to all subsurface geologic studies is an analysis of depositional facies. Development of a facies classification scheme is a particular challenging interplay between capturing enough information for environmental interpretation yet remaining simple. Particularly important is the characterization of facies such that their recognition criteria relate to critical environmental thresholds such as sea level, normal wave base, and storm wave base. These physical environmental zones regulate sedimentary textures and biotic assemblages. A good understanding of paleoecology always strengthens the interpretation and such studies should be included as part of all depositional facies studies. Depositional textures in turn affect porosity-permeability in carbonates. The vertical and lateral organization of facies is an exercise essential to sequence stratigraphic interpretations (Lucia, 1995).

5.4 FACIES ANALYSIS OF CHORGALI AND SAKESAR LIMESTONE:

The facies modelling is performed by plotting different logs depending on objectives of facies modelling. Following cross plots of logs provide the facies change in Qazian well with respective lithologies.

5.4.1 CROSS PLOT OF LLD AND RHOB

Since resistivity and density of limestone is higher than shale so limestone facies are marked at higher values Since density of shale is highly variable and concentration of organic contents is less in shale therefore the density of limestone and shale can overlap so Gamma log is used as reference log for further separation of facies. The green colour shows the shale while the red colour shows the limestone in figure 5.2.

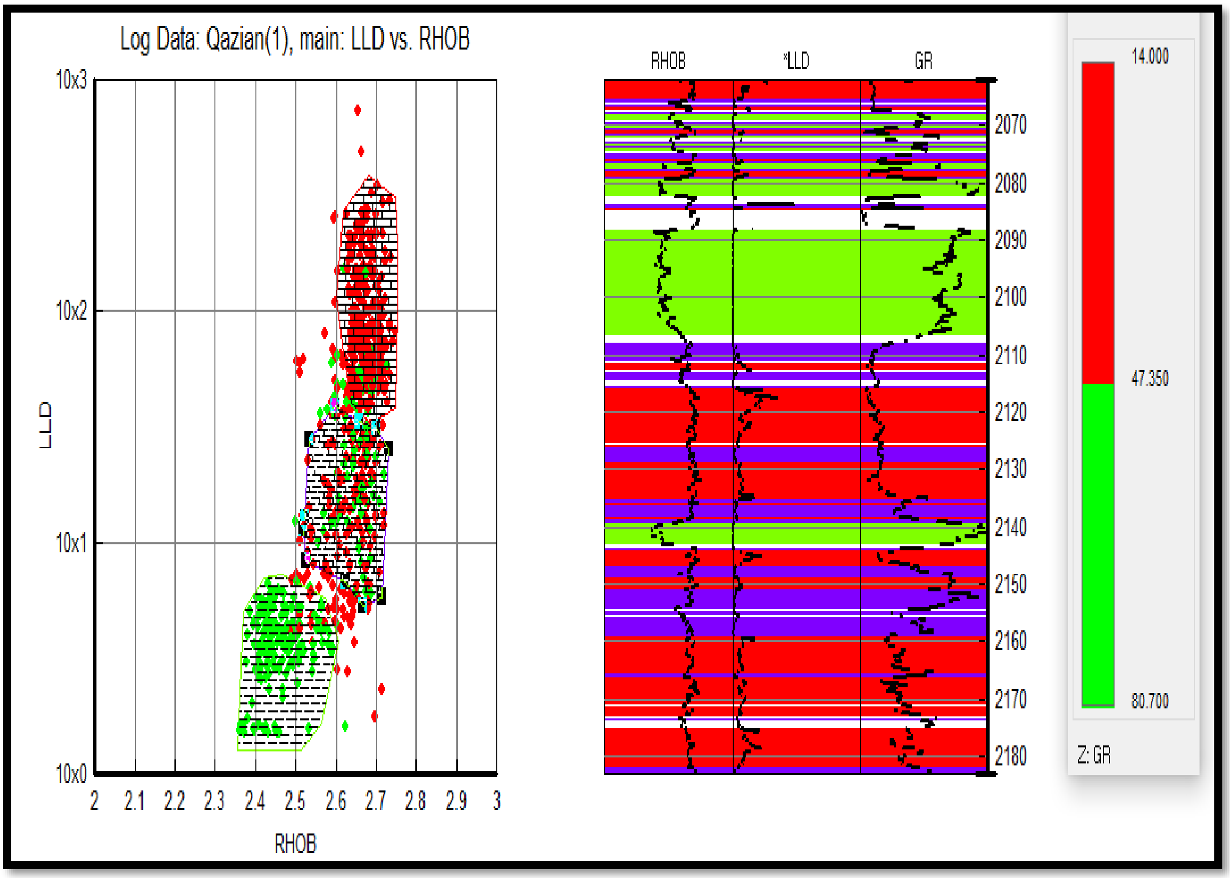


Figure (5.2) Cross plot of LLD and RHOB.

5.4.2 CROSS PLOT OF NPHI-E AND RHOB

There is a direct relation between NPHI and shale. Greater volume of shale shows high value of NPHI. Limestone has high value of RHOB and shale has low value of RHOB.

NPHI is plotted along y-axis and RHOB is plotted along x-axis. Red colour shows the limestone and green colour shows the shale. Bluish colour in cross plot represents limy shale as shown in the figure 5.3.

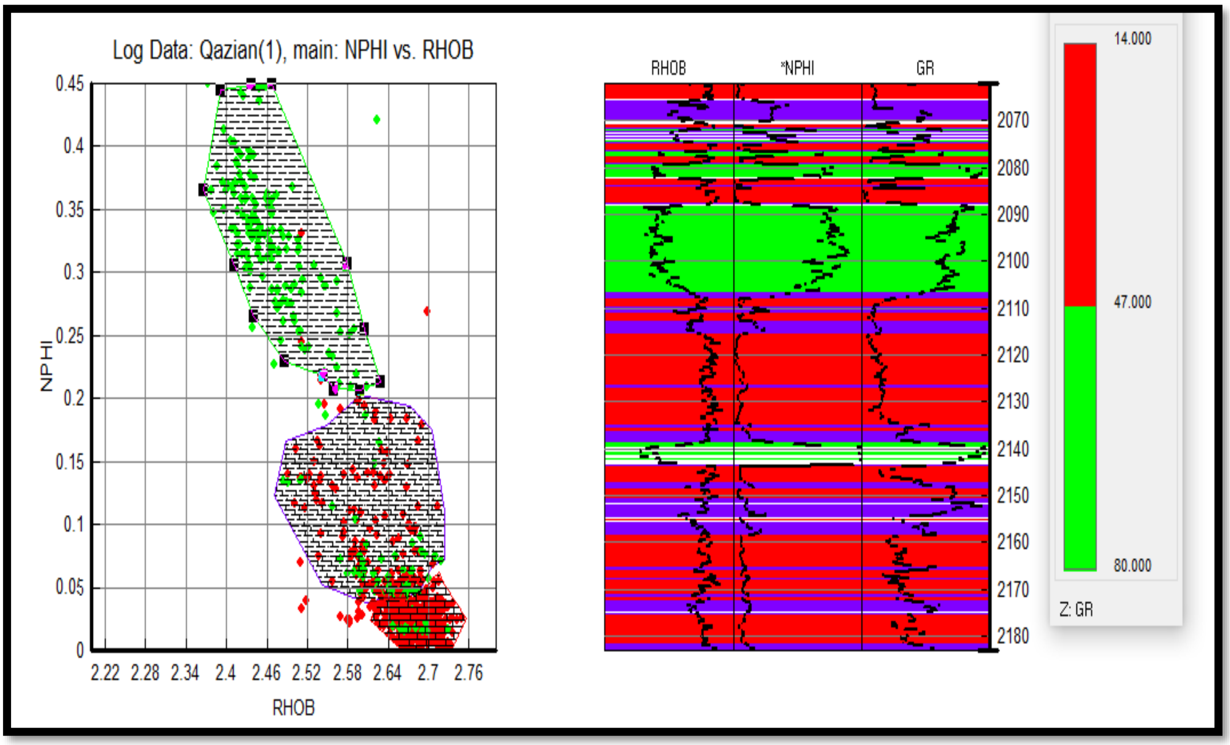


Fig (5.3) Cross Plot of NPHI and RHOB

5.5 RESULTS:

- Higher values of resistivity associated with lower values of the gamma ray logs indicate clean formation i.e. limestone. As limestone is compact lithology so we have higher values of density (2.7-2.8 gm/cc).
- Lower values of resistivity associated with higher gamma ray values indicate we have a limey shale (calcareous shale). It is also evident from the fact that LLD values decreased in the second polygon which we have designated as limey shale.
- Cluster of dots is thick in the limestone polygon. So it is interpreted that the reservoir is mainly comprises of limestone.

Conclusions:

- Missa keswal area lies in a compressional regime characterized by thrust faulting and anticline structures
- There is repetition of Eocene strata in Missa keswal 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 F1and F2 dipping towards each other from east and west. Pop up Anticlinal structure indicates the area to be economically suitable for hydrocarbon exploration as well as extraction
- 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 Qazian- 01 well.
- Time and depth contour maps show the presence of pop-up anticline structures in study area.
- Facies Analysis conclude that reservoir rocks are majorly comprised of limestone rock
- 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 good reservoirs.

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