2D-INTEGRATED SEISMIC INTERPRETATION, PETROPHYSICAL ANALYSIS, FACIES ANALYSIS AND SEISMIC ATTRIBUTES OF MISSAKESWAL AREA, UPPER INDUS BASIN, PAKISTAN

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CERTIFICATE OF APPROVAL

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DEDICATION

Dedicated to my family for always believing in me and encourage me to reach higher in order to achieve my goals

ACKNOWLEDGEMENT

As a matter of first importance, all gestures of recognition to *Allah Almighty*, the most helpful and the most benevolent. Also, my humblest appreciation to the *Holy Prophet Muhammad* (Peace Be Upon Him) whose lifestyle has been a persistent direction and data of humankind for me. This Thesis shows up in its present structure because of the help and direction of a few people. It gives me incredible delight to offer my thanks to each one of the individuals who bolstered me and have contributed in making this proposal conceivable.

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Last but not least, I would like to acknowledge my family for their constant support, unceasing prayers and best wishes. They uplifted my morale whenever I needed.

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Table of Contents

ABSTRACT

Pakistan has a high potential of oil/gas reserves in its geological provinces of Upper and Lower Indus basin as well as the Balochistan basin. Similarly our study area, of Missakeswal which is located near Gujar Khan in the district of Rawalpindi. Geologically the study area is situated in the Potwar basin bounded by strike slip faults, namely Jhelum fault in the east and Kalabagh fault in the west. The study focuses on the use of well log and 2D seismic data for the characterization of the reservoir potential of the Paleocene succession. . Reservoir characterization combines surface seismic with borehole seismic, well data i.e petrophysical data and rock and fluid properties and production history.

Results are indicative that khewra sandstone of Cambrian age serve as potentially good reservoir rocks. Petrophysical analysis confirm the presence of a high percentage of hydrocarbon saturation. The results of the petrophyscial analysis correlated with the facies analysis of the reservoir zone indicate that our prospect zone lies sandstone reservoir which also has shale content that can be identified, and effective porosity measures of the reservoir prove that our study area is a good area for drilling to extract hydrocarbons. The pop-up anticline structure proves a good trap and our study area is a good zone of future exploration prospects.

Facies modeling being one of the important tool for the confirmation of lithologies. In this thesis, with the help of facies analysis of MISSAKESWAL-03 well, we came to the result revealing sandstone as the reservoir lithology.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Petroleum geology refers to the specific set of geological disciplines that are used for hydrocarbon exploration. Investigation of the earth's interior using geophysical methods, involves taking dimensions at or near the surface of the earth for analysis that can picture both vertical and lateral variations of the physical properties of the earth's subsurface. With the advent of the oil and gas as an efficient energy source, not only the search for oil and gas reserves plays an important role in tackling the energy crisis of the population but also serves as a front economic developer for a country.

The study area is geographically located on the upper side of Dina, which is 17.7 kilometers to the north west of the Jhelum city having longitudes 73'58''E and longitude of 33'2''N. It is connected to Dina on one side and Rawalpindi on the other side through G.T road and north western railway both running from Peshawar to Lahore. 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. Geophysicists are trying since a long time for the exploration of hydrocarbons and are applying different methods in this regard. Seismic Method is one of the most widely used methods in the exploration of hydrocarbon, especially Reflection Seismology (used in the present work) has the great importance in this regard.

Pakistan has high potential of hydrocarbons in its northern (Potwar, Kohat) and southern (Badin, Mari etc.) parts. The Indus basin, including the Kohat-Potwar (study area) depression, belongs to the category of extra-continental downward basins which account for 48% of the world's known petroleum resources (Hasany & Saleem, 2012).

The Potwar sub-basin is dominated by the structural traps and mostly seismic data is incorporated for the delineation of these structures. On the other hand, the incorporation of seismological data for interpreting the structures has not been done yet by previous workers for the area of Potwar. Although in other parts of the world, the integration of seismic with seismology has been carried out since ages.

In the present work, an attempt has been made to correlate the results obtained by the seismic data to obtain a structural model of the Northern Potwar Deformed Zone (NPDZ). Interpretation of the seismic lines has been carried out in order to study the subsurface structure of the area.

The geographic location of the Missa keswal is at longitude 73’22’’0 E and latitude of 33’12’’0

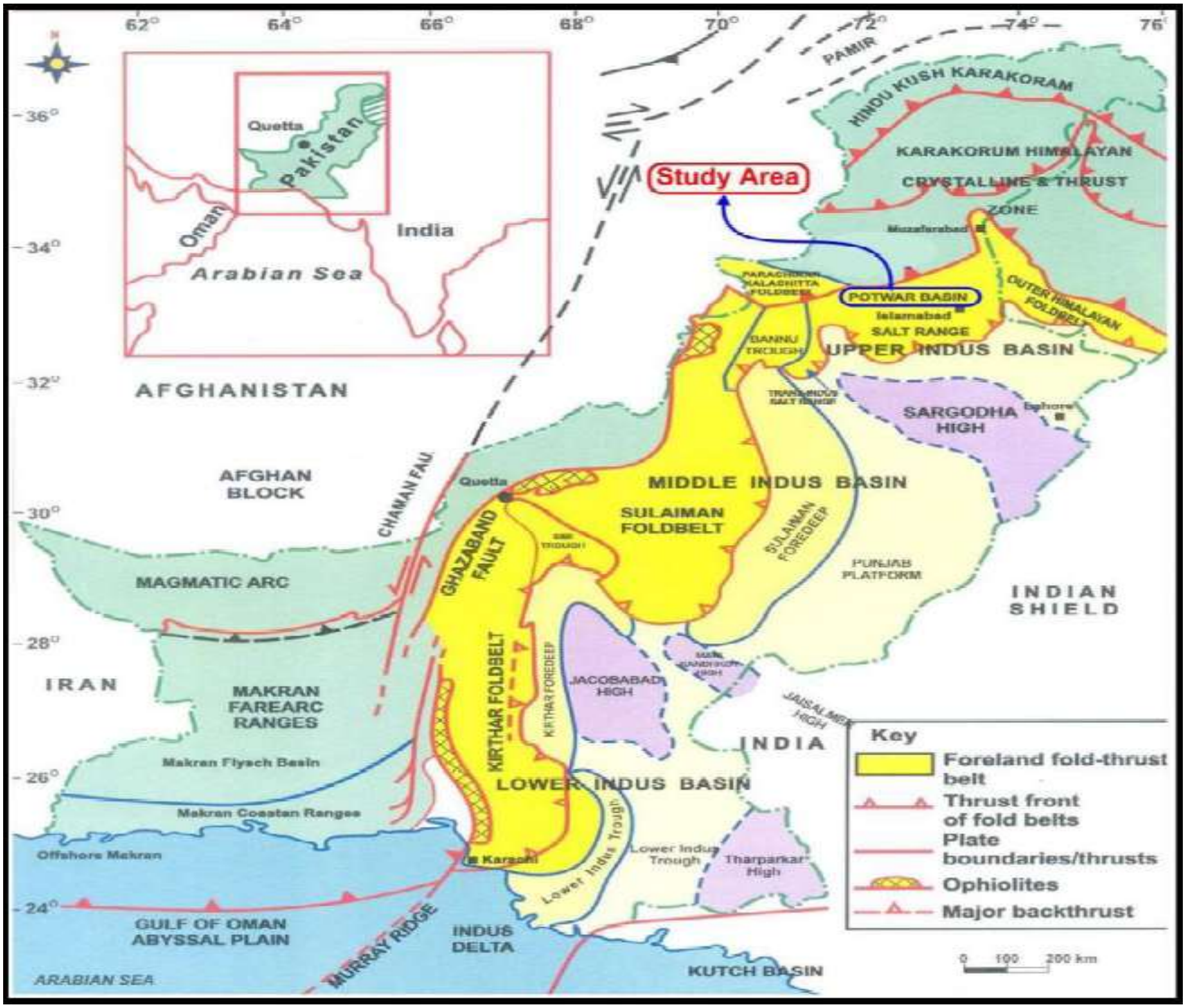

Figure 1.1 Location map of study Area (Banks & Warburton, 1986).

1.2 Survey Information

It includes all the information about the lines, wells and base map of the study area.

1.2.1 Seismic Reflection Data

The seismic reflection data of the study area was obtained by Directorate General of petroleum concession (DGPC) Pakistan in digital format .This data was acquired and processed by OGDCL.

The trend of the seismic dip and strike lines in SE-NW and SW-NE respectively. Given below in table (1.1)

S.NO.	LINE NO.	NATURE	LINE ORIENTATION
1.	GJN-15	STRIKE	NE-SW
2.	GJN-16	DIP	NW-SE
3.	GNA-19	DIP	NW-SE

Table 1.1: seismic lines issued by DGPC Pakistan.

1.2.2 Data Formats

Seismic reflection data which consist of

- SEG-Y
- LAS
- Navigation

That was provided by Directorate General Petroleum concession (DGPC),Government of pakistan upon the request of Chairman,Earthsceinces,Quaid-e-Azam Universty Islamabad.

1.3 Base Map of the Study Area

The base map is important component of interpretation, as it shows the spatial position of each picket of seismic section. For a Geophysicist a Base map is that which shows the orientations of seismic lines and specify points at which seismic data were acquired or simply a map which consist of number of dip and strike lines on which seismic survey is being carried out . A base map typically includes location of lease and concession boundaries, wells, seismic survey points and other cultural data such as buildings and roads with geographic reference such as latitude and longitude.

1.3.1 Spatial Location

The seismic lines with their orientation and well data used for the generation of Basemap are tabulated below in table (1.2).

LINE NAME	NATURE	LINE ORIENTATION	WELLS
GNA-16	Dip Line	NW-SE	
GNA-19	Dip Line	NW-SE	MISSAKESWAL-02
GNA-21	Strike Line	NE-SW	
GNA-10	Dip Line	NW-SE	
GNA-11	Strike Line	NE-SW	QAZIAN-01
GNA-14	Dip Line	NW-SE	
GNA-20	Strike Line	NE-SW	
QZN-03	Dip Line	NW-SE	
QZN-04	Dip Line	NW-SE	MISSAKESWAL-01
QZN-05	Dip Line	NW-SE	
GJN-14	Dip Line	NW-SE	
GJN-15	Strike Line	NE-SW	
GJN-16	Dip Line	NW-SE	MISSAKESWAL-03
GJN-17	Dip Line	NW-SE	
GJN-26	Strike Line	NE-SW	

Table 1.2 : lines used for making basemap.

The navigation data, well data are used to plot the base map kingdom software

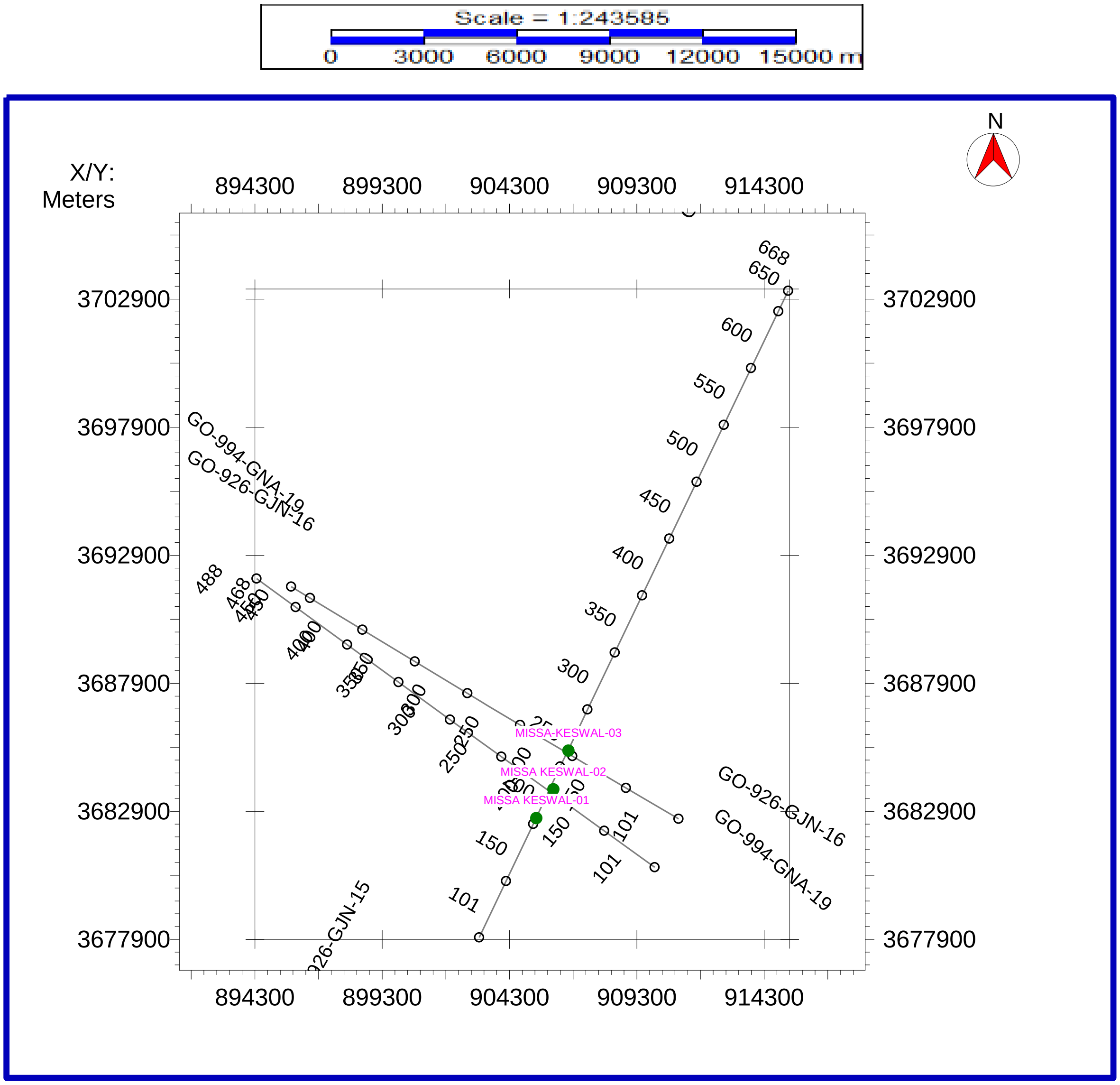

Figure 1.2 Base map of the MissaKeswal Area (Kingdom Software)

1.4 Objectives Of Study.

The main objectives of this dissertation are lined up as follows:

(a) To carry out different steps for the Seismic interpretation of migrated stacked sections.

(b) Conversion of time section to depth section.

(c) To generate time, and depth contour map of the selected reflectors.

(d) Petrophysical analysis of the reservoir rock in order to identify the zone of interest of hydrocarbon.

CHAPTER 2

GEOLOGY AND STARTIGRAPHY

2.1 Introduction to Regional Geology

Pakistan comprises of three main geological subdivisions referred to as Laurasian, tethyan and Gondwanaland domains (Kazmi, et al., 1997). Late Paleozoic is considered to be their origin. All the continents had drifted apart to form a super continent known as Pangea. By late Triassic, Laurasia drifted to the north and Gondwanaland to the south separated by Tethys seaway resulting in the split up of Pangea. Pakistan is located at the junction of Gondwanian and Tethyan domain.

2.1.1 Tectonic Framework of Pakistan

Tectonics of Pakistan is characterized by two active convergent boundaries;

(a) In the northeast there is an active continent-island arc-continental collision boundary. The west end of the Himalayan orogeny;

(b) In the southwest, there is an active boundary of oceanic lithosphere sub ducting arc trench gap sediments and continental sediments, the oceanic part of the Arabian plate passing under the Makran arc-trench gap and Afghan microplate.

These two convergent boundaries are connected by a very large displacement north-south left lateral strike slip faults of Chaman-Transform Zone.

2.1.2 Tectonic Zones of Pakistan

Based on Plate tectonic features, geological structure, orogenic history (age and nature of deformation, magmatism and metamorphism) and lithofacies, Pakistan may be divided into the following Tectonic zones.

(a) Indus Platform and fore deep, East Baluchistan fold-and-thrust belt.

(b) Northwest Himalayan fold-and-thrust belt.

(c) Koshistan-Ladakh magmatic arc.

(d) Karakoram block.

(e) Kakar Khorasaan flysh basin and Makran Accretionary Zone.

(f) Chaghai magmatic arc.

(g) Pakistan offshore.

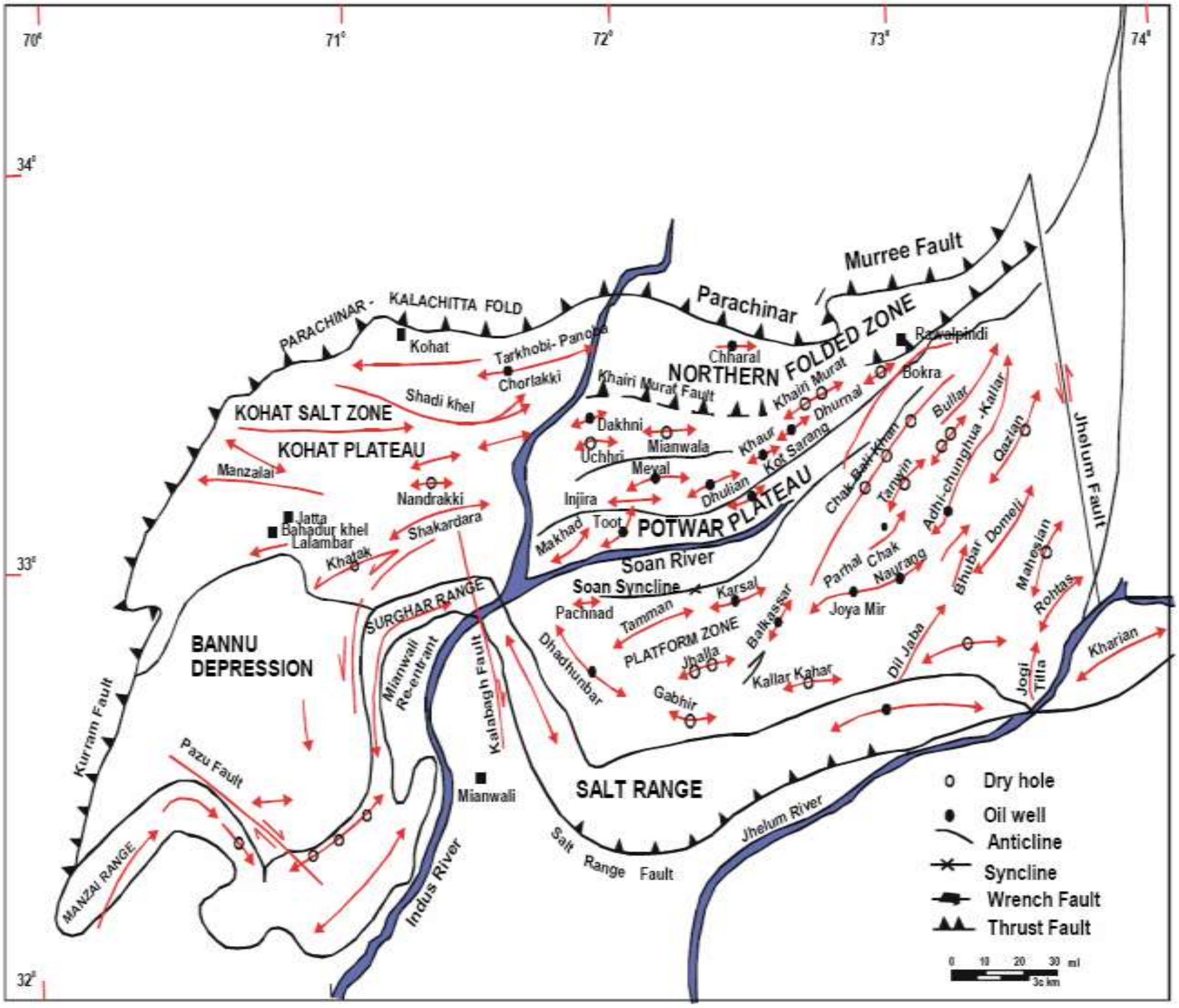

Figure 2.1: Tectonic division of Potwar Basin(Shami and Baig,1998)

2.2 Sedimentary Basins

Basin is an area characterized by regional subsidence in which sediments are preserved for the longer period of time. Basin's receptacle or container, which is basin's substratum, is known as its Basement. The container is filled with sediments accumulated that rest on basement

are known as Sedimentary cover. The gradual setting of the basin is called Subsidence. The point of maximum sedimentary accumulation is called the Depocenter. The depocenter may not correspond to the zone of maximum subsidence.

Sediments originate at a certain place. These sediments may be deposited at the same place or may be transported to some other place by transporting agents. The sediments deposited at the same place are called molasses deposits. The transported sediments rest on the basement of a basin and form a sedimentary cover.

2.2.1 Indus Basin

The geological history of Indus basin goes back to Precambrian age. The Paleotopographic features, shown on the gravity map, influenced, to a large extent, the depositional processes throughout the basin development. These features also marked the limit of the basin and its divisions. The ongoing tectonic processes further enhanced and modified the configuration and gave rise to sonic new ones creating an array of modern basis. The first split up of the super continent Pangea which disturbed the equilibrium happened in Jurassic.

Indus Basin is classified as follows;

(a) Upper Indus Basin

- (i) Kohat sub-basin
- (ii) Potwar sub-basin

(b) Lower Indus Basin

- (i) Central Indus basin
- (ii) Southern Indus basin

2.2.2 Upper Indus Basin

The basin is located in the northern Pakistan and is separated from the Lower Indus basin by Sargodha High. The northern and eastern boundaries coincide with the Main Boundary Thrust (MBT) the southern most of the major Himalaya thrust. The MBT runs through the Margalla Hills,Kala Chitta and Kohat Ranges. Western boundary of the basin is marked by an uplift of Pre-Eocene sediments and eastward directed thrusting to the west of Bannu. The basin is further subdivided into Potwar, to the east and Kohat, to the west by river Indus. Regardless of the small size of the Potwar and Kohat sub-basin they depict facies variation (Khan et al., 1986).

Potwar sub-basin preserves the sediments from Precambrian to Quaternary age in the subsurface and all of these are exposed in the Salt Range, a southern most thrust. The Tran-Indus ranges in south of the Kohat sub-basin expose sediments from Cambria to Pliocene age.Both Kohat and Potwar sub-basin are characterized by an unconformity between Cambrian and Permian. Mesozoic sediments are also exposed around the basin rim. However, this presence is governed by Pre-Paleocene erosion which progressively cut into older sequence from the Trans-Indus Ranges in the west to east Potwar through Salt Range.

In Kohat sub-basin, west of the Potwar sub-basin, Eocene through Siwaliks strata are involved in a complex fold and thrust belt in which Eocene Salt occupies the cores of many of anticlines (Khan et al., 1986)

2.3 Structral Division

The tectonic depression of Potwar sub-basin is formed as result of continent-to-continent collision at the northwest margin of the Indian Plate. Presently two-fold division is envisaged for the Potwar sub-basin. On the basis of the deformation style:

(a) Northern Potwar Deformed Zone (NPDZ).

(b) The Platform Zone.

The NPDZ is in the south of Kalla Chitta Margalla Hills. It is structurally complex zone. In these areas Tertiary rocks are exposed along a series of south verging thrust faults (Khan et al., 1986).

The platform area is mainly covered with thick fluvial sediments of Siwalik group (Chinji, Nagri and Dhok Pathan Formations). These sediments have been folded along with underlying marine sediments of the Indian Plate as the rest of the latest tertiary tectonic movements. The folded structures are generally oriented in sub-latitudinal fashion (Khan et al., 1986).

The Platform is further divided into three parts:

(a) The eastern Platform Zone.

(b) The central Platform Zone.

(c) The western Platform Zone.

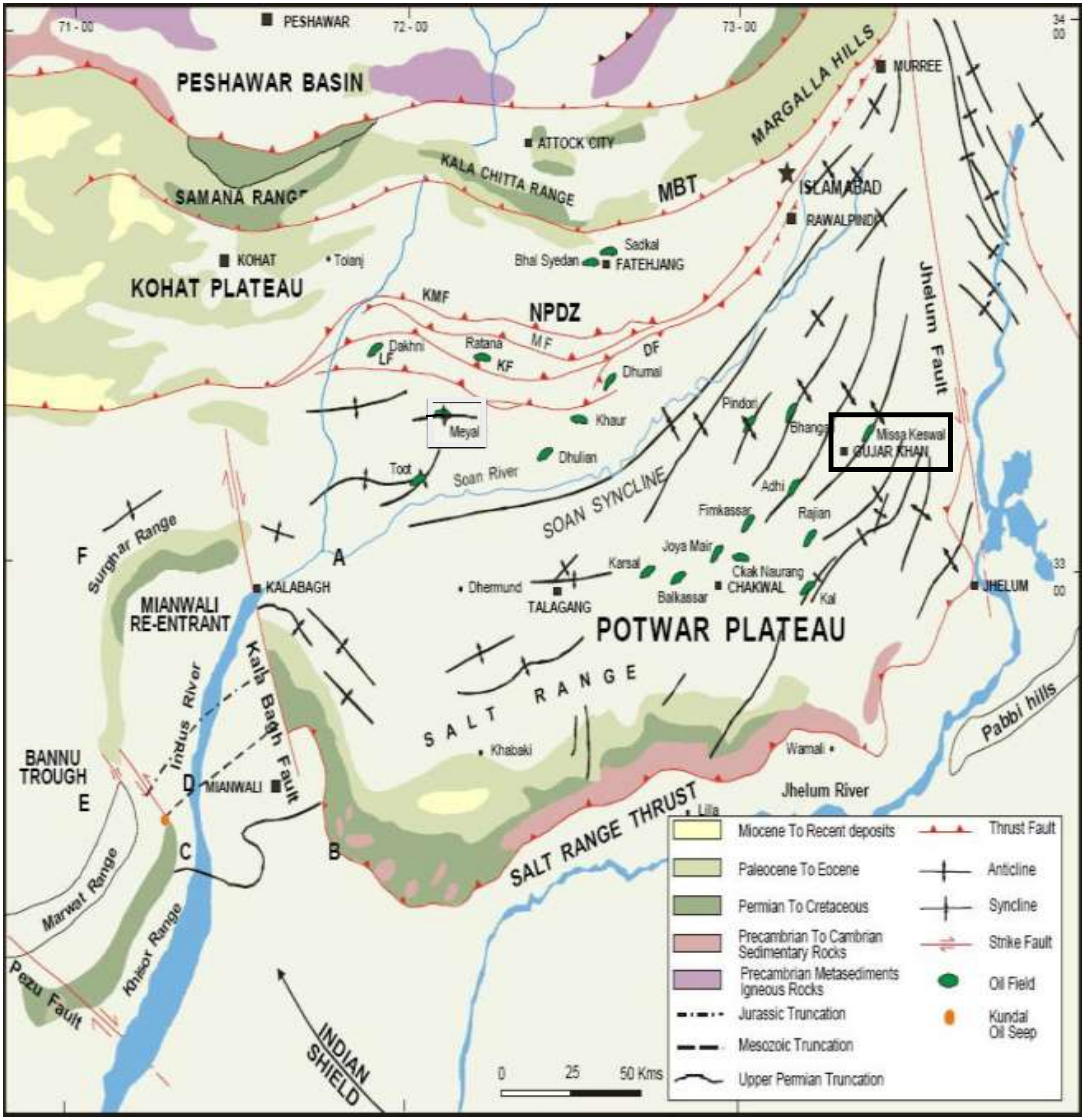

Figure 2.2: Geological and Structral map of Potwar plateau (khadri,1995)

2.3.1 Structural Style Of Potwar Plateau

Potwar Plateau is largely covered by the Siwaliks sequence, though at places upper Eocene shales and limestone crop out locally in folded inliers. Its Northern part, known as the North Potwar

Deformed Zone (NPDZ) is more intensely deformed. It is characterized by east-west, tight and complex folds, overturned to the south and sheared by steep-angle faults (Kazmi &Jan, 1997).

The structural style of the central eastern and western parts of Potwar Plateau shows a marked difference. In the central western parts of Potwar Plateau, the deformation appears to have occurred by south-verging thrusting, whereas in theeastern part the deformation is mainly in northeast-southwest direction with tight and occasionally overturned anticlines separated by broad synclines. This difference may be related to lesser amount/thickness of salt in the lnfra-Cambrian in the eastern areas and very low dip of the basement (1°-1.5°) as compared to Central Potwar (20-30).

In Central Potwar, structures are mainly fault bounded mostly by thrusts and backthrusts, while at some places,asymmetric anticlines are bound by a single fault. Based on the seismic interpretation, the structures in Potwar area may be divided into: Pop-up anticlines, Salt cored anticlines and Triangle zones (Mughal et al, 2003).

2.3.2 Major Faults In Potwar Basin

As Potwar represents the southern margin of Himalayan collisional zone, a variety of faults and folds can be seen in the area. Some of the major faults in the area are

- Khair-i-Murat Fault (KMF)
- Dhurnal Back-thrust (DBT)
- Kanet Fault (KF)
- Sakhwal Fault (SF)
- Mianwali Fault (MF)
- Riwat Fault (RF)

2.3.3 Major Folds In The Potwar Sub Basin

- Soan syncline
- Chak naurang Anticline
- Mahesian Anticline
- Tanwin-Banis Anticline
- Joya Mair Anticline
- Dhurnal Anticline

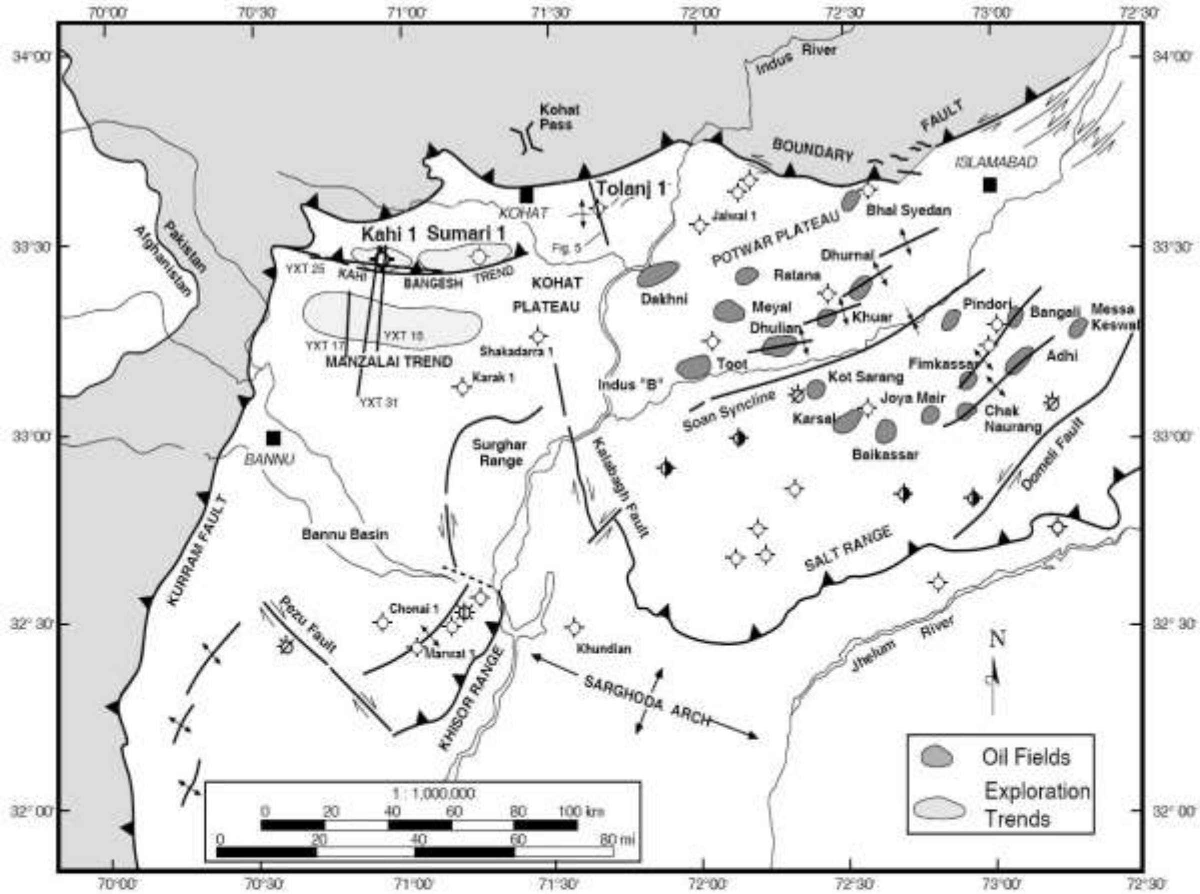

Figure 2.3:Map showing major structural features of the Kohat-Potwar plateaus. Also shown is the Potwar Plateau oil fields and control wells, full seismic coverage not shown. Messa Keswal Well is highlighted also. (William, et al., 1998).

2.4 Stratigraphy

The generalized stratigraphy of Potwar basin is given below in the (figure 2.4).

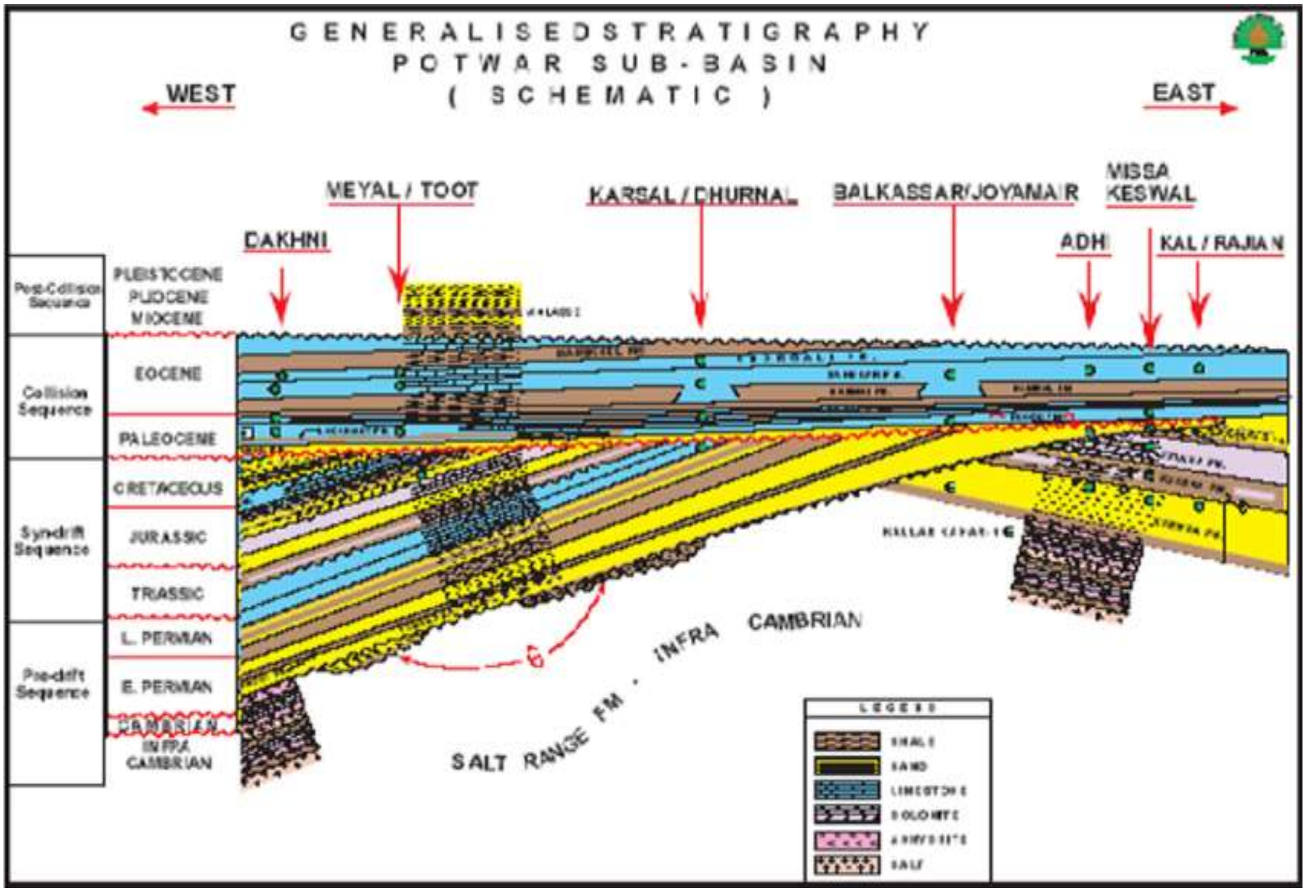

Figure 2.4: Generalized stratigraphy of Potwar sub-basin (Mughal et al., 2007).

The Stratigraphy the of Salt Range and Potwar Plateau is well established from outcrops in the Salt Range.The stratigraphy in the NPDZ is not that well constrained due to lack of deep drilling. Surface outcrops along the MBT and seismic profile, however, suggest the stratigraphy of NPDZ is similar to that of the Salt Rang and Potwar Plateau. 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).Formations, age, thickness and lithology is given in (figure 2.5)

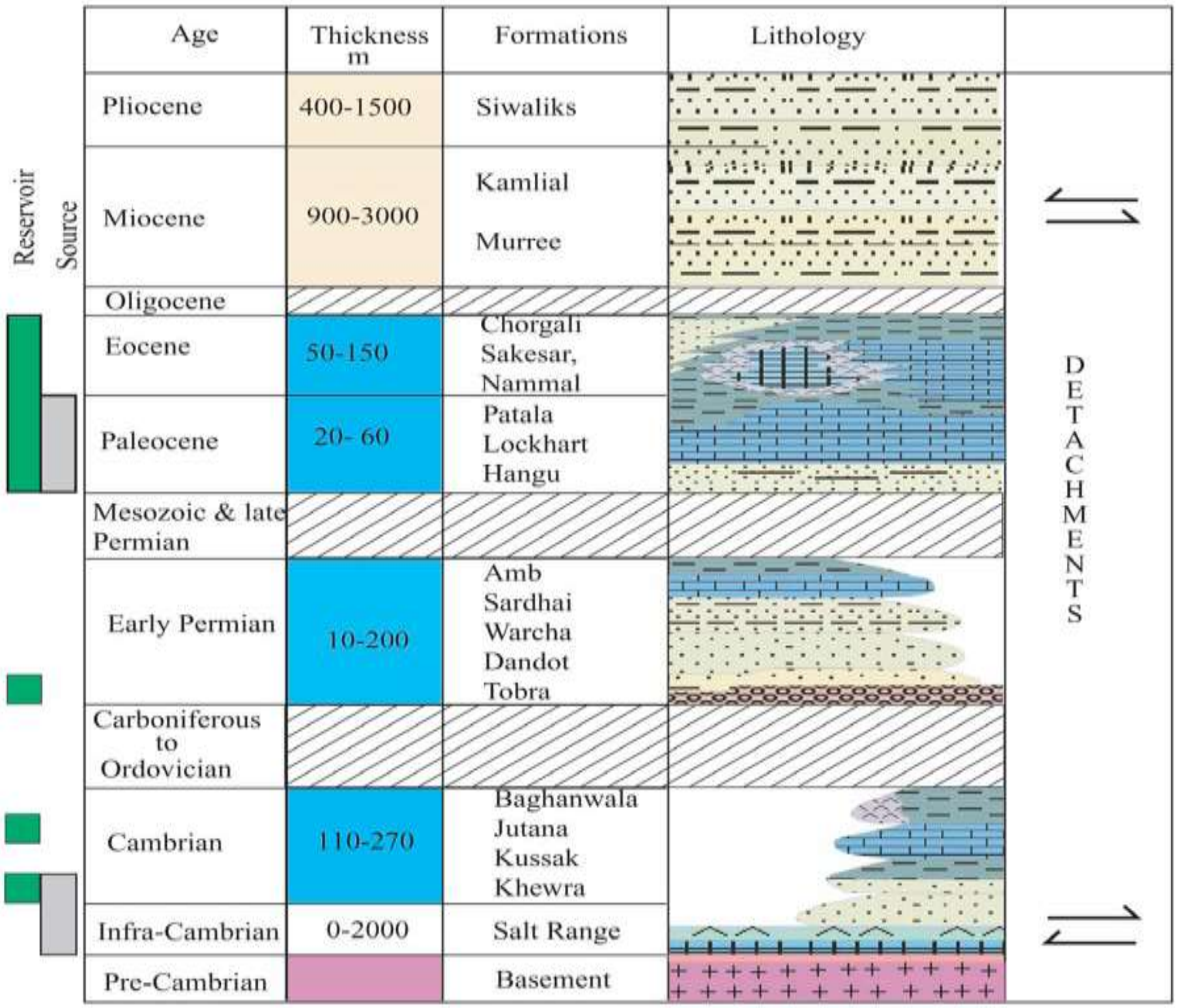

Figure 2.5: stratigraphy of upper indus basin (Amir & Siddiqui,2006).

2.5 Petroleum Play Of Potwar

Potwar marine facies has great potential of hydrocarbon. Previous drilling was restricted up to Eocene carbonate. Recent discoveries in Potwar result in delineation of deep subsurface crest. (Kadri, 1995).

Potwar region which is traditional oil producing area of Pakistan has the average geo-thermal gradient of the order of 2 degree celcieous per 100 meters. Hence the oil window lies between 2750-5200 meters. (Kadri, 1995).

2.5.1 Source And Reservior Rocks Of Potwar Basin

Noncommercial oil has been encountered in the shale of Precambrian Salt Range Formation (in well drill in Dhariala, Kallar Kahar).

In Cambrian the marine shale of Kussak, Jutana and also of Khisor formation has source potential for hydrocarbon. Oil is produced from Khewra Sandstone in Adhi field. In Permian, shale of Dondot and Sardhai and Limestone and Black shale of Zaluch group has source potential of oil. Reservoir potential of Permian is also good, as Adhi oil filed in Tobra/Dandot/Warcha., Dhurnal oil field in Amb and Wargal while Dhulian Well in Permian sandy Limestone. Triassic unit of Potwar having versatility in the environment of deposition that reason that cannot act as a good source rock. Only the Khatkiara Member of Tredian Formation have good reservoir characteristic. In Jurassic the black clay and organic content of Data and some part of Shinawri Formation are believed to be good source rocks while Data is oil producing reservoir at Meyal, Toot and Dhulian oil field. Similarly Samana Suk Formation has also good reservoir characteristic. In Cretaceous Chichali Formation has good source potential due to abundant of organic material while Lumshiwal Formation is good reservoir having gas discovered in some area of Punjab Platform. In Paleocene Patala shale is major source in this region while the Paleocene reservoir is productive in all part of the Indus Basin like in Dhulian, Toot and Meyal. Early Eocene carbonate are good source and reservoir rock, Sakesar andChorgali having fractured Limestone having hydrocarbon potential in Adhi(PPL),Dhurnal(OXY), Dakhni(OGDCL) etc.

In Dhulian the Permian and Paleocene succession is quite thin. Carbonates of Chorgali and Sakesar Formations are major oil producing unit in this area. Moreover the sandstone of Murree Formation has also good potential. Sakesar is consisted of light gray, massive and partially dolomitized carbonated that locally contains the chert concentration. Chorgali Formation contains the creamy, yellow to yellow gray, silty,partially dolomitized and thin bedded limestone. Clay and shale of Murree Formation provides good vertical and lateral seal to these Eocene carbonates. (Geomodelling of Hydrocarbon of Potwar, (Shami & Baig, 1998).

2.5.2 SOURCE ROCKS

The gray shales of the Mianwali (Triassic age), Datta (Jurassaic age) and Patala Formations (Paleocene age) are potential source rocks in Salt Range Potwar- Foreland Basin (SRPFB) (Khan et al, 1986). The oil shales of the Eocambrian Salt Range Formation include 27% to 36% total organic content (TOC) in isolated pockets of shales, and are considered as the source rock in SRPFB (Shami and Baig, 2003).

2.5.3 RESERVOIR ROCKS

The Cambrian, Permian, Jurassic, Paleocene and Eocene reservoirs are producing oil in Salt Range Potwar- Foreland Basin (SRPFB).Petroleum play reservoirs ranging in age from Infra-Cambrian to Miocene are present in the Kohat-Potwar foldbelt. The target reservoirs are clastics and carbonates of Infra-Cambrian, Lower Cambrian, Clastics of Permian, clastics of lower to middle Jurassic, clastic of lower Cretaceous, carbonates of upper Paleocene and lower Eocene and clastics of Miocene.

Marine sedimentary rocks of Paleozoic-Tertiary form petroleum systems in Potwar and are exposed in Salt Range along the Frontal Thrust. The Sakesar and Chorgali Formations have fractured carbonates that are major producing reservoirs in Missakeswal.

2.5.4 CAP ROCKS

Thick layers of evaporite and shale have good sealing potential for Infra-Cambrian reservoir. Interbedded shale, mudstone and siltstone provide seal to Cambrian reservoirs.Limetones and intraformational shales are the potential seals for the Cenozoic and Mesozoic reservoirs.

Due to thin-skinned tectonics Traps have been developed, which has produced faulted anticlines, pop-up and positive flower structures above Pre-Cambrian salt. The clay and shale of the Murree Formation also provide efficient vertical and lateral seal to Eocene reservoirs wherever it is in contact.

CHAPTER 3

SEISMIC INTERPRETATION

3.1 INTERPRETATION

Seismic Interpretation is the extraction of subsurface geologic information from seismic data. It is a tool to transform the whole seismic information into structural or stratigraphical model of the earth. The seismic section is the representative of the geological model of the earth, by interpretation, The Seismic Interpretation may determine general information about an area, locate prospects for drilling exploratory wells or guide development of an already discovered field. (Coffen, 1986). Those reflections and unconformities which are to be mapped on seismic section, which fully describe the geology and hydrocarbon potential area (Bradley, 1985).

The basic study of reservoir characterization which would be determined step by step starting with the seismic interpretation. The base map of the Missakeswal area with imposed well location is shown in the Figure 1.2 (Base map of area), which shows the location of well Missakeswal-01, Missakeswal-02, Missakeswal-03 on dip line line GO-926-GJN-16, GO-994-GNA-19. To get the complete interpretation requires gathering all the relevant data which would be helpful in providing the accurate results. 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-926-GJN-16 (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.

3.2 INTERPRETATION PROCESS

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

Base map on Kingdom Software is prepared by loading navigation data and SEG-Y in software Kingdom 8.8. Horizons of interests are marked manually with the help of synthetic seismogram. In this process faults are also marked and identified on seismic section. Faults polygons are generated and horizons are contoured to find out structural high and lows. The interpretation workflow is discussed in Figure 3.1.

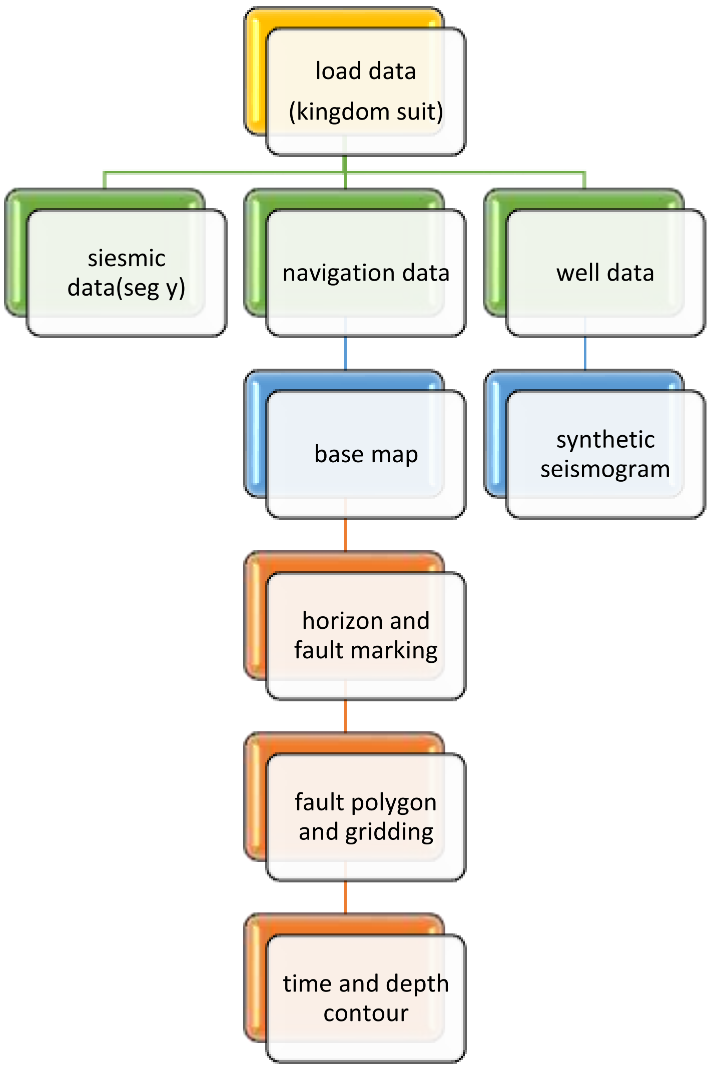

Figure 3.1 Work flow for Seismic Interpretation

3.3 Available Data

Three seismic lines, base map, and well tops of well missa keswal-03 acquired from DGPC for this project. Available seismic lines on which the interpretation was carried out are as follows:

- GO-926-GJN-16,
- GO-994-GNA-19
- GO-926-GJN-15

3.4 Synthetic Seismogram

Synthetic seismogram was generated by convolution of Sonic, density curve with the source wavelet of the well missa keswal-03. The source wavelet used was extracted wavelet shown in Figure.3.2.

Basic and most important step of interpretation is generation of synthetic seismogram. It provides a crucial link between lithological variations within a drill hole and reflectors on seismic profiles crossing the site. In essence, they provide a ground truth for the interpretation of seismic data. Synthetic seismogram are useful tools for linking drill hole geology to seismic sections, because they can provide link between observed lithologies and seismic reflection patterns. Reflection profiles are sensitive to changes in sediment impedance, the product of compressional wave velocity and density. Changes in these two physical parameters do not always correspond to observed changes in lithologies. By creating a synthetic seismogram based on sediment petrophysics, it is possible to identify the origin of seismic reflectors and trace them laterally along the seismic data as we use Missakeswal-03 data to generate synthetic seismogram for marking the horizons on seismic sections.

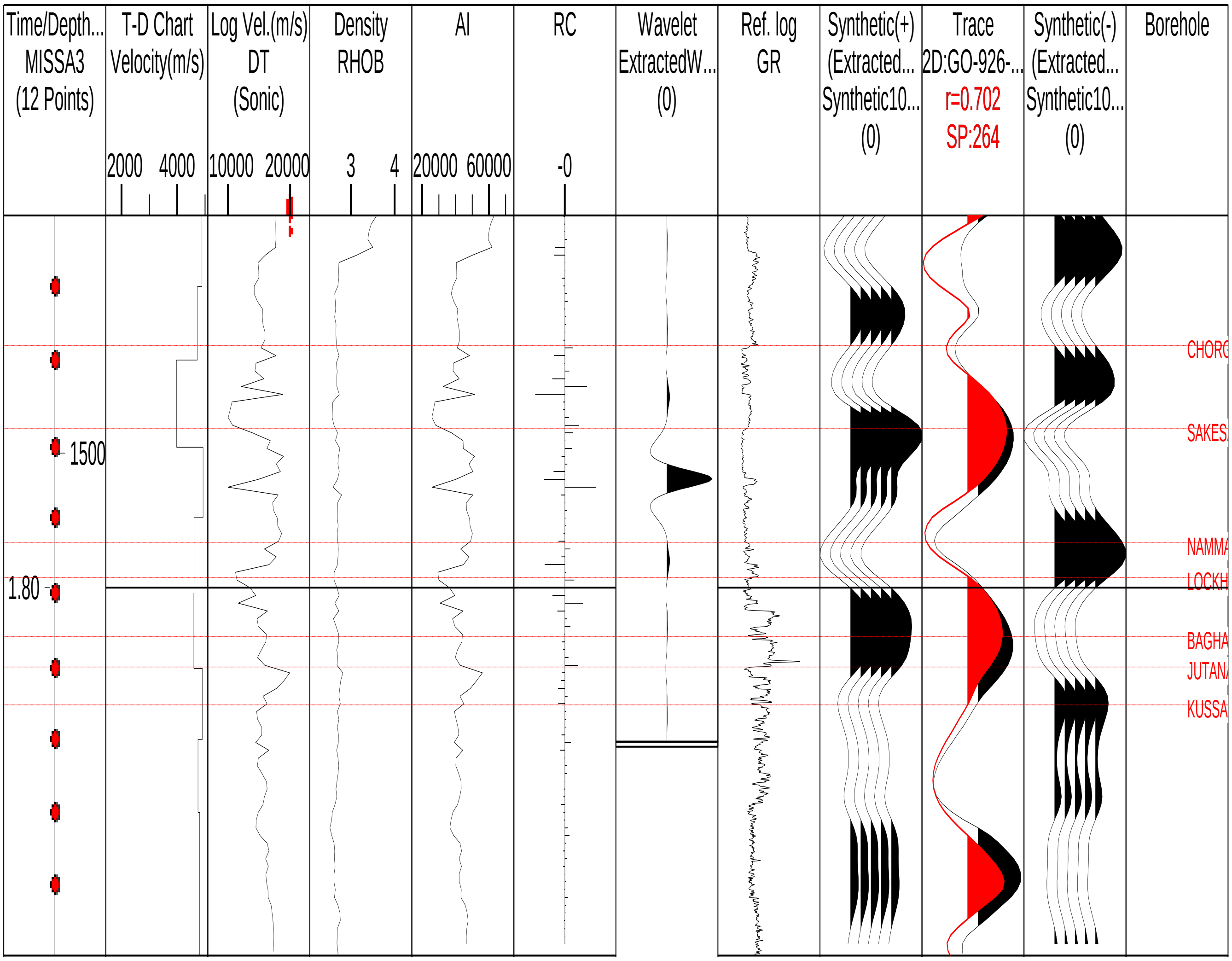

Figure 3.2 Synthetic Seismogram of Missa-Keswal-03

Well tops were also imposed on the respective synthetic seismogram showing Chorgali, Sakesar, and Khewra sandstone Formation respectively as shown in Figure.3.2.

3.5 Identification of Horizon and Faults

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 basis of prominent coherence of reflections visible, which appeal you most on the seismic section from the above subsurface interface. Three reflector were marked in the seismic section of the study area, which are designated as Chorgali,khewra sandstone and Sakesar as show in Figure 3.3.

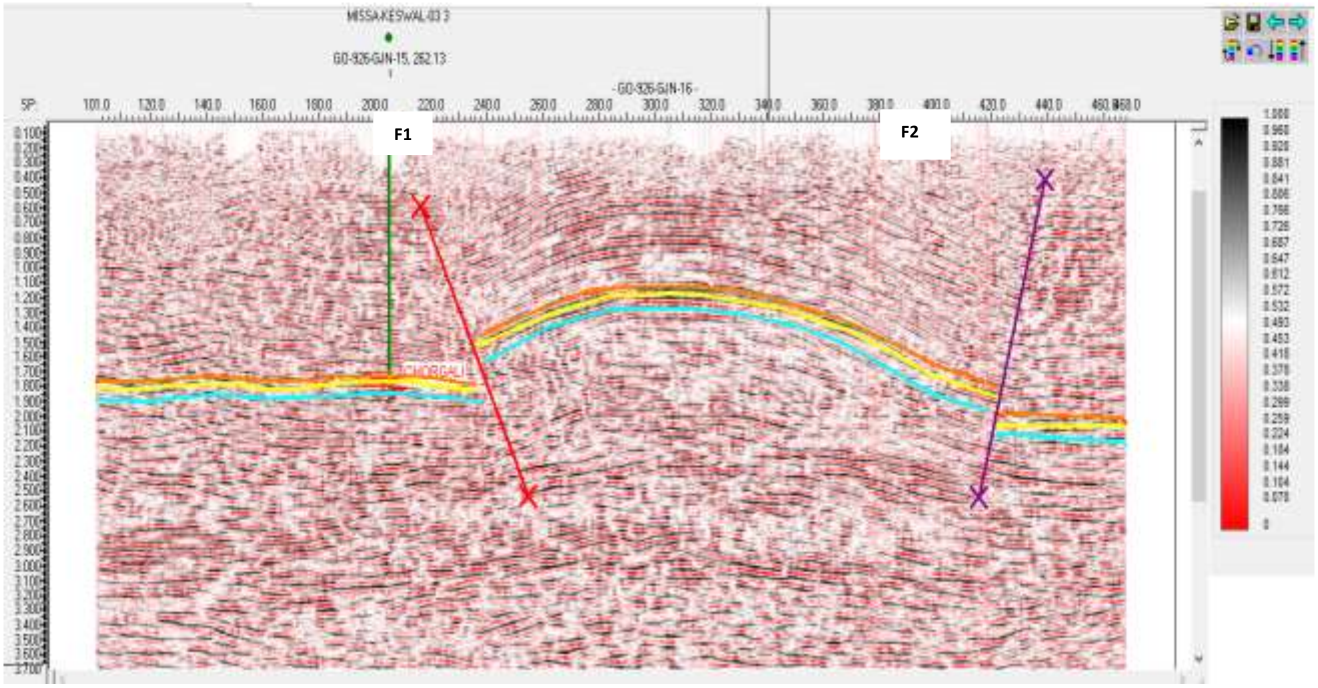

Figure 3.3 Marked section of line GO-926-GJN-16

The identification of various horizons as an interface between geological formations is one of the basic task of interpretation. For this purpose, good structural as well as stratigraphic knowledge of the area is acquired (Mavko et al., 2009). Thus during the interpretation process both horizons and faults were marked on the seismic section. three horizons Chorgali,Sakesar and khewra sandstone were marked. The horizons are named and marked on the basis of well tops encountered in the MISSAKESWAL-03 well which are showing high reflections on the seismic section making it easier to be picked. Marked section are shown is Figures 3.3 and 3.4 for dip lines given and Figure 3.5 shows strike line. three horizons (chorgali ,khewra sandstone and Sakesar) were marked on them. Also the thrust faults have been marked. Faults are the broken reflectors in seismic section, which continues after slight distortion regime. Major two faults were marked in the seismic section as show in figures.

In the figure 3.3 the two faults, are marked on the line GO-926-GJN-16. The horizons which are marked are Chorgali, Sakesar and khewra sandstone. , The Chorgali formation is shown with the orange color horizon. The Sakesar sandstone is shown with the yellow color horizon line and khewra sandstone with light blue colour. The marked section shows compressional regime characterized by thrust faulting and anticline structures. The line type is dip line and its orientation is from NW- SE.

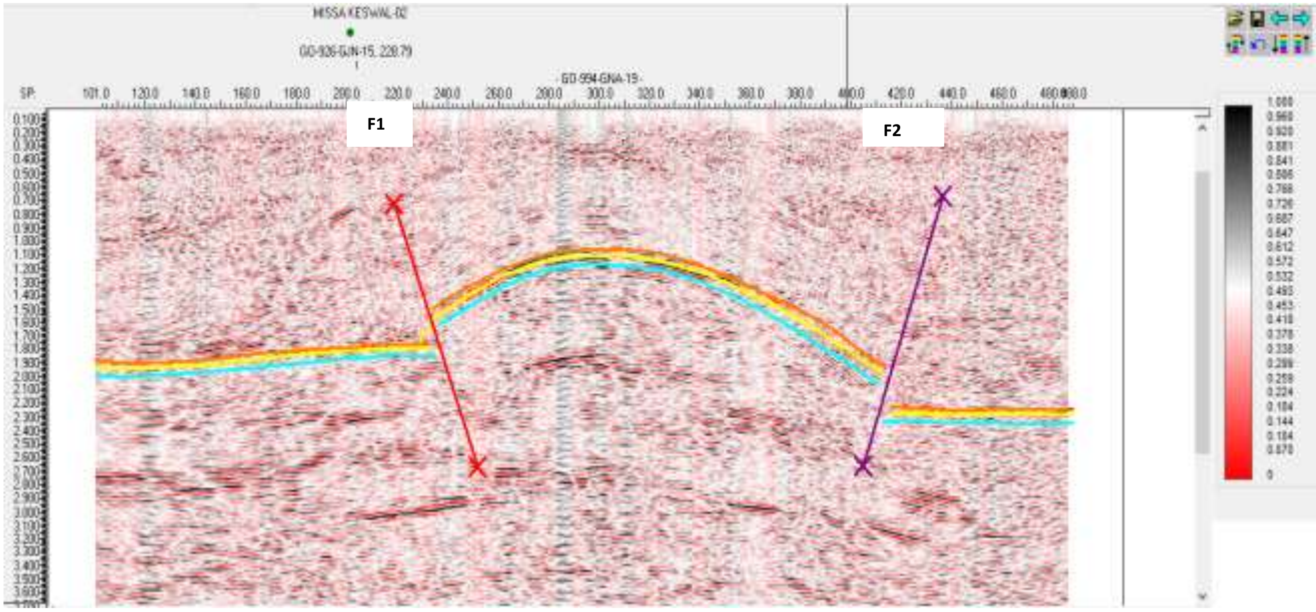

Figure 3.4 Marked Seismic section of line GO-994-GNA-19

In the figure 3.4 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. The Chorgali formation is shown with the orange colour horizon. The Sakesar sandstone is shown with the yellow colour horizon lineand khewra sandstone is marked with light blue colour. The marked section shows compressional regime characterized by thrust faulting and anticline structures. The line type is dip line and its orientation is from NW- SE.

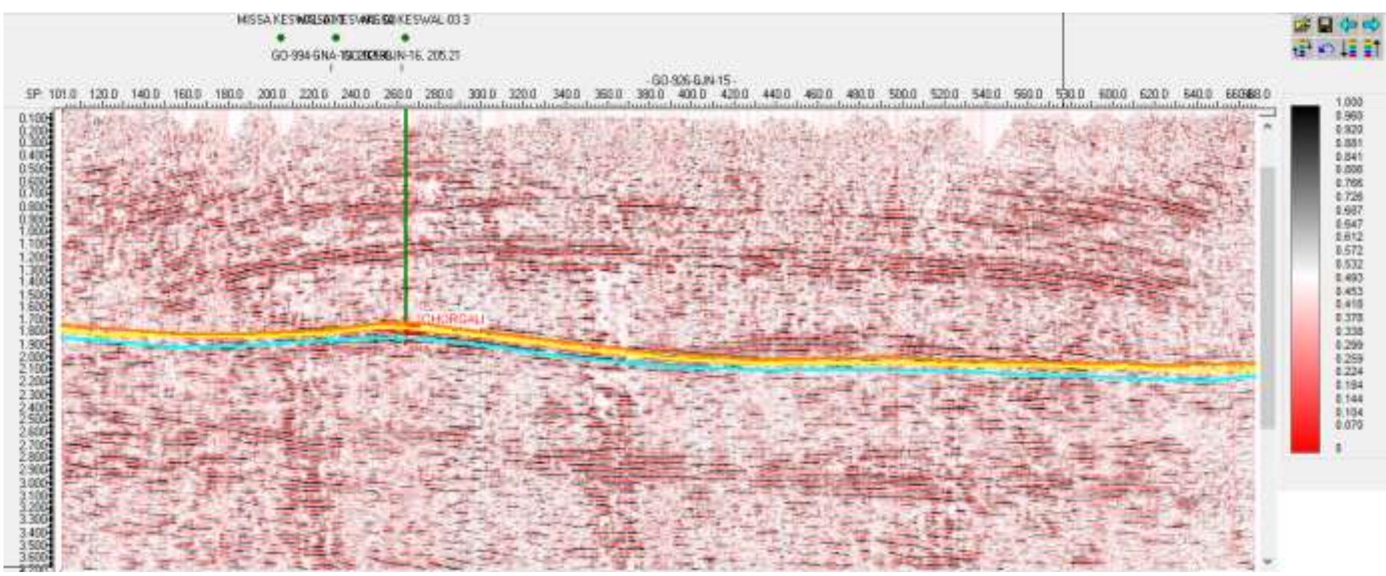

Figure 3.5 Marked Seismic section of line GO-926-GJN-15

In the figure 3.5 The Chorgali formation is shown with the orange colour horizon. The Sakesar sandstone is shown with the yellow colour horizon line and khewra sandstone is marked with light blue colour. The line type is strike line and its orientation is from NE – SW.

3.6 Construction of Fault Polygon

Marked seismic section are collectively used to generate fault polygons as any mapped software needs all faults to be converted into polygons prior to contouring. The reason is that if a fault is not converted into polygon, software doesn't recognize it as a barrier or discontinuity, thus making any possible closures against faults represents a false picture of subsurface structures.

A fault polygon represents the lateral extent of dip faults or strike faults having same trend. Fault polygons show the sub-surface discontinuities by displacing the contours. To generate 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 on base map can be manually joined to make a polygon.

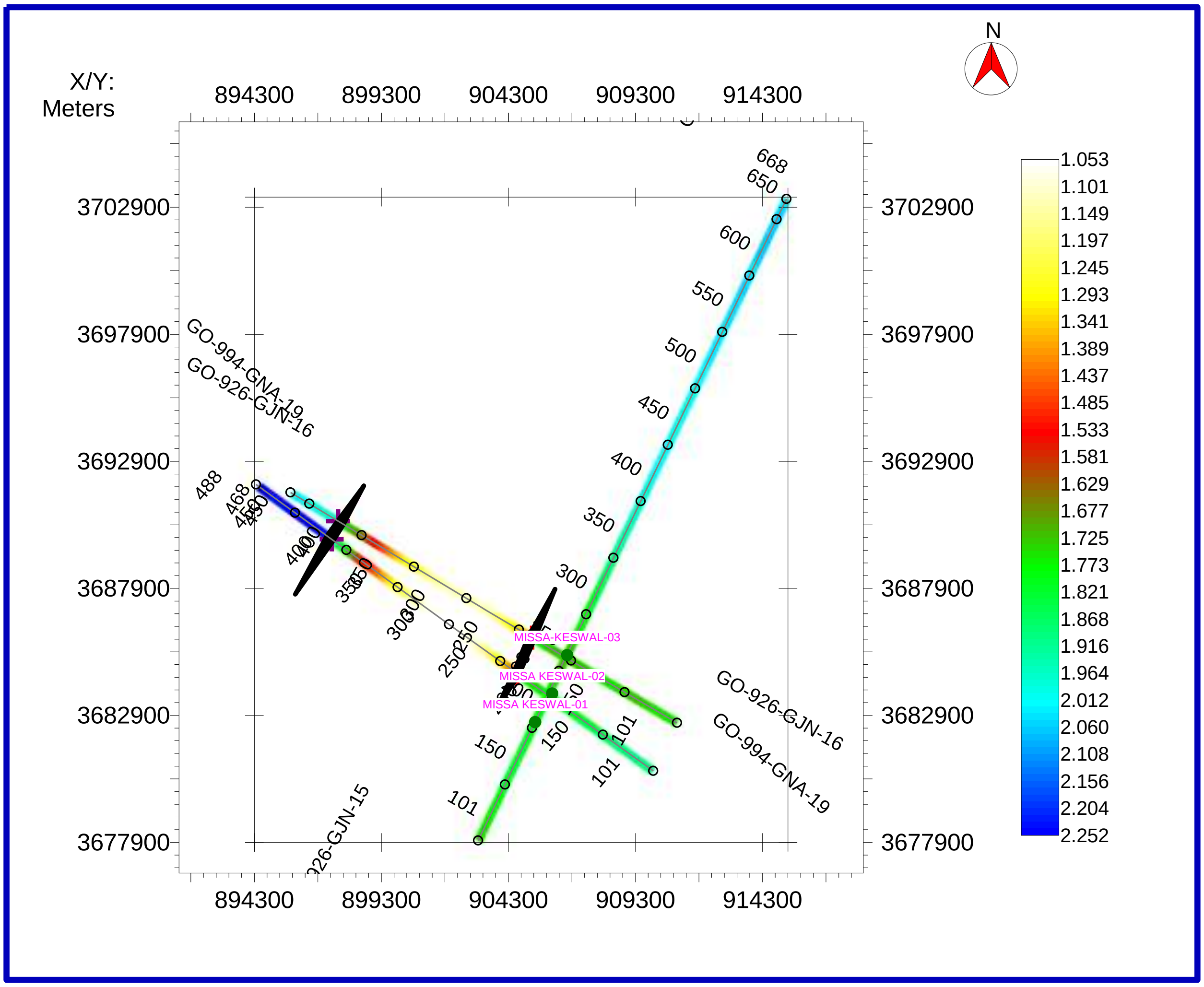

Figure 3.7: Fault polygon of chorgali.

3.7 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.

3.8 Time Contouring

Seismic sections gives the time value along shot points and the times are read directly from the sections and are immediately available for mapping. After completing horizons and fault interpretation time contour map are constructed.

The pattern of time contour map confirms the shape of the subsurface structure. Time contour maps of these formations shows 2D- variations with respect to time and the Hydrocarbons probably accumulate at those places where time contour values are low hence shallow depth.

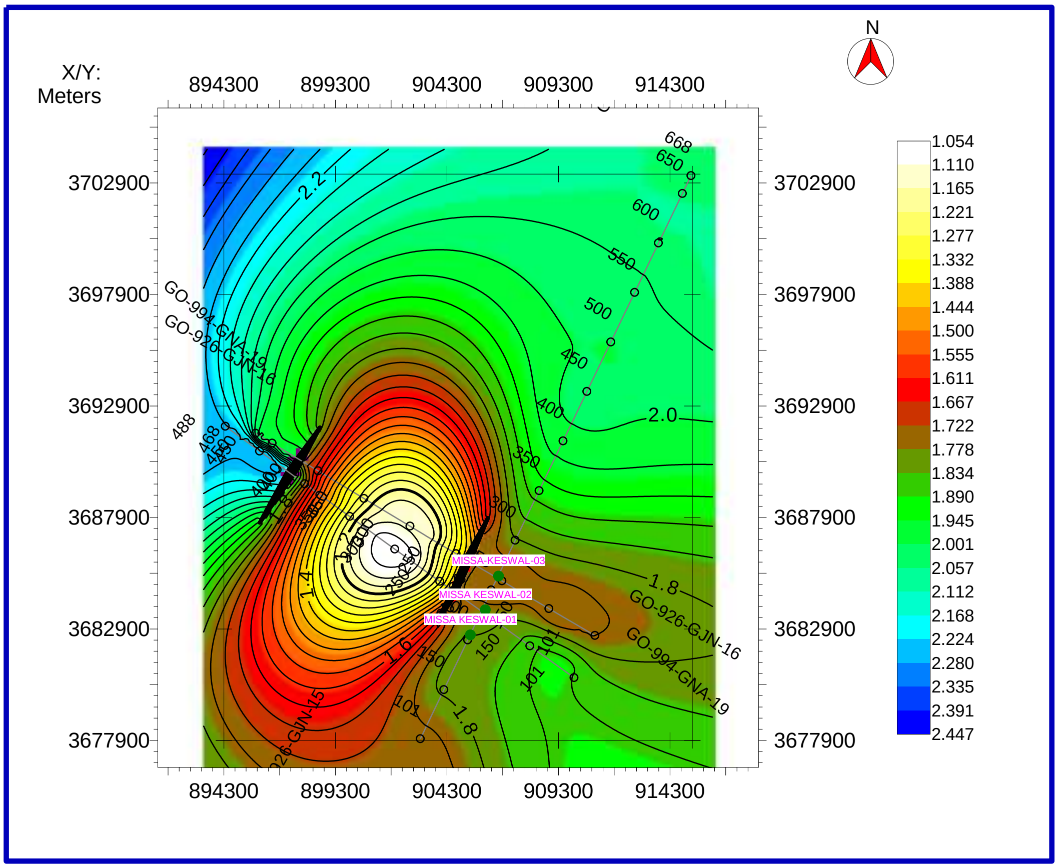

Figure 3.6 Time contour map obtained of Chorgali Formation

Low pressure zones are the favorable site for hydrocarbons accumulation and we look for such zone to dig wells. Deciding the new well location for our study area we have to mark the zone present nearest to the surface. Figure 3.6 shows time contour of Chorgali while Figure 3.7 shows time contour of Sakesar.

Two Way Time (TWT) contour map of Chorgali formation is shown in Figure 3.6 Time variation is mentioned through the color bar from (1.054 to 2.447 sec). light yellow colored portion (1.054 to 1.209sec) is showing the shallowest part while dark blue colored portion (2.391 to 2.447 sec) is showing deeper part of the formation. It is clear from the Figure that the Chorgali formation is deepening NW-SE direction as the time is increasing in this direction, while formation is uplifting toward NE-SW direction because time is decreasing in this direction

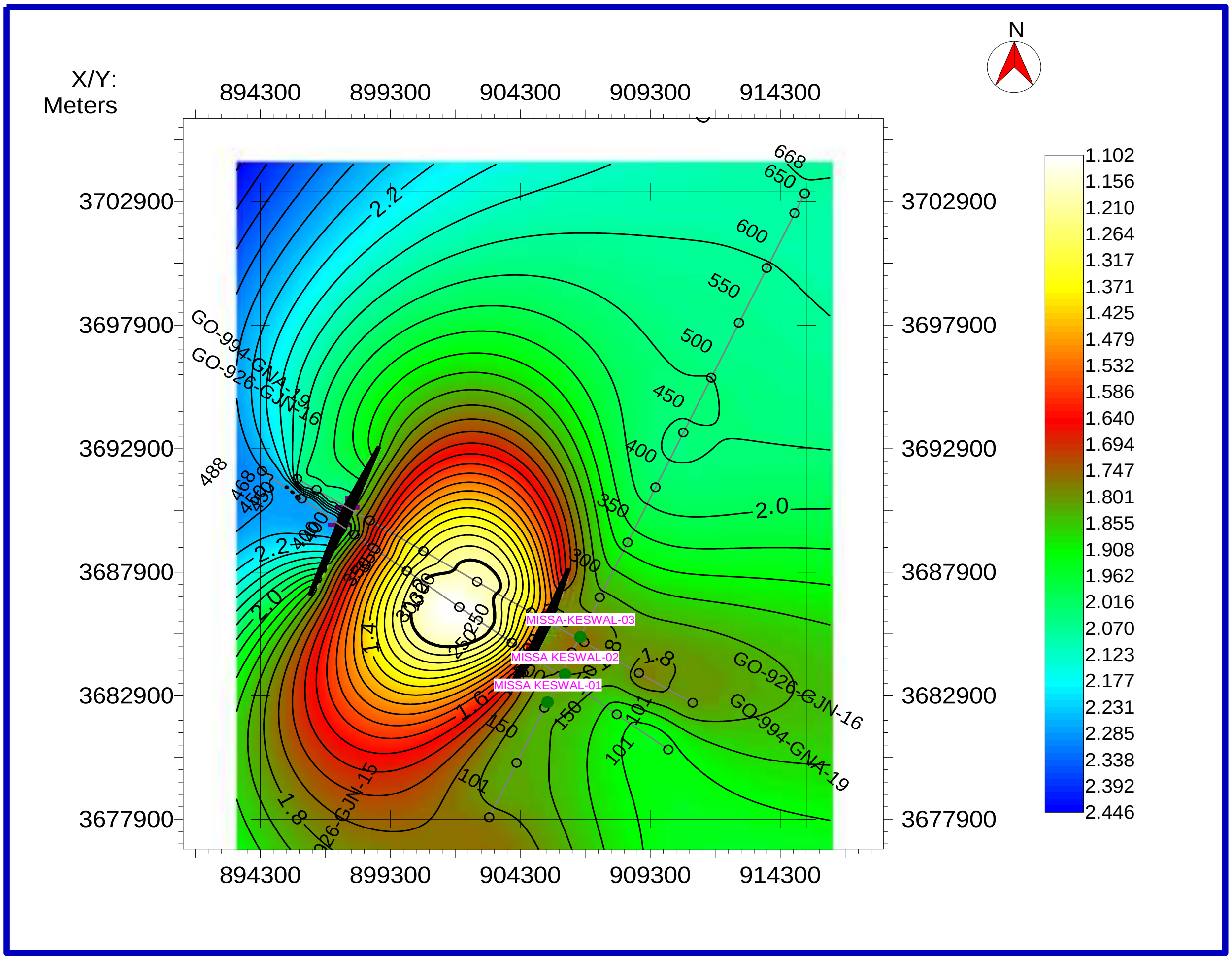

Figure 3.7 Time Contour obtained of Sakesar Formation.

Two Way Time (TWT) contour map of Sakesar formation is shown in Figure3.7. Time variation is mentioned through the color bar from (1.102 to 2.446 sec). light yellow colored portion from (1.102 to 1.317 sec) is showing the shallowest part while blue colored portion from (2.297 to 2.446. sec) is showing deepest part of formation. It is clear from the Figure that the Sakesar formation is deeper in NW-SE direction as the time is increasing in this direction, while formation is uplifting toward NE-SW direction because time is decreasing in this direction.

3.9 Depth Contouring

Our primary information is the varying time values and by using these values and subsurface velocities depth conversion is done. Depth conversion and depth contour maps are connected to see the horizons in the subsurface at their true positions. Depth must be calculated from time to make a map that is more truly related to the subsurface shapes, because structures is a matter of depth. The idea of converting the times into depths is very reasonable in case of showing the subsurface structures. Depth contour is showing same pattern to the time contour as constant velocity is multiplied with time.

Shapes of geological surfaces are complex and not readily approximated by simple mathematical functions because they result from a multitude of interacting processes that vary at different spatial scales. Ideally, spatial data should be examined with a spatial sample of regular geometric design. These designs can capture the range of variation exhibited by most spatial phenomena. However, such designs are, for all practical purposes, impossible for most geological work, although in some instances recent developments in satellite imagery allow their economic implementation. In most cases, subsurface geological features are sparsely sampled relative to their complexity and the samples are highly biased to geophysical and/or geological anomalies. Therefore, values of a variable across an area of interest must be estimated by interpolating from a sparse, irregular control point set.

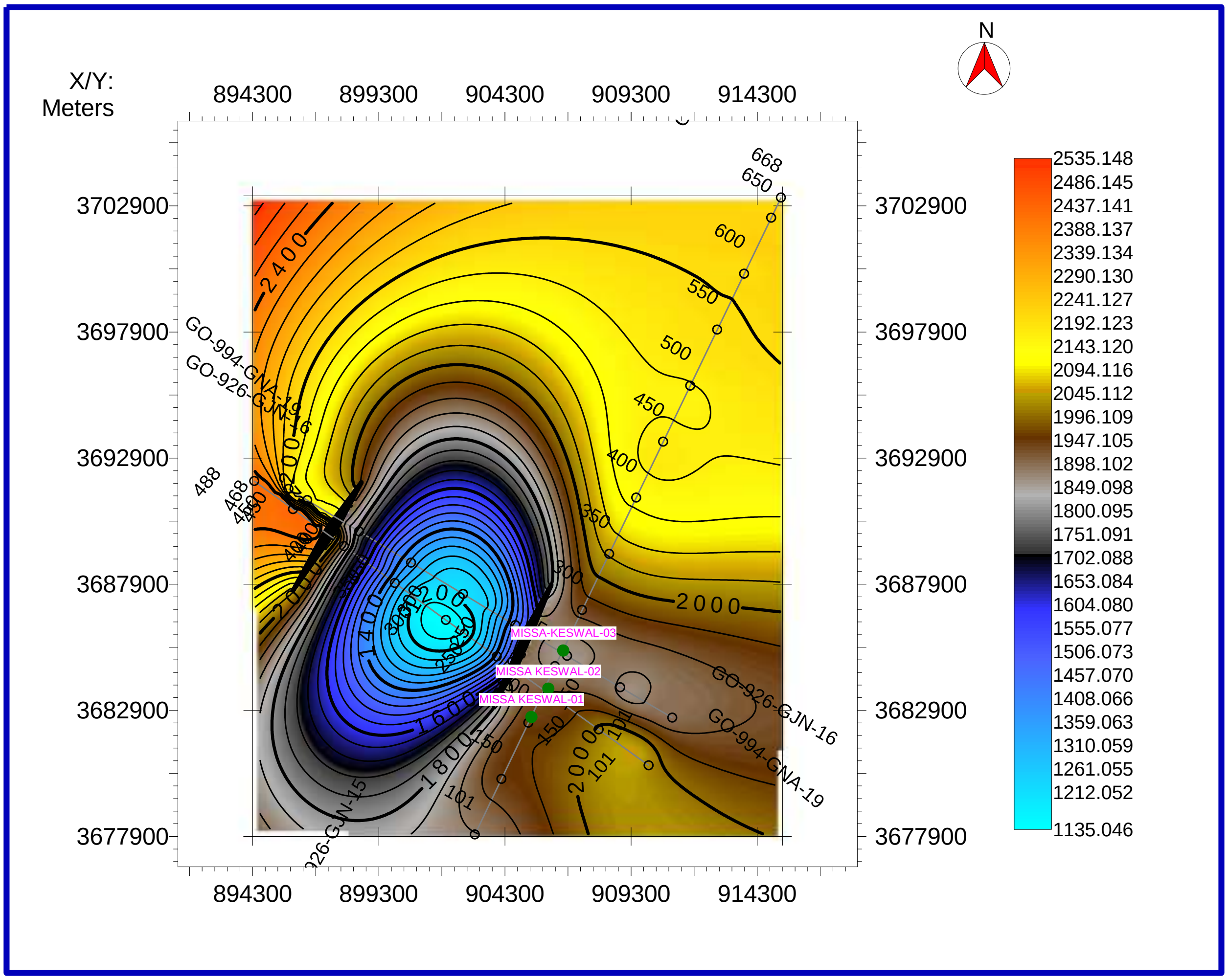

Figure 3.8 depth Contour obtained of chorgali Formation.

The Depth must be calculated from time to make a map that is more truly related to the subsurface shapes, because structures is a matter of depth. Therefore, depth contouring plays an important in understanding the subsurface geology of the area.

In Figures 3.8 depth variation is mentioned through the color bar from bottom 1135 m to top 2535m respectively, light blue (1135 to 1310 m) is showing the shallowest part while redish orange colored portion (2388 to 2535 m) is showing deepest part of the formation. It is clear from the Figure that the Chorgali formation shows deepening towards NW-SE direction as the depth is increasing in this direction, while formation is uplifting towards NE-SW direction because depth is decreasing in this direction.

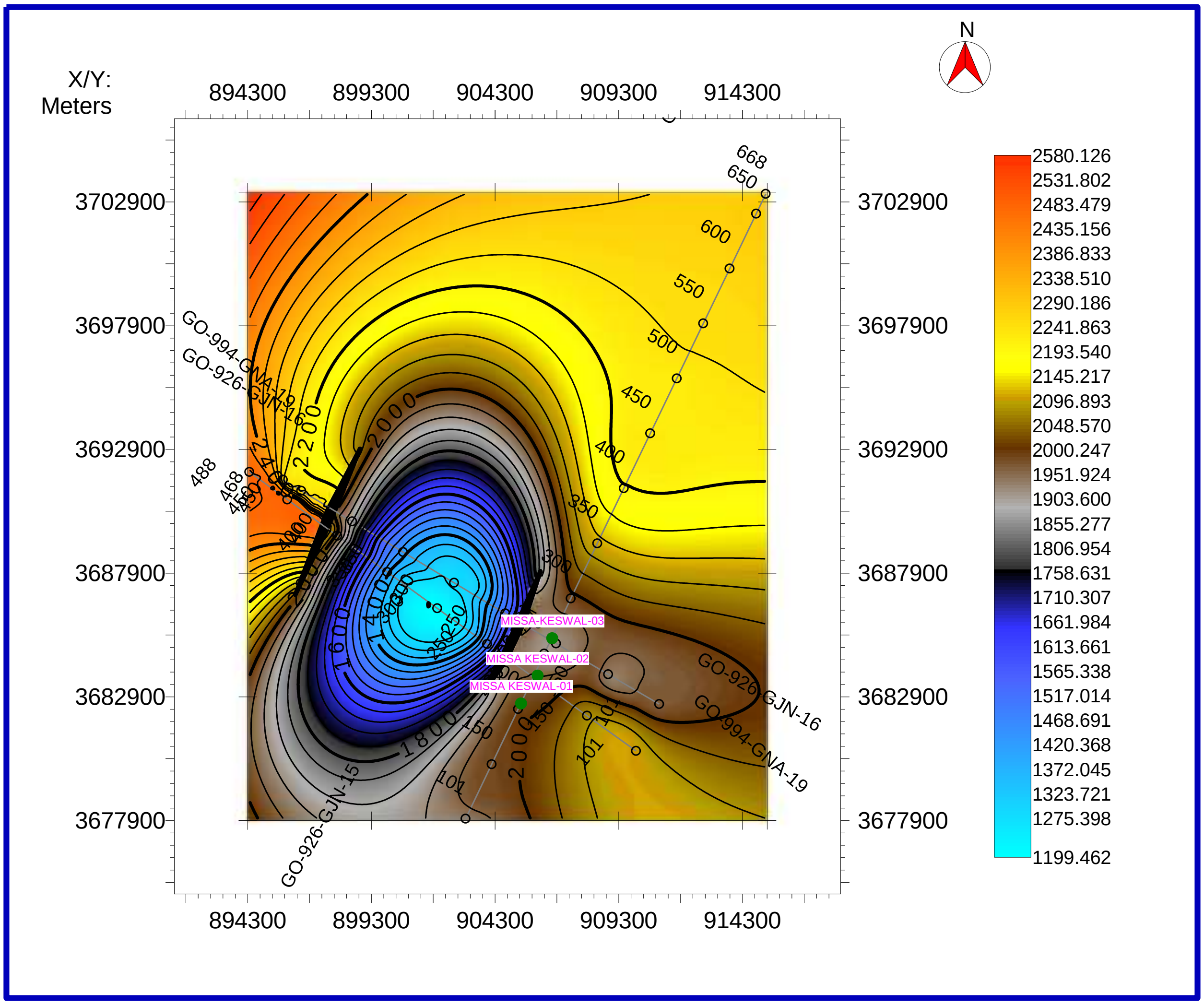

Figure 3.9 Depth Contour of Sakesar formation

In Figures 3.9 depth variation is mentioned through the color bar from bottom 1199 m to top 2580m respectively, light blue colored portion (1199 to 1411m) is showing the shallowest part while reddish orange color (2420 to 2580 m) is showing deepest part of the formation. It is clear from the Figure that the sakesar formation shows deepening towards NW-SE direction as the depth is increasing in this direction, while formation is uplifting towards NE-SW direction because depth is decreasing in this direction

CHAPTER 04

PETROPHYSICAL ANALYSIS

4.1 Introduction

Petrophysical Analysis is used to determine a method of deriving accurate values for the hydrocarbons and water saturation, the permeability, the porosity and the lithology of the reservoir rock. Petrophysics is the study of rock properties and their interactions with fluids (gases, liquid, hydrocarbons and aqueous solutions).

Petrophysics uses all kind of logs, core data and production data and integrates all pertinent information. It aims at obtaining the physical properties such as porosity, saturations and permeability, which are related to production parameters. It is generally less concerned with seismic, and more concerned with using wellbore measurements to contribute to reservoir description.

Petrophysics can provide things like

- Shale Volume
- Permeability
- Porosity
- Net pay
- Fluid contacts
- Reservoir zonation

Petrophysics is the interests of Petroleum Engineers, Well Log Analysts, Core Analysts, Geologists and Geophysicists (Dewar, 2001).

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 Track

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

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

4.3.1 Gamma Ray (GR) Log

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

4.3.2 Spontaneous Potential (SP) Log

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

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

4.4 Caliper Log

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

4.5 Porosity Log

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

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

4.5.1 Sonic (DT) 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

4.5.2 Density (RHOB) Log

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

4.5.3 Neutron Log

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

4.6 Electrical Resistivity Log

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

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

4.6.1 Laterelog Deep

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

4.6.2 Laterolog Shallow

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

4.7 Logs Used

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

4.8 Log Curves

The log information of MISSAKESWAL-03 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. Figure 4.1 shows the logs run and the results to be interpreted from the petrophysical analysis of the log data of MISSAKESWAL-03.

4.9 Properties calculated through formulas

Parameter	Formula
Porosity	$\emptyset = \frac{V_{pore}}{V_{bulk}}$ (Darling, 2005)15
Effective Porosity	PHIE=PHIA*(1-Vshl) (Schlumberger, 1967) 16
Absolute Porosity	$\Phi T = (\phi D + \phi N)$ 2 (Rider, 1996) 17
Average Porosity	$\emptyset a = (\emptyset d + \emptyset n)/2$ (Rider, 1996) 18
Sonic Porosity	$\emptyset_{sonic} = \frac{\Delta_{tlog} - \Delta_{tma}}{\Delta_{tf} - \Delta_{tma}}$ (Wyllie et al., 1958) 19
Permeability	$Q = \frac{K\Delta A}{\mu . L}$ (Selley, 2000)
Water Saturation	$Sw = \sqrt[n]{(a.Rw/\emptyset m.Rt)}$ (Archie, 1942; Rider, 1

Table 4.1 Equations used for petrophysical analysis (Altaf, 2016)

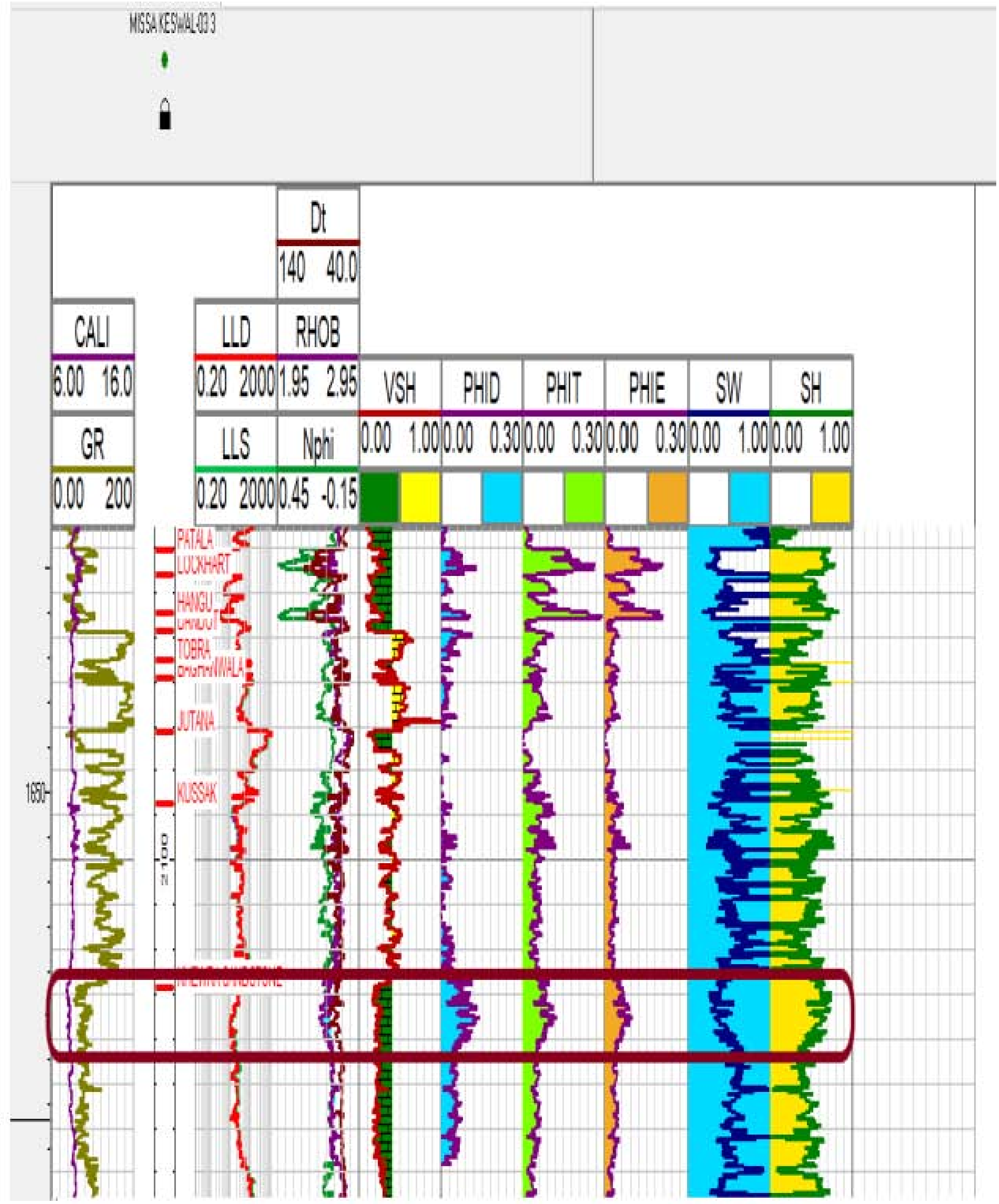

Figure 4.1 Petrophysical Analysis Of MISSAKESWAL-03 Well From 2145m to 2161m

4.10 Defining Zone of Interest

The zone of interest is marked on the basis of appreciable effective porosity, hydrocarbon saturation, less volume of shale and water saturation. The zones of interest which are marked are listed in the Table 4.1

Table 4.2 Calculation of water saturation in zone of interest and Results

Zone	Starting Depth(m)	Ending depths(m)	Thickness(m)
Khewra sandstone	2145	2161	16
Volume of Shale	**Porosity**	**Water Saturation**	**Hydrocarbon Potential**
21.75 %	6.40%	39.57%	60.43%

Petrophysical analysis were performed on MISSAKESWAL-03 in order to locate the potential hydrocarbon bearing zone. Gamma Ray, sonic, resistivity and SP logs were used for the analysis. The parameter used for petrophysical interpretation are volume of shale, sonic, porosity, effective, sonic porosity, water saturation and hydrocarbon saturation.

CHAPTER 05

FACIES MODELLING

5.1 Introduction

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).

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 (18601937) 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 33 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

5.2.1 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.

5.2.2 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 pale ecology 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).

5.3.1 Cross Plot of NPHI and RHOB

There is a direct relation between NPHI and shale. Greater volume of shale shows high value of NPHI. NPHI is plotted along y-axis and RHOB is plotted along x-axis.

In sandstone rhob and nphi is less when there is hydrocarbon present Since density of shale is highly variable and concentration of organic contents is less in shale therefore the density of sandstone and shale can overlap so Gamma log is used as reference log for further separation of facies. The golden yellow color shows the shale while the green color shows the sandtone in Figure 5.1.

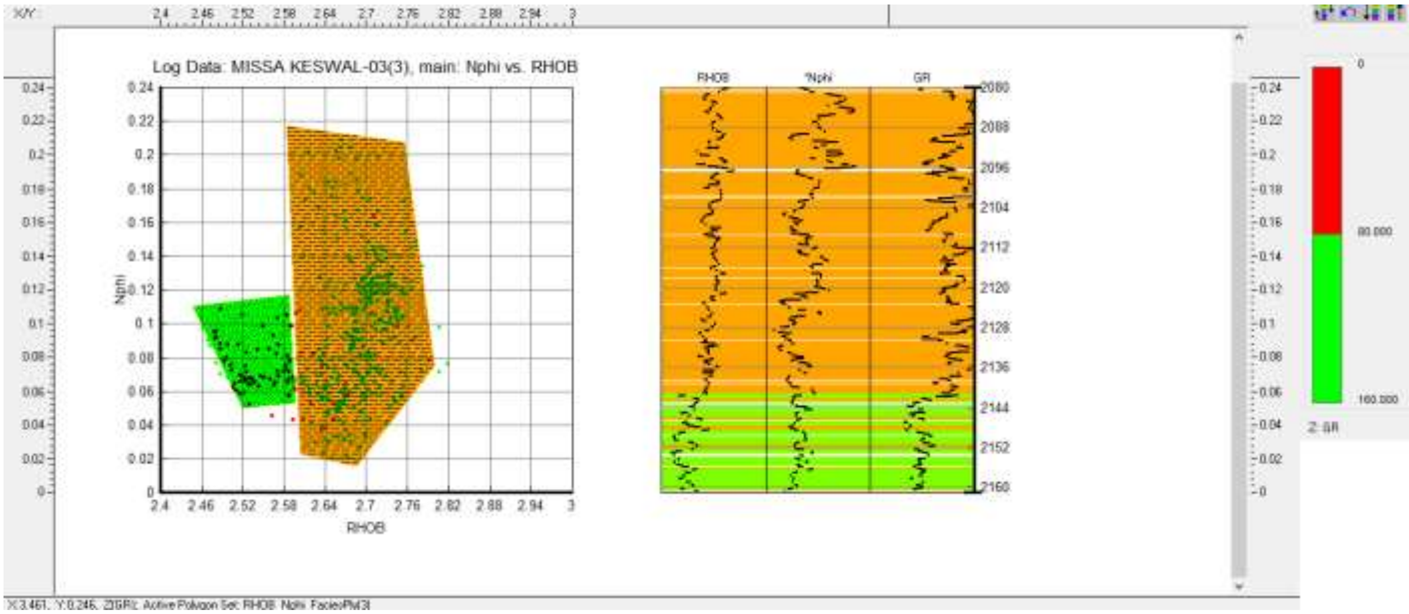

Figure 5.1 Cross plot of NPHI and RHOB.

5.3.2 Cross Plot of PHIE and DT

There is a direct relation between NPHI and DT. Greater value of DT shows high value of PHIE. DT is plotted along y-axis and PHIE is plotted along x-axis. In sandstone DT and PHIE is more when there is hydrocarbon. Gamma log is used as reference log for further separation of facies. The golden yellow color shows the shale while the parrot green color shows the sandstone in Figure

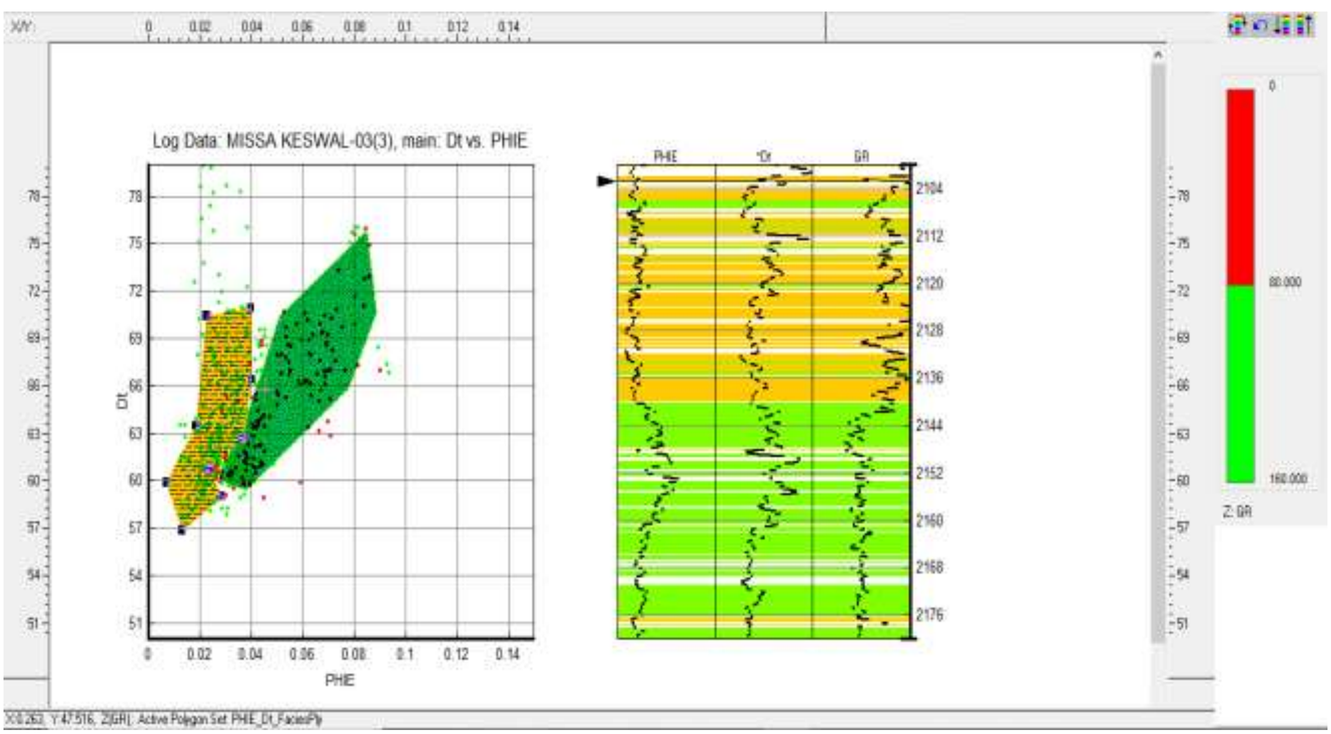

Figure 5.2 Cross plot of DT and PHIE.

5.3.3 Cross Plot of RHOB and DT

There is an indirect relation between rhob and DT. Greater value of DT shows low value of RHOB. DT is plotted along y-axis and RHOB is plotted along x-axis.

In sandstone DT is more and RHOB is low when there is hydrocarbon. Gamma log is used as reference log for further separation of facies. The golden yellow color shows the shale while the green color shows the sandstone in Figure 5.3.

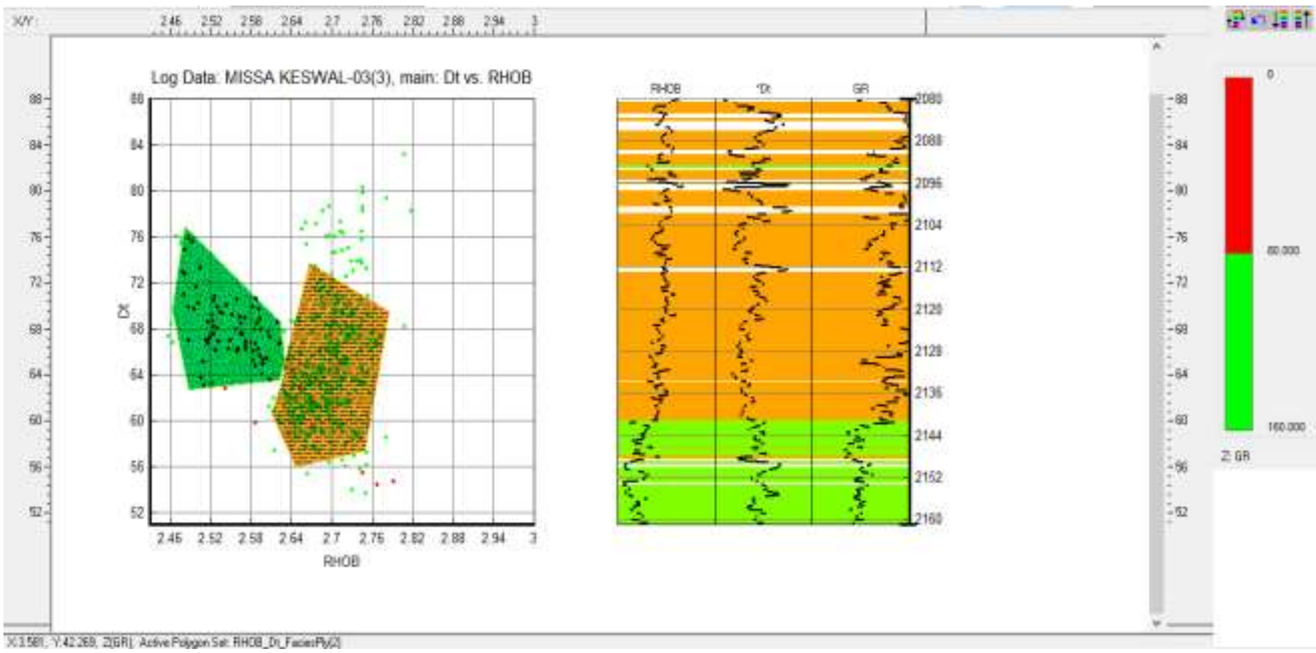

Figure 5.3 Cross plot of DT and RHOB.

CHAPTER 06

SEISMIC ATTRIBUTE ANALYSIS

6.1 Seismic Attribute

Attribute is a quality ascribed to anything.Seimic attribute is all information obtained from seismic data, either by direct measurement or by logical or experienced based reasoning. (Taner, 2001). Seismic attributes have come a long way since their introduction in the early 1970s and have become an integral part of seismic interpretation projects. Today, they are being used widely for lithological and petrophysical prediction of reservoirs. Various methodologies have been developed for their application to broader hydrocarbon exploration and development decision making (Chopra and Marfurt, 2006).

The default attribute of Seismic data is Amplitude. From the early days of seismic prospecting, Explorationists used to draw conclusions about subsurface geology and drilling locations primarily from this single seismic data attribute. Attribute computations decompose seismic data into constituent attributes. There are no rules governing how attributes are computed. An quantity calculated from seismic data can be considered an attribute. Thus attributes are of many types: pre-stack, post-stack, inversion, velocity, and horizon.

6.2 Trace Envelope

Envelop of a trace, also called as reflection strength, represents the total instantaneous energy of the complex trace which is independent of the phase

The envelope relates directly to the acoustic impedance contrasts. It may represent the individual interface contrast or, more likely, the combined response of several interfaces,depending on the seismic bandwidth. The Hilbert Transform of the real seismic trace is generates an imaginary trace and using both these traces the envelope trace is computed. shows the real, imaginary and envelope trace. It can be observed that the envelope trace always remains positive.

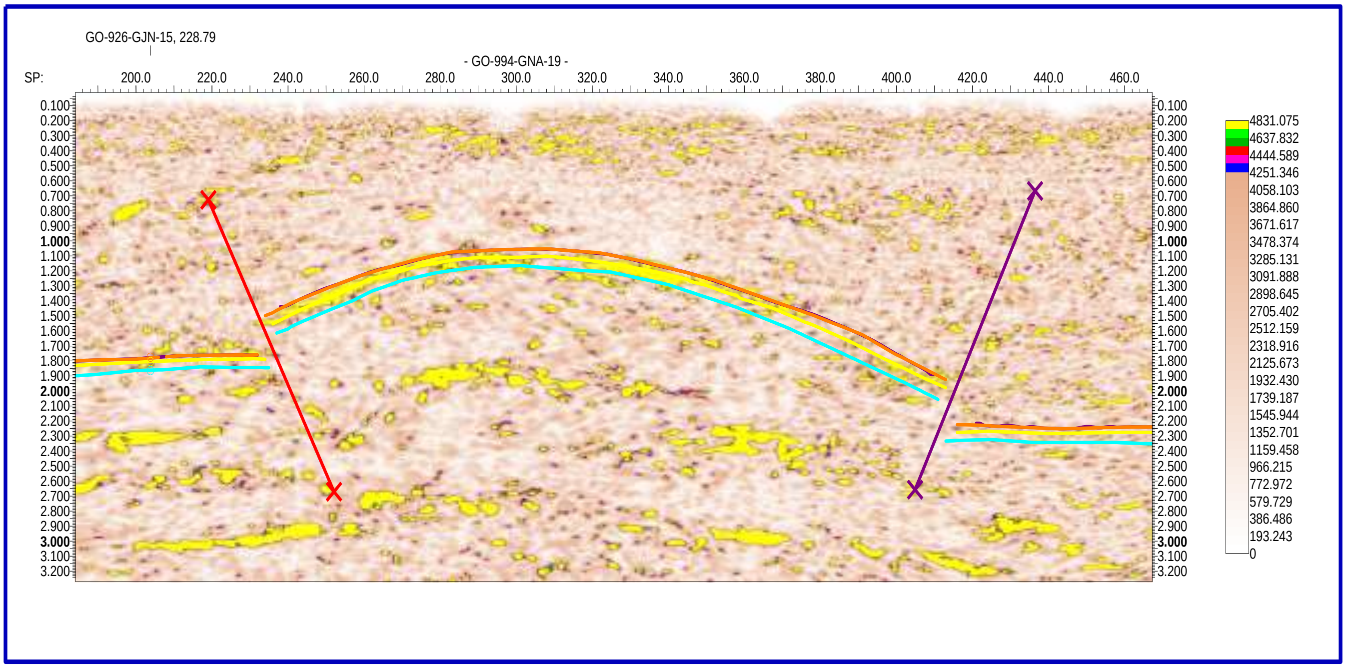

Fig 6.1: An envelope trace attribute is calculated GNA-19.

This attribute is computed for seismic line GNA-19 to see the major changes in lithologies. Even negative reflection coefficients such as limestone formation overlaid on clayey formation would generate a positive response in this attribute.

The thick (yellow) package indicates maximum reflection strength corresponding to the source, reservoir and seal rocks. It also shows spatial patterns representing changes in the limestone thickness and breakage due to the faults.

6.3 Instantaneous Phase

The phase information is independent of trace amplitudes and relates to the propagation of phase of the seismic wave front. Since, most of the time, wave fronts are defined as lines of constant phase, the phase attribute is also a physical attribute and can be effectively used as a discriminator for geometrical shape classifications. It is computed from real and imaginary traces as given below;

$$\Theta\ (t) = \tan -1\ [h\ (t)\ /\ f\ (t)]$$

Instantaneous phase is the best indicator of lateral continuity, relates to the phase component of the wave propagation and has no amplitude information, hence all events are represented. It can be used to highlight interface in sections with high decay of amplitudes and even highlight deeper horizons which are not visible in the normal amplitude sections. Figure 6.2 shows the instantaneous phase attribute which changes from -180^0 to $+180^0$. The interpreted horizons lie over the minimum phase regions indicated by orange color. This attribute further confirms the interpretation as the input data is zero phase. It can be observed in comparsion to amplitude based sections that the instantaneous phase shows much deeper horizons.

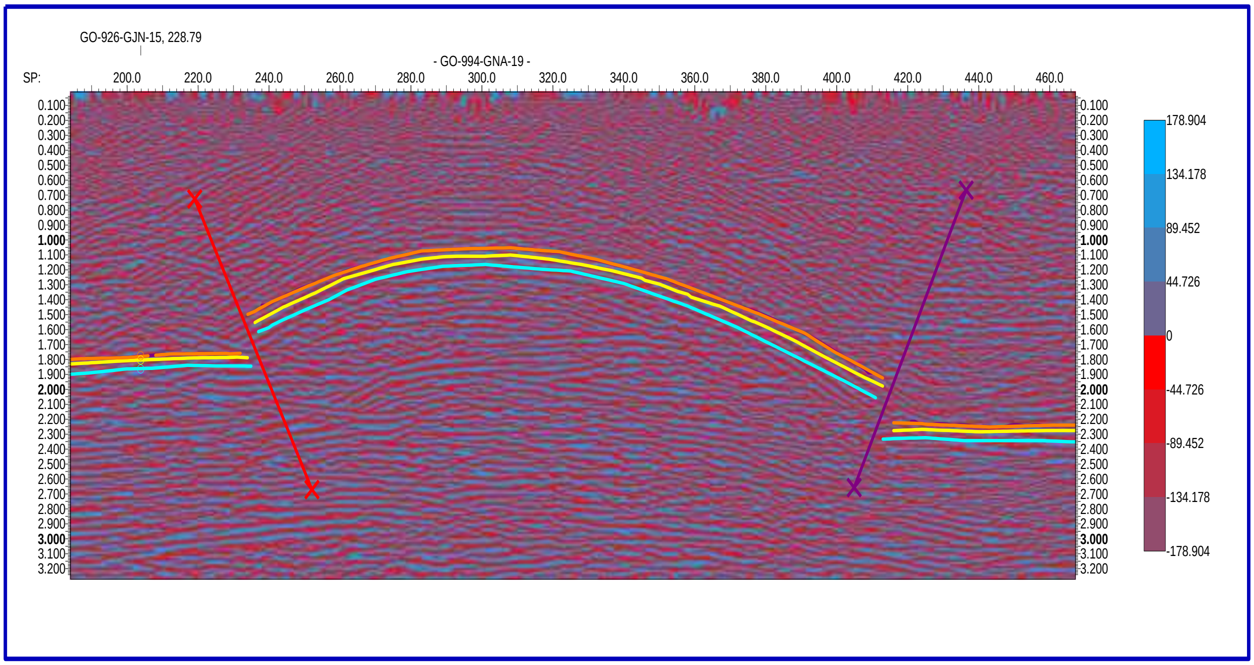

Figure 6.2: instantaneous phase attribute calculated for seismic line GNA-19

6.4 Average Energy

Average energy is a post-stack wavelet attribute, in which, within a specified window the square root of the sum of squared amplitudes is calculated and divided by their number of samples. The wavelet attributes are computed at the peak of the envelope, which represent the attributes of the wavelets within a zone defined by the trace envelope minima. These attributes indicate spatial variation of the wavelets and therefore relate to the response of the composite group of individual interfaces below the seismic resolution. The attribute has a blocky response and individually highlights the seal, reservoir and source rocks as shown in (figure 6.3)

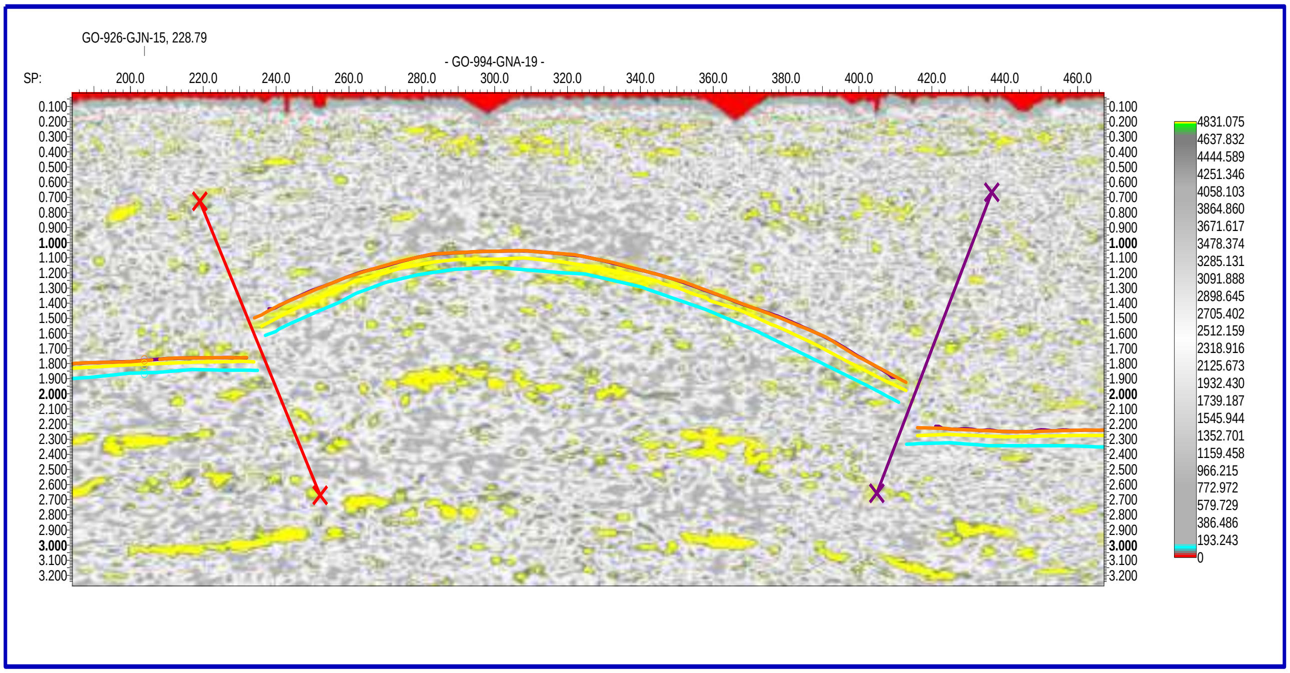

Figure 6.3: Average energy attribute calculated for seismic line GNA-19 confirming the interpreted horizon.

Conclusions

- The pop up Anticline Structures are proved to be identification for the area for accumulation of hydrocarbon.
- The repetition of Eocene strata in Missakeswal area due to over thrusting. However due to Lack of log data and lack of control on the seismic data, the repeated portion of Eocene age is not marked and confirmed.
- Reflectors of two formations marked on seismic section, with the help of synthetic seismogram of missakeswal-03. Time and depth contour maps show the presence of pop-up anticline structures in study area.
- 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.
- Contour Maps of time and depth shows the presence of pop-up anticline structures in Missakeswal Area.
- The petrophysical interpretation of well misakeswal-03 leads us to probable zones for hydrocarbon extraction in khewra sandstone formation which show the 60.43% of hydrocarbon in zone of interest.
- Further facies analysis also confirm the zone of interest by crossplotting logs

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