2D Seismic Modelling And Reservoir Characterization Using Seismic And Well Data of Chak Naurang Area, Upper Indus Basin, Pakistan.

By

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CERTIFICATE

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DEDICATION

I dedicate this achievement to my family, teachers, loving friends, and all those who helped me directly or in directly. In particular, I dedicate this to my parents, my supervisor and all-time favorite teacher Dr.Shahid Iqbal, and to the Department of Earth Sciences Quaid-i-Azam university Islamabad.

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Abstract

This dissertation pertains to investigate 2D seismic interpretation of seismic lines CW-28, CW-09, CW-24 and CW-05 of chak Naurang area. To carry out this exercise seismic reflection data recorded and processed by OGDCL&POL in 1988 is used.

Chorgali Formation, Sakesar Formation and Khewra Formation are main reservoir rocks and productive in potowar Fold and Thrust Belt. The study area is characterized by compressional regime as there are three major faults.

Three horizons are marked due to their prominent reflection on the seismic section namely Chorgali, Sakesar and Tobra. Time section is prepared by using two-way arrival time from seismic section.

Furthermore, this study contains the base map generated from the seismic and well data, fault marking, horizon picking, synthetic seismogram for time to depth conversion, time and depth contour maps of Chorgali and Sakesar formations, petrophysical analysis of Amirpur-01 well and last but not the least is the facies modeling of the well Amirpur-01.

Contents

CHAPTER: 01

INTRODUCTION TO STUDY AREA

1.1 INTRODUCTION

This study pertains to investigate the 2D seismic interpretation of Chak Naurang area. To carry out this exercise, seismic reflection data of Chak Naurang area situated in the upper Indus basin, Data was recorded and process in 1988 by OGDCL & POLs. The log data of

Amirpur_01 well was used for interpretation, which is located in Chak Naurang in Chakwal District of Punjab province. Chak Naurang oilfield is located in Chakwal District about 35Km south of Islamabad.

Since area is tectonically very complex, that is why, seismic study of this area is very tough. There is high concentration of hydrocarbons in this area. Thrust related structural like pop up, duplex and anticlinal traps are common in this area.

1.2 OBJECTIVES OF MY DISSERATION

- The main objective of dissertation is to present a subsurface model, estimates the reservoir properties and to identify the new well location. All objectives are stated below in points.
- Detailed seismic interpretation for identification of the structures favorable for hydrocarbon accumulation.
- Petrophysical analysis for the identification of the reservoir types and various petrophysical properties of reservoir encountered in study area.
- Preparation of depth map.
- Preparation of time map.
- Horizon marking.

1.3 DATA USED

- One strike line(782-CW-28) and three dip lines i.e CW-09, CW-24 and CW-05 has been used .The base map is developed from the navigation data.
- Seismic section of lines (CW-05, CW-28, CW-24, CW-09).
- Well data and well tops of Amirpur_01.

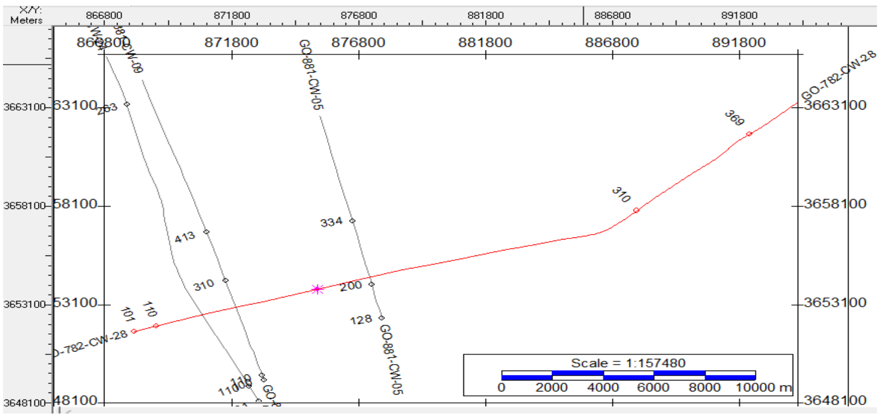


Figure 1.1 Base Map

S.NO	LINE NO	
1	CW-09	Dip line
2	CW-24	Dip line
3	CW-28	Strike line
4	CW-05	Dip line

1.4 METHODOLOGY

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

1.5 STRUCTURAL INTERPRETATION

In structural analysis main emphases is on the structural traps in which tectonic play an important role. Tectonic setting usually governs which types of the structure are present and how the structural features are correlated with each other, so tectonic of the area is helpful in determining the structural style of the area and to locate the traps. Structural traps include the faults, folds anticline, pop up, duplex, etc.

1.6 TIME AND DEPTH CONTOURS

After the marking of the horizons at different levels, the next step is to make the time and depth contours.

1.7 STRATIGRAPHIC INTERPRETATION

Stratigraphic analysis involves the delineating the seismic sequences, which present the different depositional units, recognizing the seismic facies characteristic with suggest depositional environment and analysis the reflection characteristic variation to locate both stratigraphy change and hydrocarbon depositional environment.

CHAPTER: 02

TECTONIC SETTING OF THE AREA

2.2 REGIONAL SETTING

Before Paleozoic, all the continents were jointed together into one super land called Pangea that was surrounded by one great ocean called Panthalassa. Later in late Paleozoic this Pangea was split into two sub-continent Gondwanaland (south) and Laurasia (north). The great India rifted away from Gondwanaland about 130 million years ago moved northward and collided with Eurasia (a part of Laurasia) about 50-55 million years ago after covering a distance of 5000 km. This result in different tectonic features those are well located in the north of Pakistan. Presence Pakistan is located at the junction of both converging plates. This great disaster was result in the formation in the Great Himalayas. The limit of the Himalayas in the east and west is marked by the eastern and western arc of Himalayan bends. Between these bends the Himalayan range is approximately 2400 km long and 200 km to 300 km wide. The Himalayas cover an area of approximately 600,000 sq. km in south Asia.

2.3 TECTONIC SETTING OF PAKISTAN

Pakistan possesses the northwestern boundary of the Indian lithospheric plate. The under thrusting of Indo-Pak Plate beneath the Eurasian Plate is producing compressional thin-skinned tectonic features since Eocene time on the northern and northwestern fringes of the Indo-Pak Plate. The continued under thrusting of the Indo-Pak Plate since Cretaceous produced the spectacular mountain ranges of the Himalaya and a chain of foreland fold-and-thrust belts as thick sheets of sediments thrust over the Indian craton.

Foreland Fold-and-Thrust belts are conspicuous features of convergent continental plate boundaries and are very important areas for the recent tectonic movements. NW Himalayan Fold-and-Thrust belt is one of these and is characterized by a number of active faults, (Mona liza & Azam,2004). Pakistan lies at the junction of two converging plates. Himalayas are the youngest mountain system of the world. In northern Pakistan there are three mountains ranges Hindukush, Karakorm and Himalaya. Geographically two rivers Hunza and Indus separate them. The ranges in the west of Hunza River are Karakorm

Ranges, between Hunza and Indus River (northwest of Pakistan) are Hindukush Range and in the west of Indus River Himalayas are located.

Pakistan has been divided into the following zones:

1. Indus platform and foredeep.

2. East Balochistan fold and thrust belt.

3. Northwest Himalayan fold and thrust belts (The study area lies in the Potwar plateau, which is the part of NW Himalyan fold and thurst belt).

4. Kohistan-Ladakh magmatic arc.

5. Karakoram block.

6. Kakar Khorasan flysch basin and Makran accretionary zone.

7. Chagai magmatic arc.

2.4 BASINS IN PAKISTAN

Area in which sediments are accumulated and preserved for a geologic time is known as a basin. Pakistan has three major tectonic basins i.**e (1) Indus Basin, (2)Peshawar Basin and (3)Baluchistan Basin**.

As the research area is located in Indus basin, so we will focus on the Indus basin

2.4.1 INDUS BASIN

Indus Basin including the 25000 square Km of South-East of Pakistan. It includes the Thar-Cholistan desert and Indus Plain. Tectonically it is much stable area as compared to other tectonic zones of Pakistan. It comprises of buried ridges, platform slop, zone of up warp and dawn warp. Indus Basin is further divided into three main parts:

- Upper Indus Basin
- Middle Indus Basin
- Lower Indus Basin

2.4.1.1 Upper Indus Basin

It is located in northern Pakistan and separated from the lower Indus Basin by the Sargodha High. In its north MBT, while in east and west strike slip faults Jhelum and Kalabaugh is located, Upper Indus basin is subdivided into Potwar and Khot Basins along the Indus River.

1. **Potwar Basin**

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

   - **Petroleum Play:** 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)

   - **Source and Resorvoir Rocks Of Potwar Area**: Non-commercial 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 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 and Chorgali having fractured Limestone having hydrocarbon potential in Adhi (PPL), Dhurnal (OXY), Dakhni(OGDC)etc.In post Eocene soan is considering being major kitchen area which is filled by sediments. First commercial oil produced in Khaur in 1905 from Murree Formation (Miocene). (Kadri, 1995)

- **STRATIGRAPHY OF POTWAR AREA:** The stratigraphic column is divided into three unconformity bounded sequences. These unconformities in the study area are Ordovician to Carboniferous, Mesozoic to Late Permian, and Oligocene in age. These unconformities are not easily identified in the seismic profiles due to complex thrusting. The Potwar sub-basin is filled with thick infra-Cambrian evaporate deposits overlain by relatively thin Cambrian to Eocene age platform deposits followed by thick Miocene-Pliocene molasse deposits. This whole section has been severely deformed by intense tectonic activity during the Himalayan Orogeny in Pliocene to middle Pleistocene time. oldest formation penetrated in this area is the Infra-Cambrian Salt Range Formation, which is dominantly composed of halite with subordinate marl, dolomite, and shales. The Salt Range Formation is best developed in the eastern salt range. The salt lies unconformably on the Precambrian basement. The overlying platform sequence consists of Cambrian to Eocene shallow water sediments with major unconformities at the base of Permian and Paleocene. The Potwar Basin was uplifted during Ordovician to Carboniferous, therefore no sediments of this time interval were deposited in the basin. The second abrupt change to the sedimentary regime is represented by the complete absence of the Mesozoic sedimentary succession, including late Permian to Cretaceous. (Gee,1934). Throughout the eastern Potwar area. In Mesozoic time, the depocenter was located at central Potwar where a thick Mesozoic sedimentary section is present. A major unconformity is also found between the platform sequence and overlying molasse section where the entire Oligocene sedimentary record is missing. The molasse deposits include the Murree, Kamlial, Chinji, Nagri, and Dhok Pathan Formations. (Kadri, 1995)

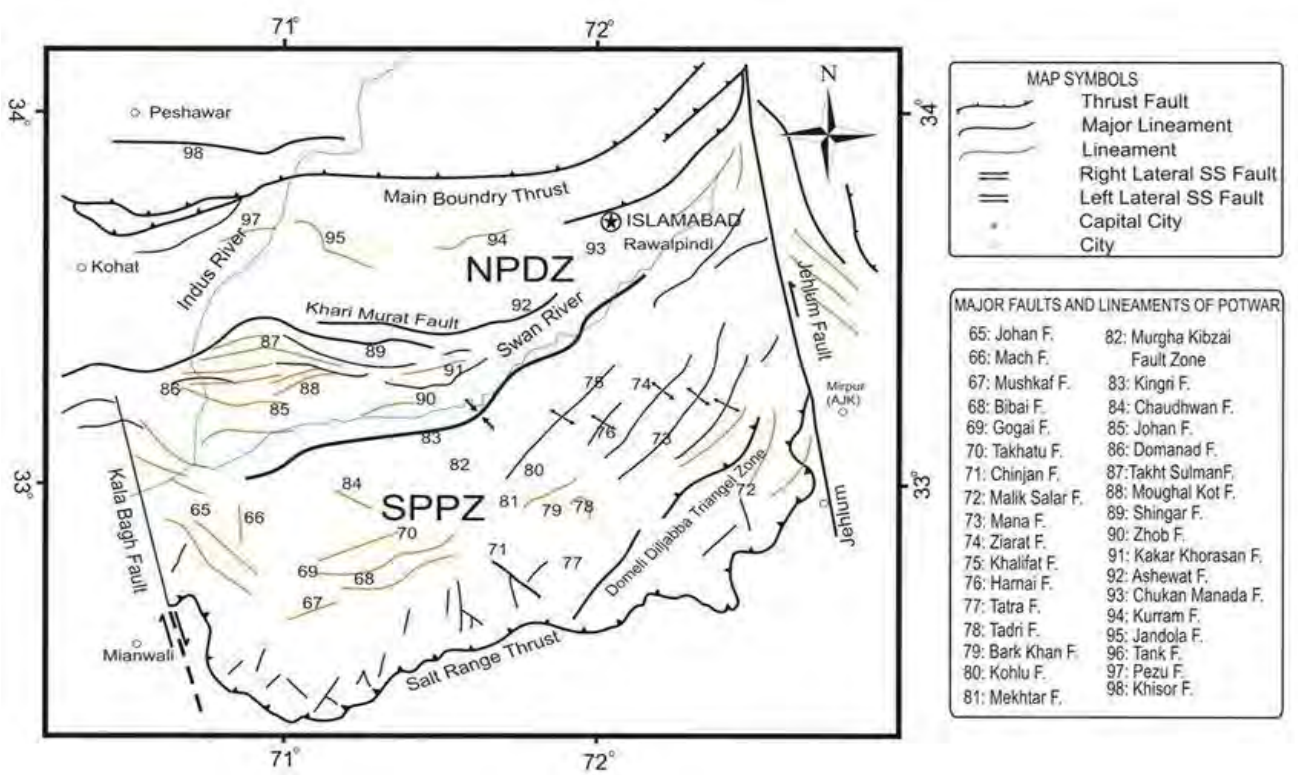


Figure 2.1 Tectonic map of the Potwar area. The major tectonic subdivisions are marked i.e., Northern Potwar Deformed Zone (NPDZ) and Southern Potwar Platform Zone (SPPZ

Middle Indus Basin The Central Indus Basins are separated by Jacobabad and Mari Kandhkot highs together termed as the Sukhur Rift. The basin is separated form upper Indus Basin by the Sargodha high and Pezu uplift in the north. It is bounded by Indian Shield in the east, marginal zone of Indian Plate in the West, and Sukhur Rift in the Plate in the west. The oldest rocks exposed in this basin are of Triassic age (Wulgai Formation) While the oldest rocks penetrated through drilling are of Precambrian Range Formation on Punjab Platform. The depth to the basement is about 15000 meters in the through area. Pre-Himalayan non-Orogeny movements resulted in prolonged sea regression causing unconformities which have large gaps in secessions. Precambrian rocks are largely missing from the basin although. Precambrian shield rocks are evident along the rim of the Indian Plate. Cambrian aged shallow marine rocks are recorded in Karampur well (Shell, 1958). The basin comprises of three main units on the basis of the topography of Indian Shields and later development. From west to east these are Punjab Platforms, Sulaiman Depression and Sulaiman Fold Belt.

Lower Indus Basin Southern Indus Basin is bounded from north by the Sukhar Rift, from the east by the Indian Shield, from by the Kerther fold belt and from west by the Indus off shore. Both Central and Southern Indus Basins have same stratigraphy up to Cretaceous but in Paleocene with the uplift of Sukhur Rift they have different deposition,(Kadri,1995).

CHAPTER: 03

INTERPRETATION

3.1 INTRODUCTION

Seismic interpretation is the interface between the exact mathematics of seismic data processing and inexact geological; receivers on the surface detect acoustic energy reflected from geological interfaces within the earth. The recorded data are processed in ways which ease interpretation (Leslie R. Denham). The process of translating seismic information in to geological terms is known as 'geological interpretation', it calls for the coordination between geology and geophysics if to be carried out successfully. According to Dobrin and Savit (1976) interpretation is the transformation of the seismic reflection data into a structural picture by the application of correction, migration and time depth conversion.

After seismic map is constructed, an important part of it its interpretation is integrating the seismic data on it with geologic information from surface and subsurface sources e.g. fault traces or geologic contacts. This involves identifying reflectors and making tie to wells or surface features. All this depends upon the amount of information available.

In seismic method physical measurements are made at the surface, which are then interpretation in terms of what might be in the subsurface the position and behavior of interfaces, which gives rise to each reflection event is then calculated from arrival times. Resulting information is then combined into cross section, which represent the structure of geological interface responsible for the reflection event.

The major aim of seismic reflection surveying is to reveal as clearly as possible the structure of the subsurface. The geological meaning of seismic reflection is simply an indication of an acoustic impedance boundary where we want to know that whether this boundary marks a fault or a stratigraphic contact with any other boundary. We want to distinguish the feature that is not marked by the sharp boundaries.

3.2 SEISMIC SECTION

The seismic section is simply a diagram of a cross section of the earth, composed of data of individual shots. It is composed of many wiggly lines, called traces. Each seismic section has two scales.

1. **Horizontal scale**
2. **Vertical scale**

A horizontal scale shows the no. of traces/inches and the vertical scale is in inches/sec. The variation in these scales enhances the physical appearance of the seismic section. Each wiggle on the seismic section shows the change in the impedance in the rock body. Each seismic section has its own header, having the basic information about the acquisition and the processing the seismic section. A combination of the wiggles extending laterally is called horizon. The main objective here is picking of the horizons.

SEISMIC SECTIONS:

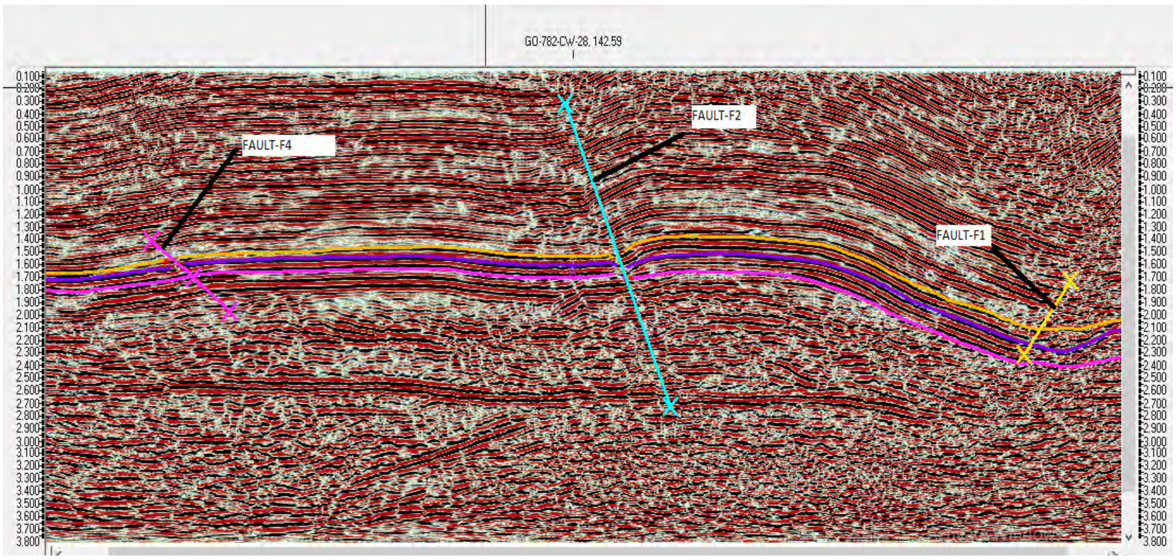


Figure 3.1 Seismic section of line CW-09:

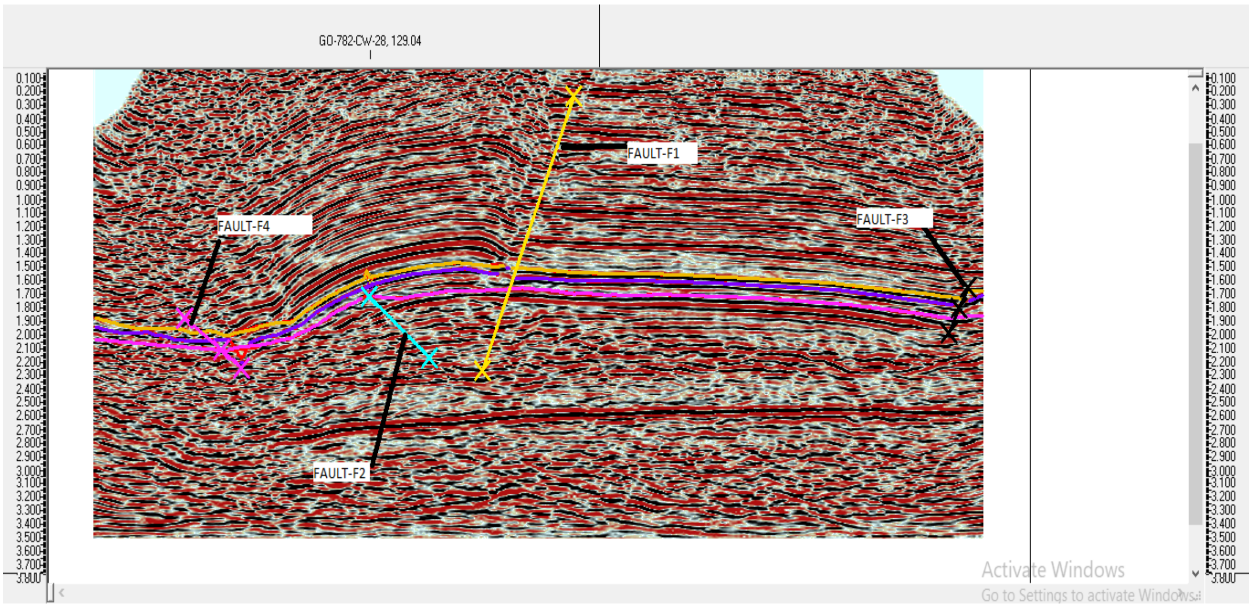


Figure 3.2 Seismic section of line CW-24:

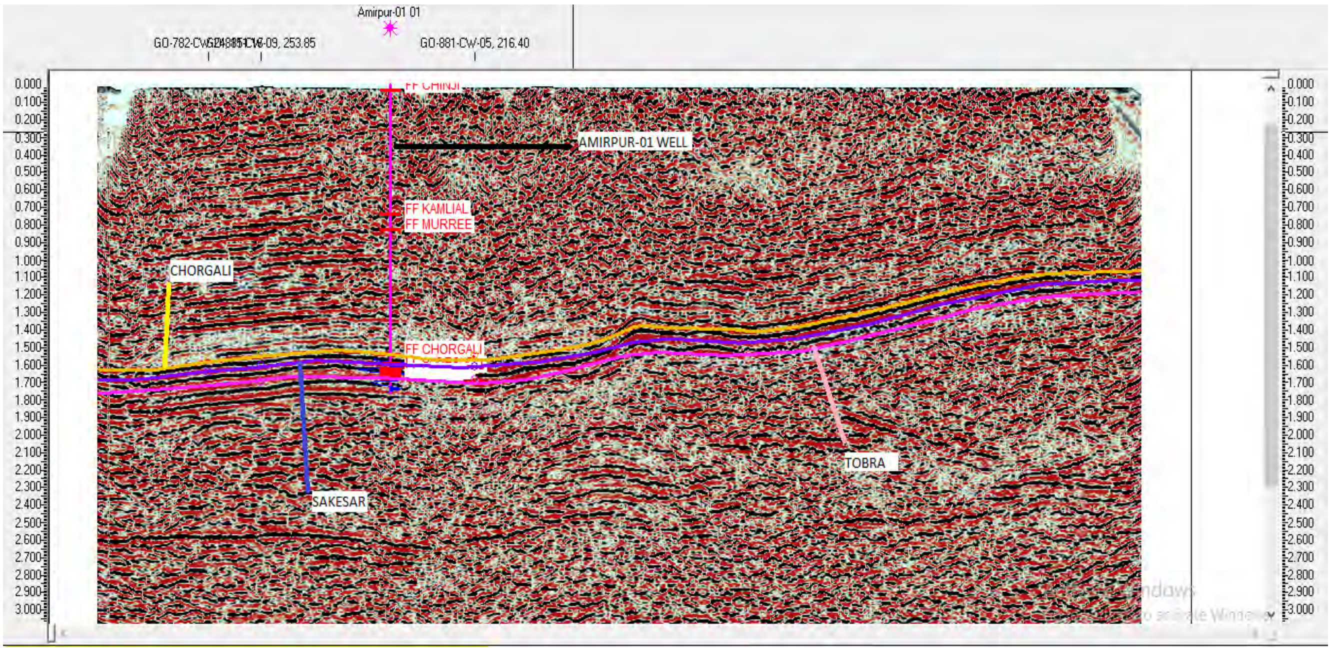


Figure 3.3 Seismic section of line CW-28 (WELL LINE):

3.3 Interpretation Of Geological Features

Interpretation differs with the geological condition in the area.

- Anticlines are simplest to interpret, by finding locally the high points, where the layers have been bent upward.
- Faults are interpreted by finding breaks in reflections. These can be very difficult to map from line to line.

- Reefs are found by recognizing some indication of buildup.
- Salt domes easily recognized, forcing their way to the bedding, but their shapes and position of the traps associated with them are hard to determine.
- Pinch out and unconformity traps are found by reflection configuration and more subtle clues.
- Exceptionally strong, weak or flat reflections on the sections can be clue to the presence of gas in rocks.

3.4 METHODS

3.4.1 Structural Analysis

Structural maps are constructed to display the geometry of selected reflected events. Discontinuous reflections clearly indicate parts and undulating reflections reveals folded beds. Similarly diffraction may be because of termination of bed or fault.

The study area, chak naurang lies in intense compressional region, so general structures are reverse faults, folds and thrusts related. A thrust fault develops under high pressure system because hanging wall moves upward, so called antigravity faults. The generation of antigravity faults required high pressure under the fault plane.

3.4.2 Stratigraphic Analysis

Seismic stratigraphy is used to find out the depositional processes and environmental settings, because genetically related sedimentary sequence normally consists of concordant strata that show discordance with sequence above and below it. It also helps to identify formations, stratigraphic traps and unconformity.

This method also facilitate for the identification of the major pro-gradational sedimentary sequences which offer the main potential for hydrocarbon generation and accumulation Stratigraphic analysis therefore greatly enhances the chances of successfully locating hydrocarbon traps in sedimentary basin environments. In study area strongest reflector are basement and Chorgali Formation. In case of basement there is greater impedance contrast because Salt Range Formation overlies the basement and Salt Range Formation is composed of salts while basement is composed of crystalline rocks.

3.5 MARKING OF HORIZONS

The first step of interpretation process is to mark the reflectors. A reflector is defined as an interface or boundary between two rock units (formation). Those reflectors are selected which are real, show good character and continuity, and can be followed throughout the area. (Badely, 1985).

Three horizons are picked up on each line the of the research area.These horizons were marked through the same steps and little bit of difficulty was faced. Some reflectors were strong enough to be picked due to variation in acoustic impedance that is eventually caused by changes in lithology while some were difficult to be marked.

3.6 SYNTHETIC SEISMOGRAM

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

The primary well data required to generate synthetic seismic trace is sonic log and density log. The following procedure is adopted to generate synthetic seismogram:

- Multiply sonic and density log to obtain acoustic impedance log.

$$Z = \rho \times v$$

Where Z = Acoustic impedance, ρ = density log and v = sonic log.

- Now compute reflection coefficient for each interface using Zeopprittz Equation:

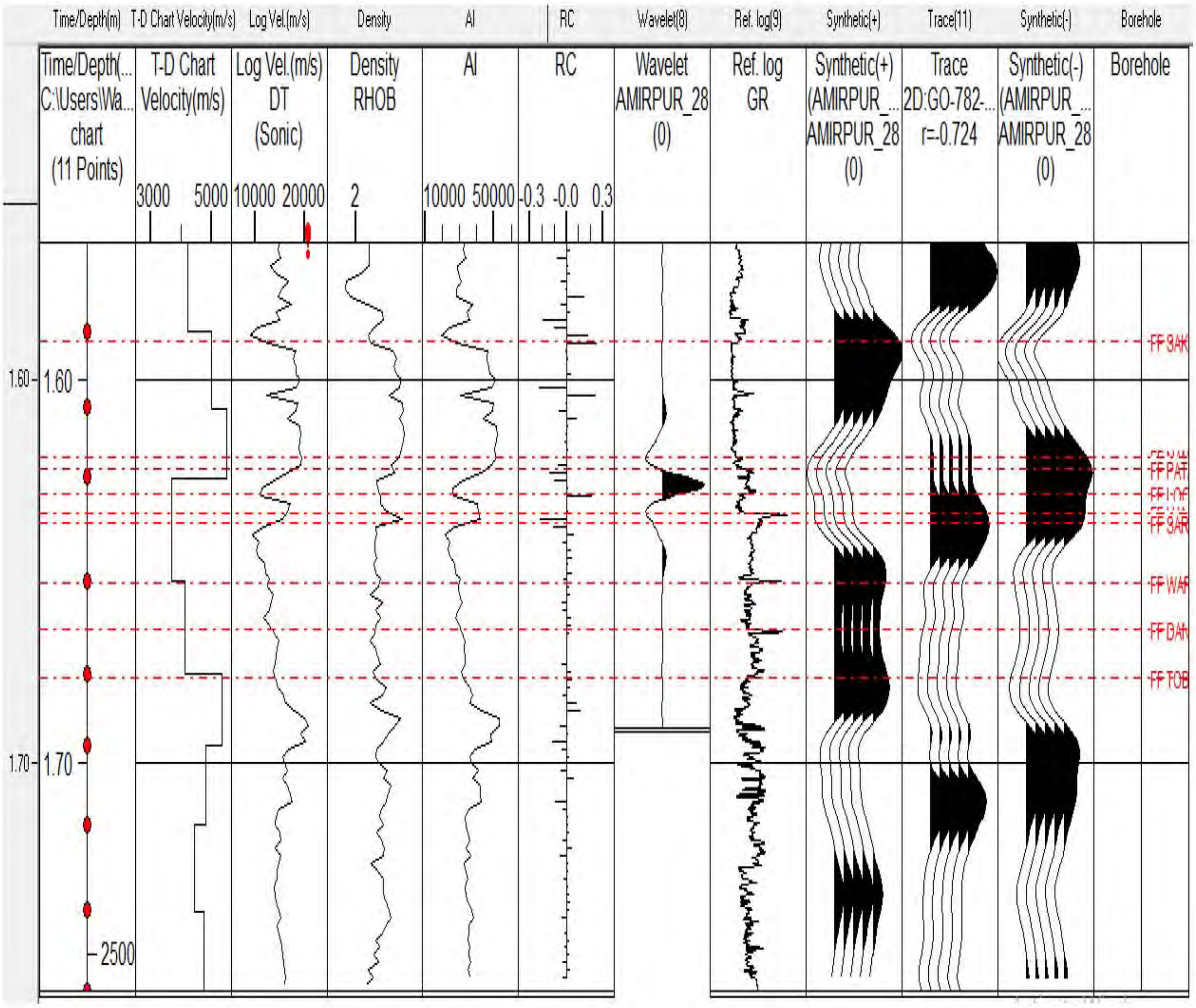
$$R_i = \frac{Z_{i+1} - Z_i}{Z_{i+1} + Z_i}$$

- In the last step convolve source wavelet with the reflection coefficient to compute seismic trace.

$$S(t) = S(w) * RC$$

Where S(t) = Synthetic seismic trace, S(w) = source wavelet and RC = Reflection coefficient.

Following is the Synthetic seismogram of Amirpur-01 well;



3.7 CONTOUR MAPPING

The results of seismic interpretation are usually displayed in the form of maps. 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 3D earth on a 2D surface. The spacing of the contour lines is a measure of the steepness of the slope i.e. closer the spacing, steeper the slope. A subsurface structural map shows relief on a subsurface horizon with contour lines that represent equal depth below a reference datum or two way time (TWT) from the surface. These contour maps reveal the slope of the Formation, structural relief of the Formation, its dip, and any faulting or folding. The interpreted seismic data is contoured for producing seismic maps which provide a 3D picture of the various layers within an area which is limited by intersecting shooting lines.

In this Project, both, on time and depth contour, the values between the fault polygons are lower which indicate shallow depth. These contours support our argument that the area of interest is a pop-up anticline having some thrust faults and structural traps.

In this particular topic we will have a look on the following contour maps;

- Time contour map of chorgali
- Time contour map of sakesar
- Depth contour map of chorgali
- Depth contour map of sakesar

Following are the contour maps of Chorgali and Sakesar formation;

3.7.1 Time contour of Chorgali;

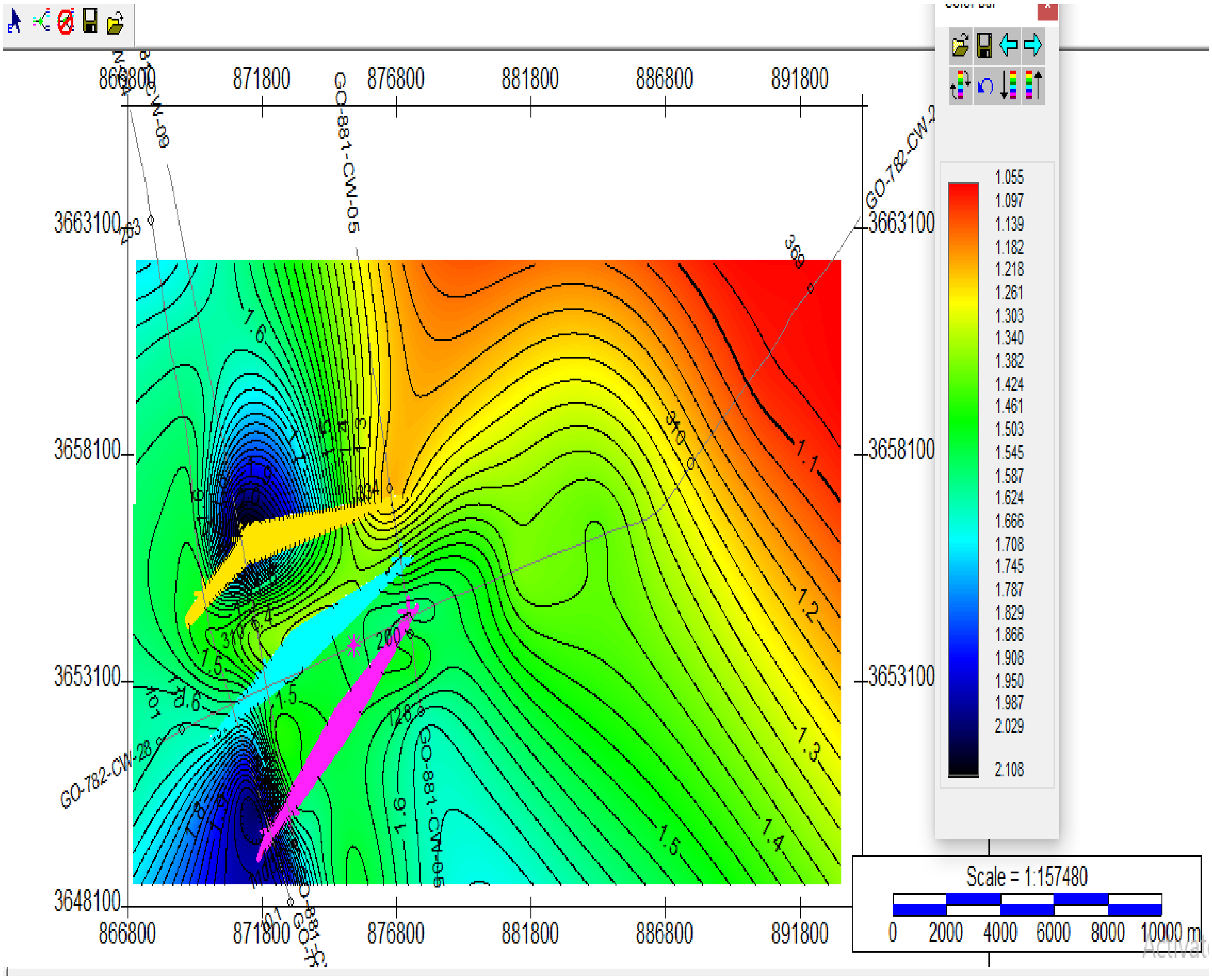


Figure 3.4 Time Contour map of Chorgali

3.7.2 Depth contour of Chorgali;

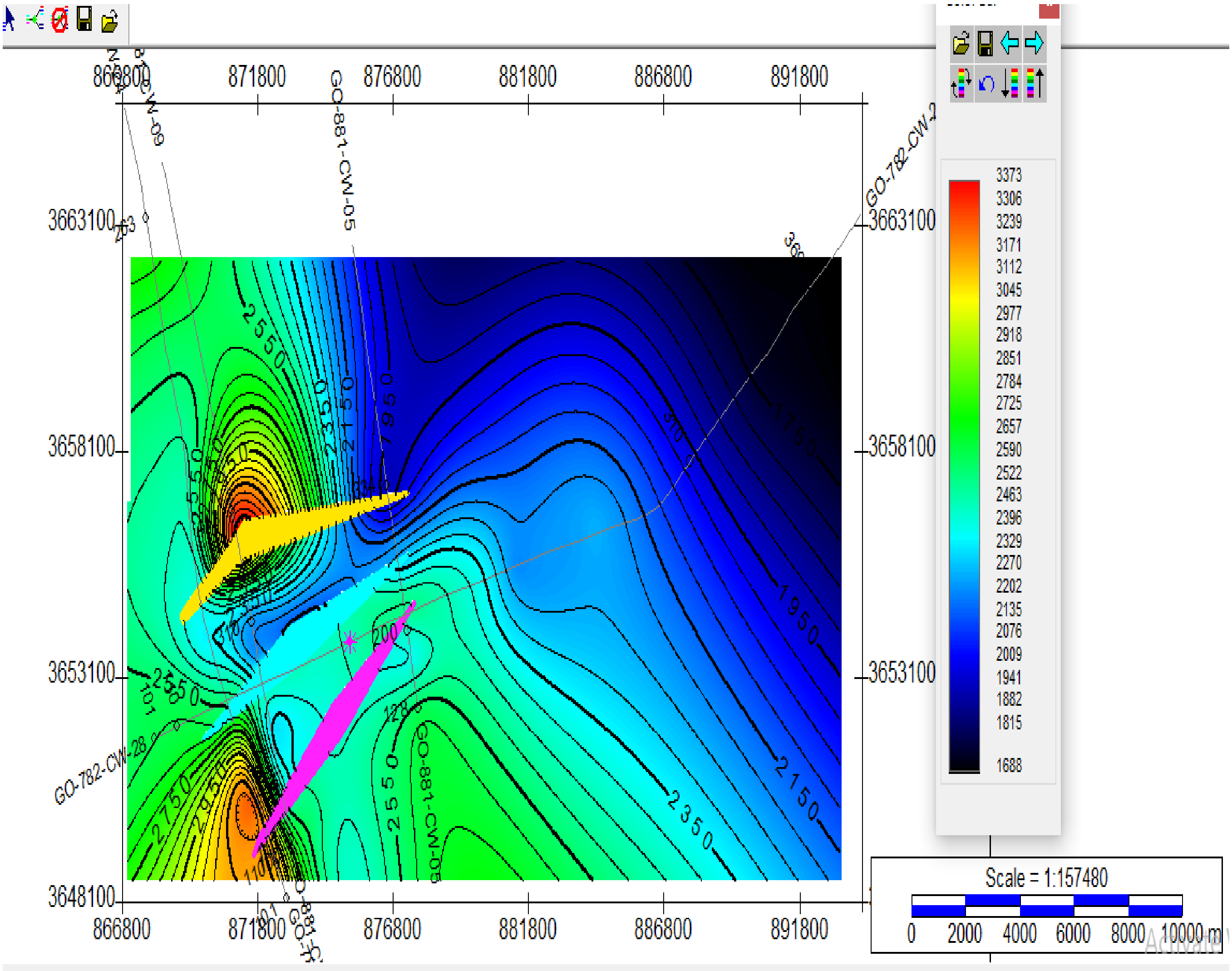


Figure 3.5 Depth Contour map of Chorgali

3.7.3 Time contour map of Sakesar;

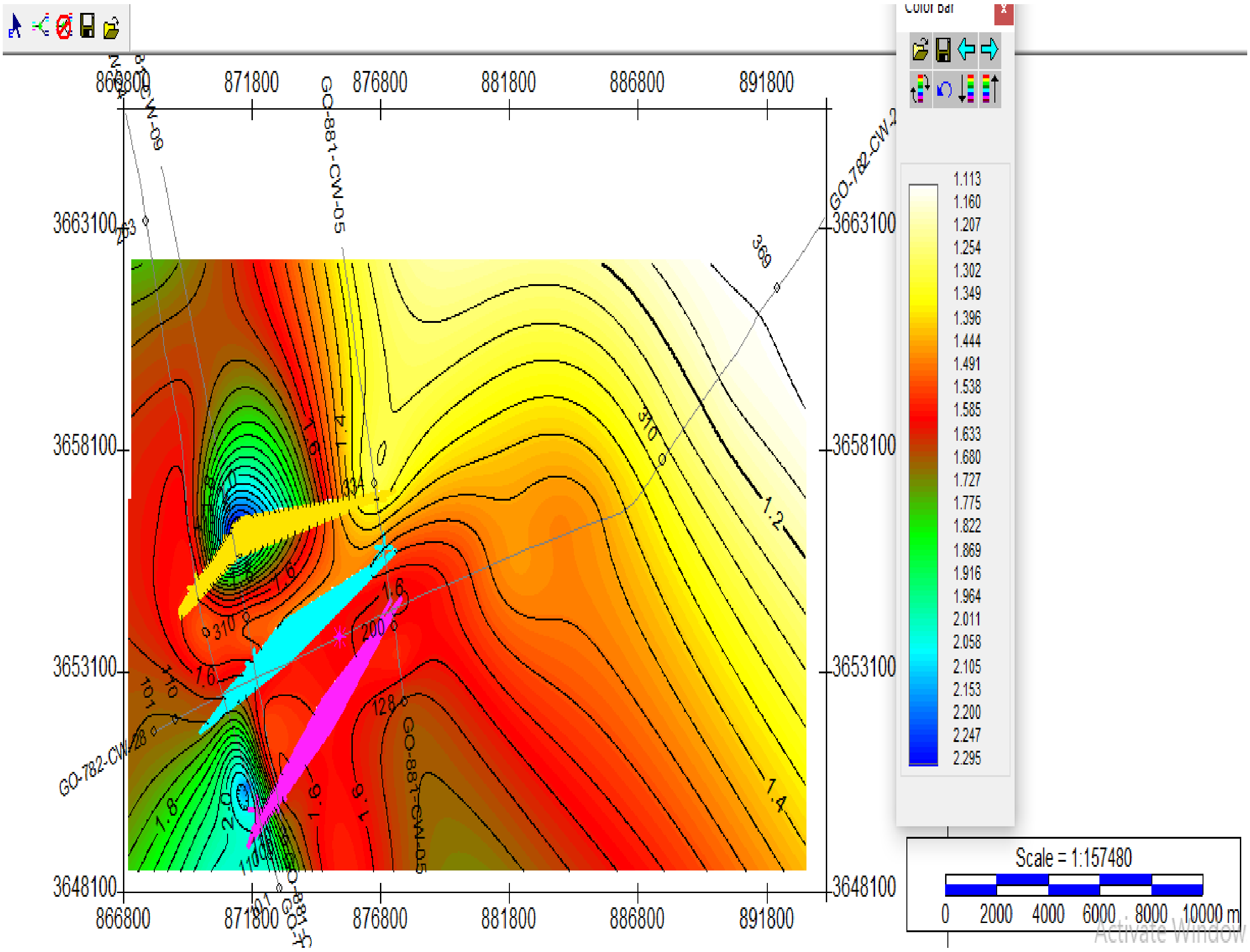


Figure 3.6 Time Contour map of Sakesar

3.7.4 Depth contour map of Sakesar;

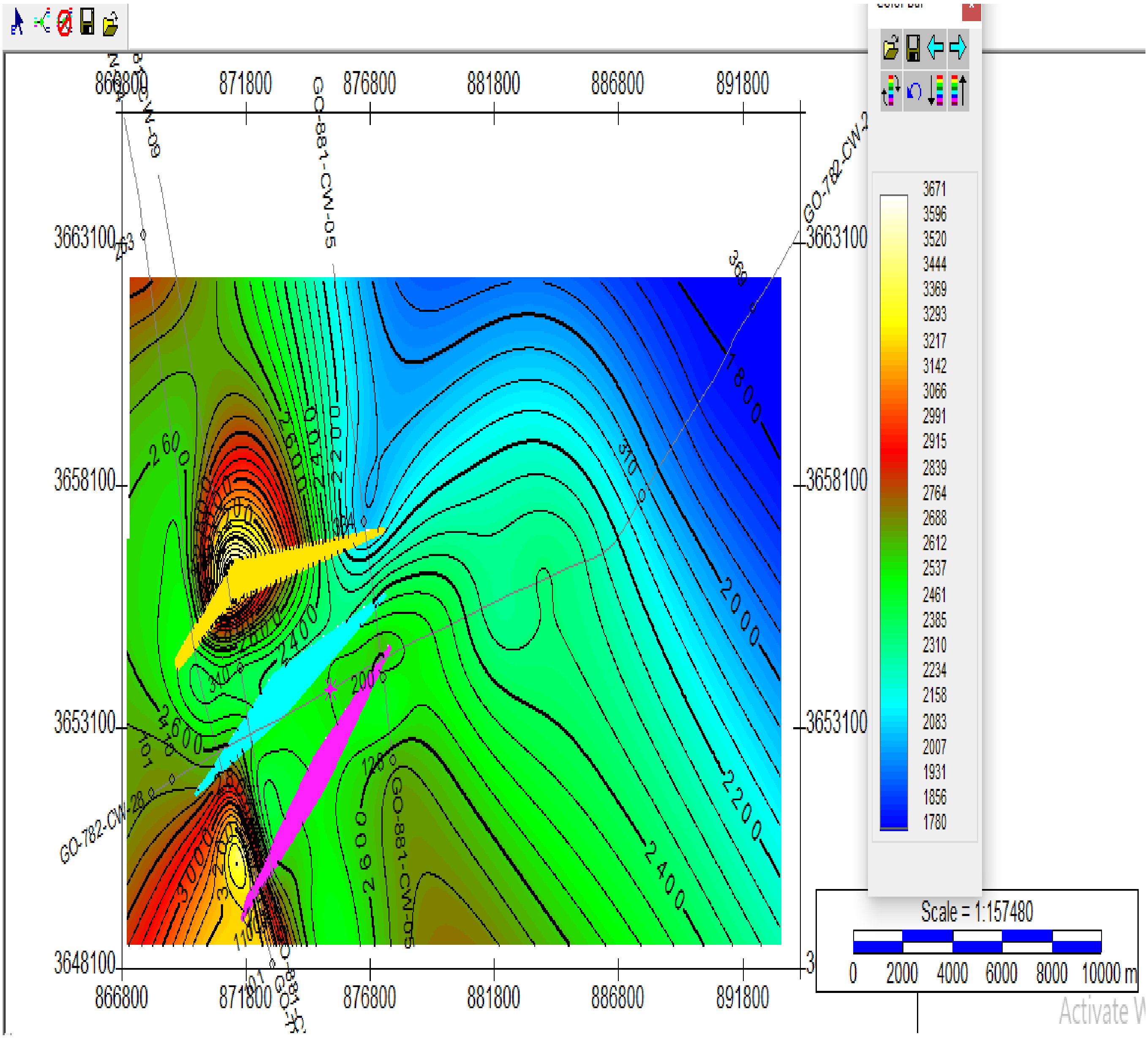


Figure 3.7 Depth Contour map of Sakesar

CHAPTER: 04

PETROPHYSICS

4.1 INTRODUCTION

Petrophysics is the study of the physical and chemical properties that describe the occurrence and behavior of rocks, soils and fluids. Petrophysicists evaluate the reservoir rock properties by employing well log measurements, core measurements and seismic measurements, and combining them with geology and geophysics (Paal Fristad, 2012).

It is mainly used in the hydrocarbon industry to study the behavior of different kinds of reservoirs. It also explains about the chemistry of pores of the subsurface and how they are connected. It helps in controlling the migration and accumulation of hydrocarbons. While explaining the chemical and physical properties, petrophysics also explains many other related terms such as lithology, water saturation, density, Irreducible water saturation, Hydrocarbon saturation, Net pay thickness, permeability, and porosity and many more. The key role of petrophysics is to evaluate the rock properties by placing measurement tools in the bore hole.

4.2 PETROPHYSICAL PROPERTIES OF RESERVOIR

Most Petrophysicists are employed to compute what are commonly called reservoir Petrophysical Properties. These are discussed one by one as follow:

4.2.1 Lithology

Lithology indicates the type of rock. When combined with local geology and core study, geoscientists use log measurements such as natural gamma, neutron, density, Photoelectric, resistivity or their combination to determine the lithology down the hole.

4.2.2 Porosity

The porosity is the amount of pore (or fluid occupied) space in the rock. This is typically measured using an instrument that measures the reaction of the rock to bombardment by neutrons or by gamma rays. Sonic wave speed and NMR logs are also run to derive rock porosity.

4.2.3 Water Saturation

The fraction of the pore space occupied by water is called water saturation. Water saturation is measured by running the resistivity log in the well.

4.2.4 Hydrocarbon Saturation

The fraction of the pore space occupied by hydrocarbon is called hydrocarbon saturation.

Basic scheme which has been followed for petrophysical well logging is shown in the following figure ;

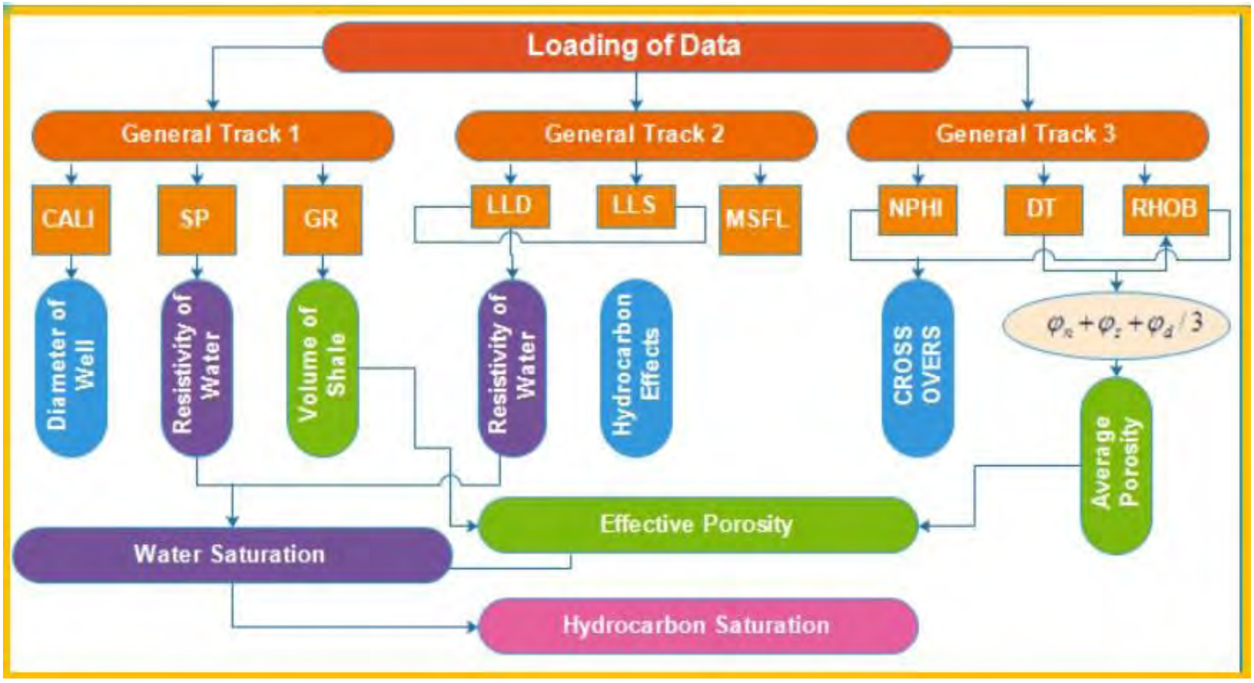


Figure 4.1 Flowchart of scheme used for Petrophysical Analysis

4.3 TRACKS

Log is a record. Well log is a profile showing different properties of formation, that is measured through wells. Every log gives some information about subsurface. Some logs are correlated with other log to assure our prediction of lithologies.

4.3.1 Lithology Track

Gr Log

GR logging tool detect the natural Gamma radiations across the formation. These radiations come from radioactive element like Potassium, Uranium and Thorium etc. GR show maximum deflection for dirty lithologies (Shale) and minimum against clean lithologies. A clean lithology (Sandstone) has smaller quantity of clay minerals while a dirty lithology is enrich in clay minerals (Shale). From GR log we not only interpret lithologies but we can also find Volume of shale.

Spontaneous Potential Log

The spontaneous potential log (SP) measures the natural or spontaneous potential difference (sometimes called self-potential) that exists between the borehole and the surface in the absence of any artificially applied current. It is a very simple log that requires only an electrode in the borehole and a reference electrode at the surface. These spontaneous potentials arise from the different access that different formations provide for charge carriers in the borehole and formation fluids, which lead to a spontaneous current flow, and hence to a spontaneous potential difference. The SP log has four main uses: The detection of permeable beds, determination of Rw. The indication of the shaliness of a formation and for Correlation.

Caliper log

Caliper log tell us about borehole diameter. Borehole diameter is actually equal to the bit size. A line is drawn on the Caliper log which shows the size of borehole. A simple mechanical measures a vertical profile of borehole diameters. Any deflection from this line show the variation of borehole diameter and it actually gives us clue of the lithology. It is run in track 1 with Sp and GR log.

Increase of borehole diameter indicates Caving and Washouts and similarly decrease in borehole diameter indicates that Mud Cake has formed on the wall of borehole. Caliper log showing the decrease in bore size indicates that mud cake is formed on the walls of bore hole, which is a good indicator of Permeable lithology because mud Cake only form when rock is permeable. Caving and washouts show loose lithology, i.e. Shale, so increase of bore hole diameter is an indication of shale.

4.3.2 Resistivity Track

Resistivity logs

A log of the resistivity of the formation is expressed in ohm-m. The resistivity can take a wide range of values, and, therefore, for convenience is usually presented on a logarithmic scale from, for example, 0.2 to 2000 ohm-m. The resistivity log is fundamental in formation evaluation because hydrocarbons do not conduct electricity while all formation waters do. Therefore a large difference exists between the resistivity of rocks filled with hydrocarbons and those filled with formation water. Clay minerals and a few other minerals, such as pyrite, also conduct electricity, and reduce the difference. Resistivity logs are of various types these are described below ;

- **LLD**

  (Deep Laterolog) Laterolog log deep also measures the true formation resistivity beyond the outer boundary of invaded zone.

- **LLS**

  Shallow Laterolog deep measures the resistivity in the invaded zone

- **MSFL**

  Micro spherically focused log measures the resistivity of the flushed zone (Rxo).

4.3.3 Porosity Track

Density Log

Density porosity log (RHOB) displays the electron density of formation in contact by detecting the scattered gamma rays. It gives an indication of porosity, lithology and can assist to detect gas bearing zone. Cross over of Neutron and density log is an indicator of

Gas/hydrocarbons called Gas Effect. The overlapping curves indicate the presence of water.

Sonic log

Sonic log is a porosity log that measures interval transit time of compressional sound waves. It displays travel time of P-waves versus depth. Sonic logs are typically recorded by pulling a tool on a Wireline up the wellbore. The tool emits a sound wave that travels from the source to the formation and back to a receiver. (1).the interval transit time is dependent upon both lithology and porosity. For porous rock the travel time increases and hence the larger deflection occurs on the log display and for denser and nonporous material the traveling velocity increases and hence the travel time decreases.

To calculate porosity from sonic log we must know formation matrix velocity. By Wyllie's formula

$$\varphi_{sonic} = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

Where, Δt_{log} is the interval transit time of formation.

Δt_{ma} is the interval transit time of the matrix.

Δt_f is the interval transit time of the fluid in well bore.

Neutron log

Neutron log is based on effect of the lithology on fast neutrons emitted by a source. Hydrogen has the largest effects on these neutrons in slowing down and absorbing them. Since hydrogen is found in with water and hydrocarbons. This is found mainly in pores, so neutron is direct indicator of porosity.

4.4 OBJECTIVE

The petrophysics analysis has been carried out in order to measure the reservoir characterization of the Chak Naurangr area using the borehole data of Amirpur-01 well. Log curves including spontaneous potential log (SP), Gamma ray (GR), Sonic log (DT), Latero Log Deep (LLD), Latero Log Shallow (LLS), Neutron log, density log were used for petro physical analysis the following parameters are calculated for reservoir rock.

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

4.4.1 Volume Of Shale

We have two methods for the calculation of volume of shale . In linear method we compute IGR by following formula.

$$IGR = \frac{(GR)_{LOG} - (GR)_{MIN}}{(GR)_{MAX} - (GR)_{MIN}}$$

IGR can give us maximum volume of shale and we have to found minimum volume of shale by nonlinear method.

4.4.2 Porosity

In the next step we have to calculate Porosity parameters, like

- Density Porosity
- Sonic porosity
- Effective Porosity
- Neutron porosity (Given)

Density Porosity

Density log data is given but we need density porosity for the cross plot with Neutron porosity to have better interpretation. Porosity values calculated from density log is call density porosity.

$$RHOB\varphi = \frac{RHOB_{mat} - RHOB_{log}}{RHOB_{mat} - RHOB_{fl}}$$

The value of density of matrix given in the exercise is 2.71 gm/cm^3 which is for carbonates and density of fluid is 1gm/cm^3.

Sonic porosity

For Sonic porosity we will use formula of consolidated rocks because we know that these rocks are old and well consolidated.

$$\varphi s = \frac{\Delta t_{log} - \Delta t_{mat}}{\Delta t_{fl} - \Delta t_{mat}}$$

The interval transient time of Formation increased due to presence of hydrocarbon known as hydrocarbon effect. This effect should be removed because it affects the values of calculated porosities.

Effective Porosity

The interconnected pore volume or void space in a rock that contributes to fluid flow or permeability in a reservoir. Effective porosity excludes isolated pores and pore volume occupied by water adsorbed on clay minerals or other grains.

Effective porosity is less than total porosity. Effective porosity log was created by using total porosity logs and volume of shale log.

The mathematical relation for effective porosity is as follows:

$$\varphi_e = (1 - V_{sh}) \times \varphi_{avg}$$

Neutron Porosity

The neutron log is sensitive mainly to the amount of hydrogen atoms in a formation. Its main use is in the determination of the porosity of a formation. The count rate will be low in high porosity rocks and the count rate will be higher in low porosity rock. Neutron porosity is given in the data and calculated by well log w.r.t depth.

<u>Total Porosity</u>

The total porosity is the sum of all the porosities calculated from different logs divided by the number of logs used for calculating porosities

$$\varphi_T = \frac{\varphi_d + \varphi_n + \varphi_s}{3}$$

Where φ_T = Average porosity

4.4.3 Water Saturation

Water saturation is the percentage of pore volume in rock that is occupied by water of formation. To calculate saturation of water in the formation, a mathematical equation was developed by Archie shown below. All the parameters of Archie equation can be calculated from resistivity and spontaneous potential logs. The resistivity of water is calculated with the help of Spontaneous potential log.

The resistivity of water calculated is 0.042Ωm for Chorgali and 0.049 Ωm for Sakesar. After calculating all these parameters, we use Archie equation for calculating saturation of water stated below.

$$S_w = \left[\frac{R_w * F}{R_t}\right]^{1/n}$$

4.4.4 Hydrocarbon Saturation

The fraction of pore spaces containing hydrocarbons is known as hydrocarbon saturation. The simple relation used for this purpose is given below:

$$S_w + S_H = 1$$

The saturation of hydrocarbons is percentage of pore volume occupied by hydrocarbon. Where, S_H = Hydrocarbon saturation and S_w = Water saturation

4.5 AMIRPUR-01 WELL

Amirpur-01 is an exploratory well and it is located at south eastern part of the potowar basin in chakwal district. Amirpur-01 well is located at 32°-57′-34”.37 Lattitude and 73°-00′-46”.51 Longitude. The well was completed on 30th Oct 1995 to reach total depth of 3027m. this is also an oil producing well. Different formation were hit in this well i.e NAGRI,CHINJI,KAMLIAL,MURREE,CHORGALI,SAKESAR,NAMAL,PATALA,TOBRA and KEHWRA etc.

NAMAL and PATALA shales are the main source rocks in the region while clays of MURREE and KULDANA formations act as seal rocks. KEHWRA sandstone is the main reservoir rocks in the area.

4.6 PETROPHYSICAL ANALYSIS

4.6.1 Chorgali Formation

Shale volume of zone of interest is 5.8%. Effective porosity is about 7.5% and potential of the hydrocarbon is 73.46% and water saturation is 26.34%.The zone of interest is from 2617-2622 meters where GR values fall, caliper is stable, Crossover of LLD and LLS and crossover of NPHI and RHOB is observed.

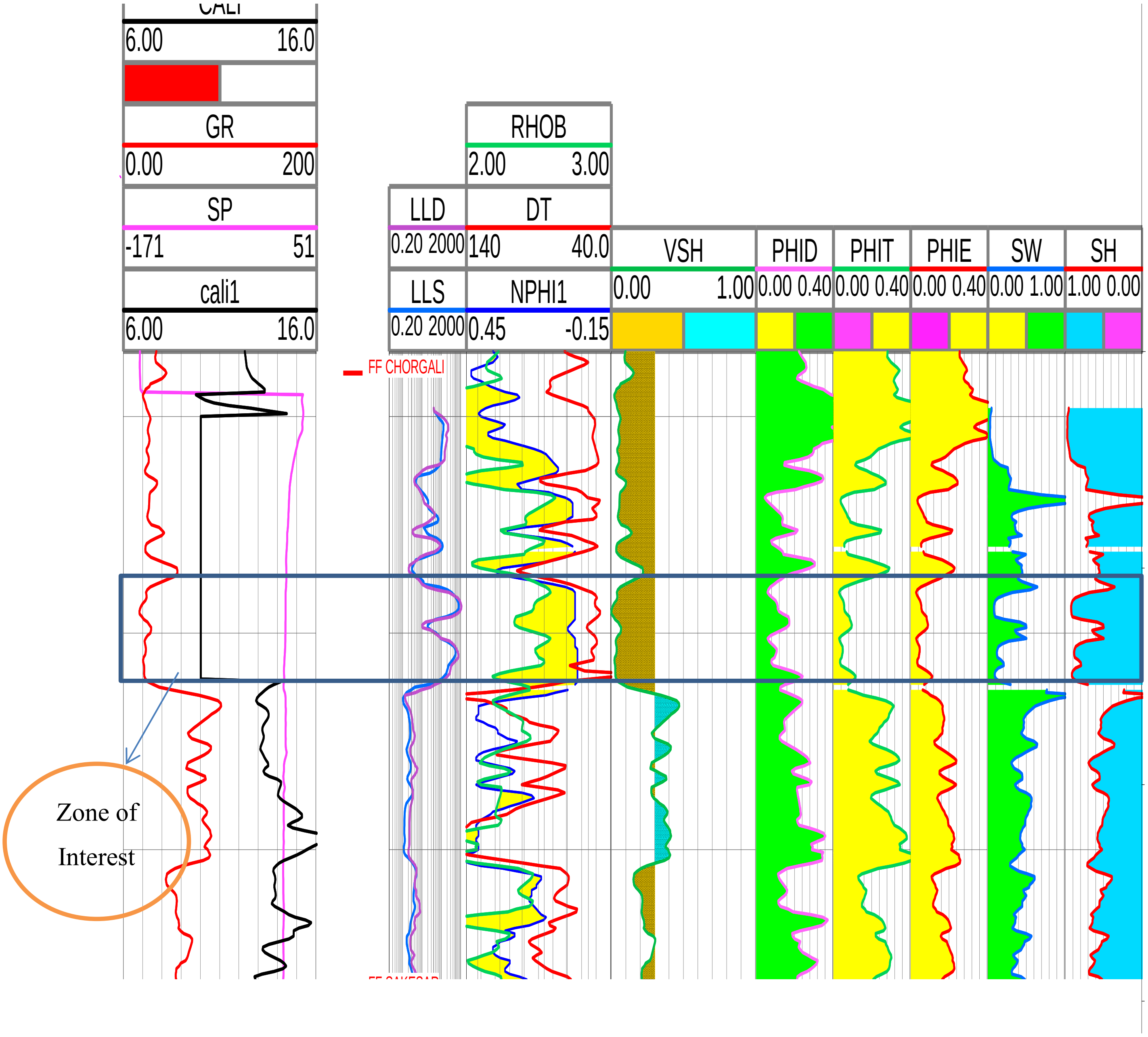


Figure 4.2 Petrophysical logs of Chorgali

CHAPTER: 05

FACIES MODELING

5.1 INTRODUCTION

In geology, facies is a body of rock with specified characteristics. Generally, the facies is distinctive rock unit that form under certain condition of the sedimentation that reveals the environmental process.

The differentiation between the shale and sand has been constantly challenged for the geoscientist. In this process the key challenge is identifying the facies, from logging and core data, and degree to which the shale content affects the reservoir properties. This gives the main indication about the productive zone in the reservoir (Kurniawan, 2005). This problem leads us towards the cross plots which provides us the relationship between the reservoir properties and log response (Naji et al., 2010).

These facies are related to the certain depositional environment. Basically, the depositional environment is specific type of place where the facies are deposit, Such as the Glaciers, Lakes, Abyssal plain, Sea bottom, Stream and Delta etc.

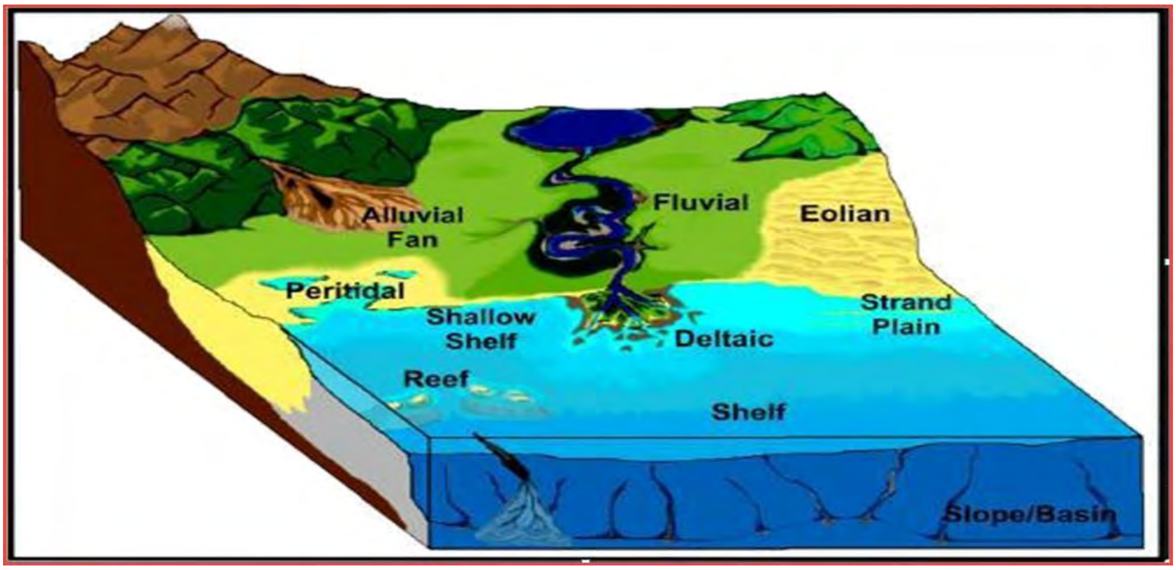


Figure 5.1 Diagram of major depositional environments, (Rais etal, 2012)

5.2 Sedimentary Facies

The sedimentary facies can be differentiated from each other on the basics of the change in the depositional environment Sedimentary facies are defined as a really restricted, three-dimensional bodies of rock or sediment that are distinguished from other bodies by their lithology, sedimentary structures, geometry, fossil content, and other attributes. Lithofacies are defined solely based on their lithology. Similarly, bio facies are defined based on their fossil content. Sedimentary facies analysis is based on the concept that facies transitions occur more commonly than would be expected if sedimentation processes were random.

The characteristics of the rock unit come from the depositional environment and from the original composition. Sedimentary facies reflect their depositional environment, each facies being a distinct kind of sediment for that area or environment.

The sedimentary environment of reservoir formations of Chorgalli and Sakessar are shallow Marine lagoon environment. The only Tobra formation in Potwar area has glacial environment except that all other have shallow marine lagoon environment.

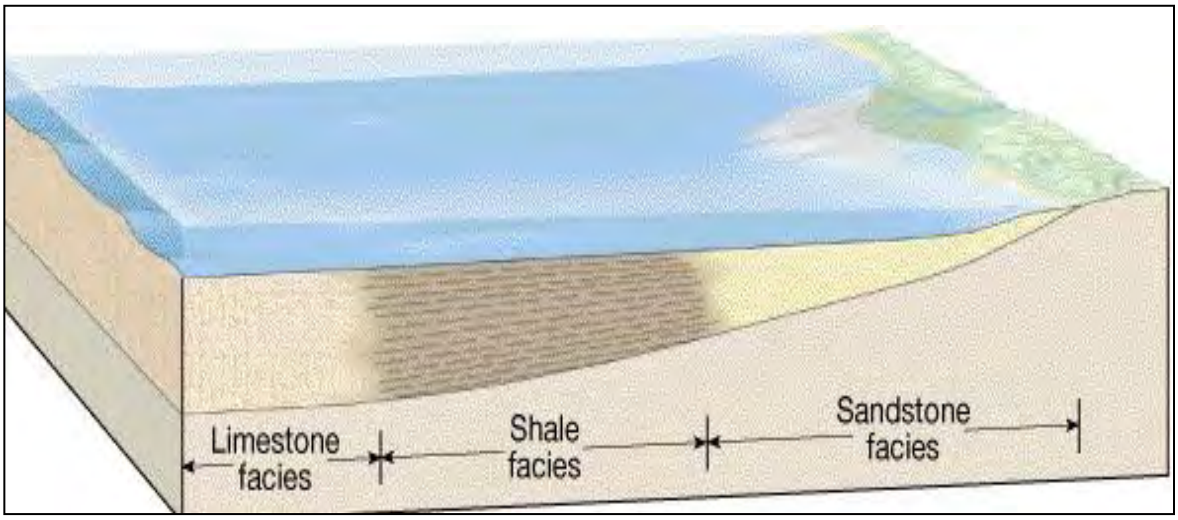


Figure 5.2 Sediment deposited in a different depositional environment.

5.3 Walther's Law of Facies

Walther's Law of Facies, or simply Walther's Law, states that the vertical succession of facies reflects lateral changes in environment. Conversely, it states that when a depositional environment "migrates" laterally, sediments of one depositional environment come to lie on top of another. A classic example of this law is the vertical stratigraphic succession that typifies marine transgressions and regressions. However, the law is not applicable where the contact between different lithologies is non-conformable (Lucia 1995).

5.3.1 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.

5.3.2 Regression

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

5.4 Facies Analysis

Fundamental to all subsurface geologic studies is an analysis of depositional facies. Development of a facies classification scheme is a challenging interplay between capturing enough information for environmental interpretation. A good understanding of paleoecology always strengthens the interpretation and such studies should be included as part of all depositional facies' studies. Depositional textures in turn affect porosity-permeability in carbonates. The vertical and lateral organization of facies is an exercise essential to sequence stratigraphic interpretations (Lucia, 1995)

5.5 Facies Analysis of chorgali and sakesar

For the facies analysis of the formations, we have generated cross plots of DT vs NPHI and LLD vs RHOB from the log data of the Amirpur-01. These cross plots helped us to identify the major lithology of the formations. For instance, as our zone of interest is chorgali, knowing the depth, we can identify the major lithology of chorgali from the above mentioned cross-plots, i.e, at 2605m depth the major lithology of chorgali is limestone. Similarly, sakesar comes after chorgali at depth of 2636.5m, and the corresponding major lithology at this depth again is limestone along with the presence of some shelly limestone.

5.6 DT Vs NPHI Cross Plot

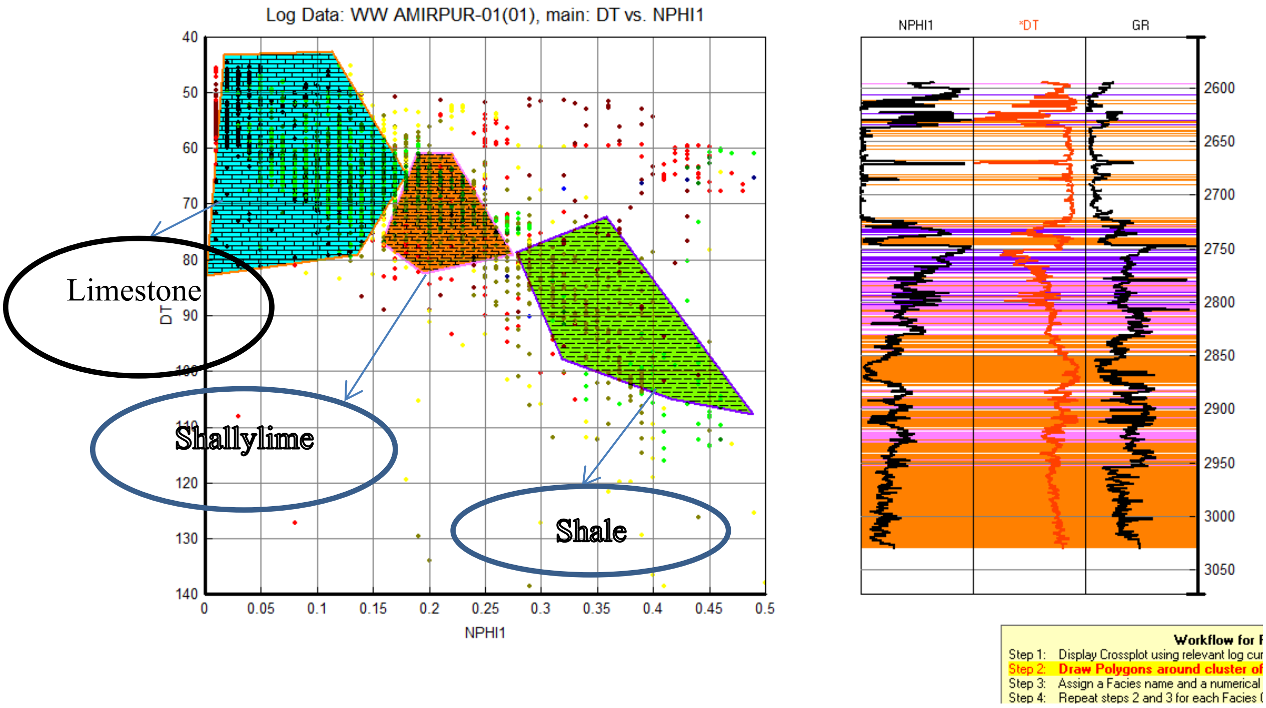


Figure 5.3 Crossplot between DT and NPHI

5.6 LLD VS RHOB CROSS PLOT

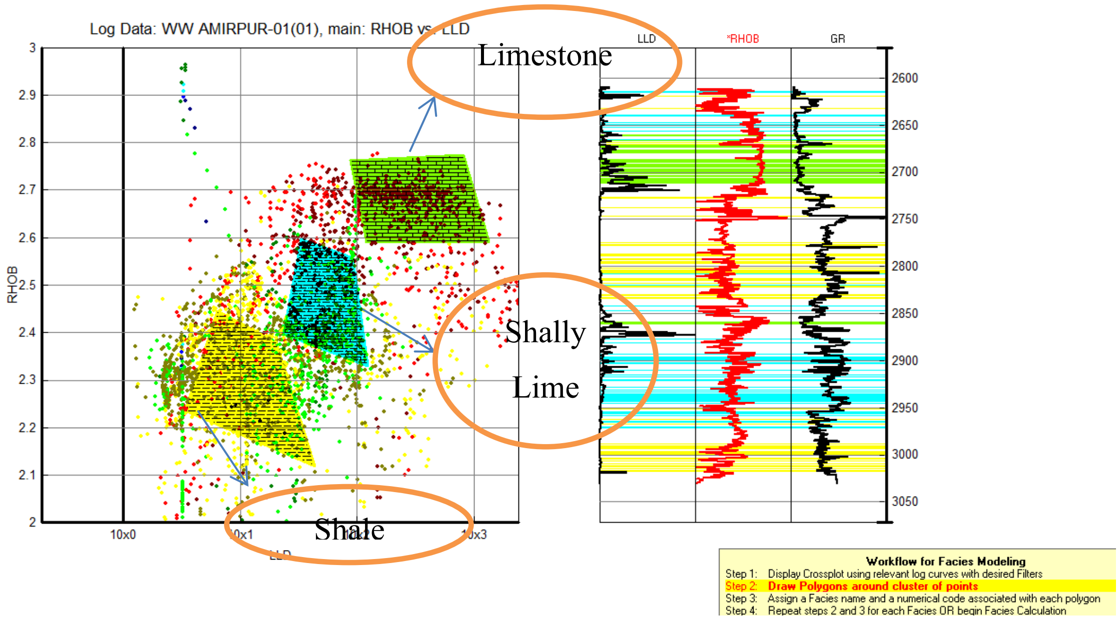


Figure 5.4 Crossplot LLD and RHOB

5.7 RESULTS OF CROSS PLOTS AND DISCUSSION

The cross plots of LLD vs RHOB and DT vs NPHI are computed. As Limestone is a compact lithology, so low DT, high RHOB, low NPHI and high LLD recognizes limestone. Limestone is more compact, more denser, and more resistive than shelly limestone and shale that is why it is showing higher values on LLD and RHOB logs. The transit time for a compacted lithology is low so DT log gives lower value on limestone. Furthermore, the lithologies are confirmed by their known RHOB values, i.e, the density in g/cc for limestone is more or less 2.71.So having having this value on RHOB is clear indication of limestone, further confirmed by NPHI, LLD and DT logs. We are focused on limestone because our zone of interest in this particular study is chorgali(reservoir), lies at 2608m depth which is majorly comprised of limestone.Also another formation which we have marked is Sakesar(resorvoir), which lies at 2636.5m, and it is also comprised of limestone, confirmed by noting the corresponding litholohy on these depths from the above crossplots.

CONCLUSION

- Three Horizons Chorgali, Sakesar and Tobra are marked on the basis of well data after correlating it with Seismic data.
- Three horizons where shows discontinuity, indicates Reverse faulting in Chak Naurang area.
- Time / Depth Contours are prepared for all the three marked horizon. And fault polygons are marked over the grids. The contours show shallow depth which indicates pop up anticlines and thrusting in the area.
- The petrophysical analysis of Amirpur-01 shows only one zone of interest marked from depth 2617-2622 meters having shale volume 5.81%, Water Saturation 26.34%, Hydrocarbon saturation 73.46% and Effective porosity 7.48%.
- Facies Analysis differentiate Limestone, Shally limestone and shale from each other.

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