2D INTEGRATED SEISMIC INTERPRETATION, PETROPHYSICAL ANALYSIS, ROCK PHYSICS BASED FACIES ANALYSIS , CRUSTAL SHORTENING, VELOCITY MODEL BUILDING .

&

MODEL-BASED INVERSION ANALYSIS OF MISSAKESWAL AREA, UPPER INDUS BASIN PAKSITAN .

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CERTIFICATE

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بسم الله الرحمن الرحيم

To start with the greatest name of Almighty Allah. Most gracious and merciful, with Him is the knowledge of the Hour, He sends down the rain, and knows that which is in the wombs. No person knows what he will earn tomorrow, and no person knows in what land he will die. The knower of the unseen is Allah these are the keys of the unseen, whose knowledge Allah alone has kept for himself and no one else knows them unless Allah tells him about them.

DEDICATION

I would like to dedicate this thesis work to my parents, Brothers, Sisters whose love, encouragement, guidance and prays make me able to achieve such success and honor.

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

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ABSTRACT

The present study pertains to the modeling of the productive zones from seismic and well log data. This was carried out by seismic lines GNA-14, GJN-16, GJN-26 and well logs data (LAS format) of Missakeswal-03 provided by the Directorate General of Petroleum Concession (DGPC). The area is a part of Potwar sub-basin. The area is important for its hydrocarbon (oil and gas) structural traps. Missakeswal oil field is located at the distance of 60 kms in the South- East of Islamabad. The field was discovered in June 1991 and came on regular production from December 1992.

The seismic interpretation shows pop-up structures bounded by thrust faults. After time to depth conversion the true structural geometry is obtained in the form of depth sections. The horizons were identified using formation tops from wells and their depths were confirmed through correlation with synthetic seismogram from Density log (RHOB) and Sonic log. Time, depth and horizon velocity contour maps of the horizons of interest have been generated to understand the spatial geometry of the structures. Crustal shortening analysis has also been carried out on the depth section which indicates a compressional regime. Seismic structural model shows major thrust faults, which confirm the compressional tectonic regime in the study area. The petrophysical analysis for the selected zones of the interest shows reservoir quality. 2-D seismic model and synthetic seismic model confirms the position and depth of the marked horizons, relief and structural configuration of the study area. Rock Physics cross-sections have generated to further confirm the interpretation.

TABLE OF CONTENTS

LIST OF FIGURES

1 CHAPTER 1 INTRODUCING AREA

1.1 INTRODUCTION

Hydrocarbons are vital resources for the economics of any country. Hydrocarbon exploration (or oil and gas exploration) is the search by petroleum geologists and geophysicists for hydrocarbon deposits beneath the Earth's surface, such as oil and natural gas (Tissot et al, 2012). Geophysicists are applying different techniques for exploration of hydrocarbons. Different geophysical methods are mostly used for hydrocarbon exploration in which well logging and seismic method is of great importance. Seismic reflection surveying is the most extensively used and familiar geophysical technique (Steepless et al, 1997). Seismic interpretation conveys the geologic meaning of seismic data by extracting subsurface information from it. Seismic interpretation technique has several steps which involve picking of fault and horizons, fault polygons, applying seismic attributes, time contour and depth contour maps.

Seismic structural interpretation involves identifying proper geological structures (i.e. orientation of faults, information about reflections i.e. horizons, and depositional settings) for probable accumulation of hydrocarbon. Tectonic setting usually oversees the structural network and associated features. Structural interpretation of 2D seismic data mainly involves primary evaluation by mapping a number of subsurface reflectors (horizons) and is generally accomplished in less explored areas (Nanda, 2016). For modification of results obtained from seismic data well logging provide a best way. Well logging is practice of making a detailed record of geologic formations penetrated by borehole (Pruchnik and Paul, 1988). Petrophysical evaluation of well log data has always been fundamental for documentation and valuation of hydrocarbon bearing zones (Kumar et al, 2017).

1.2 OBJECTIVES

The main objectives of this dissertation based on seismic section interpretation are:

- 2-D Structural interpretation to find out the structural traps and horizons of the formation
- Create subsurface Velocity model that can be used for 2D seismic modeling
- Petrophysical analysis for the identification of the hydrocarbon bearing zone.
- Rock Physics and facies modeling

1.3 INTRODUCTION TO AREA

Missa Keswal area lies in the Upper Indus Basin further more in Potwar Basin and politically in Punjab province of Pakistan. It is located 60km's southeast of Islamabad. The field was discovered in June1991 and its regular production started in December 1992.The Potwar sub basin is located in the western foothills of Himalayas in the northern Pakistan. It includes the Potwar plateau, the Salt range and the Jhelum plain. It is bounded in the north by Main Boundary Thrust-MBT, Salt range in the south, Jehlum strike slip fault occurring in the east and Indus River and Kalabagh strike slip fault in the west. Kohat plateau happens to be the western strike extension of the Potwar sub basin with relatively intensely deformed structures.

The area is located on following geographic coordinates

- Latitude 32° 12' to 32°55' North
- Longitude 72° 22 to72° 55' East

1.3.1 DATA USED

The data used for current research includes highlighted seismic lines and a well i.e. Missakeswal -03. Seismic data is of three different vintages 1992, 1993 and 1994 acquired by orient petroleum Inc in which 2 are dip lines and 1 is strike line. The orientation of seismic lines with the location of wells is shown in the base map Fig 1.2 The detail of these seismic lines is given in Table 1.1

Line Name	Nature of Line	Orientation	Wells
GJN-15	Strike	SW-NE	
GJN-16	Dip	SE-NW	Missa-03
GNA-14	Dip	SE-NW	
GNA-11	Strike	SW-NE	Missa-04
GNA-16	Dip	SE-NW	
GNA-19	Dip	SE-NW	Missa-02

GNA-20	**Strike**	**SW-NE**	
GNA-21	**Strike**	**SW-NE**	
QZN-03	**Dip**	**SE-NW**	
QZN-04	**Dip**	**SE-NW**	Missa-01
QZN-05	**Dip**	**SE-NW**	
QZN-06	**Dip**	**SE-NW**	
GNA-10	**Dip**	**SE-NW**	
GJN-20	**Dip**	**SE-NW**	
GJN-26	**Strike**	**SW-NE**	

Table 1.1: Seismic reflection data used for Base map

1.3.2 DATA FORMATS

The data set used extensively in preparing this dissertation contained data regarding.

- SEG-Y
- LAS
- Navigation
- Velocity Data.

1.3.3 BASE MAP

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.

Following 2-D reflection seismic lines are used to construct the Base map of 2-D seismic survey for given study area as shown in Figure

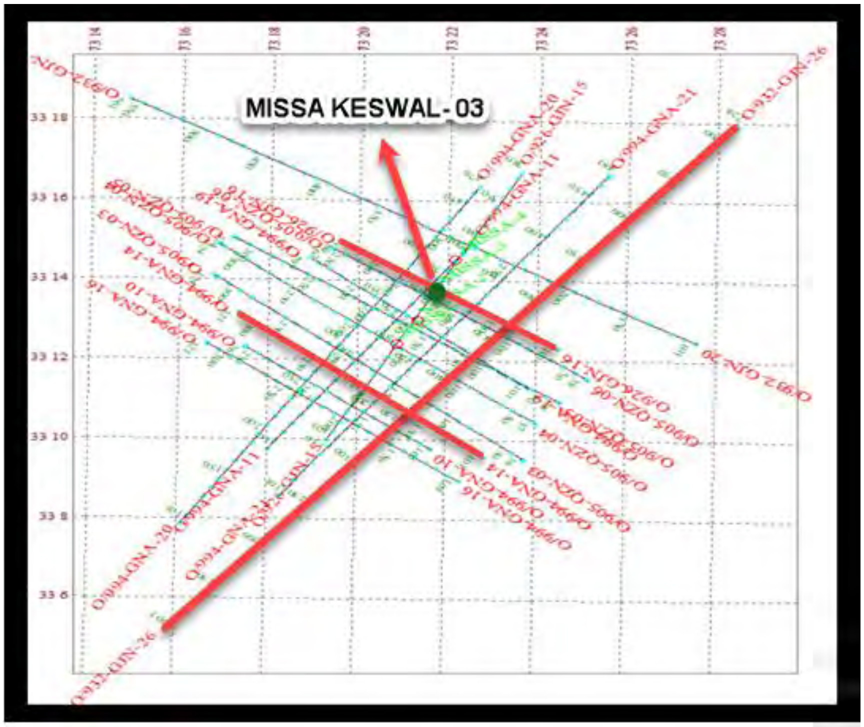
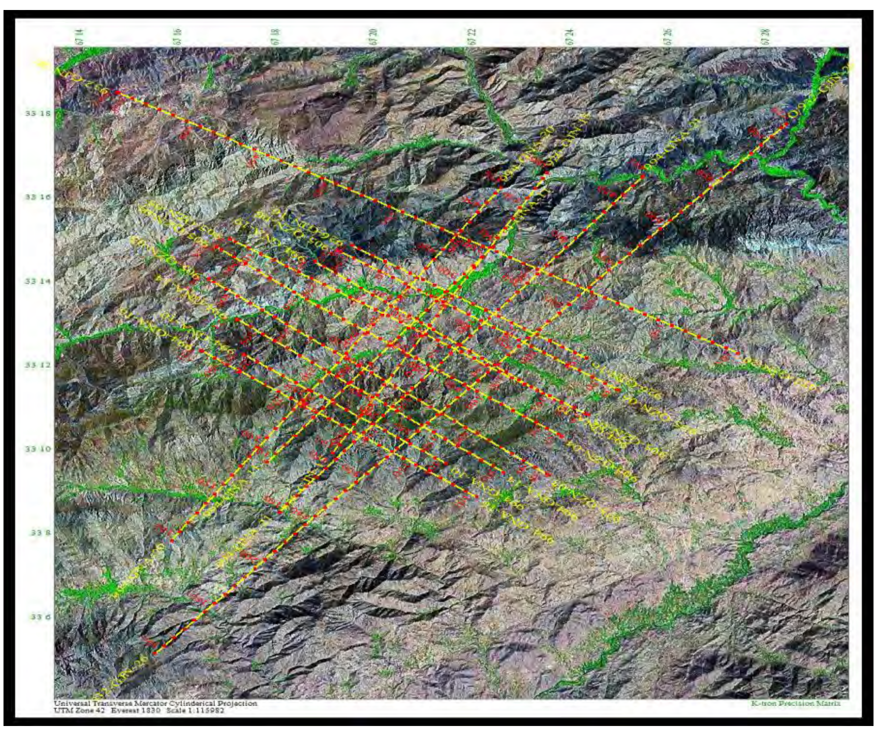
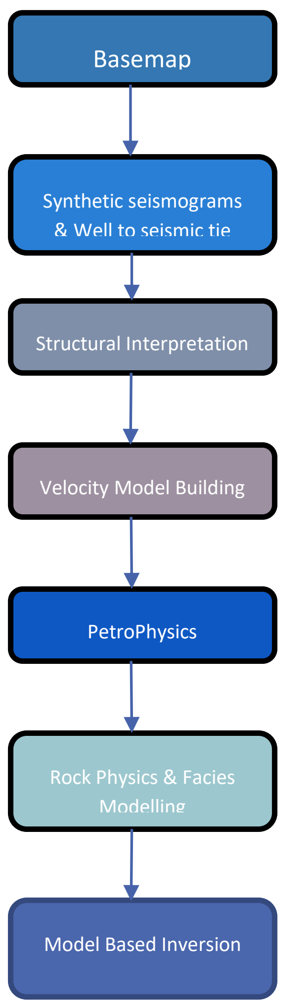


Figure 1.1 (Base Map of study Area)



1.4 METHODOLOGY

Seismic reflection data of the Upper Indus Basin of Missakeswal area is given in order to interpret the sub surface structures and other properties. In this practice, software **Kingdom 8.8** was used for structural interpretation. For this purpose seismic lines data were uploaded on kingdom, synthetic seismogram was generated, from well. After that faults and horizons were marked on seismic section, polygons were developed and time and depth contours were made. Petrophysical analysis have been done by using software **GEOGRAPHICS DISCOVERY** for the identification of hydrocarbon bearing zones. Rock physics and Facies modelling were performed using **Wavelet** software. Velocity models were developed using software **K-tron X-Works**. Root mean square velocities were used for generating velocity models. After that, velocities were converted into depths. Software **HAMPSON RUSSELL** is used for Model Based Inversion



1.5 SOFTWARE TOOLS AND APPLICATIONS

1.5.1 PRECISION MATRIX

- Base Map

1.5.2 SMT KINGDOM 8.8

- Structural Interpretation
- Synthetic Seismogram

1.5.3 GEOGRAPHIX

- Petrophysical Analysis

1.5.4 WAVELETS

- Rock Physics
- Facies Modeling

1.5.5 K-TRON X WORKS

- Velocity Analysis
- 2D Seismic Modelling

2 GENERAL GEOLOGY AND STRATIGRAPHY

2.1 GEOLOGY OF PAKISTAN

Pakistan comprises of three main geological subdivisions referred to as Laurasian, tethyan and Gondwanaland domains (Kazmi, et al., 1997). Their origin is considered to be Late Paleozoic. Pangea was the name of the super continent from which all the continents are drifted apart. Laurasia was drifted towards north and Gondwanaland to south and they were separated by Tethys, the seaway which was the result of split of super continent.

Pakistan is located at the junction of Gondwanian and Tethyan domain (fig 2.1). Subsequently, thrusting shifted southward, along the Main Central Thrust and the Main Boundary Thrust, respectively. South of MBT, the Salt Range/Potwar Plateau (SR/PP) represents the Himalayan forelands fold and thrust belt in Pakistan. The SR/PP manifests itself as a broad (about 100 km) thrust sheet that is relatively undeformed towards foreland and is strongly deformed toward hinterland in the footwall of the MBT.

The region consists broadly of a number of faulted anticlines and synclines superimposed to the main Soan syncline, which trends from east-northeast to west-southwest, roughly collinear with the Soan River. The axial planes of the folds and fault planes lie parallel or sub-parallel to the major regional trend. The intensity of deformation of these faults, fold structures increases away from Soan syncline towards Kala Chitta ranges and salt Range. Moreover, the faults replace the crests of the anticlines, which provide an example of the crustal tectonics, where most of the movements had been taken place in the crustal area.

2.2 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 orogen;

(b) In the southwest, there is an active boundary of oceanic lithosphere subducting 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

2.3 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 foredeep, 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.

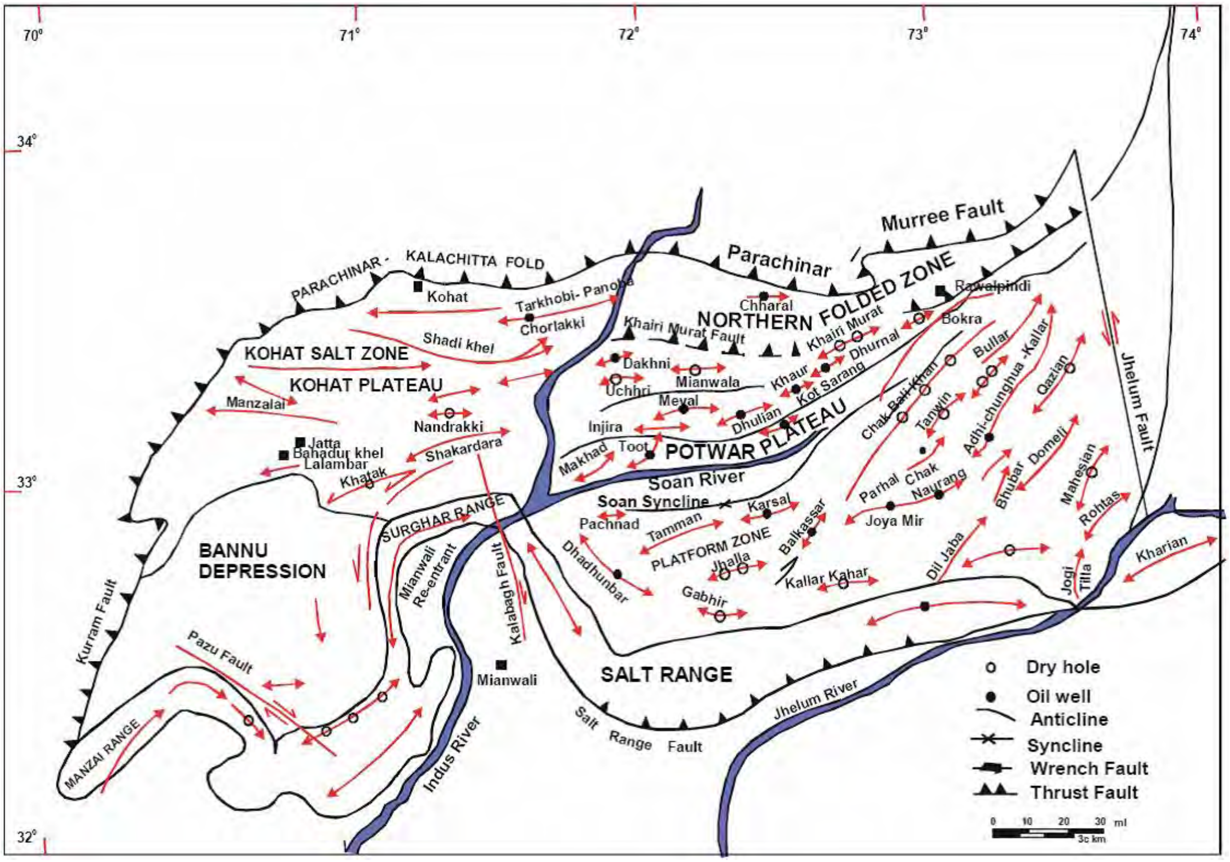


Figure 2.: Tectonic division of Potwar Basin (Shami and Baig,1998)

2.4POTWAR PLATEAU

In Potwar basin, the Upper Indus basin is one of the oldest oil producing basins in this region. Figure 2.3 shows the oil fields and exploration trends in the area. Here, mostly the productive reservoirs are Eocene and Paleocene carbonates although more recent exploration are some deeper targets zones of Permian formations.The Potwar is surrounded by Kalachitta ranges and Margala Hills, the Indus River and Kohat Plateau to the west, and the Jhelum River and the Hazara-Kashmir syntaxes to the east. It is covered by the Siwalik sequence in large scale, although at some places upper Eocene shales and limestone's locally in folded outliers. The Soan syncline divides the Potwar Basin into two major zones as Northern Potwar Deformed Zone (NPDZ) and Southern Potwar Platform Zone.

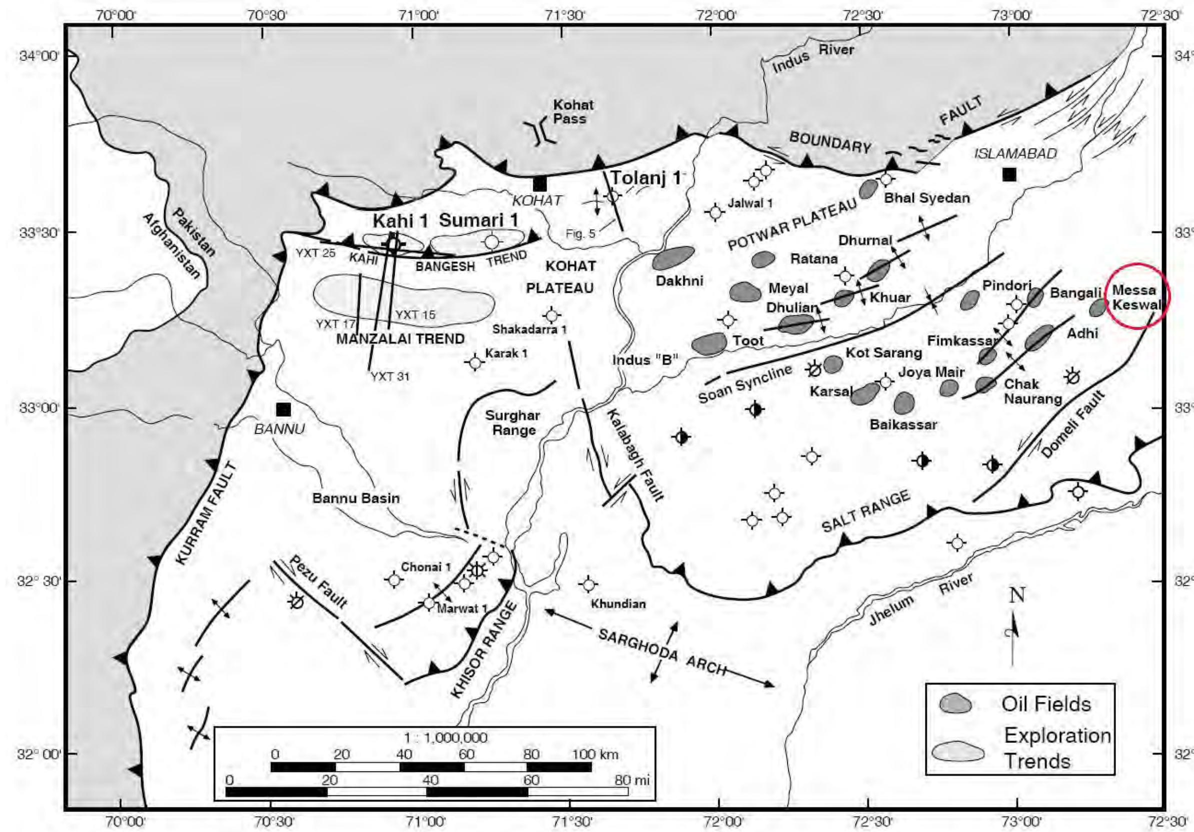


Figure 2.1 Structural Features Of Kohat Potwar (William, et al., 1998).

Figure 2.1 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. Study area is also highlighted (William, et al., 1998).

2.5 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.

2.6 INDUS BASIN

The geological history of Indus basin goes back to Precambrian age. The Paleo topographic 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. (Wadood et al, 2020)

Indus Basin is classified as follows;

(a) Upper Indus Basin

(b) Kohat sub-basin

(c) Potwar sub-basin

(d) Lower Indus Basin

(e) Central Indus basin

(f) Southern Indus basin

2.7 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. (Jamil et al, 2012)

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

2.8 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)

2.9 MAJOR FOLDS IN THE POTWAR SUB BASIN

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

2.10 STRATIGRAPHY

The Stratigraphy of the 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, and lithology is given in (Fig).

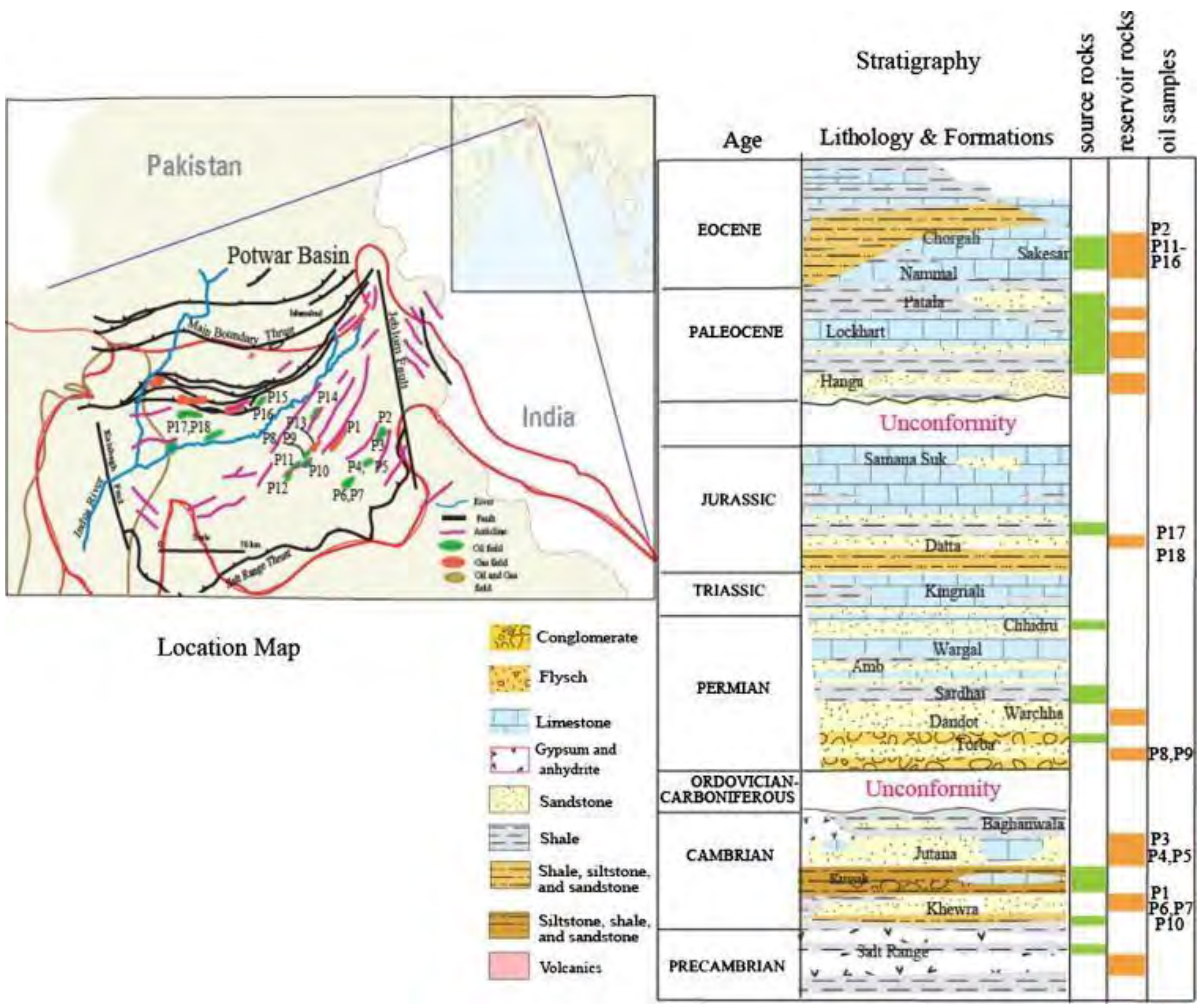


Figure 2.2 (Genral Stratigraphy of Potwar Sub-Basin (Moghal et al., 2007))

2.11 HYDROCARBON POTENTIAL OF THE POTWAR AREA

2.11.1 HYDROCARBON OCCURRENCE

The Potwar is the oldest oil province of the world. The first commercial discovery was made in 1914 at Khaur. The eastern Potwar region is an important oil and gas producing area. The oil and gas discoveries in the eastern part of Potwar plateau, located southeast of Soan-Syncline are mostly from NE-SW elongated anticlines. The Eocene to Cambrian plate form deposits are about 40m thick in the eastern Potwar .Throughout the eastern Potwar ,oil production has been established from Eocene-Permian and Cambrian age rock .The areas which are producer in the Potwar are shown in the Figure

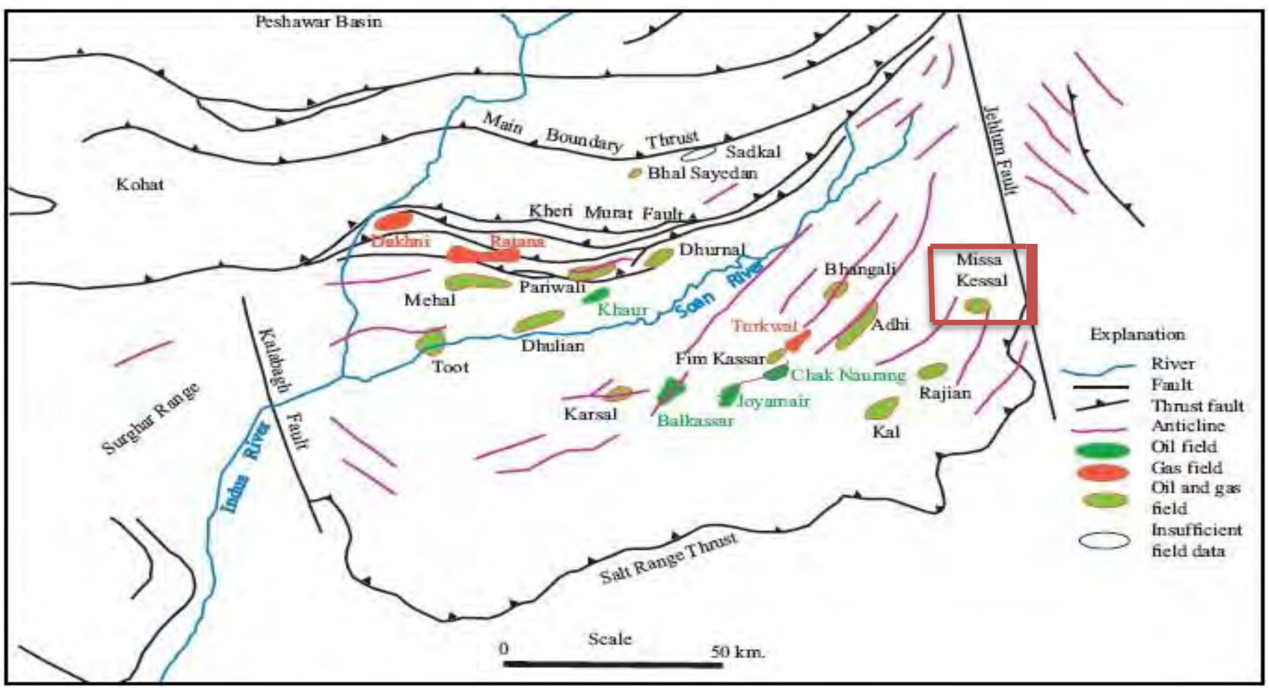


Figure 2.3 Oil and Gas field of Potwar-Sub-Basin. Missakeswal field is also highlighted. (Jaswal, et al., 1997)

2.11.2 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. Potwar region which is traditional oil producing area of Pakistan has the average geo-thermal gradient of the order of 2^0C per 100 meters. Hence the oil window lies between 2750-5200 meters. (Kadri, 1995)

2.12 SOURCE & RESERVOIR ROCKS OF STUDY POTWAR

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, Meyal and Missakeswal. Early Eocene carbonate are good source and reservoir rock, Sakesar and Chorgali having fractured Limestone having hydrocarbon potential in Adhi(PPL) , Dakhni(OGDCL), Missakeswal 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, 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).

3 CHAPTER SEISMIC INTERPRETATION

3.1 INTRODUCTION

This chapter deals with the structural interpretation of 2D seismic data of **Misss Keswal area.** Seismic interpretation is the transformation of the 2Dseismic reflection data in to a Geological image by the application of corrections, migration and time to depth conversion The seismic reflection data interpretation usually involves calculating the position and identifying geologically hidden interfaces or sharp transition zone formed seismic pulses return to ground surface by reflection. The impact of varying geological condition is brightened along the profiles to transform the irregular recorded travel time in to acceptable sub surface models. This is very important for confident approximation of the depth and geometry of the bed rock or target horizons.

3.2 MARKING AND IDENTIFICATION OF SEISMIC HORIZONS

To distinguish different horizons on seismic sections is an important query in the interpretation of seismic data, which may be structural or Stratigraphic. For this purpose the seismic data is correlated with well Top data and already known geology of area (Dobrin and Savit 1988).The first step of Seismic data interpretation is to mark the prominent reflectors also called horizons on the seismic sections. A reflector (Horizon) is defined as "an interface or boundary between two rock units (formations)". Those reflectors are selected which are real, show strong character, continuity and can be followed throughout the seismic line and can be correlated at tie points of other seismic lines of the area. Four prominent Horizons are marked i.e (Murree Sandstone , Chorgali Limestone , Sakesar Limestone , Lockart limestone) on the seismic lines. These horizons were marked through the same steps and all the sections are correlated at their respective tie points. The reflectors are strong enough to be picked because of contrast in acoustic impedance that is ultimately caused by changes in lithology. Normally the VSP data is used for naming the marked horizons

3.2.1 MISSTIE ANALYSIS

After marking horizons on a seismic section, the next step is to tie the seismic section with the other intersecting seismic lines of the area. In this study horizons on the seismic line 0/926-GJN-16 are marked first because it is nearer to the MISSA KESWAL-03 The tie points of the lines are confirmed from the base map, where tie points of the lines have been mentioned. At the tie point of both intersecting seismic lines have same horizons at the same time. If the horizon does not have same time then there may be mistie that may be removed later on, taking seismic line 0/926-GJN-16 as a reference line, all other seismic sections used in the study are marked. At the tie point we not only mark the horizons but also mark the points of faults are also marked in the same manner all the faults were correlated. Hence the first step before the Marking of the horizons is the generation of the synthetic seismogram. The steps used in generation of synthetic seismogram are mentioned below.

3.2.2 SYNTHETIC SEISMOGRAM

Synthetic seismograms provide 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 seismograms are useful tools for linking drill hole geology to seismic sections, because they can provide a direct link between observed lithology's and seismic reflection patterns (Handwerger et al., 2004).

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

- ✓ Load the Las file of the well in the software.
- ✓ Open 1D forward modeling Project and select the well logs.
- ✓ Integrate the sonic log to rescale from depth in meters to two-way travel time in seconds.

Compute velocity from sonic log for P and S wave

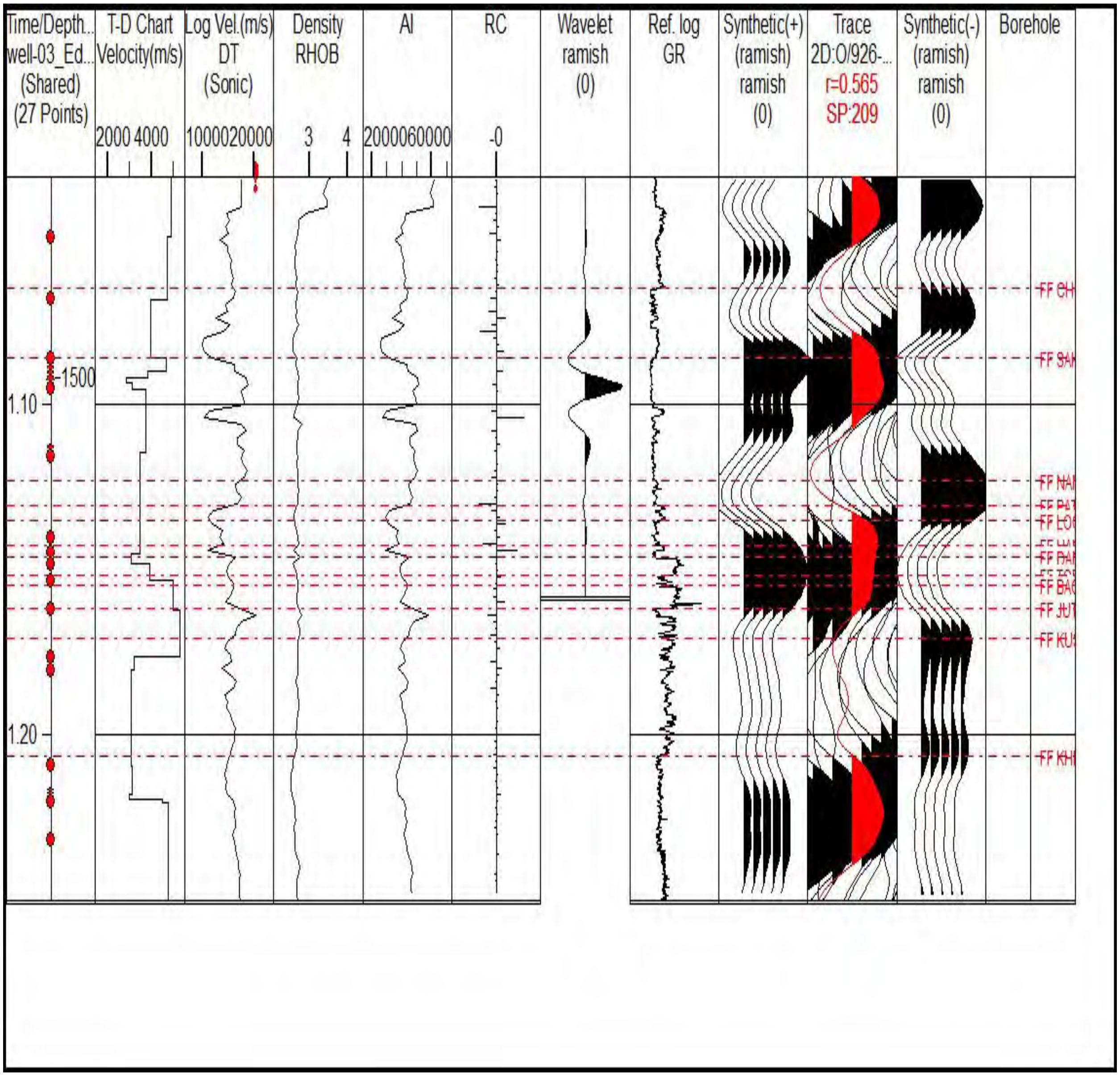


Figure 3.1 SYNTHETIC SEISMOGRAM

Create a TD chart for the well from the velocity logs.

- ✓ Compute Acoustic impedance log using velocity and density log.
- ✓ Compute the reflection coefficients from the time-scaled velocity log.
- ✓ Convolve the reflection coefficient log with the Extracted wavelet to generate amplitudes of the synthetic seismogram.

3.3 FAULT MARKETING

Skills and thorough experience in Geology and Geophysics is required for Conventional seismic interpretations (Mc. Quillin et al., 1984). Fault marking on real time domain seismic section is quite a hard work to do without knowing tectonic history of area (Sroor, 2010). Faults are mark on the basis of breaks in the continuity of reflection. This Discontinuity of the reflector shows that the data is disturbed here due to the passing of the faults.

3.4 HORIZON MARKING

According to the Schlumberger Oilfield Glossary, “horizon is an informal term used to denote surface in or of rock, or a distinctive layer of rock that might be represented by a reflection in seismic data. Reflectors corresponding to one horizon may appear disconnected as a consequence of noise or of the interference with another geological object. One can visually recognize that several disconnected reflectors are attached to the same horizon, by comparing their thickness, their orientations, their colors (amplitude value) and their time relationships with other reflectors. Basic aim in seismic section interpretation is picking a horizon, and mostly, reflections on the section represent a certain geological formation where change in acoustic impedance occurred and this is the seismic way to interpret subsurface stratigraphic features. Following are interpreted seismic sections of all lines assigned to me for completion of this dissertation .

3.5 INTERPRETATION OF SEISMIC DIP LINE 0/926-GJN-16

Shows well tie with real time domain section. In the interpretation of the line 0/926-GJN-16 the reverse faulting can be seen. Due to this reverse faulting the P0P UP structures are formed.

- The following color scheme is used to mark the horizon:

  - MURREE(blue)
  - CHORGALI (pink)
  - SAKESAR(yellow)
  - LOCKART(green)

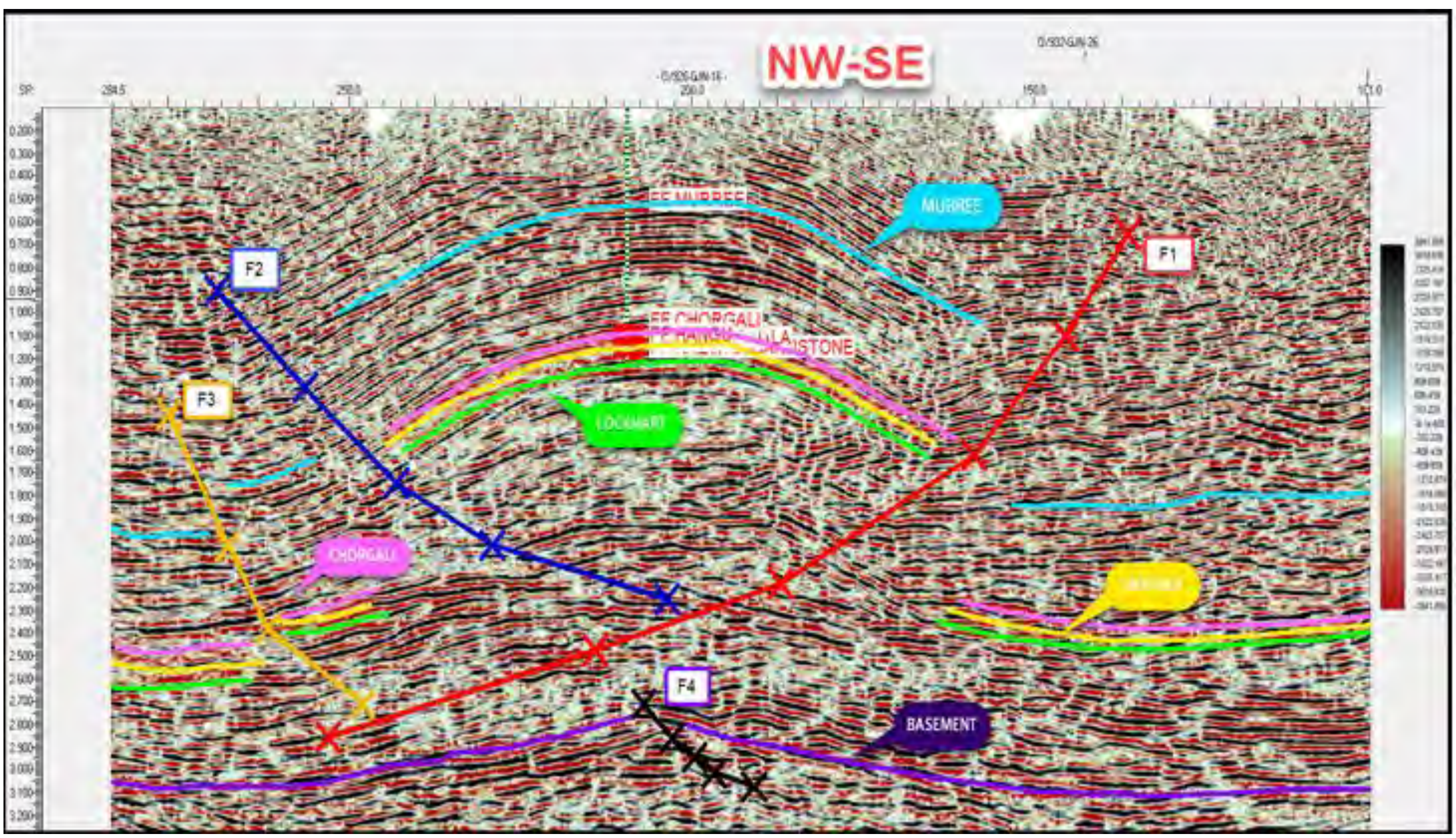


Figure 3.2 INTERPRETATION OF SEISMIC Dip LINE 0/926-GJN-16

3.6 INTERPRETING SEISMIC STRIKE LINE 0/932-GJN-26

The given seismic section doesnt show any faults. The reason behind is that the given line is a strike line .

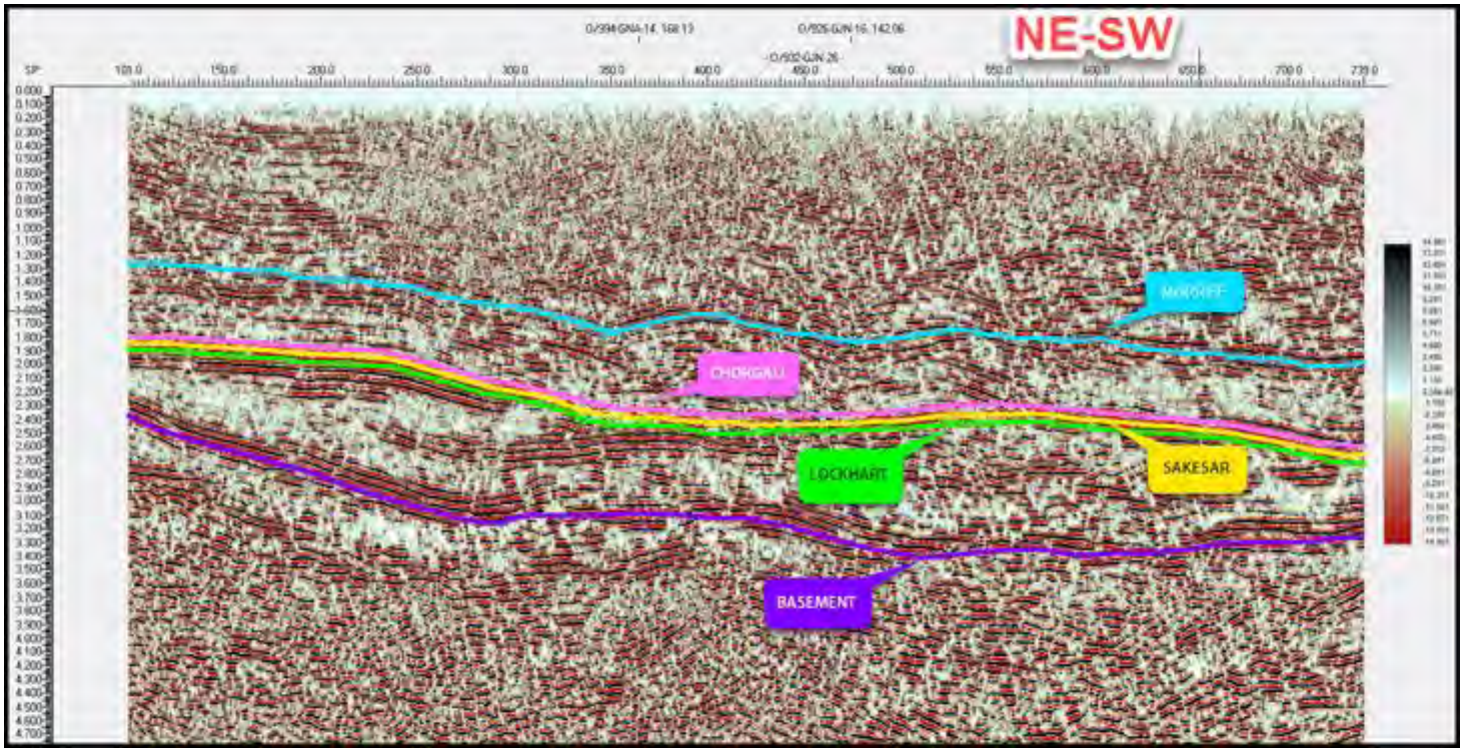


Figure 3.3INTERPRETATION OF SEISMIC STRIKE LINE 0/932-GJN-26

3.7 INTERPRETATION OF SEISMIC DIP LINE 0/994-GNA-14

After marking the seismic strike line 0/932-GJN-26 we mark dip line 0/994-GNA-14 with the help of strike line because this strike line was crossing all the dip lines which are shown in the base map.

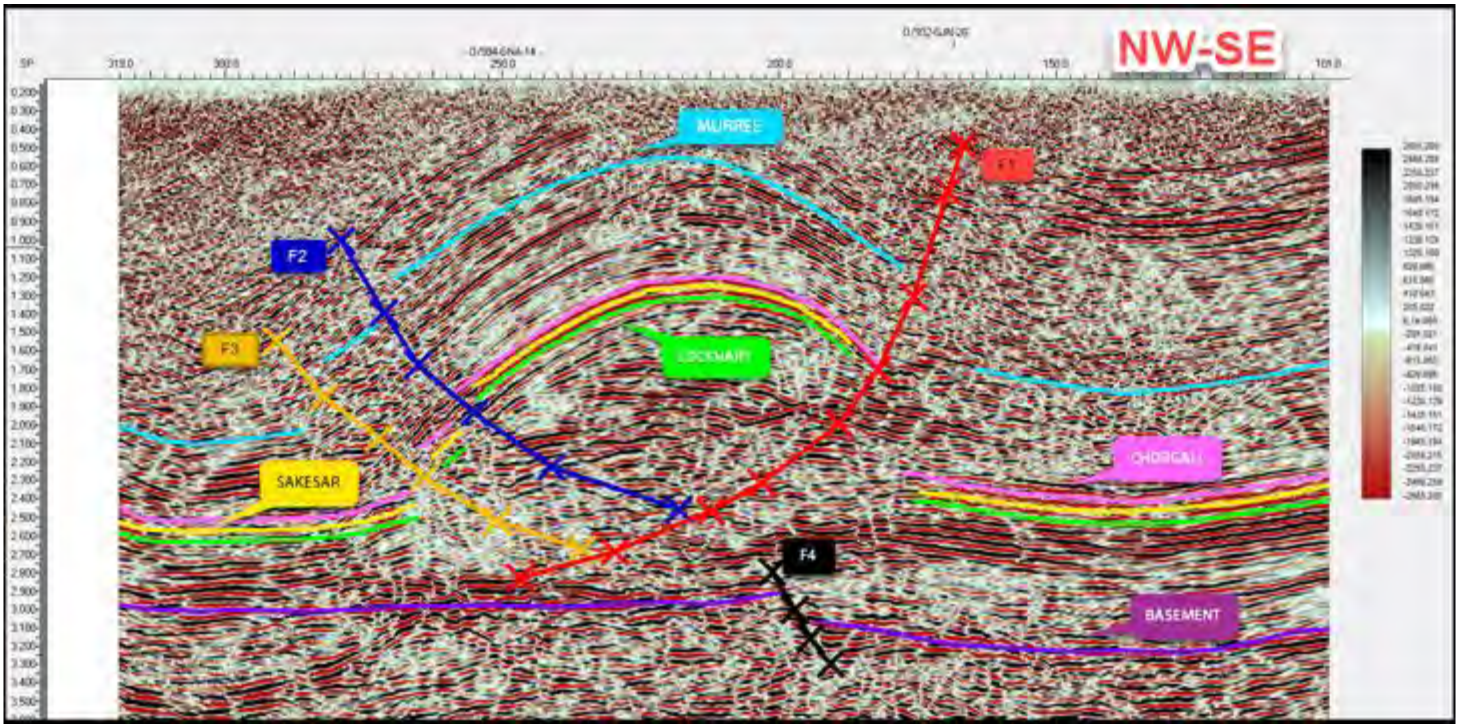


Figure 3.4Interpretation for dip line 0/994-GNA-14

3.7.1 CONTOUR MAPS

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

In constructing a subsurface map from seismic data, a reference datum must first be selected. The datum may be sea level or any other depth above or below sea level. Frequently, another datum above sea level is selected in order to image a shallow marker on the seismic cross- section, which may have a great impact on the interpretation of the zone of interest (Gadallah & Fisher, 2009).

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

3.8 TIME CONTOUR MAPS OF CHORGALI FORMATION

Chorgali formation is the main formation of interest; it is producing both Oil & Gas and is composed of limestone with some amount of shale contents on its upper portion. The two way time contour maps have been generated using the kingdom software. Chorgali formation is marked on the basis of seismic correlation from previous work in the area. Tectonically/structurally the area lies in the compressional regime, and at Chorgali Formation it is bounded by two major thrust faults both dipping inwards. Pop up structure is formed due to these major thrust faults. The shallowest contour is of 1.068 second showing upper most portion of the structure and deeper contour is 2. 649s .The orientation of the structure NE-SW, similar is the trend of the contours forming closures at some locations. Contours are at the farther distance along the northeastern side of the strike line rather than southwestern side.

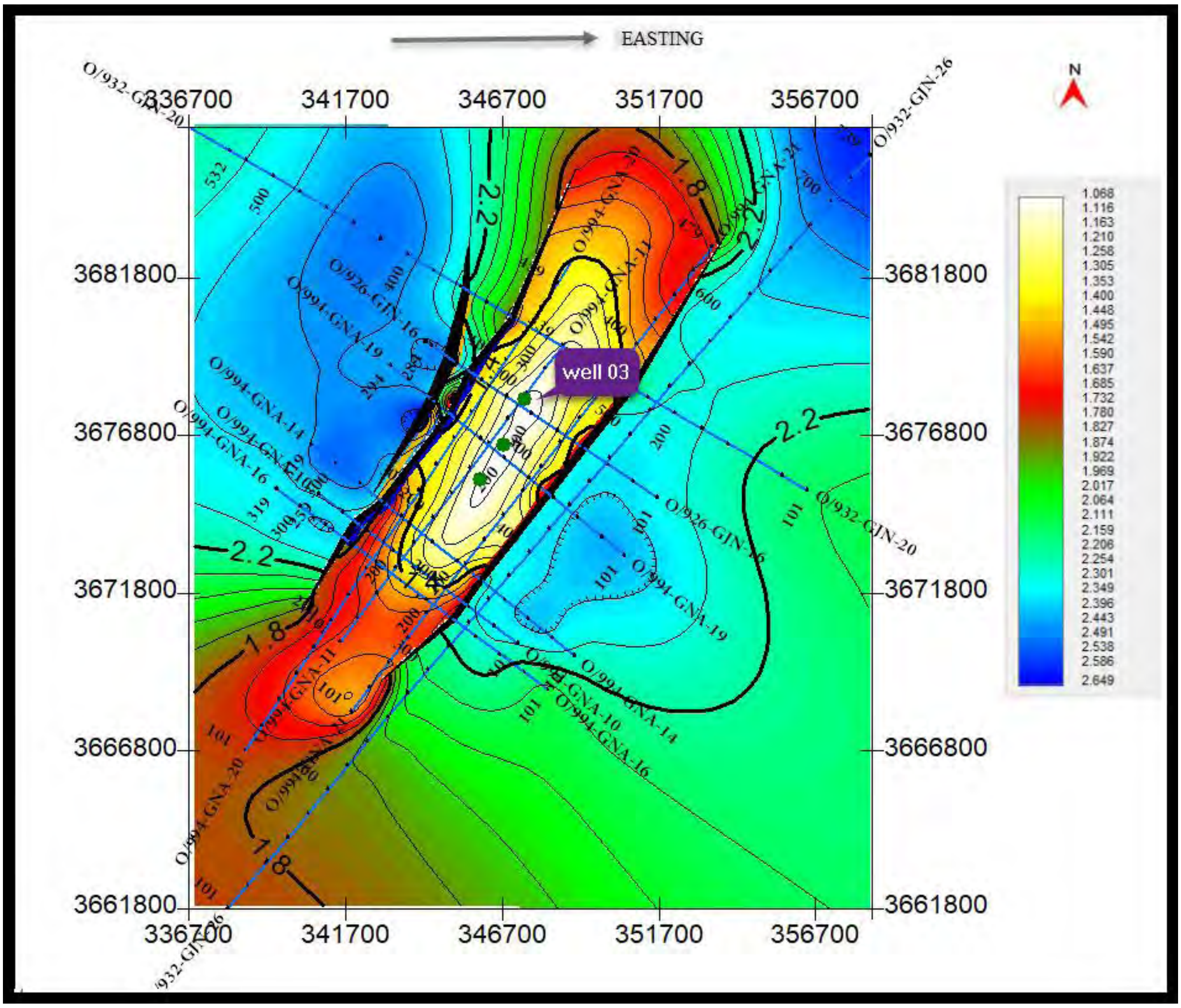


Figure 3.5Time Contour Map of Chorgali formation.

3.8.1 DEPTH CONTOUR MAP OF CHORGALI

Depth Contour map of Chorgali Formation has been prepared with incorporation of structure in depth section . In the depth contour map of Chorgali Formation the orientation and the dip of the structure is similar to its time contour map. The depth contour ranges between 854 meters to 3619 meters

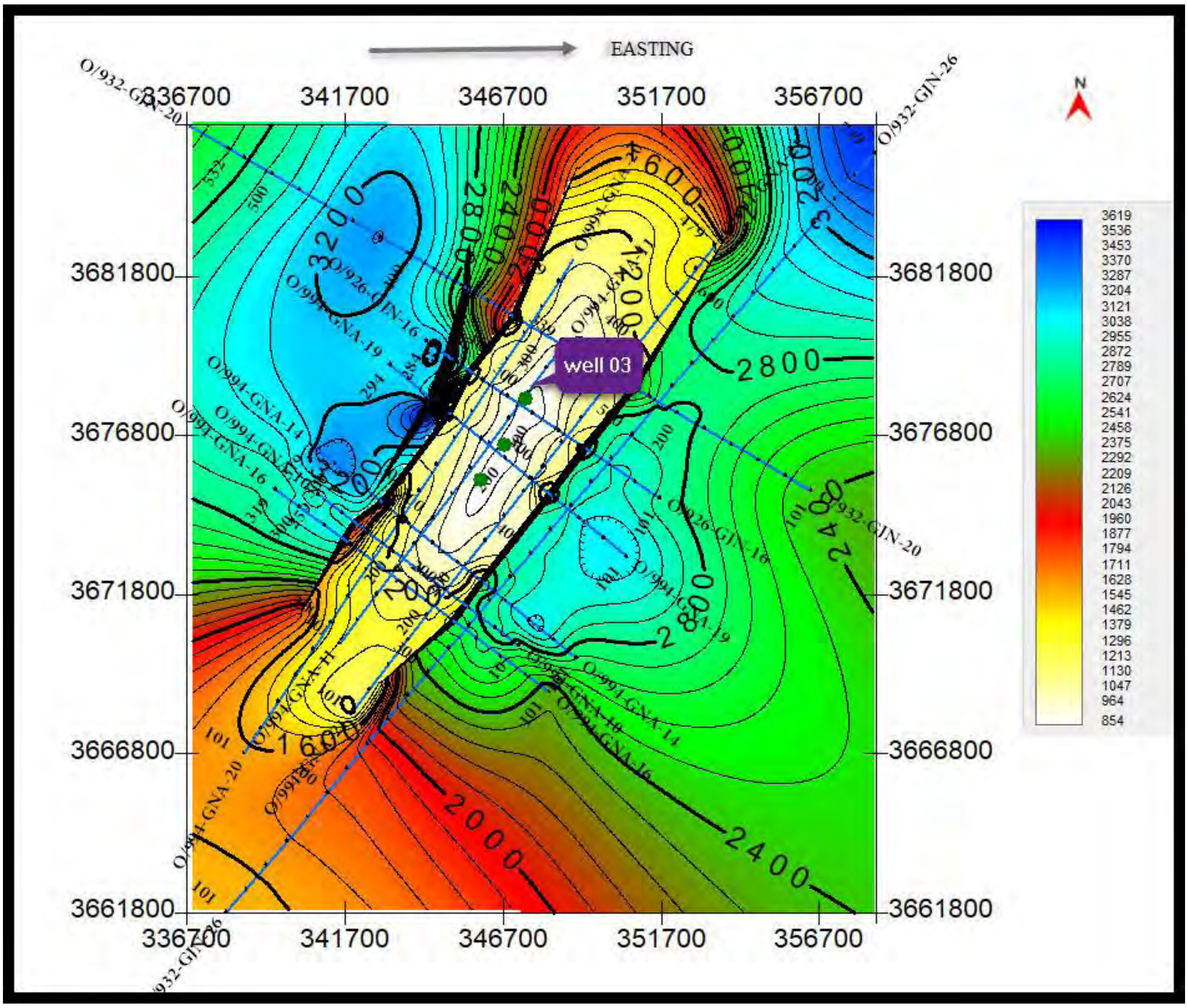


Figure 3.6 Depth Contour map of Chorgali

3.8.2 3D-SURFACE CONTOUR MAP OF CHORGALI FORMATION

Three-dimensional surface contour map constructed with faults show view of Chorgali formation. True picture of this horizon shows the actual trend of the structure in 3D.

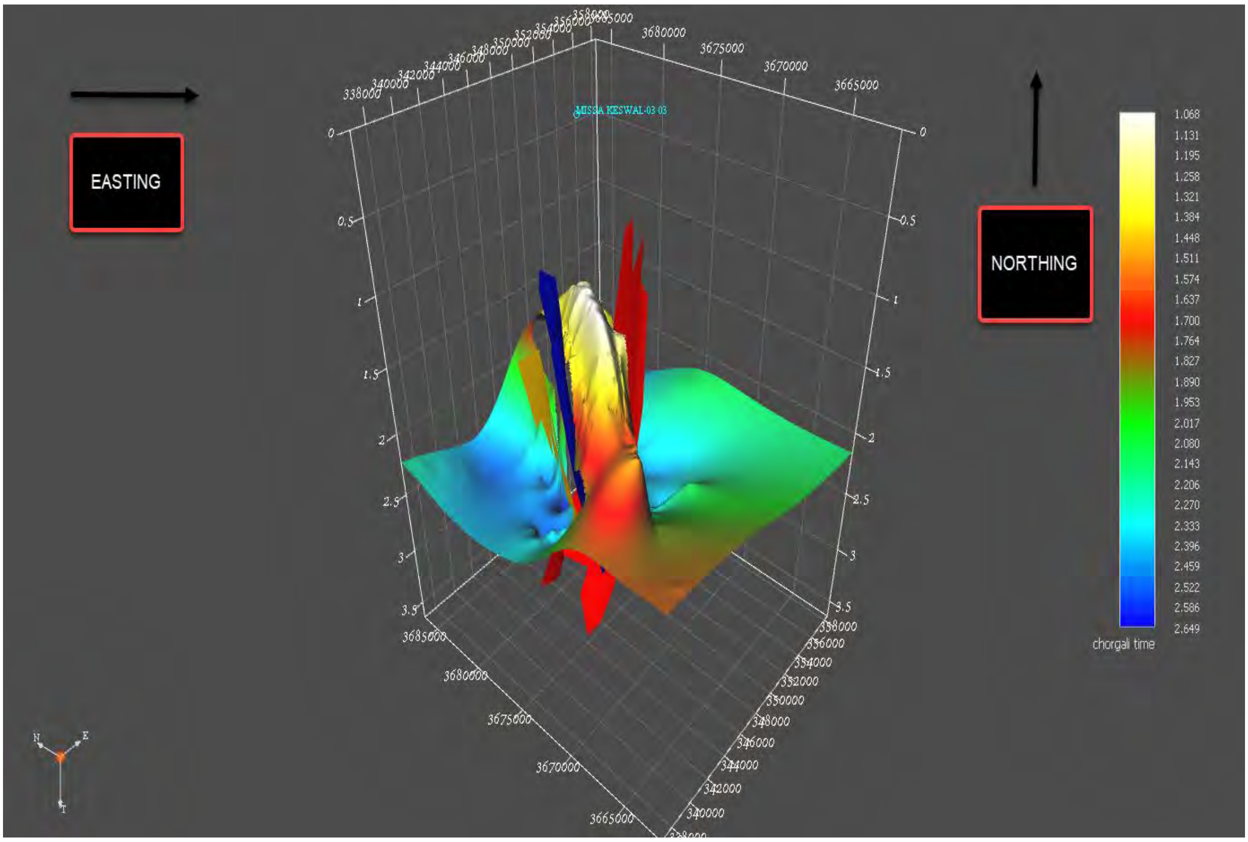


Figure 3.73D-Surface Contour Map of Chorgali formation

3.9 TIME CONTOUR MAP OF SAKESAR FORMATION

Time contour of Sakesar Limestone, as shown in the figure, Sakesar Limestone is marked on the basis of seismic correlation from previous work in the area. The shallowest contour is of 1.121 second showing upper most portion of the structure and deeper contour is 2.669.

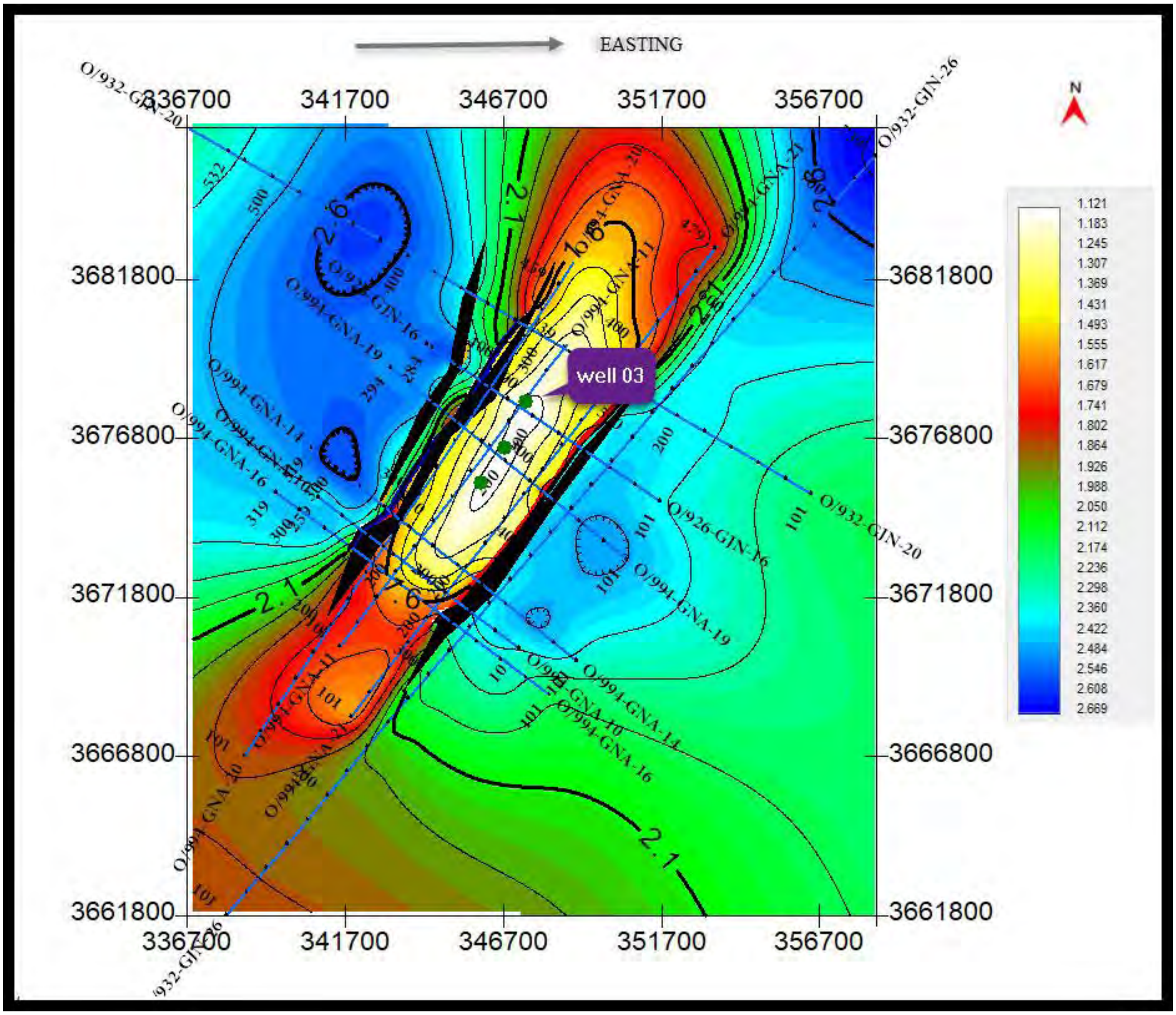


Figure 3.8Time Contour of Sakesar Formation

3.9.1 DEPTH CONTOUR MAP OF SAKESAR

The depth contour ranges between 896 meters and 3668 meters. Depth contour map of Sakesar Limestone is shown in the figure below.

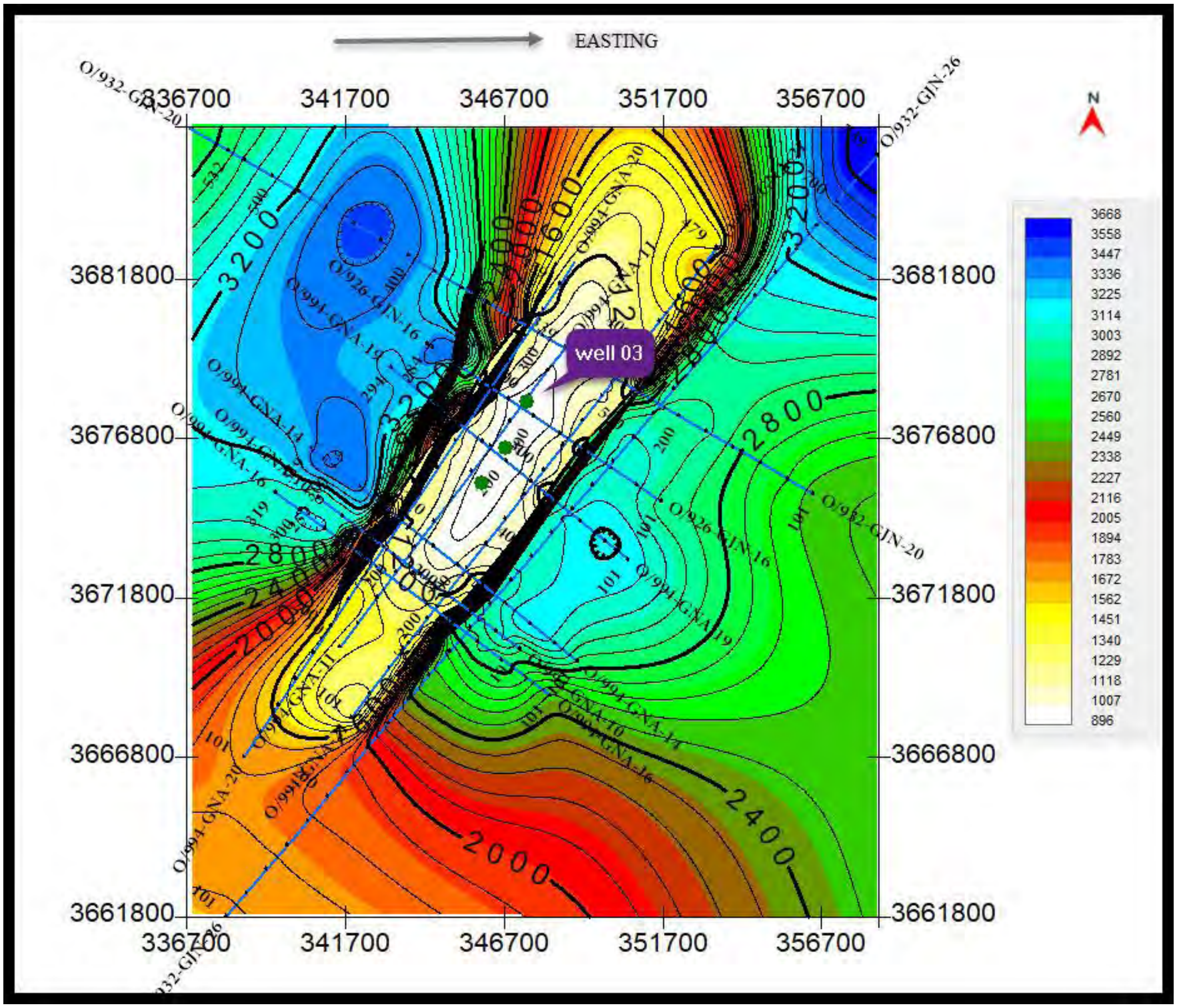


Figure 3.9Depth Contour map of Sakesar

3.10 TIME CONTOUR MAP OF LOCKHART FORMATION

The pattern of both Contour Maps confirms the sub-surface shape of the structure present there. Lockhart Formation is composed of limestone which is highly fossiliferous and act as a source rock. The shallowest contour is of 1.167 second showing upper most portion of the structure and deeper contour is 2.728.

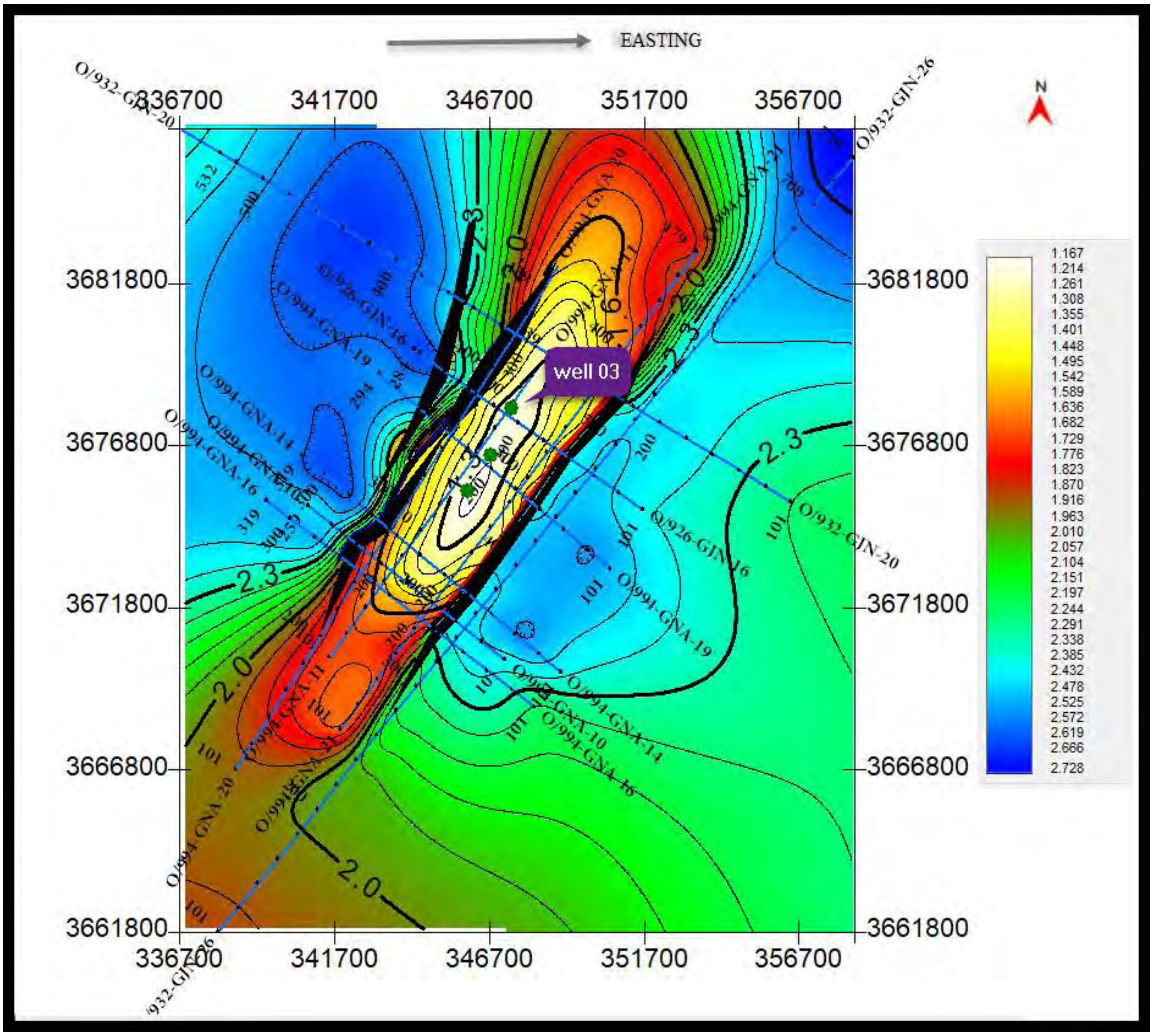


Figure 3.10(Time contour map of Lockhart Formation)

3.10.1 DEPTH CONTOUR MAP OF LOCKHART FORMATION

The depth contour ranges between 933 meters and 3806 meters.

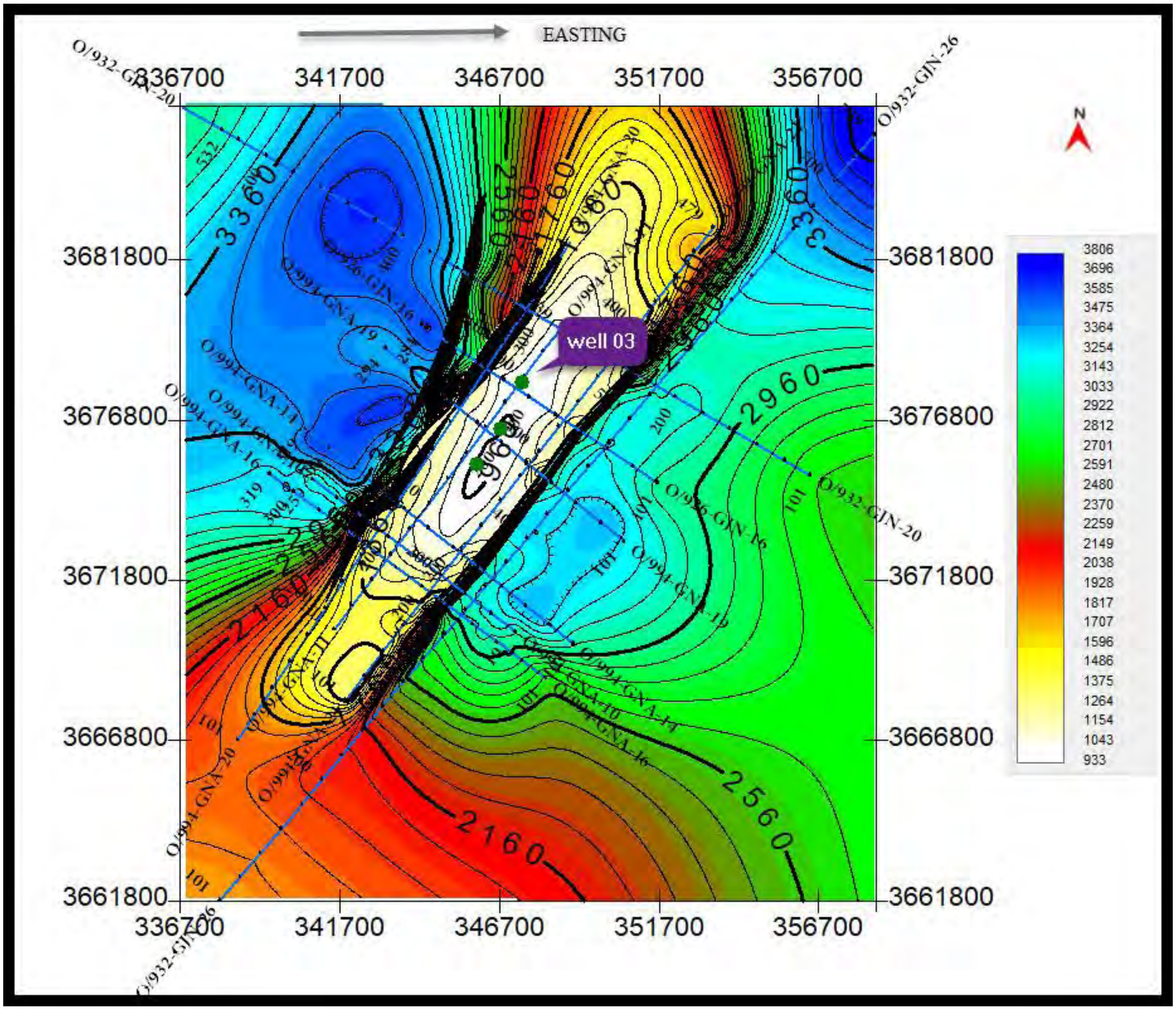


Figure 3.11 (Depth contour map of Lockhart Formation)

3.11 TIME CONTOUR MAP OF MURREE FORMATION

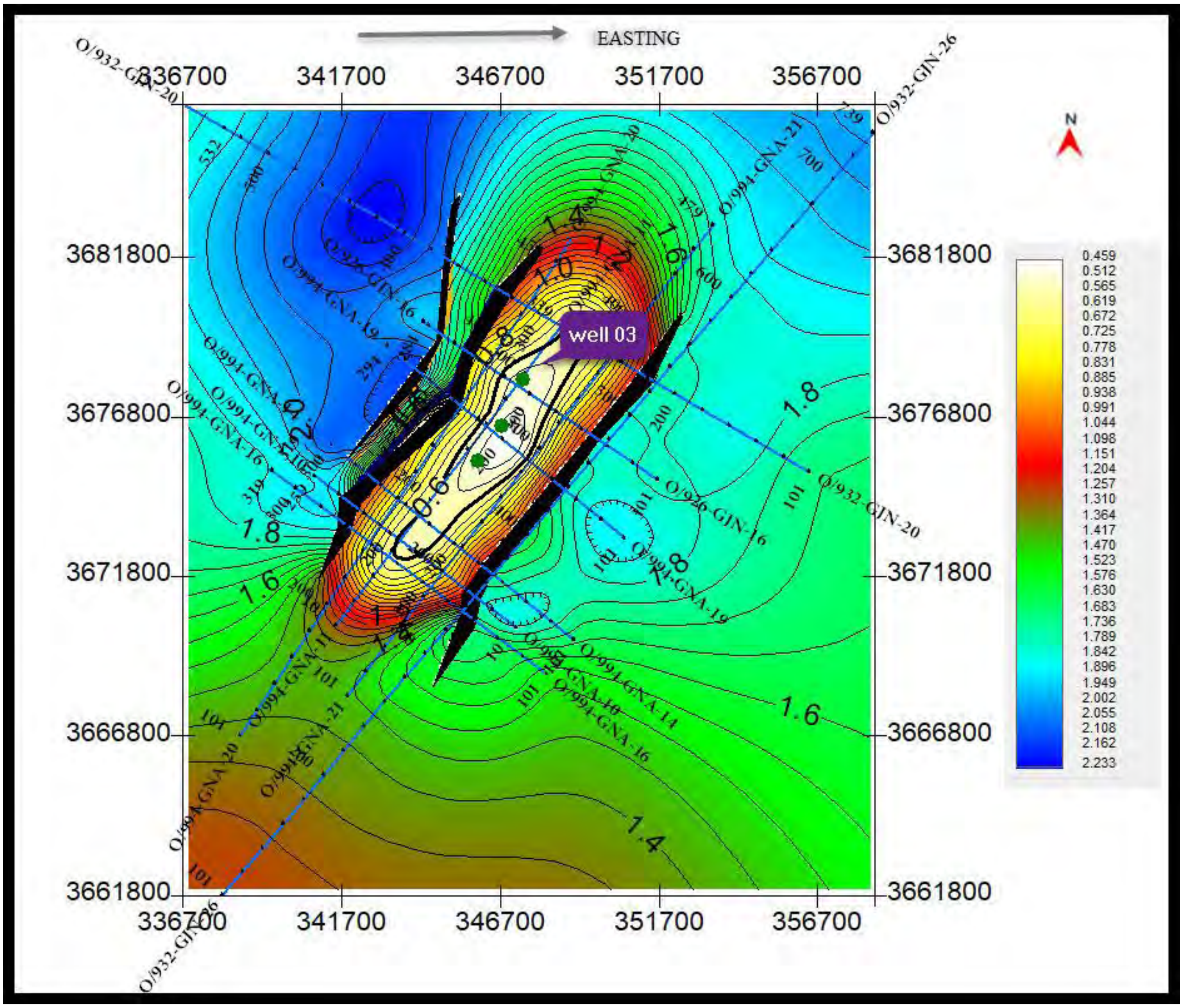


Figure 3.12 (Time contour map of Murree Formation)

4 CHAPTER VELOCITY ANALYSIS AND 2D SEISMIC MODELLING

4.1 TIME SECTION

By using X-works, the scanned section of the Lines 0/926-GJN-16, 0/932-GJN-26 and 0/994-GNA-14 are loaded individually and, horizons and faults are marked. Horizons and faults are assigned different colors so they are easily distinguished.

- MURREE FORMATION (BLUE)
- CHORGALI FORMATION (PINK)
- SAKESAR FORMATION (YELLOW)
- LOCKHART FORMATION (GREEN)

4.2 INTERPRETED LINE 0/926-GJN-16

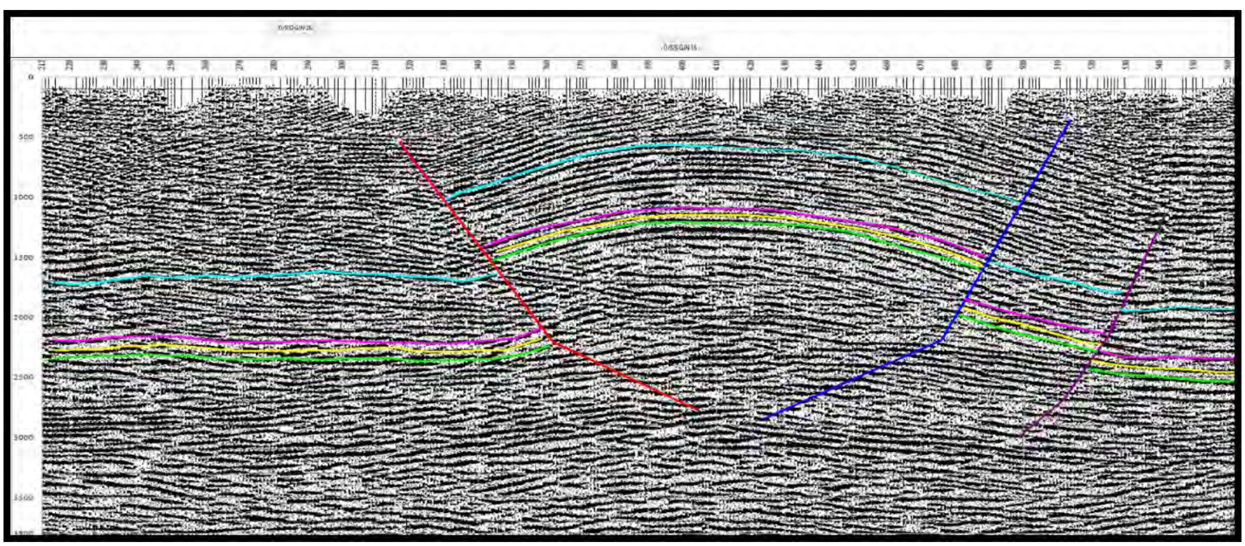


Figure 4.1 (Interpreted Line 0/926-GJN-16) using Xworks.

4.3 INTERPRETED LINE 0/932-GJN-26

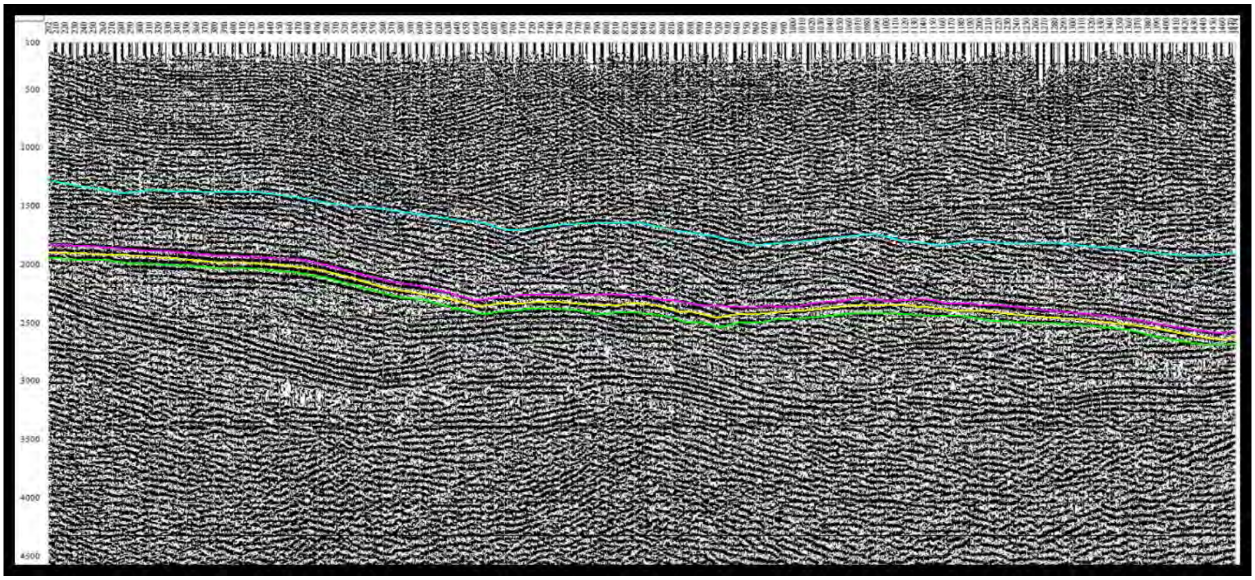


Figure 4.2 (Interpreted Seismic line 0/932-GJN-26) Using Xworks .

4.4 INTERPRETED LINE 0/994-GNA-14

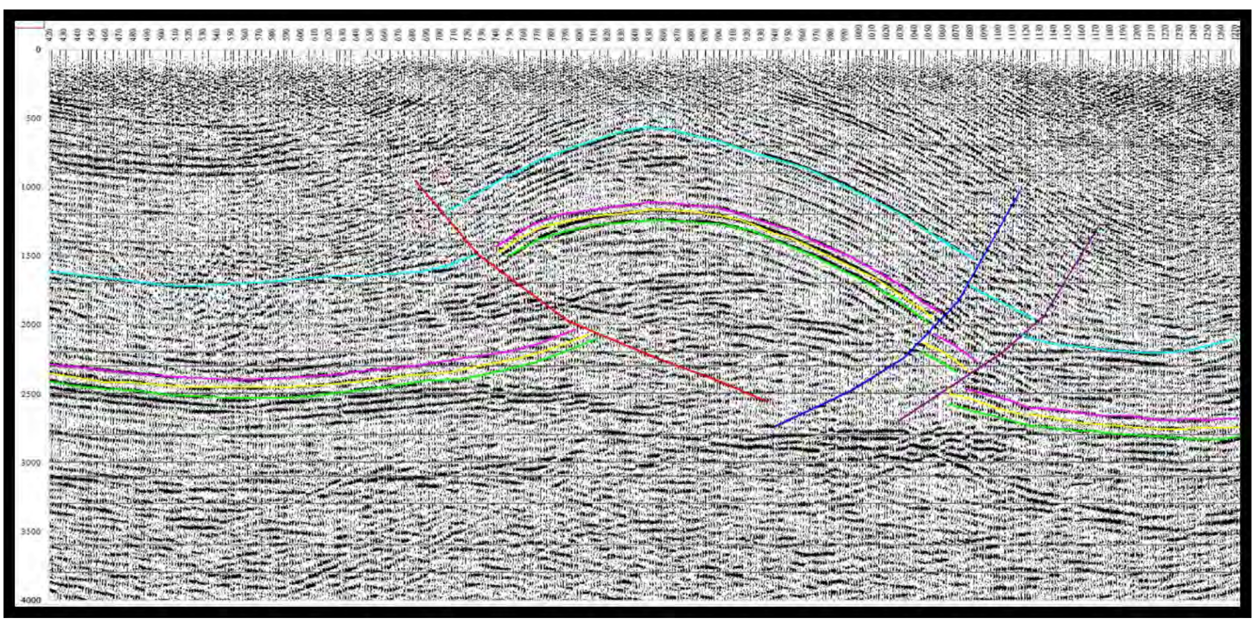


Figure 4.3 (Interpreted Seismic Line 0/994-GNA-14) Using Xworks

4.5 USES OF SEISMIC VELOCITIES

The seismic velocities may be used to establish the following

- True depth
- Possible porosity estimates
- Migration of seismic data
- Stacking of seismic data

4.6 VELOCITY ANALYSIS

The velocity data provided along with seismic sections are Root Mean Square (RMS) velocities. These must be converted into interval and finally average velocities (Dix, 1955) for time to depth conversion. X-Works uses a velocity processing engine which automatically converts the input RMS velocities into interval and finally average velocities for time to depth conversion.

When the velocity data is loaded the velocity functions for all three types are displayed at their corresponding CDP locations i.e.

- ✓ RMS VELOCITY (SKY BLUE)
- ✓ INTERVAL VELOCITY (DARK GREEN)
- ✓ AVERAGE VELOCITY (BLUE)

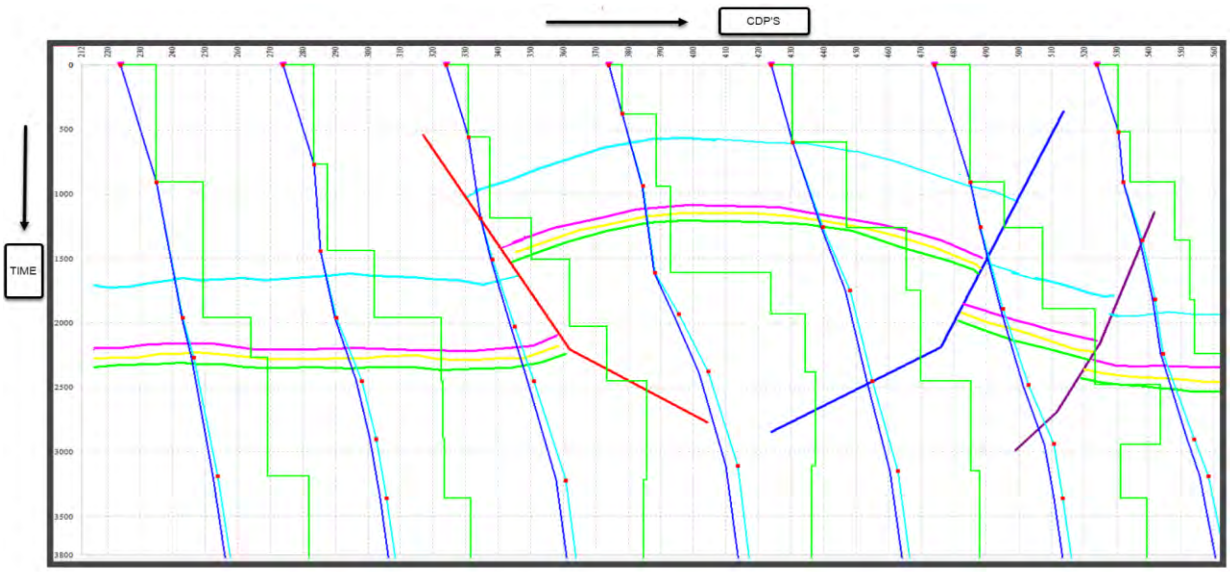


Figure 4.4 (geological cross-section of GJN-16 with various velocities overlapped).

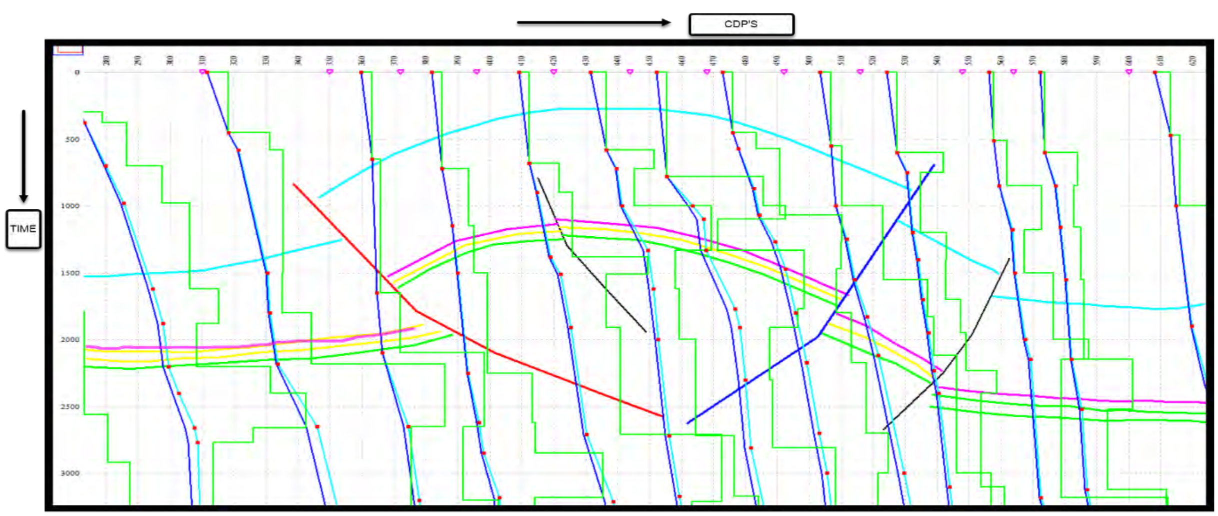


Figure 4.5(geological cross-section of GNA-14 with various velocities overlapped).

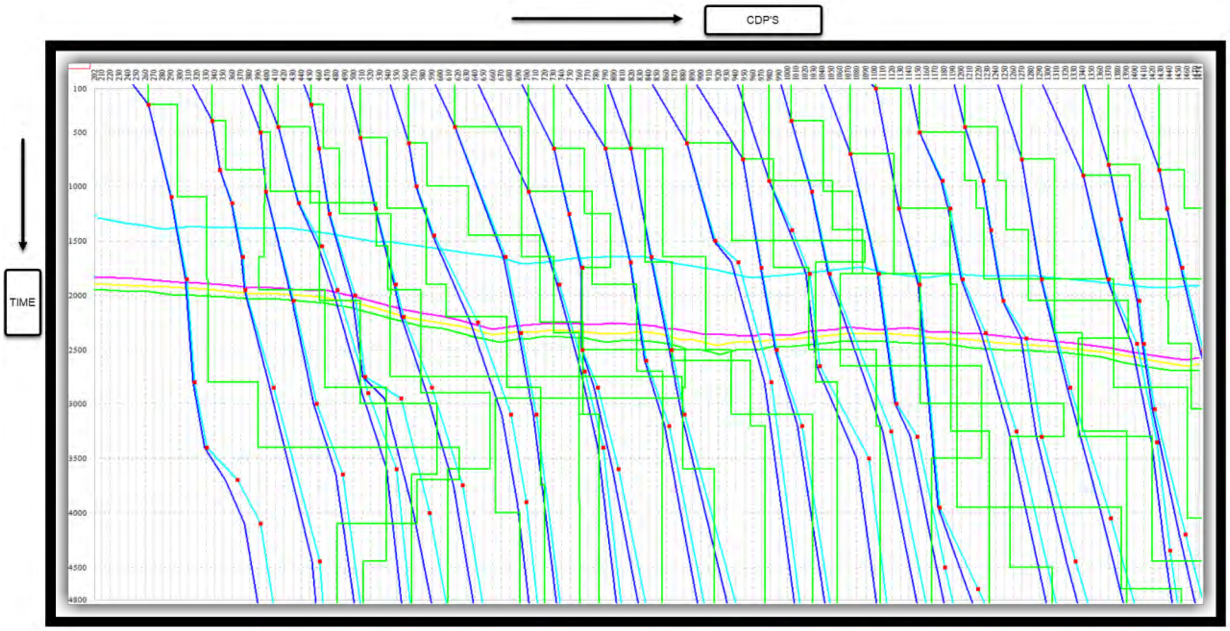


Figure 4.6(Geological cross-section of GJN-26 with various velocities overlapped).

4.7 SPATIO-TEMPORAL INTERPOLATION

Velocity functions are interpolated (Time Slice and Horizon Slice) and smoothed for velocity model building. **Thus, the velocity model is further processed by applying spatio-temporal interpolation.**

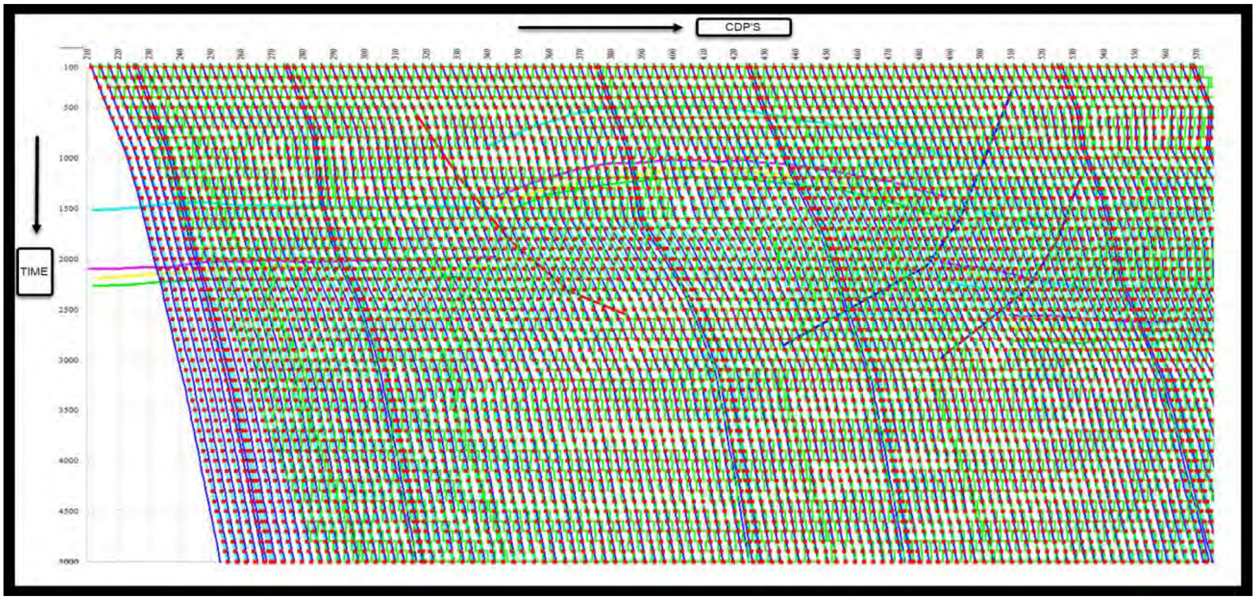


Figure 4.7 (Interpolated Velocity Function OF Gjn - 16)

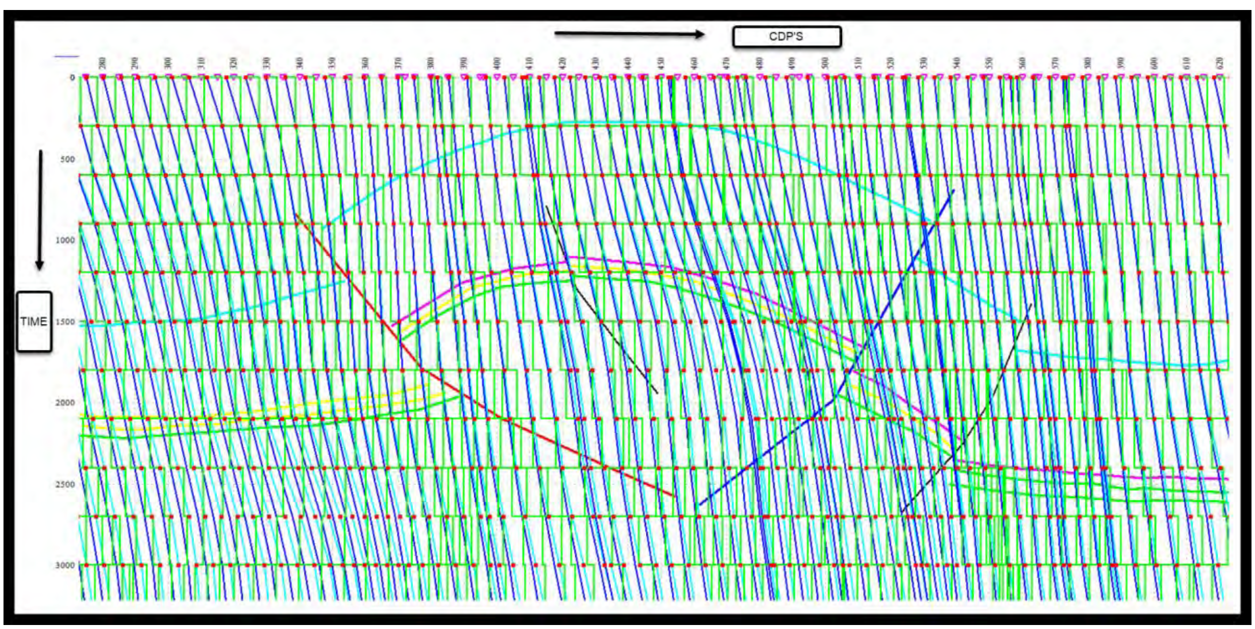


Figure 4.8 (Interpolated Velocity Function OF GNA - 14)

4.8 2D SEISMIC MODELING

2D seismic models are generated for 0/994-GNA-14 and 0/932-GJN-16. It is generated from the velocity models discussed in the previous sections. In this method a Ricker Wavelet of 35Hz sweep frequency with 20% linear tapering along with a Blackman amplitude decaying function is used as a source. The wavelet is convolved with velocity models at every 10 CDP to generate a seismic section. This type of modeling is commonly used to adjust acquisition parameters for new surveys based on geological cross-sections with velocities assigned to each formation.

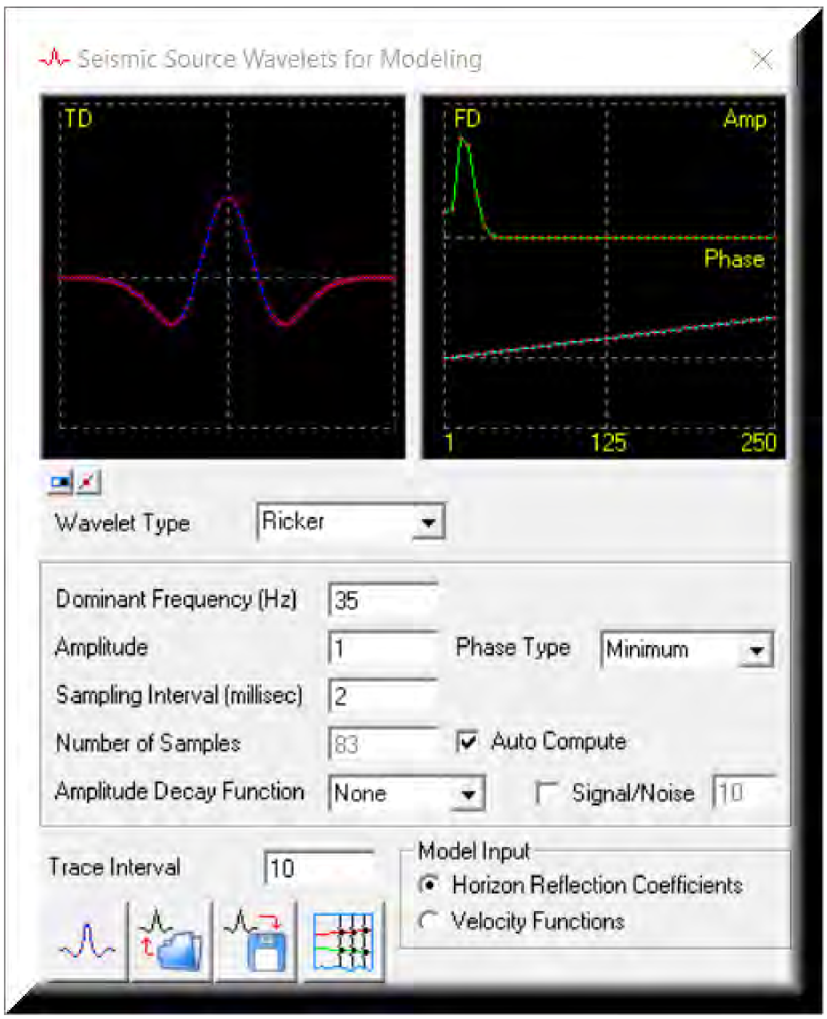


Figure 4.9 (Ricker wavelet of sweep frequency 35 Hz)

4.8.1 SEISMIC MODEL BASED ON SPATIO-TEMPORAL INTERPOLATION

The spatio-temporal interpolated velocity model is used as input. The interval velocity functions are interpolated from the RMS velocity functions. The interval velocity functions are then used to produce reflectivity sequence which is convolved with the source wavelet to produce seismic records mounting a 2D seismic model.

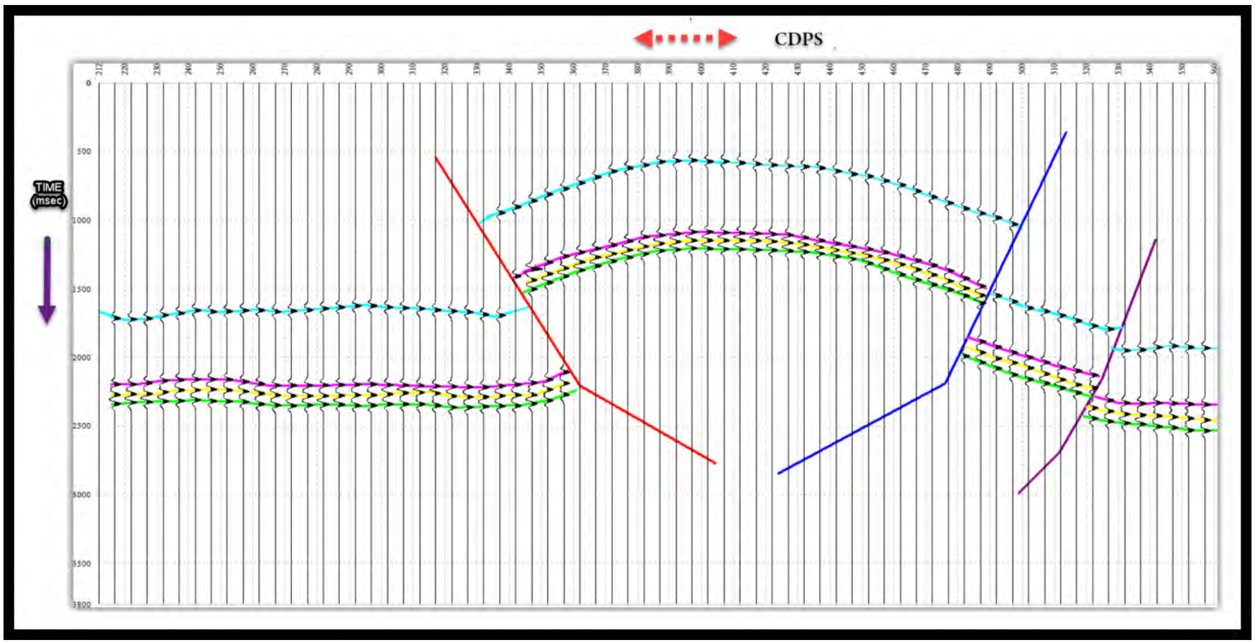


Figure 4.10 (2D synthetic model along with geological cross-section of GJN-16)

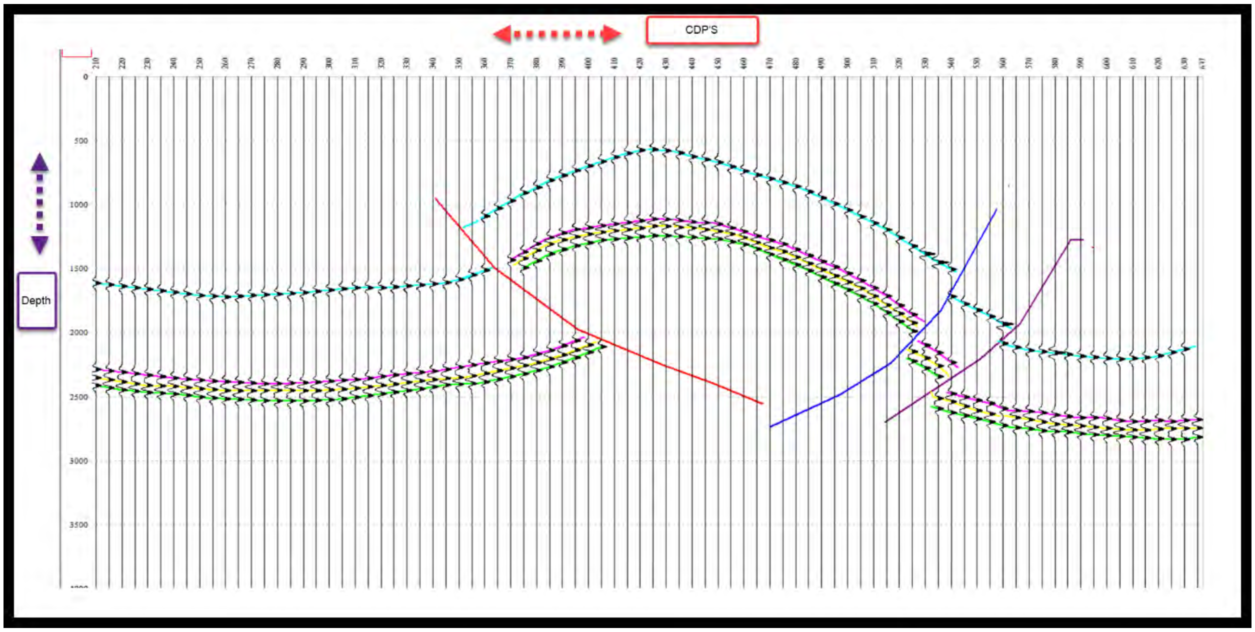


Figure 4.11 (2D synthetic model along with geological cross-section of GNA-14)

Depth Section

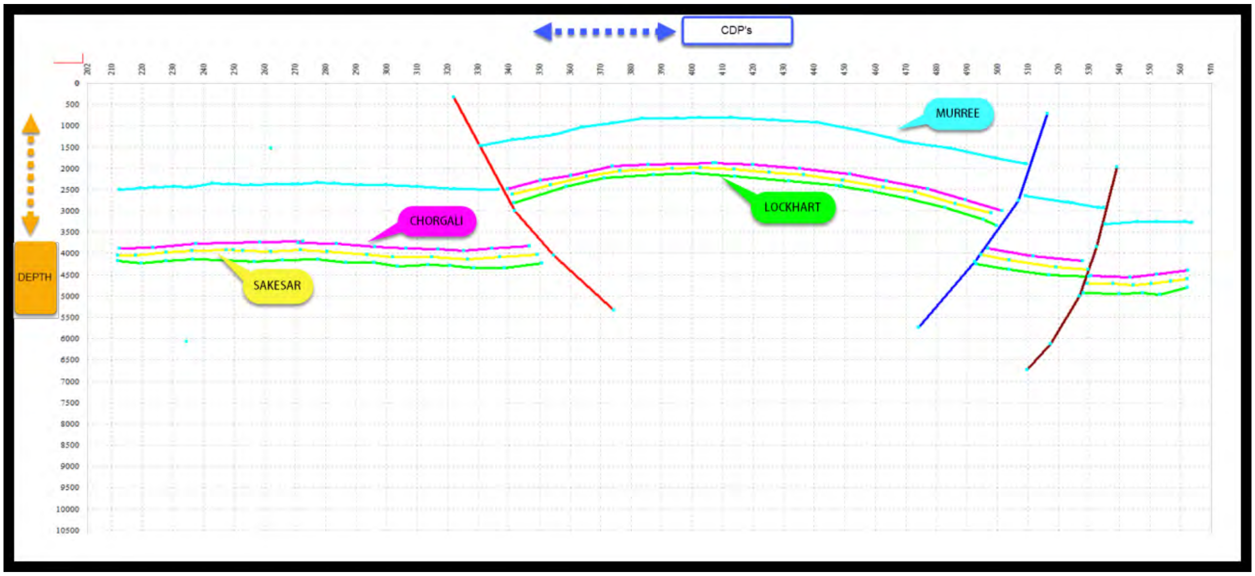


Figure 4.12 (Depth Section of Gjn _ 16)

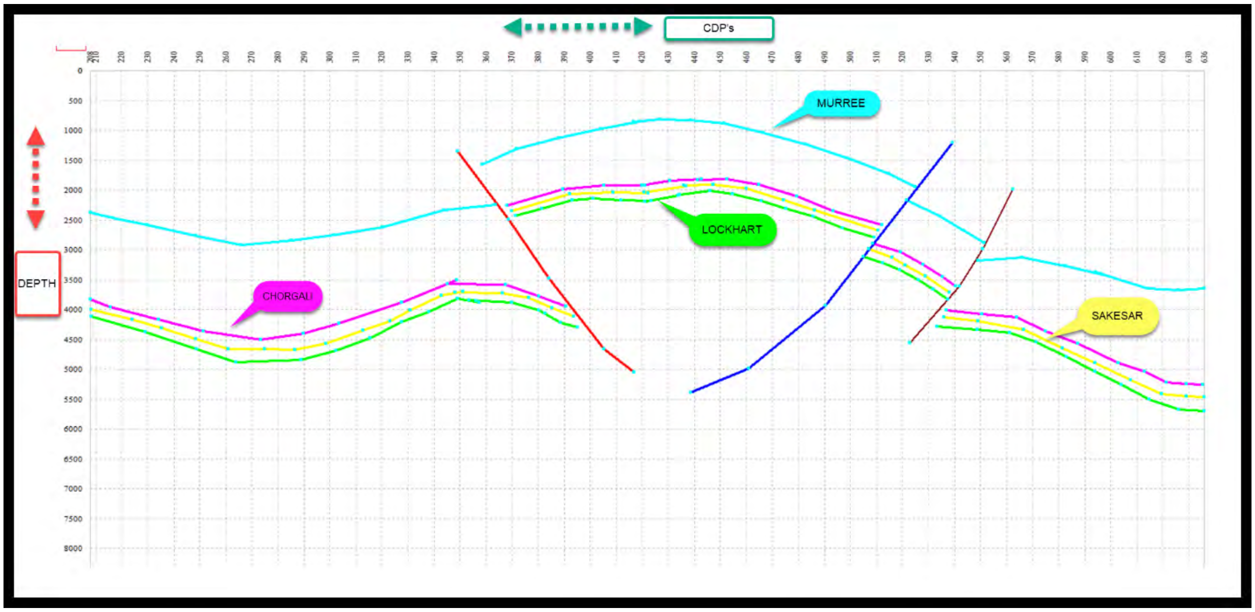


Figure 4.13 (Depth Section of Gna_14)

5 CHAPTER PETROPHYSICS

5.1 INTRODUCTION

Petrophysics is study of the physical properties relating the incidences, behavior of the rocks and fluids inside the rocks Reservoir characterization is the key step in oil and gas industry as it helps in defining the well and field potential so identify the zones within the reservoir which bears the hydrocarbons and can be recovered (Cosgrove et al., 2001).

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

5.2 PETROPHYSICAL ANALYSIS

The Petrophysical analysis is carried out by using the wireline logs used in the given well. The petrophysical analysis was carried out by using the following wireline logs of MISSA KESWAL-03 issued by DGPC.

- Density log
- Neutron log
- Resistivity log
- Spontaneous Potential log
- Gamma Ray log

5.3 DATA SET

Petro physics has been conceded in order to measure the reservoir characterization of the Missa keswal area using the borehole data of MISSA KESWAL-03. We used the log curves including caliper log, Gamma ray (GR), Sonic log (DT), Laterolog deep (LLD), Laterolog shallow

(LLS), Neutron log, density log. Following parameters are essential for petro physics analysis on the basis of the log curves.

- Volume of shale
- Hydrocarbon saturation
- Water saturation

We must have to know different types of logs before going to calculate the properties that mentioned above.

5.4 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 .

- **Lithology Track**

Lithology track is the first track, and in lithology tract following two logs are displayed which are explained as follows.

1. Gamma Ray log
2. Caliper log
3. Spontaneous Potential Log

5.4.1 GAMMA RAY LOG

Gamma ray log is used to measure radiation. Gamma rays are high energy electromagnetic waves which are emitted by atomic nuclei as a form of radiation. Gamma ray log is measurement of natural radioactivity in formation verses depth. It is also known as shale log. GR log reflects shale or clay content. Clean formation has low radioactivity level. For radiation measurement a detector is used which is consisting of a thallium-doped sodium-iodide crystal. When the tool is run in the borehole the crystal emits light by absorbing radiation of the radioactive mineral. These light emissions are counted and displayed as count per second which is termed as gamma ray log.

This log is mainly used to differentiate between sand and shale and also used for the determination of shale volume (Asquith et al, 2004).

5.4.2 CALIPER LOG

Caliper log is used to confirm the diameter of borehole. It provide continuous measurement of the size and shape of borehole along its depth. The caliper log measure the variation in borehole diameter as it is withdrawn from the bottom of the borehole, using two or more articulated arms that push against the borehole wall. Caliper log typically remain constant throughout. Caliper log is important log in petro physical logs.

5.5 SPONTANEOUS POTENTIAL LOG (SP):

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

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

Qualitative measure of permeability

5.5.1 RESISTIVITY TRACK

Resistivity track basically include three logs. Resistivity logs are electric logs which are used to determine hydrocarbon versus water-bearing zones, indicate permeable zones, determine resistivity porosity. All of these logs are plotted on the logarithmic scale due to more variations in resistivity with depth. Resistivity logs are:

1. Laterolog Deep (LLD)

2. Laterolog Shallow (LLS)

3. Micro Spherical Focused Log (MSFL)

(But MSFL was not present in my data of MissaKeswal 03).

5.5.2 LATEROLOG DEEP

Deep Laterolog resistivity curves measure true formation resistivity, the resistivity of the formation beyond the outer boundary of the invaded zone. In water bearing zone, the curve reads a low resistivity because the pores of the formation are saturated with low resistivity.

5.5.3 LATEROLOG SHALLOW

SS

Shallow Laterolog resistivity curves measure the resistivity in the invaded zone. In a water bearing zone the LLS, records a low resistivity. It is used for the shallow investigation of the of the invaded zone, beacause depth of investigation is smaller than LLD.

5.5.4 POROSITY TRACK

Porosity log measure velocity in volume of rock. .These logs are also helpful in order to distinguish between the oil, gas and water in combination with the resistivity log. Porosity track include following logs:

1. Sonic log (DT)

2. Density log (RHOB)

3. Neutron log (NPHI)

5.5.5 SONIC LOG (DT)

Sonic log is also called acoustic log or porosity log. It basically measures intervals transient time of compressional sound waves which travel through the formation. In its simplest form, a sonic tool consists of a transmitter that emits sound pulse and two receivers that pick up and record the pulse as it passes each receiver. The difference in arrival times is the transits time which is related to porosity and lithology. Shale will have a higher transit time (lower velocity) than sandstone of a similar porosity, which sometime allows the sonic log to be used as grain size indicator. Sonic log is mainly used to determine the porosity in a reservoir.

5.5.6 DENSITY LOG (RHOB)

It is basically a porosity log which is used to the bulk electron density of the formation. The tool is consists of a cobalt-60 or cesium-137. The density tool emits gamma radiation which is scattered back to a detector in amount proportional to the electron density of the formation. The higher the gamma ray reflected, the greater the porosity of rock. The electron density is directly related to the density of the formation except in condition of evaporates, and interstitial fluids presence. Density log helps in identification of different lithology's except between dolomite and limestone.

5.5.7 NEUTRON LOG

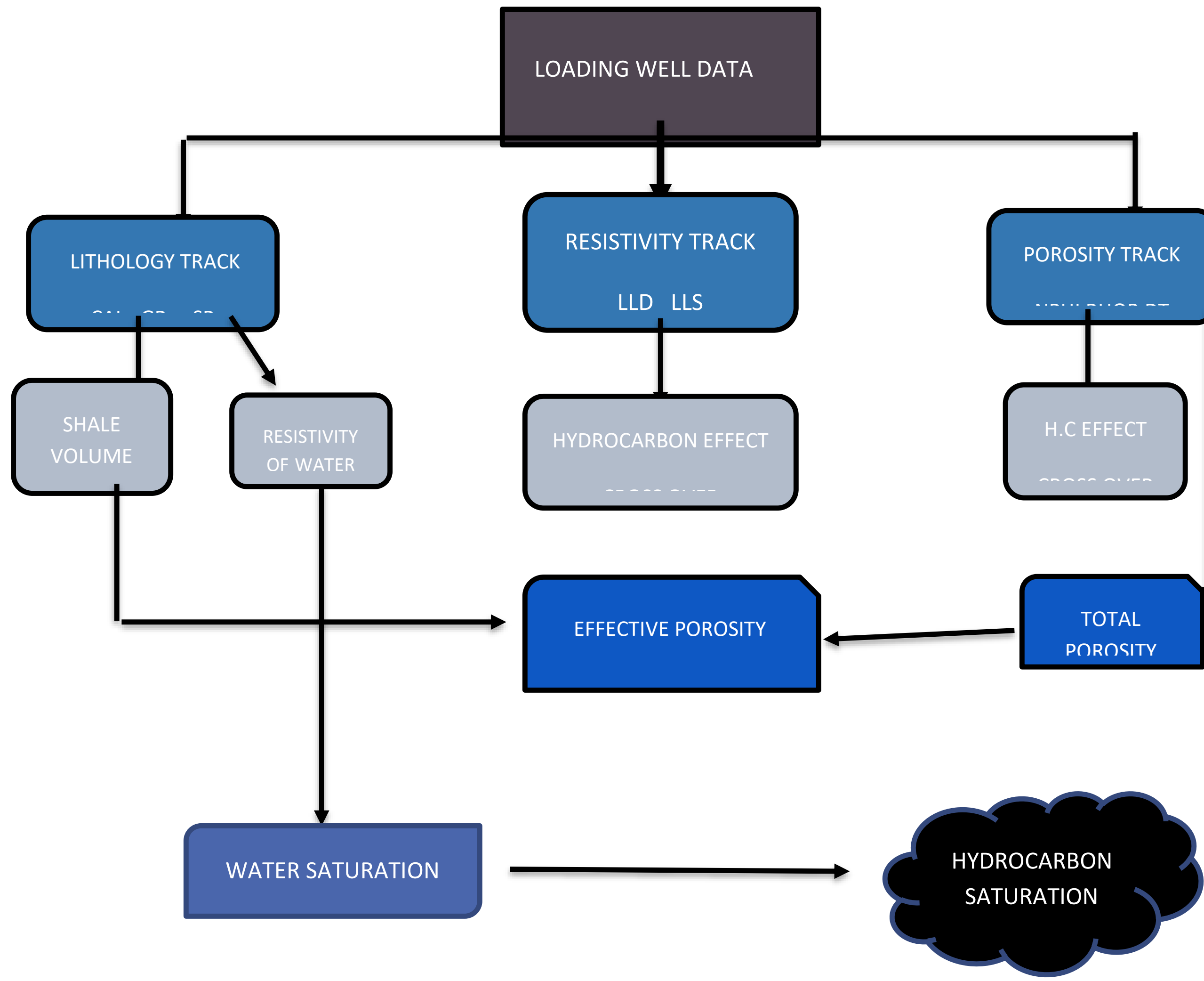
Neutron logs are used principally for delineation of porous formation and determination of their porosity. Neutron logs measure hydrogen ion concentration in a formation. If a formation is fill of water or oil so the neutron log measure the pore spaces which are filled. So we can say that neutron log measures the liquid fill pores. Neutron log works on the bombarding neutrons in the formation, as the water and oil both consists of hydrogen ion so the pores space which is filled by both these fluids the reflected neutron shows its quantity.

5.6 SCALE USED FOR DIFFERENT LOG TRACK

Table Scales Used for Different Logs By Geo Grapix .

N.0	LOGS NAME	SCALE	ABREVIATION	UNIT
1	Gamma Ray	0 TO 150	GR	API
2	Calliper	6 TO 16	CALLI	INCHES
3	SONIC	140 TO 40	DT	Sec/feet
4	DENSITY	2 TO 3	RHOB	Gm/c
5	Neutron	0.45 TO -0.15	NPHI	PU
6	Laterolog DEEP	0.2 TO 2000	LLD	
7	Laterolog SHALLOW	0.2 TO 2000	LLS	**Ωm**

5.7 WORK FLOW FOR PETRO PHYSICAL ANALYSIS



5.8 DETERMINATION OF ROCK PROPERTIES

By using geophysical wee logs many rock properties can be identified. Rock properties are identified by using distinct equation given in table

Table Different equations for calculating rock properties

N.0	PROPERTIES	MATHEMATICAL FORMULAS
1	Volume of shale (VSH)	VSH=(GR-GRCLN)(GRSHL-GRCLN)
2	Density of porosity (PHID)	PHID = (RhoM - RHOB) / (RhoM - RhoF)
3	Sonic porosity (DT)	PORS=(DLT-DLTM)(DLTF-DLTM)

4	Total porosity (PHIT)	PHIT=(DPHI+NPHI)2.0
5	Effective porosity (PHIE)	PHIE = PHIA* (1-Vshl)
6	Static spontaneous potential (SSP)	SSP=SP(CLEAN)-SP(SHALE)
7	Hydrocarbon Saturation (HS)	HS=1-SW

5.8.1 VOLUME OF SHALE

We find out volume of shale with the help of GR log. . With the help of GR log we easily differentiate between reservoir and non-reservoir rocks. The value of gamma ray is low in LIMESTONE and carbonate while it having high value in SHALE. The shale volume is estimated by using the equation given table.

5.8.2 CALCULATION OF POROSITY

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

5.8.3 AVERAGE POROSITY

Average porosity is the sum of the all porosities.

5.8.4 EFFECTIVE POROSITY

The effective porosity is the ratio between the pores volume of the rock and the total volume of the rock calculated after removing the effect of the shale. The effective porosity is used to estimate the water saturation.

5.8.5 WATER SATURATION

Water saturation is percentage of water in a volume of rock which is highly porous. It has a symbol. For the evaluation of water saturation, first, we determine the water resistivity of the formation.

5.8.6 HYDROCARBON SATURATION

The fraction of pore spaces containing hydrocarbons is known as hydrocarbon saturation.

5.8.7 PETRO PHYSICAL INTERPRETATION

Petro physical analysis of well is carried out on the basics of the different logs' curves. The first indicator is Gamma ray which is very useful to differentiate between lithology's. So on the basics of the gamma ray the clean and shaly zones are marked to make the further interpretation easily. Where there is low value of the shale, we can say that this is the zone in the reservoir where the hydrocarbon can be existent, but not confirm. Mainly to confirm the types and amount of hydrocarbon we go towards the integrative results of other logs that give a complete report about the hydrocarbon and water present in that zone. The main use of the resistivity log is to detect the hydrocarbon zone. With the help of the resistivity log volume of the oil and gas can be originated in the particular zone of the reservoir.

In petro physical term the hydrocarbon saturation can be defined as, that when in the porous formation the water saturation is not 100% then the hydrocarbon will be present there. The higher value of the resistivity usually indicate the presence of the hydrocarbon or the fresh water. If the separation between the LLS and LLD is informed then it is quite possible that hydrocarbon will be present there. In the case of the presence of the oil and gas the value of the LLD is much higher than the LLS, because the LLD reads the resistivity of the formation .If the formation the hydrocarbon will present then there resistivity will quietly higher. The other main important result is obtained when Neutron and density logs are combined, because their crossover possibly gives the best clue of the presence of the hydrocarbon (Rider, 1996).

5.9 CHORGALI

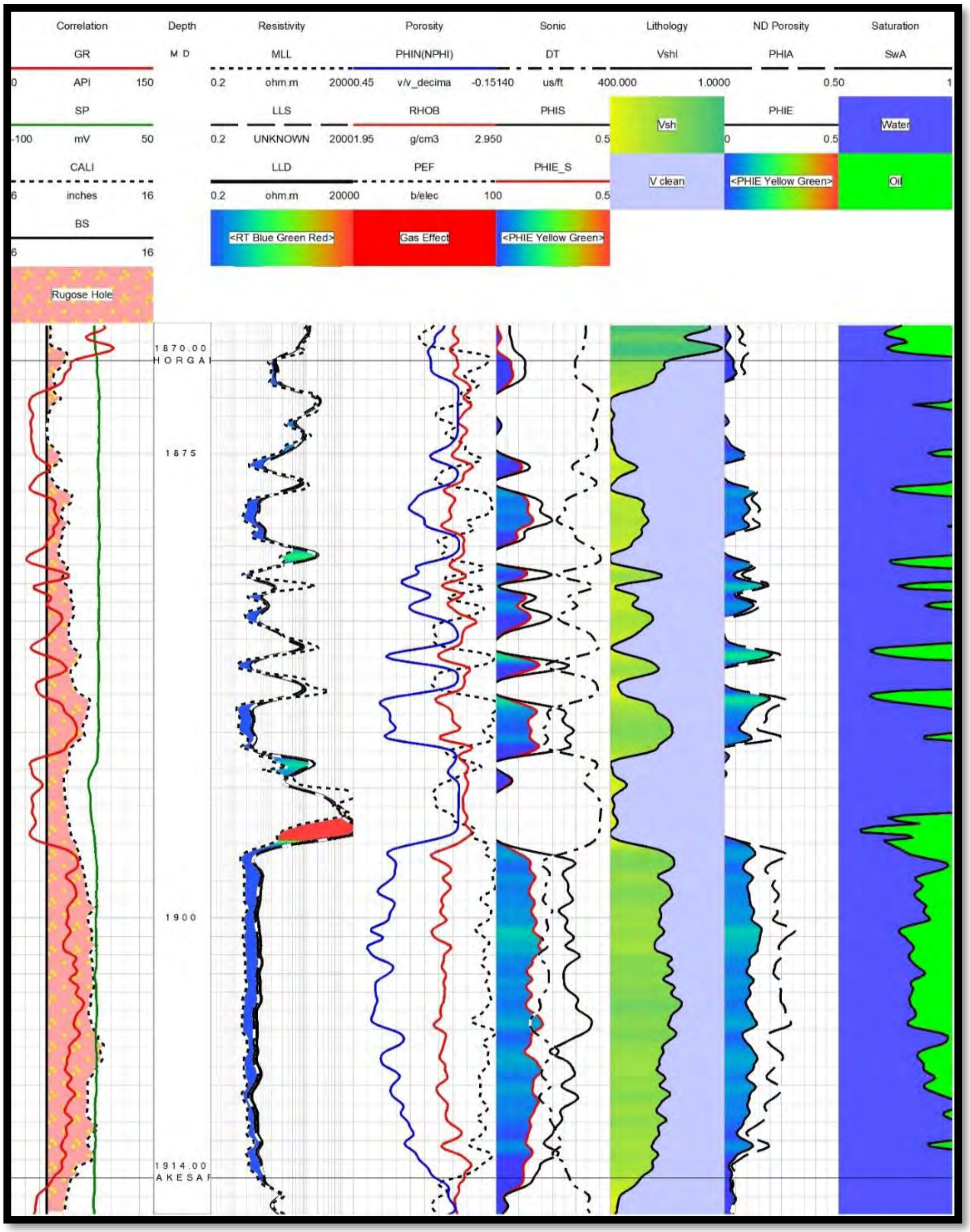


Figure 5.1 : Chorgali zone

Choargali Formation ranges from 1870 to 1914 meters, having gross thickness of 44 meters is show in figure above. Upper portion of Chorgali Formation has low borehole rugosity and volume of shale ranges from 20 to 30%. Average effective porosity in upper portion of Chorgali Formation is about 6% whereas average saturation of water is above 90%. Lower porion of Chorgali Formation has high borehole rugosity with volume of shale ranges from 55 to 60%.

Average effective porosity in lower portion is about 10% whereas average saturation of water is about 70%. Overall, no prominent hydrocarbon bearing zone has encountered in Chorgali Formation.

5.9.1 SAKESAR

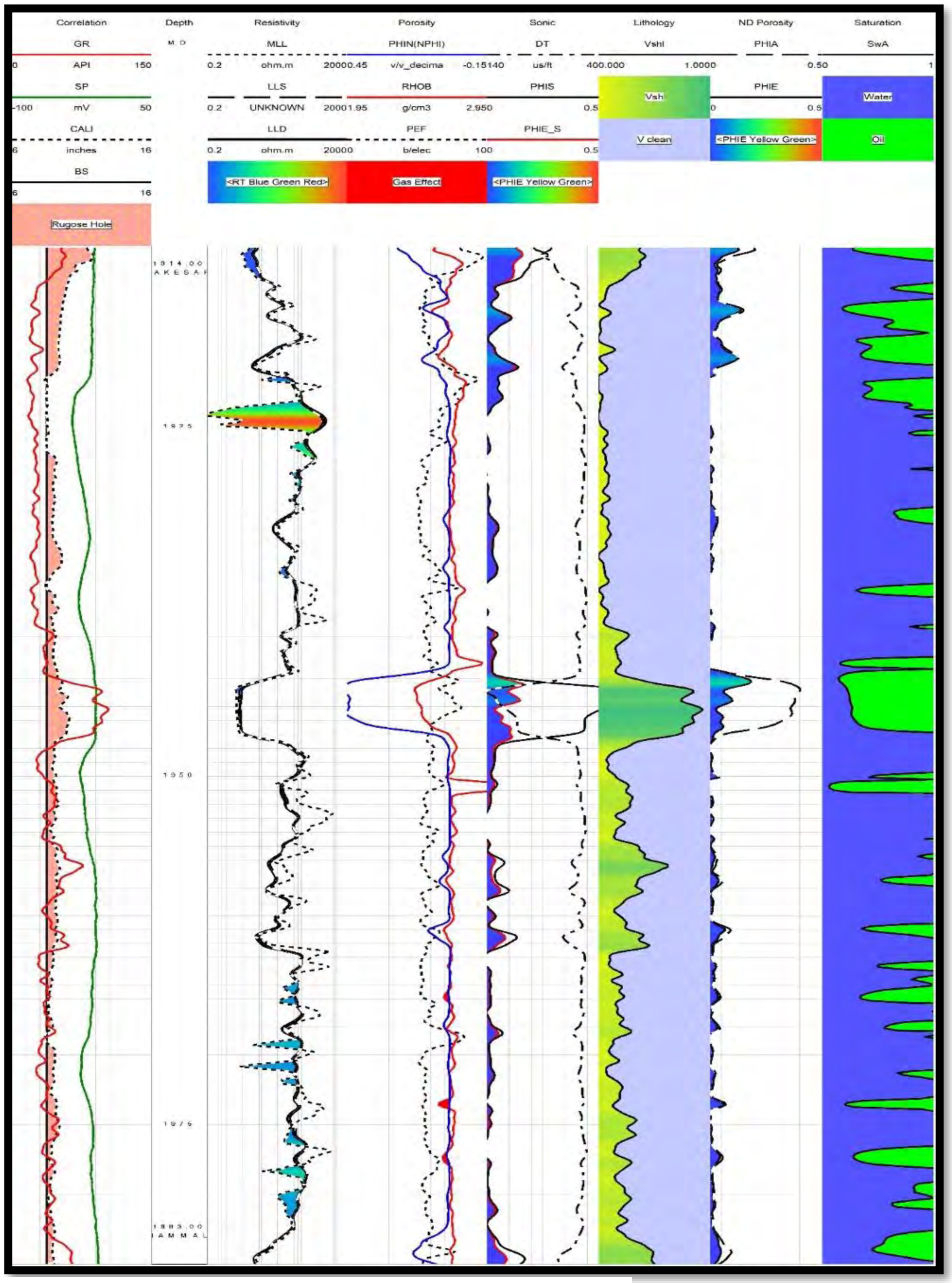


Figure 5.2: Sakesar Zone

Sakessar Formation ranges from 1914 to 1983 meters, having gross thickness of 69 meters. Sakessar Formation exhibit good, gauged hole as borehole rugosity is very low. Upper portion of Sakessar formation is clean with more than 90% volume of clean while lower portion has some volume of shale which ranges from 15 to 20%. Both average and Effective porosities are extremely low throughout the Sakessar Formation in Missa Keswal well-03. There is no significant of Hydrocarbon bearing portion throughout the Sakessar Formation as all the formation has water saturation more than 85%.

5.9.2 LOCKHART

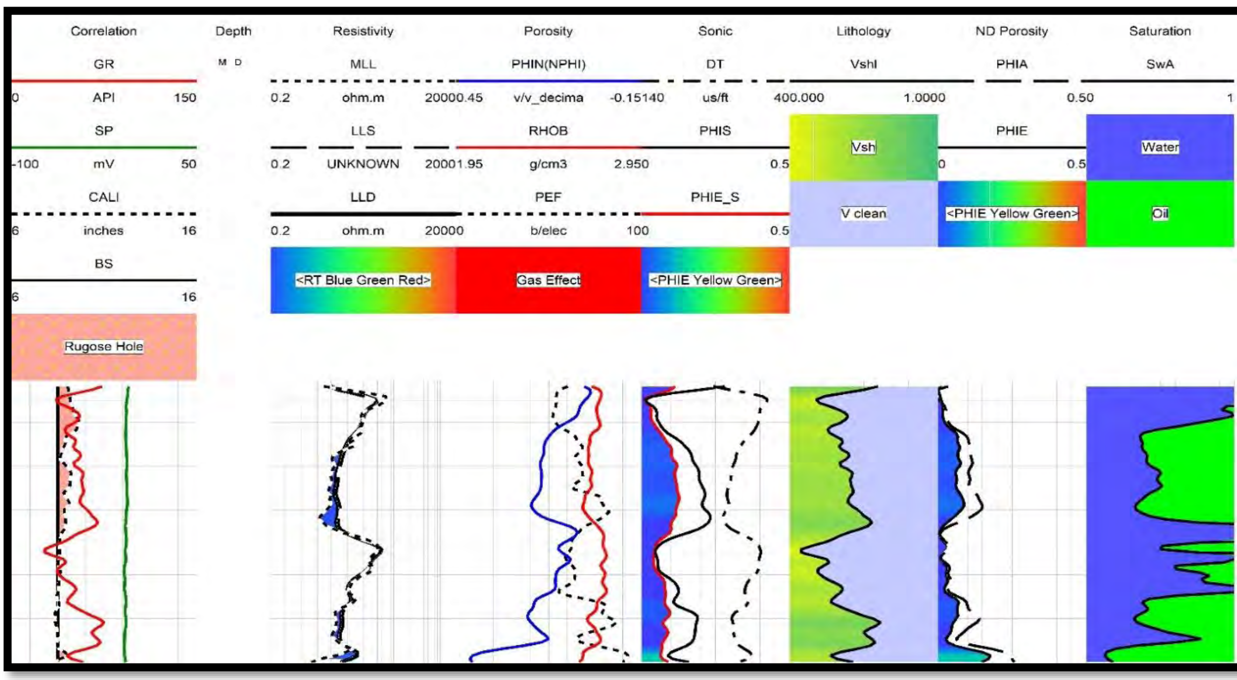


Figure 5.3: Lockhart Zone.

Lockhart Formation ranges from 2004 to 2017 meters with gross thickness of 13 meters. Borehole rugosity is very low which marks a good, gauged borehole. Average volume of clean in Lockhart is 70% but average effective porosity is only 5% which makes it unfavorable to consider as prominent reservoir formation. Moreover, Neutron-density crossover is absent and resistivity values are also lower side. Though there is about 70% average saturation of hydrocarbon but due to low porosity and higher shaliness, Lockhart Formation in Missa Keswal Well-03 cannot be considered as prominent reservoir.

6 CHAPTER CRUSTAL SHORTENING ROCK PHYSICS AND FACIES ANALYSIS

6.1 INTRODUCTION

The intricate phenomena of earth deformation, and particularly that form of deformation called folding, has led geologists to assume, in order to account for the facts in the field, that the surface of the earth must have been vastly shortened during geological time. When an oceanic crust collides with a continental crust, the denser oceanic crust subducts beneath the continental crust. This causes the oceanic crust to be subducted back into the mantle and melt, reducing the size of the crust. When two continental crusts collide and neither subducts, the material is being pushed up towards Earth's surface, resulting in mountains like Mount Everest. This causes the crusts to reduce in size (Van Hise). To determine the tectonic regime of the area under investigation crustal shortening has been computed along seismic line 0/926-GJN-16 using X-Works software.

6.2 COMPUTATIONAL PROCEDURE

The procedure involved in calculating Crustal Shortening is as follows:

The interpreted seismic line 0/926-GJN-16 has four formation including Seal, Reservoir and source rock. After time to depth conversion its geological cross-section is obtained which shows the deformation in the horizons (formations) due to thrust faulting. The computation of crustal shortening is simple.

$$C=L-L0$$

The length of the section (Lo) is computed by multiplying the number of Common Depth Points (CDP) with the CDP interval.

Similarly the length (L) of the horizon is computed by adding the lengths of its faulted segments.

C stands for Crustal Shortening.

6.3 CRUSTAL SHORTENING OF SOURCE, RESERVOIR, SEAL ROCKS

The crustal shortening is computed for Murree Formation, Chorgali Limestone, Sakesar Limestone, Lockhart limestone. The current length of 0/926-GJN-16 is 18400 meters.

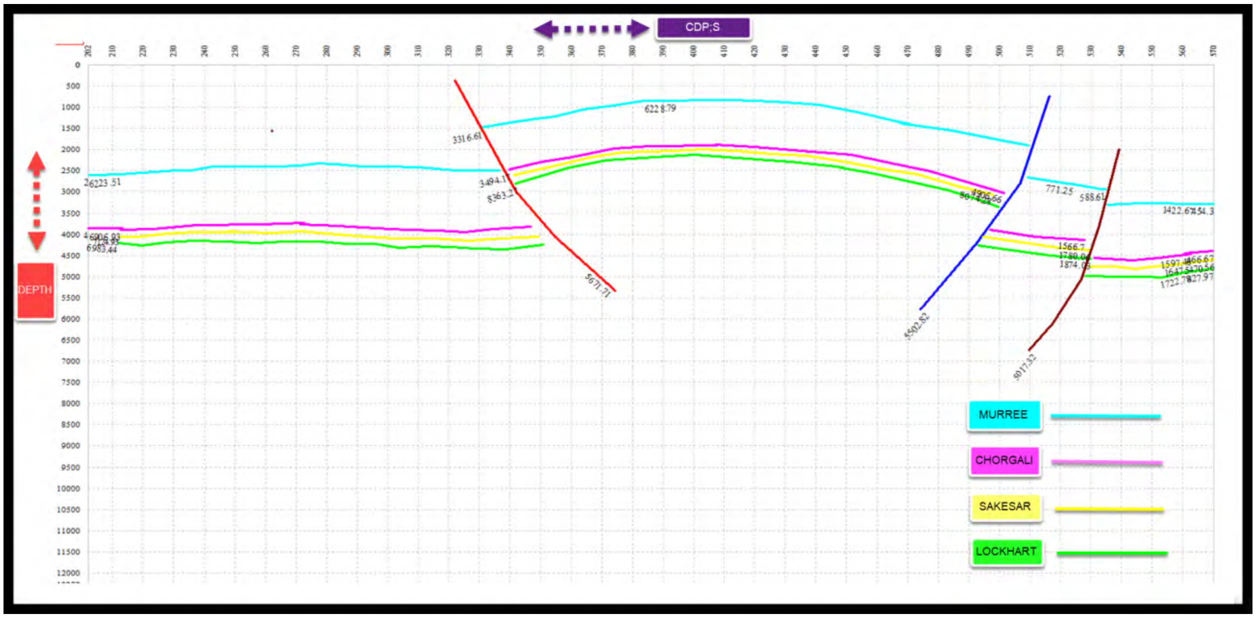


Figure 6.0.1 (Geological Depth section of 0/926-GJN-16 with calculated length of each horizon and fault segment)

- The total horizon lengths and their crustal shortening are given in Table below:

N.0	Horizon Name	Horizon Length L(m)	Section Length Lo(m)	Crustal Shortening (L-Lo)m
1	Murree Formation	18900	18400	500 m
2	Chorgali Limestone	18936.59	18400	536.59 m
3	Sakesar Limestone	18948	18400	548 m
4	Lockhart Limestone	18942.44	18400	542.44 m

6.4 ROCK PHYSICS

6.4.1 INTRODUCTION

Techniques that relate the geological properties (e.g. porosity, lithology, saturation) of a rock with the corresponding elastic and seismic properties (e.g. elastic modulus, velocity, impedance) at certain physical conditions (e.g. pressure, temperature) termed as Rock Physics. These techniques are used for rock physics modeling, i.e. to estimate geology from seismic observations or rock physics inversion (Dewar & Pickford, 2002). In Rock physics we usually use Sonic, Density and Dipole logs to establish relationship between P-wave velocity (Vp), S-wave velocity (Vs), Density with Bulk, Rigidity module Porosity, etc.

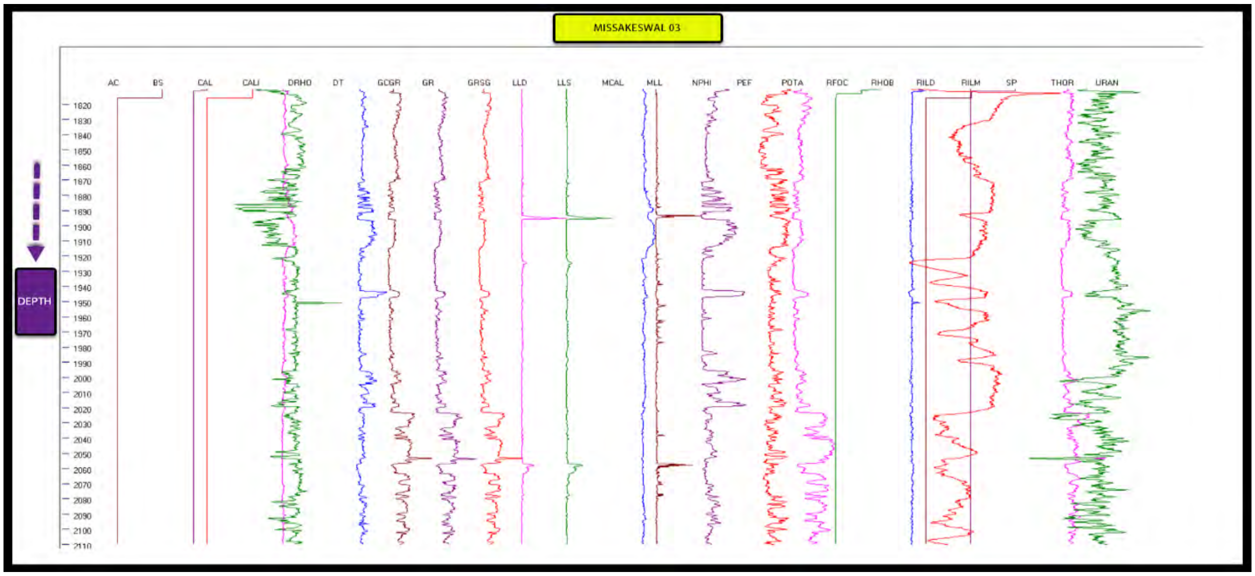


Figure 6.0.2 (LOGS OF MISSAKESWAL WELL 3 FROM 1820 TO 2110)

6.5 1D ROCK PHYSICS ENGINEERING PARAMETERS

There are 3 governing parameters that are required for the calculation of rock physics and we need at least two parameters for the calculation of rock physics parameters. As we have density and Vp so by using these parameters we have calculated and plotted the rock physics parameters. Using wavelet software Petro physical logs are being run. Using Sonic and Density logs rock physics parameters are computed for the reservoir at a depth range of 1820 to 2100 meters as shown in figure.

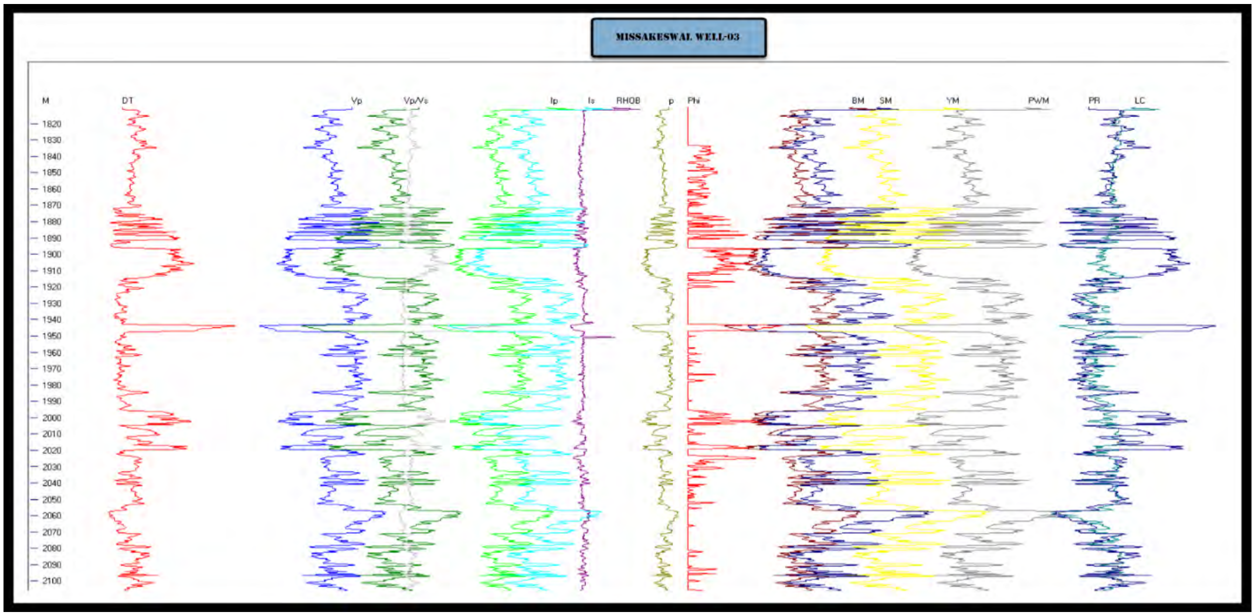


Figure 6.0.3 (Engineering Parameters of MISSAKESWAL 03 using wavelet)

6.6 EQUATIONS FOR COMPUTATION OF ROCK PHYSICAL & ENGINEERING PROPERTIES

$$V_p = 1.16 * V_s + 1.36$$

$$V_p = \sqrt{\frac{K + \frac{4\mu}{3}}{\rho}}$$

$$V_s = \sqrt{\frac{\mu}{\rho}}$$

$$V_s = (V_p - 1.36) / 1.16$$

$$\rho = 0.31 * V_p^{.25}$$

$$A = V_p * \rho$$

$$VpVs_{Ratio} = \sqrt{\frac{K}{\mu} + \frac{4}{3}}$$

$$\mu = \rho V_s^2$$

$$K = \rho(V_p^2 - \tfrac{4}{3} V_s^2)$$

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

$$M = K + \frac{4\mu}{3}$$

$$\sigma = 0.5(V_p^2 - 2V_s^2) / (V_p^2 - V_s^2)$$

$$\lambda = K - \frac{2\mu}{3}$$

6.7 FACIES ANALYSIS

Geologically facies are a rock body which having some specific features which differentiate it from the other (Matysik and Michal, 2016). Generally, the facies are distinct rock unit that form under certain condition of the sedimentation that exposes the environmental process. The difference 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 recommendation about the productive zone in the reservoir (Pritchard et al, 2010). Facies modelling leads us towards the cross plots which offers the relationship between the reservoir properties and log response (Naji et al., 2010)

6.8 CROSS PLOT OF VP/VS VERSUS IP

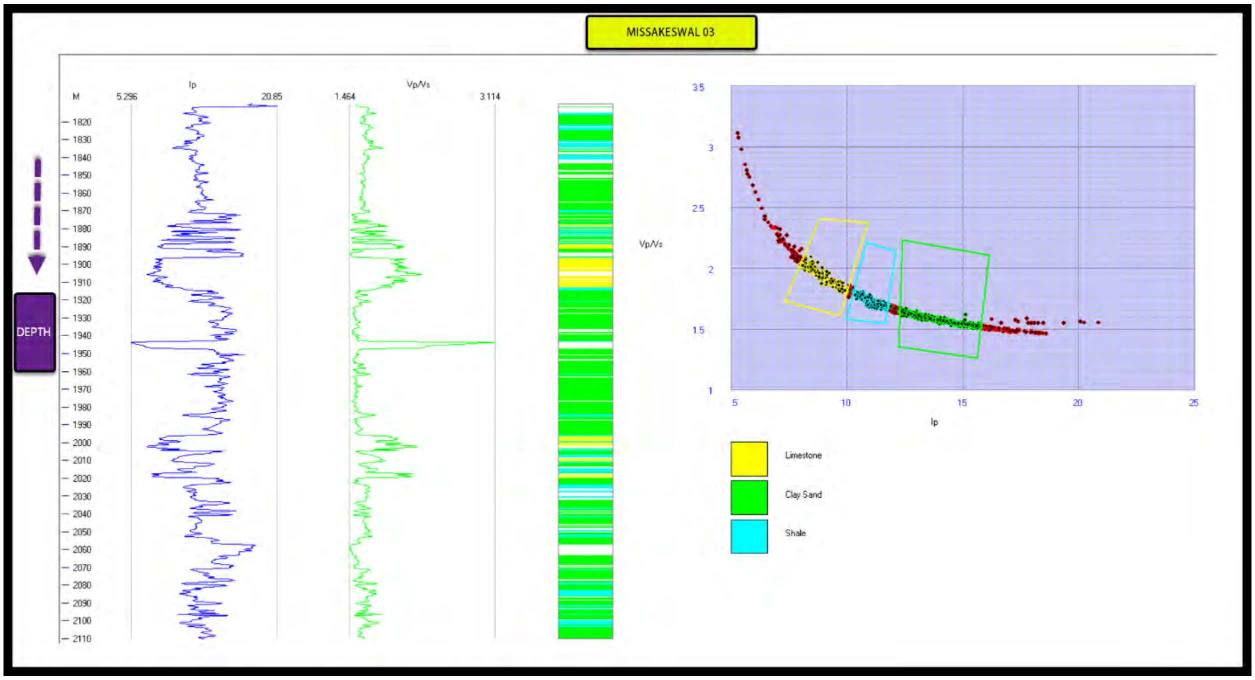


Figure 6.0.4 (Cross Plot of Vp/Vs and Ip)

6.8.1 EXPLANATION

Vp/Vs versus Acoustic Impedance is considered as an import cross plot for classification of sand and shale facies. The Vp/Vs ratio can be expressed in terms of represents Poisson's ratio (σ) by the following equation:

$$\frac{V_p}{V_S} = \sqrt{\frac{0.5 - \sigma}{1 - \sigma}}$$

This cross plot shows lithology discrimination along the acoustic impedance axis. It describes the conditions in terms of lithology and fluid content than VP/VS ratio. P-impedance and VP/VS ratio relationship discriminate both fluid and lithology.

Through this cross plot we observed that clay sand, shale and limestone are easily differentiated and characterized. Hydrocarbon zone have low values of acoustic impedance.

6.9 CROSS PLOT OF LAMBDA-RHO VERSUS VP/VS

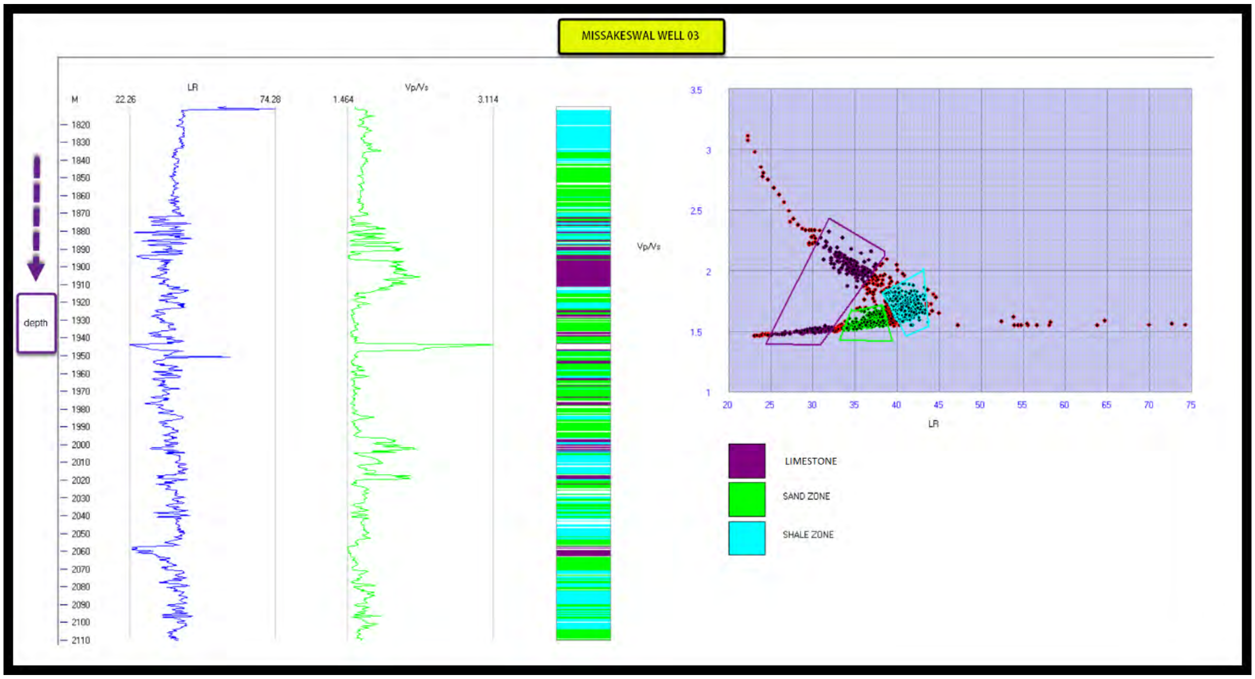


Figure 6.0.5 (Cross plot of Lambda-Rho versus Vp/Vs)

6.9.1 EXPLANATION

Lambda-Rho (Incompressibility) against Vp/Vs. The plots are better aligned towards the lambda rho axis, thus making lambda rho a better lithology discrimination tool.

6.10 CROSS PLOT OF µ-RHO AGAINST DENSITY

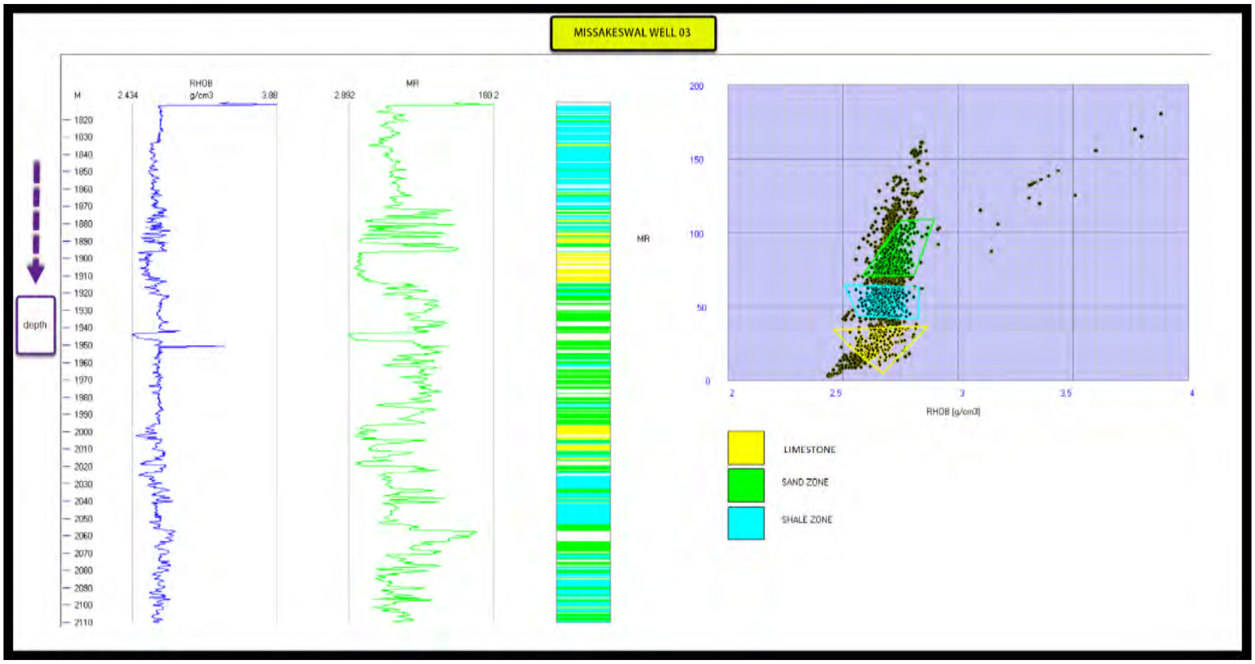


Figure 6.0.6 (Cross Plot of µ -Rho against Density)

6.10.1 EXPLANATION

In the cross plot of µ rho against density, both µ rho and density are lithology discriminators, with density also being a fluid discriminator. µ rho values are high for sand and low for shale. Conversely, the density of shale is higher than that of sand. Furthermore, due to presence of hydrocarbon, density value decreases. Due to this we would easily identify our hydrocarbon zone and also distinguished between sand and shale zone.

6.11 CROSS PLOT OF LAMBDA-RHO (Λ_P) AGAINST µ -RHO (M_P)

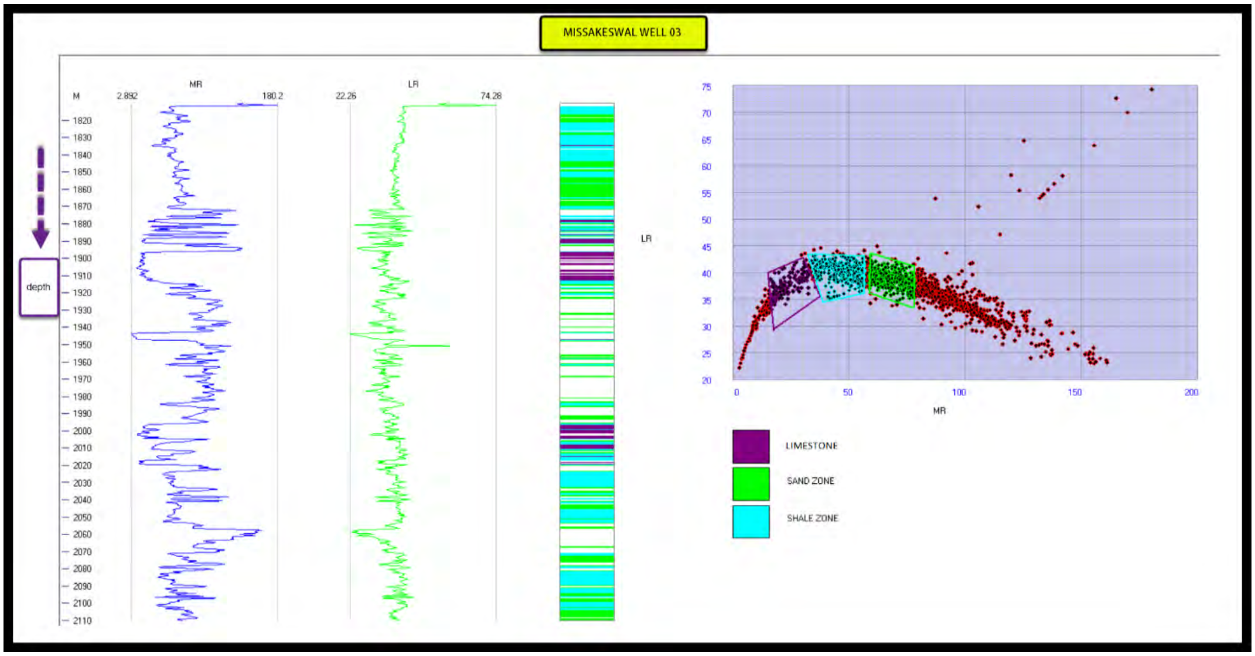


Figure 6.0.7 (Cross plot of Lamda-Rho against μ -Rho)

6.11.1 EXPLANATION

The parameters of λρ and μρ are measures of the incompressibility and rigidity of rocks.

Cross plots of lamda-rho (λρ) against μ -rho (μρ) in figure, shows separation into three zones, that can be inferred to be probable (limestone) in yellow, (sand zone) in green and (shale zone) in blue. λρ is more robust than μρ in the analysis of fluids in the field of study, and that μρ values are relatively low for the reservoir, due to this we identify probable hydrocarbon zone. The plot indicates that μρ decreases as clay content increases for increase in the porosity, but λρ may represent opposite trends. This proves λρ to be a good indicator for lithology.

6.12 CROSS PLOT OF NPHI VERSUS VP

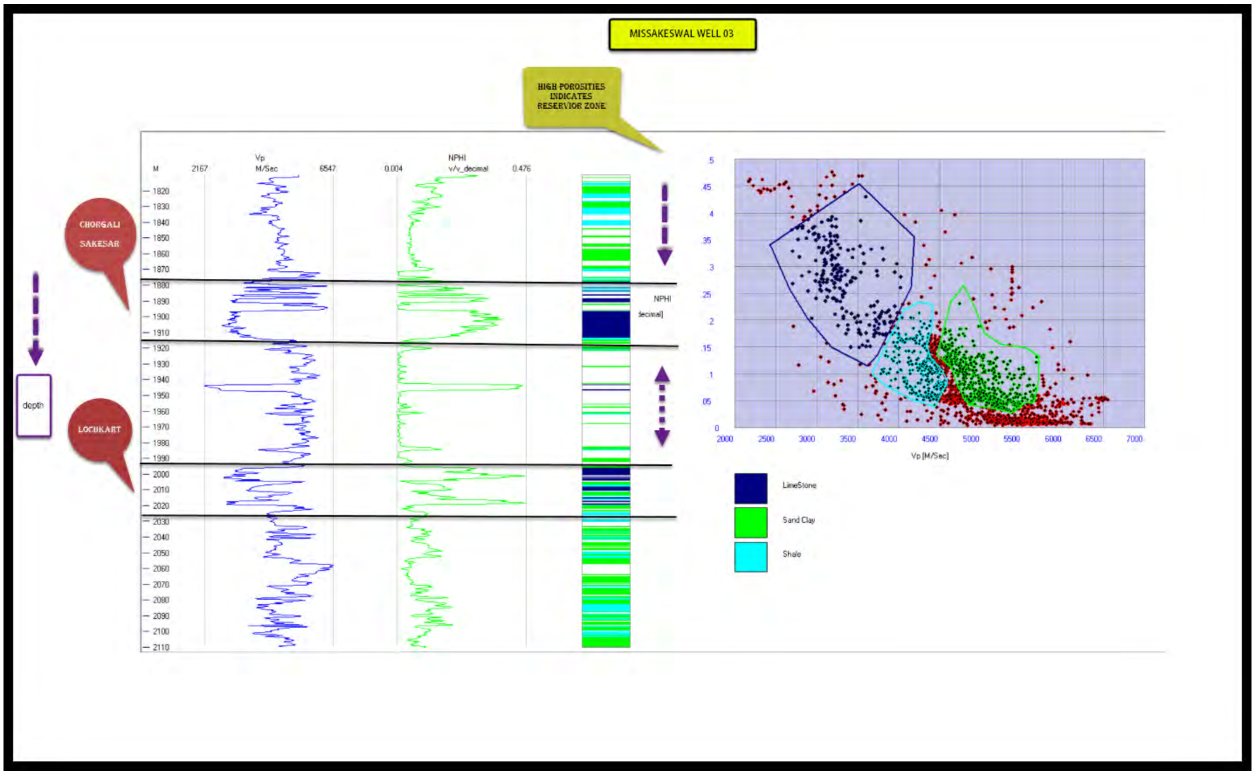


Figure 6.0.8 (Cross Plot of NPHI versus Vp)

6.13 RESULT

After all these cross plots we have Concluded that at the depth of 1890m to 1910m we have our reservoir zone. Because at that depth values of Porosities are high, Mu-Rho values decreases, Density value decreases and last Acoustic Impedance values decreases.

7 CHAPTER SEISMIC INVERSION MODEL BASED INVERSION

7.1 INTRODUCTION

In any Seismic reservior characterization studies the first step towards a successful hydrocarbon discovery is the mastering of good subsurface image of seismic data. The reflected seismic wave amplitudes are function of acoustic/elastic impedances which project a contrast between lithology above and below reflecting boundary. Seismic inversion is the process of extracting information about elastic rock properties from seismic data based on the travel-time, amplitude, and phase information contained within a seismogram. In this chapter, model based post-stack seismic inversion analysis is used to identify the hydrocarbon bearing potential zones.

7.1.1 DATA USED

Seismic Dip Line 0/926-GJN-16

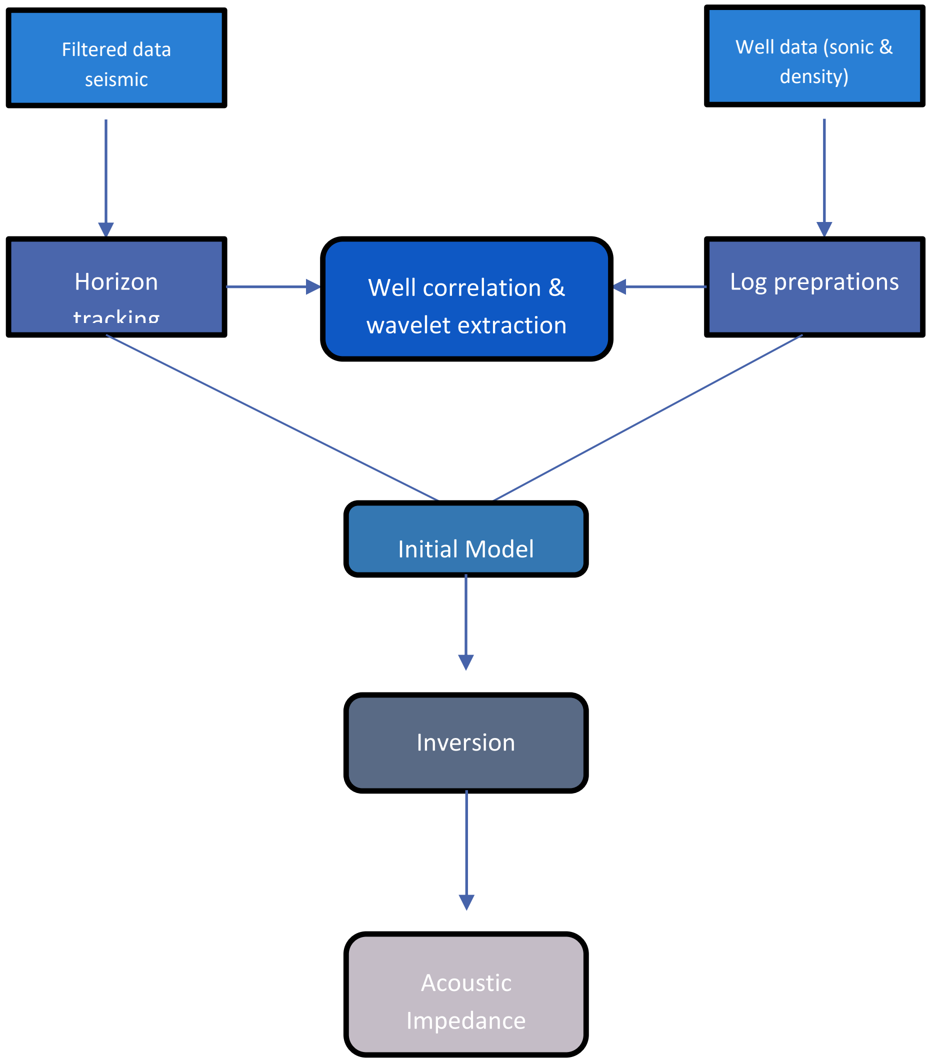
Las File of (MISSAKESWAL WELL 3)

7.1.2 SEISMIC INVERSION

Seismic inversion is essentially a very simple procedure. In a seismic inversion the original reflectivity data, as typically recorded routinely, is converted from an interface property (i.e. a reflection) to a rock property known as impedance, which itself is the multiplication of sonic velocity and bulk density. In a conventional seismic reflectivity section the strong amplitudes are associated with the boundaries between geological formations, such as the top reservoir. This type of data is most suited to structural interpretation. In an inverted dataset the amplitudes are now describing the internal rock properties, such as lithology type, porosity or the fluid type in the rocks (brine or hydrocarbons). Inverted data is ideal for stratigraphic interpretation and reservoir characterization. (Geo Expro) .

There are two main types of inversion currently being used. The first is *band-limited inversion* and the second is *Sparse spike inversion or Model Based inversion.*

7.2 POST STACK INVERSION WORK FLOW



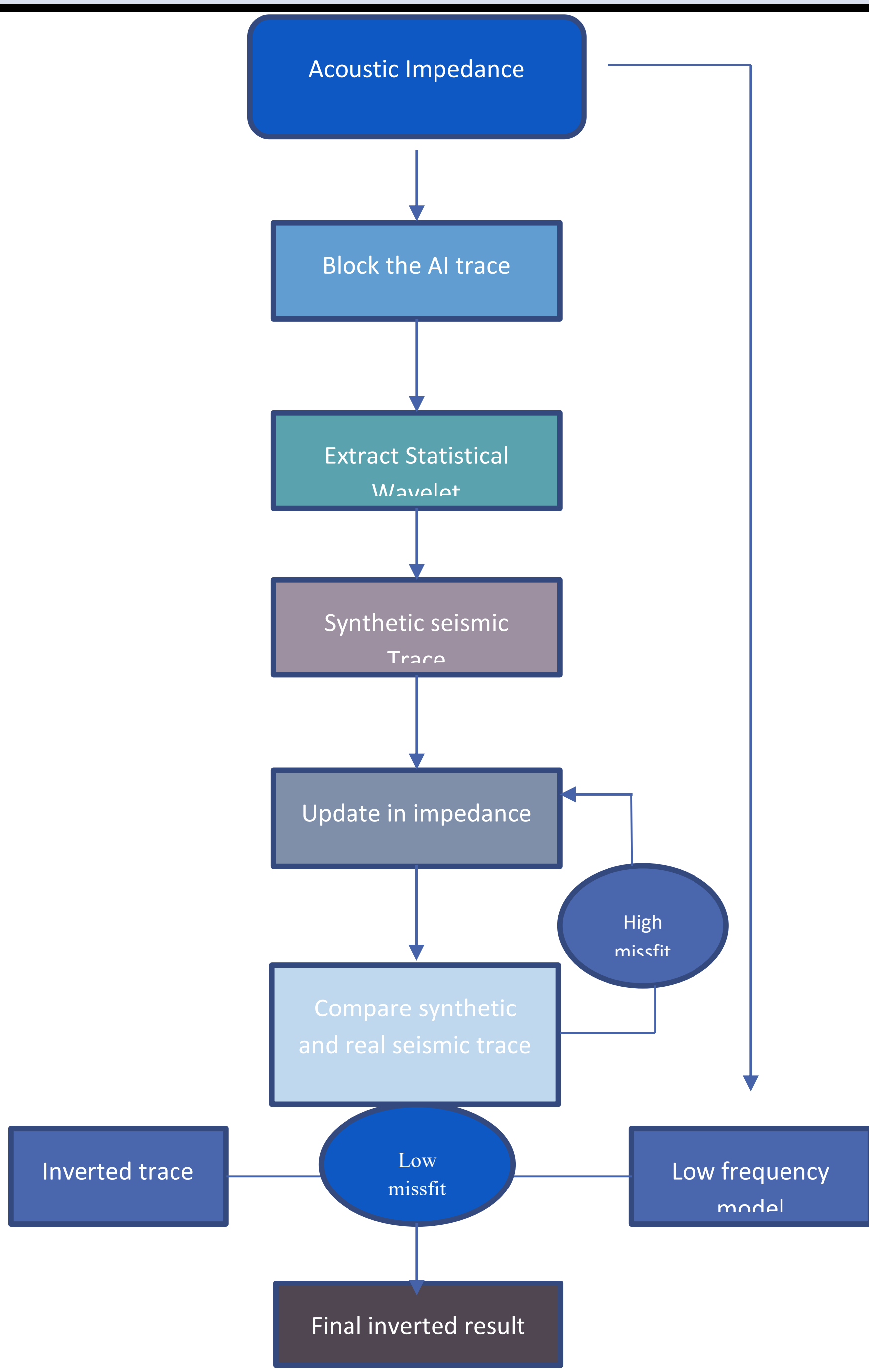
7.3 MODEL BASED INVERSION

The Model Based Inversion (MBI) is a type of post stack inversion to compute acoustic impedance from the seismic datasets. The model-based inversion technique is also known as blocky inversion. This method is based on the convolutional theory which states that the seismic trace can be generated from the convolution of wavelet with the reflectivity function. The seismic trace is however noisy due to many factors that influences the data from instrument, multiples to cultural noise.

Seismic trace =Wavelet* Reflectivity + Noise

If the noise in the data is uncorrelated with the seismic signal, the trace can be solved for Earth Reflectivity function. This is a non-linear equation which can be solved iteratively. That solution is gradually improving the fit between synthetic traces and the observed seismic data. The solution attempts to simultaneously solve the best-fit reflectivity and minimize the differences between the observed and predicted seismic.

7.4 WORK FLOW OF MODEL BASED INVERSION



7.5 RESULTS AND DISCUSSIONS

Model based inversion is performed in Hampson Russell software.

7.5.1 WELL DATA

We have to import Well Las file, navigation file and (KB) in Hampson Russell software. We also compute P-impedance Trans curve by multiplying density and velocity.

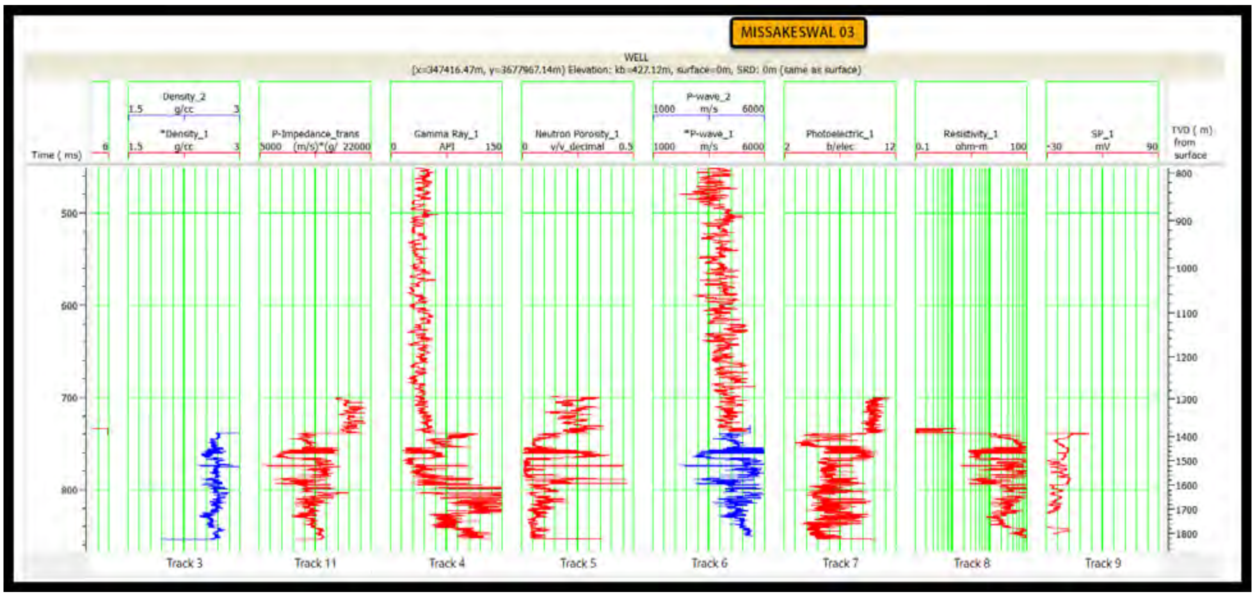


Figure 7.1 (Represents Logs of Missakeswal 03 on Hampson Russel)

7.5.2 SEISMIC DATA

We have to Upload seismic line, here I’ve upload seismic dip line 0/926-GJN-16. As we have already interpret this line on kingdom software in chapter 3 so we will extract horizon from kingdom software and import them on Hampson Russell.

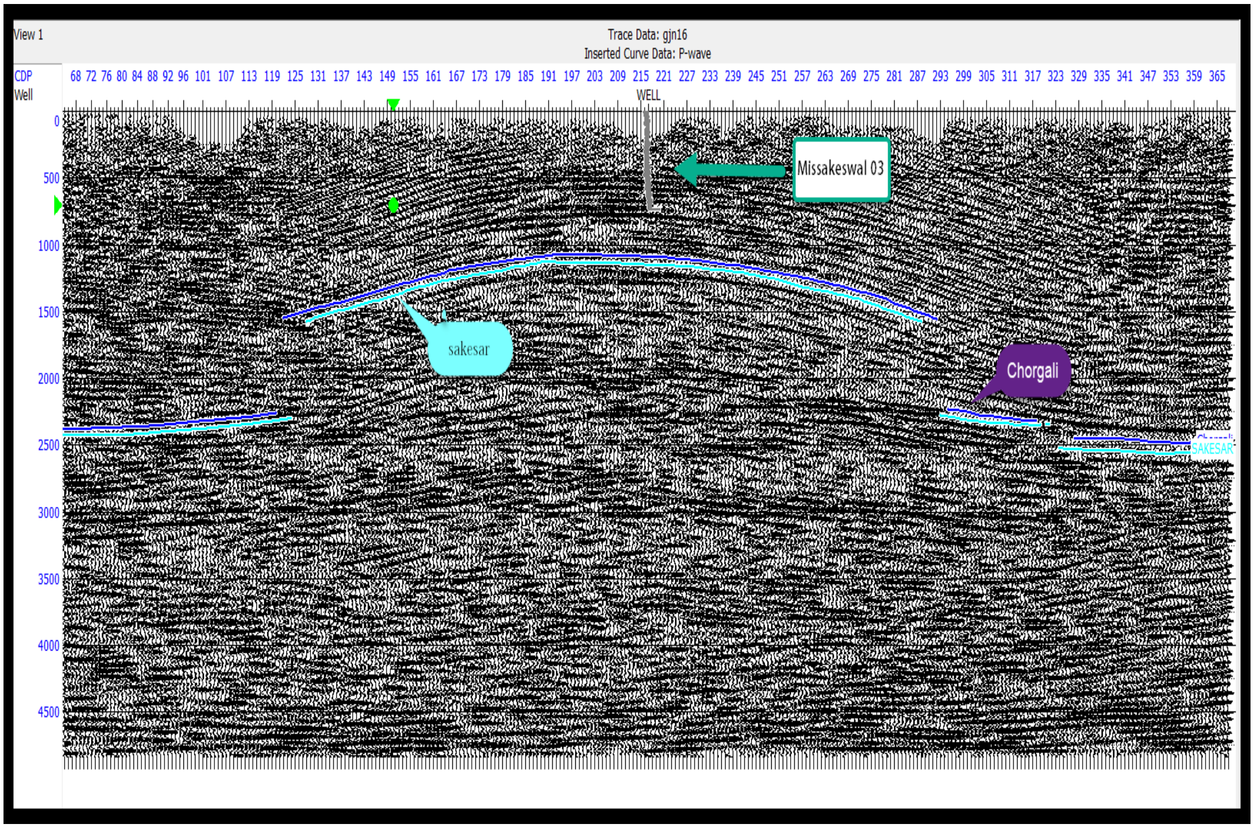


Figure 7.2 (seismic dip line 0/926-GJN-16 on Hampson Russell)

7.5.3 WAVELET EXTRACTION

A seismic wavelet is nothing but the source signature, which is required during the inversion process of seismic data (Shifa UL karem) . A good wavelet is the core of inversion. We extract statistical wavelet. For statistical wavelet extraction. This process extracts wavelet from seismic data. It considers all input seismic traces within the analysis region specified by the input probe. The frequency spectra of the autocorrelation of all input traces are stacked to produce the wavelet.

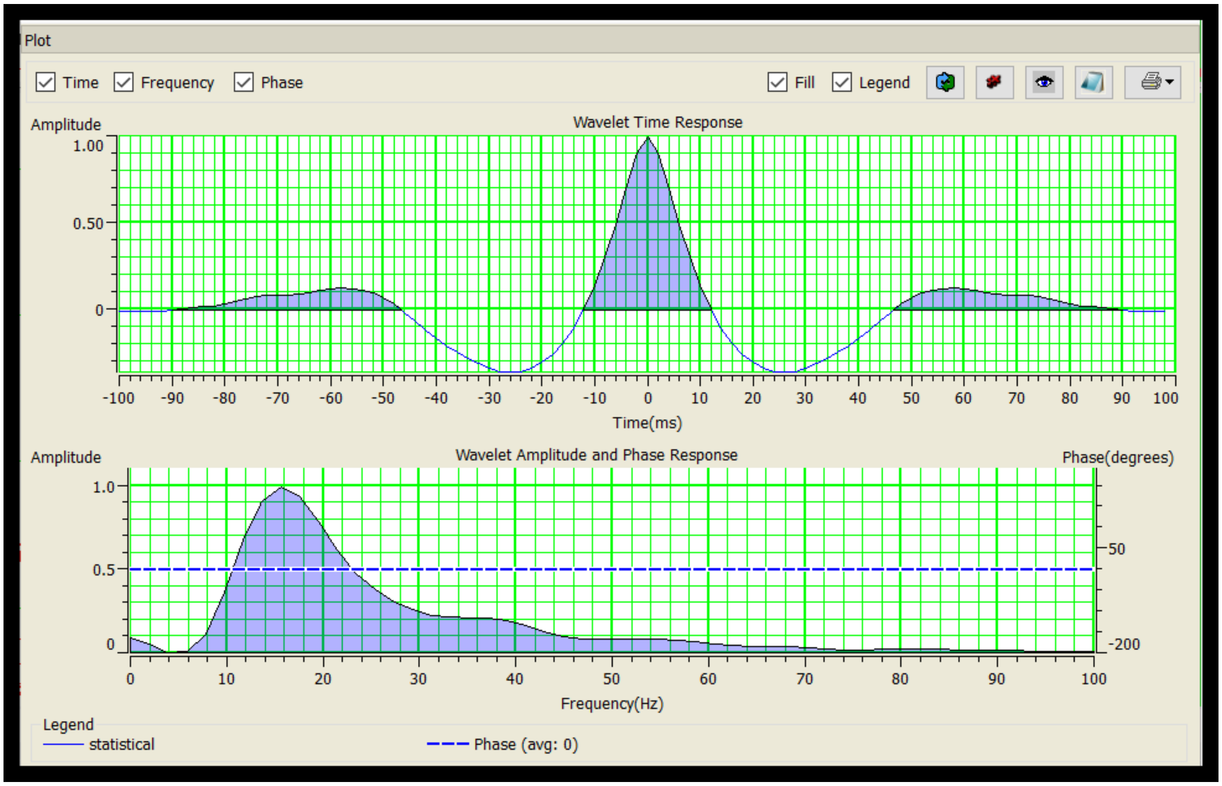


Figure 7.3 (statistical wavelet generated from seismic data)

7.6 GENERATING SYNTHETIC TRACE

The synthetic trace is computed from the calibrated sonic, density logs with the statistical wavelet. The sonic log is converted to a velocity log and this velocity is multiplied with density log to find out the impedance. This impedance is then used to compute the Earth reflectivity function which is convolved with the extracted seismic wavelet to yield the synthetic trace.

7.6.1 WELL TO SEISMIC TIE

In well to seismic tie, a synthetic trace was generated to correlate with recorded seismic trace. Since the well logs are in depth domain while seismic data is in the time domain, a check shot data were applied before correlation to convert well data into time domain.

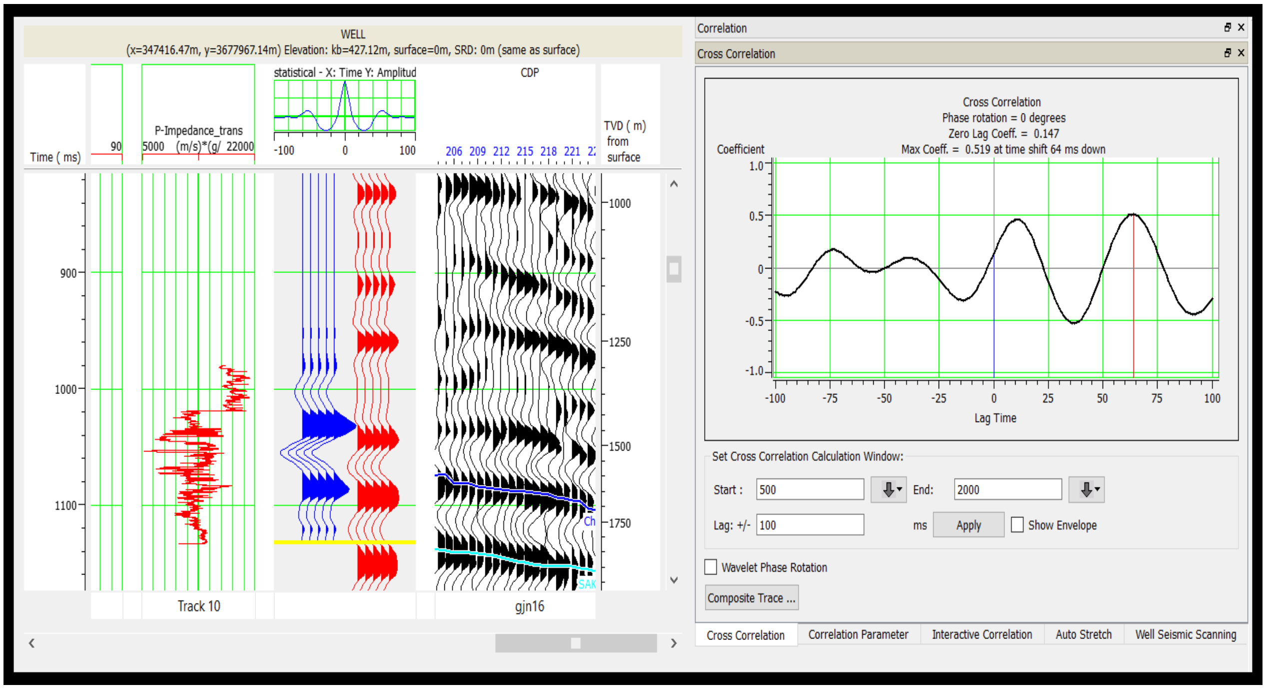


Figure 7.4 (Well to seismic tie)

In above Figure seismic to well tie task is shown. The synthetic trace is shown in blue color, the composite seismic trace in red and the seismic section in black color. We will match synthetic trace with seismic trace by applying stretch and squeeze. We have applied down shift of 64 ms and our maximum coefficient is 0.519.

7.7 BUILD STRATA MODEL

Model provides the low and high-frequency components missing from the seismic data, during processing which were used to reduce the non-uniqueness of the solution. Several band-pass filters were applied to the seismic data to the best estimate of the missing frequency range.

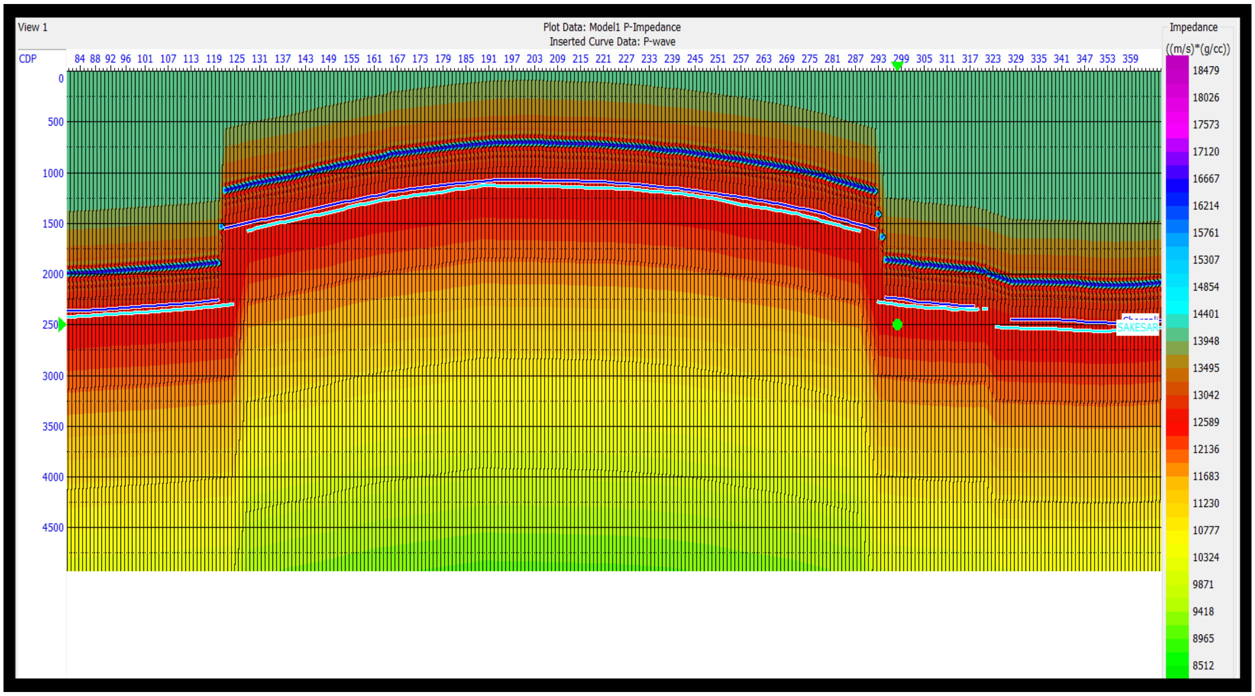


Figure 7.5 (low frequency model)

7.8 INVERSION ANALYSIS

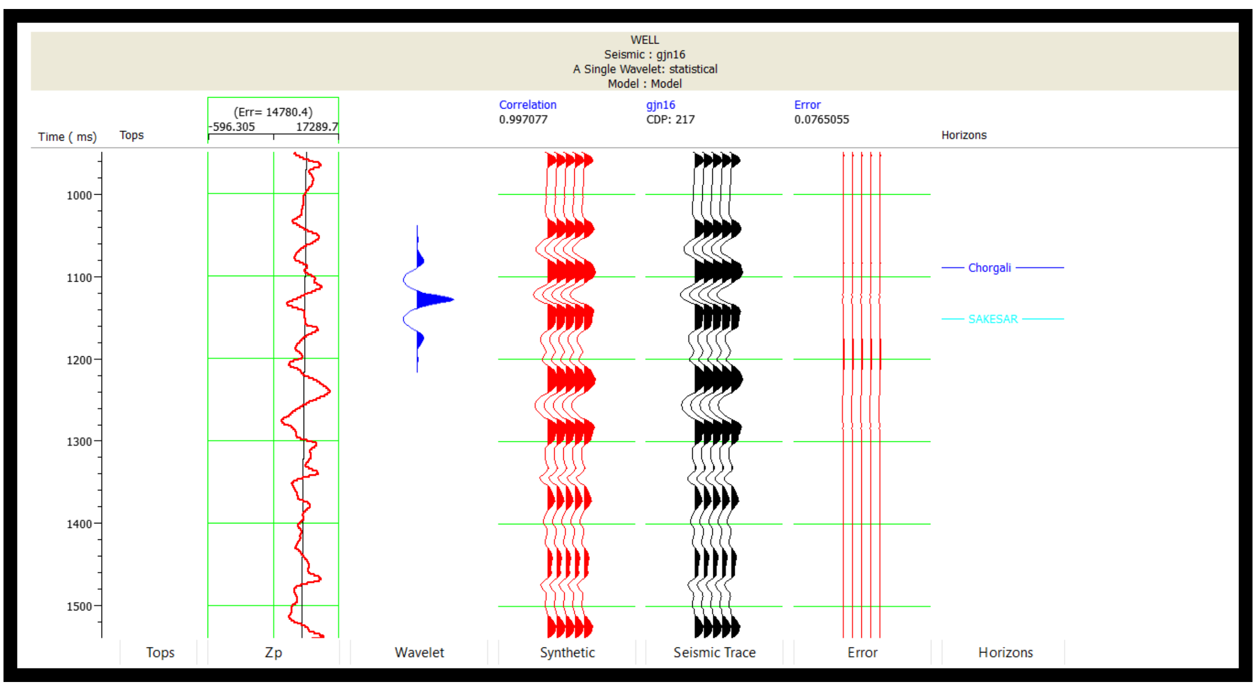


Figure 7.6 (seismic and well correlation)

A high CC suggests all the wells tie extremely well with the seismic data. In the above picture the correlation is 0.99 which is very best and error is minimum. Number of iterations: 10

7.9 FINAL INVERSION

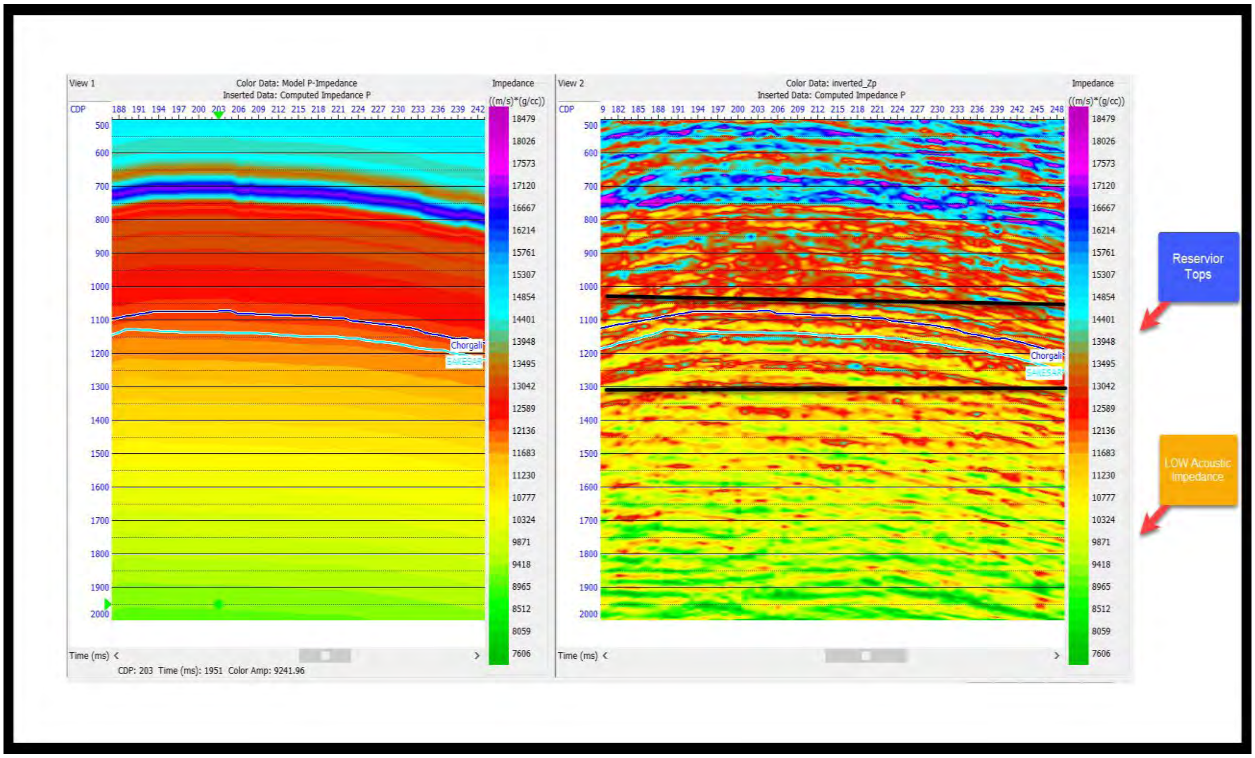


Figure 7.7 (final inversion)

Low amplitude may be indicating the potential zones. Above Chorgali and Sakesar high values of impedance indicating seal rock and below Chorgali and Sakesar low values of impedance indicating potential hydrocarbon zone.

8 CONCLUSIONS

- ✓ On the basis of general stratigraphic column present in the area and the formation tops of the MISSAKESWAL– 03 well, four reflectors are marked on seismic sections.

- ✓ The marked horizons are named as MURREE FORMATION, CHORGALI LIMESTONE, SAKESAR LIMESTONE and LOCKHART LIMESTONE. Horizons are marked with the help of synthetic seismogram of well MISSAKESWAL -03 which is generated from well log data by using density log and sonic log.

- ✓ Seismic interpretation of the area with available seismic lines show the thick skin tectonics of the area.

- ✓ Seismic structural model shows major thrust faults which confirm the compressional tectonic regime in the area under study.

- ✓ In petrophysical analysis Choargali Formation ranges from 1870 to 1914. Upper portion of Chorgali Formation has low borehole rugosity and volume of shale ranges from 20 to 30%. Average effective porosity in upper portion of Chorgali Formation is about 6%. Sakessar Formation ranges from 1914 to 1983 meters . Upper portion of Sakessar formation is clean with more than 90% volume of clean while lower portion has some volume of shale which ranges from 15 to 20%..

- ✓ Petrophysical logs have been used to compute Elastic logs and petro-elastic cross plots have been generated for facies modeling. The facies modeling interpretation is confirmed through cross plots, which provide the same interpretation.

- ✓ Velocity Analysis on interpreted geologic section GJN-16, GNA-14 has been performed to generate a geologically realistic velocity model. 2D Modelling has been carried out on the velocity model to generate a 2D synthetic seismic section which further validates the velocity model.

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