INTEGRATED SEISMIC INTERPETATION, PETROPHYSICAL ANALYSIS ALONG WITH AND SEISMIC ATTRIBUTE ANALYSIS OF MISSAKESWAL AREA

BY

MUHAMMAD SAJJAD

(04111613058)

BS (GEOPHYSICS)

2016-2020

DEPARTMENT OF EARTH SCIENCES

QUAID-I-AZAM UNIVERSTY

ISLAMABAD, PAKISTAN

"IN The Name of ALLAH, the Most Merciful & Mighty"

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

(AL-QURAN)

CERTIFICATE

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

RECOMMENDED BY

Dr. MATLOOB HUSSAIN ______________________________

(Supervisor)

Dr. AAMIR ALI ______________________________

(Chairman Department of Earth Sciences)

EXTERNAL EXAMINER ______________________________

DEDICATION

TO MY BELOVED PARENTS (ABU AND AMMI) WITHOUT THEM I AM NOTHING, TO MY CUTE SISTERS AND BROTHERS.

ACKNOWLEDGEMENT

In the name of Allah, The Most Gracious and the Most Merciful, Beneficent Alhamdulillah. I bear witness that Holy Prophet Muhammad (PBUH) is the last messenger, whose life is perfect model for the whole mankind till the Day of Judgement. I am thankful to Allah for the strengths and His blessing in completing this thesis.

Special appreciation goes to my supervisor Dr Matloob Hussain for his supervision and constant support. His invaluable help of constructive comments and suggestions throughout the experimental and thesis works have contributed in the success of this research.

I would like to specially thanks to our respected Yawar Hussain.

I would like to express my appreciation to of my whole family, specially my father mother and brother for their support and help without which I was unable to reach at this stage. I also wish to thank the whole faculty of my department for providing me with an academic base, which has enabled me to take up this study.

I Sincerely thank to all my friends especially (Usama Taj, Falak Sher, Aasia Hassan) for their endless love, care and moral support during my study. Thanks for the friendship and memories.

I am extremely thankful to all my teachers for their endless love, prayers and encouragement and my special appreciation to those who indirectly contributed in this research.

MUHAMMAD SAJJAD
BS (GEOPHYSICS)
QAU ISLAMABAD
(2016-2020)

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ABSTRACT

MissaKeswal area is part of Potwar sub-basin of Upper Indus basin which is known for hydrocarbons and structural traps. Our work has been done on three lines, along with nine lines of group fellows. For the interpretation of seismic data the licensed softwares are used, two reflectors have been marked depending on prominent wiggles and named as Sakesar, Lockhart on the basis of generalized stratigraphic column encountered in well MissaKeswal-03 lying on the given seismic line GNA-15. Faults were also marked to examine the subsurface structure. Pop-up structures can be seen in the marked seismic section.

Time sections are converted into the depth sections to view the real picture of the interpreted horizons.

Time and depth contour maps of all Formations are also prepared at a particular level to analyze the variations on the basis of time and depth, Pop up(anticlinal) structure acts as a trap in the area, which is considered to be best for hydrocarbon accumulation.

Petrophysical analysis is done which shows hydrocarbon and water saturation potential Crustal shortening calculated for all horizon which shows breakage and compressions in the structres due to faulting and salt of Pre-Cambrian age disturbed the basement creating popup structres.

Seismic attribute analysis is used for the confirmation of 2D Seismic interpretation and it also highlights the zone of interest.

CHAPTER 1

INTRODUCTION

1.1 Background:

Hydrocarbons are one of the most essential part of economics of any country. Even on the smaller scale hydrocarbons play a wide role in everyday life. Geoscientists are trying since a long time for the exploration of hydrocarbons and are applying different methods in this regard. Geophysical methods are the most widely used methods in the exploration of hydrocarbons; especially reflection seismic has a great importance in this regard. Seismic method plays an important role in the search of hydrocarbon. It is the leading exploration technique used now days. This study would highlight the role of seismic method in exploration geophysics. In order to carry out this study, seismic data of Missakaswal Area located in potowar was used. The early workers have executed the work of surface geological mapping of MissaKeswal Oil and Gas field. However, the Oil and Gas Development Company Limited (OGDCL), Pakistan has determined characteristics exploratory behavior of the area by drilling four wells. The production was obtained through three wells while one well was abandoned.

1.2 Objectives:

- The 2-Dimensional Structural interpretation for the identification of the traps that is favorable for the hydrocarbon accumulation.
- Petrophysical analysis in order to delineate the reservoir characteristics of the study area.
- Facies analysis at the MissaKeswal-03 Well for the determination of lithology.

Geographical Location of MissaKeswal Area:

Latitude and longitude of Area:

Latitude

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

Longitude

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

1.3 Data Used:

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

1.3.1 Well data

WELL NAME : MissaKeswal 03,

TYPE OF WELL: EXPLORATORY.

1.3.2 SEISMIC LINES USED.

1) 994-GNA-14 DIP LINE
2) 994-GNA-15 DIP LINE
3) 994-GNA-26 STRIKE LINE

1.3.3 SOFTWARE USED.

SMT KINGDOM 8.6

1.4 An Introduction to the Study Area.

Missakaswal area is located ten kilometers from Gujar Khan, Rawalpindi district of Punjab. Geographically the study area lies between 33° 11' 06" and 33° 11' 18.24" North and from 73° 20' 42" to 73° 21' 00" East. Stratigraphically, it lies in the Upper Indus which is characterized by large numbers of thrust and normal faults producing asymmetrical structures (anticlines/ synclines)..

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

The area under study is Missakaswal oil field which is located ten kilometers from Gujar Khan. Geographically the study area lies between 33° 11' 06" and 33° 11' 18.24" North and from 73° 20' 42" to 73° 21' 00" East. Geologically, it lies in the Upper Indus Basin of Pakistan. Pakistan has high potential of hydrocarbons in its northern (Potwar, Kohat) and southern (Badin, Mari etc.) parts. The Indus basin, including the Kohat-Potwar (study area) depression, belongs to the category of extra-continental downward basins which account for 48% of the world's known petroleum resources (Hasany & Saleem, 2001).

The main purpose of this study is to understand the tectonic and structural trends present in the subsurface. The structural analysis of the subsurface is done using seismic interpretation, which helped in getting a better understanding of the geological and stratigraphic nature of the area.

1.5 Base Map of the Study Area.

A base map is a map on which primary data and interpretation can be plotted. A base map typically includes location of concession boundaries, wells, seismic survey points and length of seismic spread, longitude and latitude of the study area. Following 2-D reflection seismic lines are used to construct the Base map of 2-D seismic survey for given study area. Base map of the following lines are shown in Figure 1.1

- 994-GNA-14
- 994-GNA-15
- 994-GNA-26

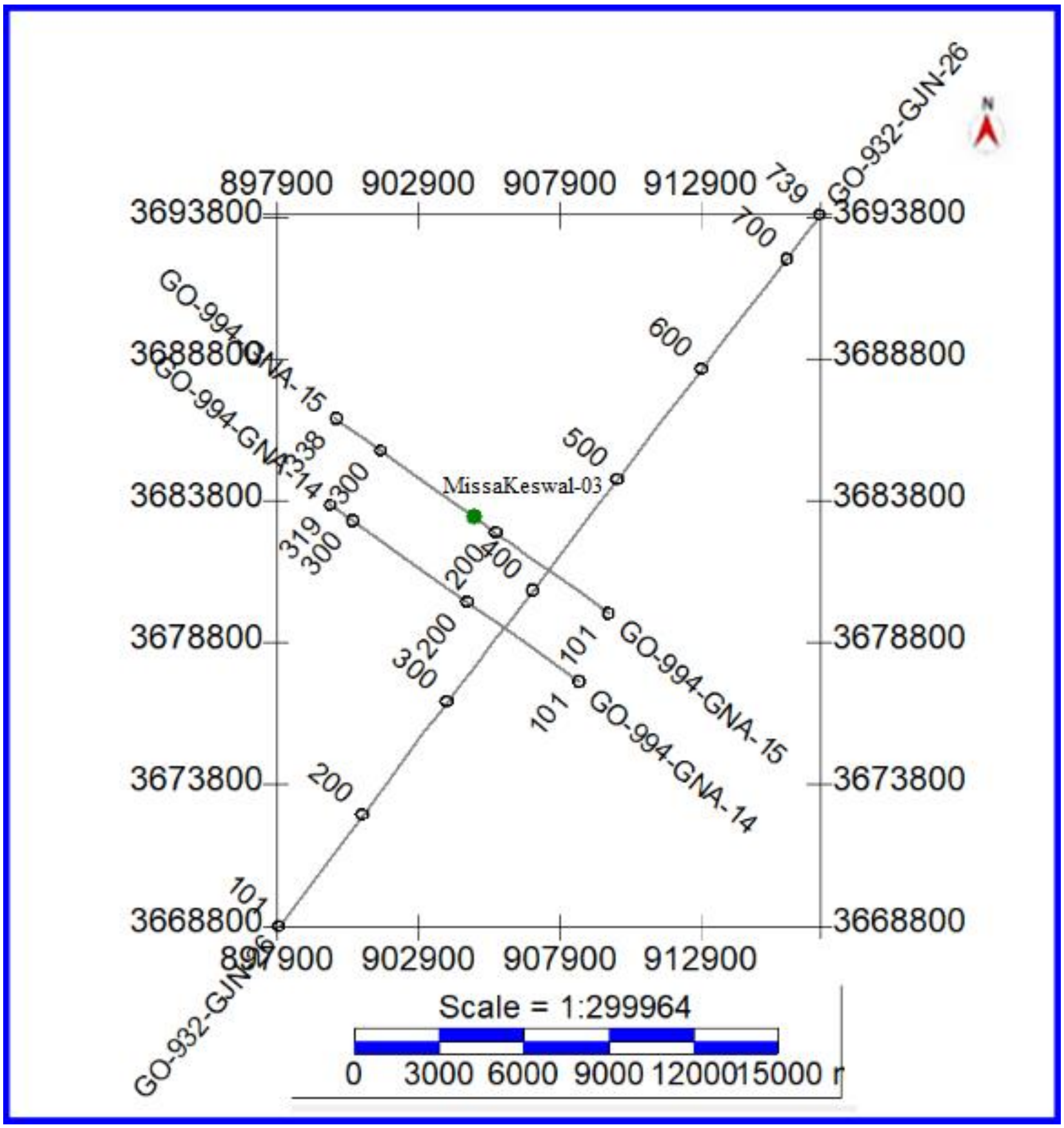

Figure 1.1 Base map of the lines used in the project.

1.6 Brief Methodology:

The thesis highlights the 2D structural interpretation and well log integration in order to delineate the subsurface structure and hydrocarbon potential. Two-way time structure and depth contour maps have been prepared using Kingdom software. The depth structure map shows high relief anticlinal structure in the subsurface bounded to west and east by reverse faults. According to the petroleum geology, source rock in the study area is Patala Formation of Paleocene age; Chorgali Formation and Sakesar Limestone of Eocene age are acting as reservoir rocks while Murree Formation of Miocene age is acting as a seal Petrophysical analysis has enabled to picture the hydrocarbon potential of the interested reservoir zones. The data provided for study includes a base map, four 2D seismic lines and well log data/well tops of the Missakeswal well. The well is located at some offset of the dip line GNA 15. The horizons were marked and confirmed through the synthetic seismogram. The geological data was collected from the available literature.

CHAPTER 2

TECTONICS AND STRATIGRAPHY

2.1 Regional Geology of Pakistan

Pakistan is covered of the three broad geological subdivisions that, from North to South, may be referred to as the Laurasian, Tethyan and Gondwanaland domains (Kazmi, I.B.Qadri 1995). Their origin may be traced back to Late Paleozoic. In late Paleozoic all the continent had drifted to form a continuous landmass, the super continent of Pangaea. By Late Triassic, Pangaea had split into two super continents, Laurasian to the north and Gondwanaland to the south separated by the Tethys seaway. Pakistan is located at the junction of Gondwanaland and Tethyan domain. Pakistan is unique in as much as it is located at the junction of these two diverse domains. The Southern part of Pakistan belongs to Gondwanaland Domain and is sustained by the Indo-Pakistan Crustal Plate.

Sedimentary Basins of Pakistan

A basin is an area characterized by regional subsidence and in which sediments are preserved for a longer period of time.

Pakistan comprises of three major basins which are also further characterized into smaller basins for exploratory matters.

- Indus basin
- Balochistan basin
- Pishin basin

2.1.1 Indus Basin

Upper Indus Basin is located in northern Pakistan and is separated from central Indus Basin by Sargodha high. It consists of fold and thrust belt to the south of MBT. It forms the southern part of the Himalayan fold belt. The thrusting is terminated to the west and east by longitudinal transcurrent fault systems. The Indus river further divides the Indus Basin into Kohat sub-basin (west) and Potwar sub-basin (east) (Kadri,I.B.1995).

Indus Basin includes the 25000 square Km of South-East of Pakistan. It comprises the Thar Cholistan desert and Indus Plain. It has 80% of Pakistan population. Tectonically it is much stable area as compare to other tectonic zone of Pakistan. It comprises of buried ridges, platform slop, zone of up warp and dawn warp. (Kazmi,I.B.Qadri, 1995)

2.1.2 Upper Indus Basin

Upper Indus Basin is located in northern Pakistan and is separated from central Indus Basin by Sargodha high. It consists of fold and thrust belt to the south of MBT. It forms the southern part of the Himalayan fold belt. The thrusting is terminated to the west and east by longitudinal transcurrent fault systems. The Indus river further divides the Indus Basin into Kohat sub-basin (west) and Potwar sub-basin (east) (Kadri, 1995).

The general Stratigraphy of Upper Indus Basin is shown in the Figure 2.1, which shows two main unconformities and some small unconformities.

Potwar plateau lies in Western sub-Himalayan tectonic zone, This east west trending fold belt comprises the low rolling hills and valleys of the uplifted Kohat-Potwar Plateau, The salt range and its westward extension; it is about 85 km wide and extend for 200km. it is diverted structural zone bounded in the north by north dipping Main boundary Thurst (MBT).

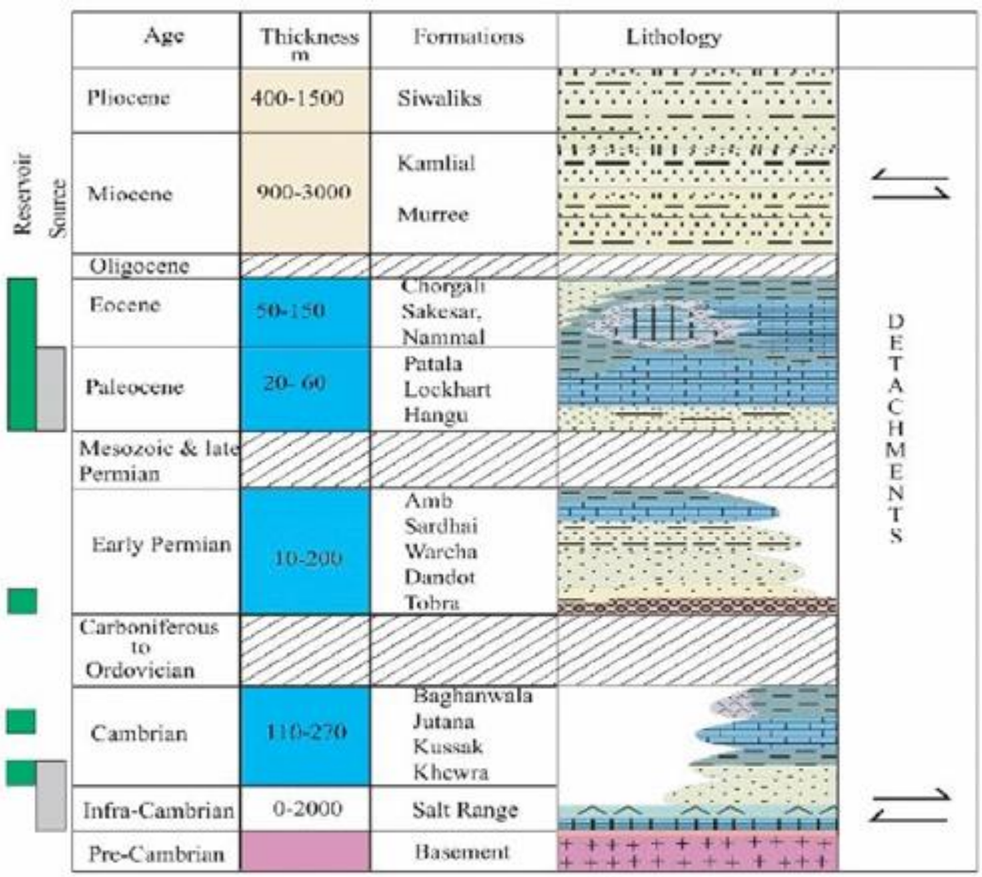

Figure 2.1:Stratigraphy divison of Upper Indus Basin Pakistan (Amir and Siddique 2006)

Tectonic of the Potwar plateau is controlled by following factors:

- Slope of the basement (steeper in western Potwar Plateau).
- Thickness of Cambrian evaporates beneath the cover.

- Reactivation of basement brittle tectonics (more enhanced in eastern Potwar plateau).

2.3 Petroleum play of study Area

Presence of continental margin, thick marine sedimentary sequence, potential source, and reservoir and cap rocks make this region suitable for hydrocarbon accumulation. It contains a thick overburden (about 3000 m) of fluvial sediments, which provide the burial depth and optimum geothermal gradient for seeps found in this area (Moghal et al., 2003). The Salt range-Potwar foreland basin with an average geothermal gradient of $2^{o}C/100$ m is producing oil from depth of 2750-5200m (Shami & Baig, 2014).

2.3.1 Source Rock

The source rock of Infra- Cambrian to Eocene in the Potwar basin identified by many companies. In Potwar basin the organic-rich shale of Paleocene age (Patala Formation) is the main source of Potwar Oil field. (Bannert et al., 1995).

In Potwar Basin, Patala shale of Paleocene have proven as the main source rocks. Due to buckling of basin floor the organic shale of Paleocene age were partly deposited in anoxic conditions. The oil shale intervals contain in Precambrian Salt Range Formation, which show potential of source rock .

2.3.2 Reservoir Rock

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

2.3.3 Cap/Seal

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

2.4 Lithological Description of Formations

Seismic Section shows the different depths interpreted that has been encountered in MissaKeswal-03. Below explained in tabular form are the lithological description of the section drilled at MissaKeswal-03 which was drilled down to a depth of 2143 meter into formations of post

Cambrian age. The Formation tops were initially picked at the well site, which were further refined / confirmed by the electric logs. A list of final formation tops and thickness drilled in MissaKeswal-03, are presented in the Table 2.1.

KB = 427.12

Formation	Formation Top(m)
CHINJI	0
KAMLIAL	935
MURREE	1125
CHORGALI	1870
SAKESAR	1914
NAMMAL	1983
PATALA	1996
LOCKHART	2004
HANGU	2017
DANDOT	2023
TOBRA	2033
BAGHANWALA	2039
JUTANA	2057
KUSSAK	2081
KHEWRA SANDSTONE	2143
TD	2250

Table 2.1 Formation tops of well Missakeswal-03X

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CHAPTER 03

SEISMIC INTERPRETATION

3.1 Introduction:

In interpretation of seismic data, we convert our processed data into structural model of earth. We prepare a picture of subsurface which shows the subsurface condition of geological formations where seismic data is acquired (Kearey et al.,2013) have described two main approaches for analysis of seismic data:

- Structural analysis

Identification of structural features.

- Stratigraphic analysis

Identification of stratigraphic features.

3.2 Objective of seismic data interpretation:

Objective of seismic data interpretation is to extract all available information from data. We mark faults and horizons on seismic section which requires complete grip on basin geology and tectonic history. Final task in interpretation is depth contour mapping which shows structural relief and extension of formations in area. Finely interpretation gives us that on a particular depth which type of structure is present.

The Interpretation was carried forward using different techniques and steps with each step Involve different processes which were performed using the software tools as mentioned above.

Simplified workflow used in the dissertation is used in which provides the complete picture depicting how the dissertation has been carried by loading navigation data of seismic lines and SEG-Y in SMT Kingdom Software, base map was generated. Faults and Horizons of interest were then marked manually. Identification of marked horizons was done with help of synthetic seismogram, generated with help of well data and faults were marked by keen observation on seismic section and knowing geologic history of study area. Fault Polygons were also generated, and horizons are contoured to find out structural information of study area. Then time and depth contour maps were generated to check structural relief in area. Base map of study area is discussed in chapter 01, here I will proceed with next steps which I carried in the entire interpretation.

3.3 Basic interpretation of seismic line:

In seismic interpretation we mark the faults and horizons on the seismic section. Seismic section is composed of seismic traces the seismic traces are actually seismic waves which are reflected from subsurface reflectors and are recorded on geophone which are placed on surface to record the seismic waves.

Seismic waves are recorded in time domain after they are recorded the seismic data passes through processing sequence. After processing we obtain few traces since seismic data is acquired on CMP assumption. These traces are stacked to obtain the seismic section. On seismic section we mark the faults and horizons in this synthetic seismogram is used.

Synthetic seismogram is obtained using well data. Seismic interpretation is done one the following lines.

1) 994-GNA-14 DIP LINE
2) 994-GNA-15 DIP LINE
3) 994-GNA-26 STRIKE LINE

3.4 Synthetic seismogram:

The seismic data which is recorded don't truly represent the subsurface reflectors because of attenuation of energy seismic waves. A wave which is reflected by subsurface reflectors with original frequency (Spike) will truly represent the reflectors which are not possible practically, so this is done synthetically. By using density and sonic log we calculate acoustic impedance and by using zoprit equation we calculate reflection coefficient. Since we use well data, so measurements are authentic and this reflectivity series shows the capability of reflectors to reflect seismic waves. By convolving source wavelet with reflectivity series, we obtain a trace which is synthetic seismogram. Here I generate synthetic seismogram using MissaKeswal-03 well. The method of preparation of synthetic seismogram is discussed above.

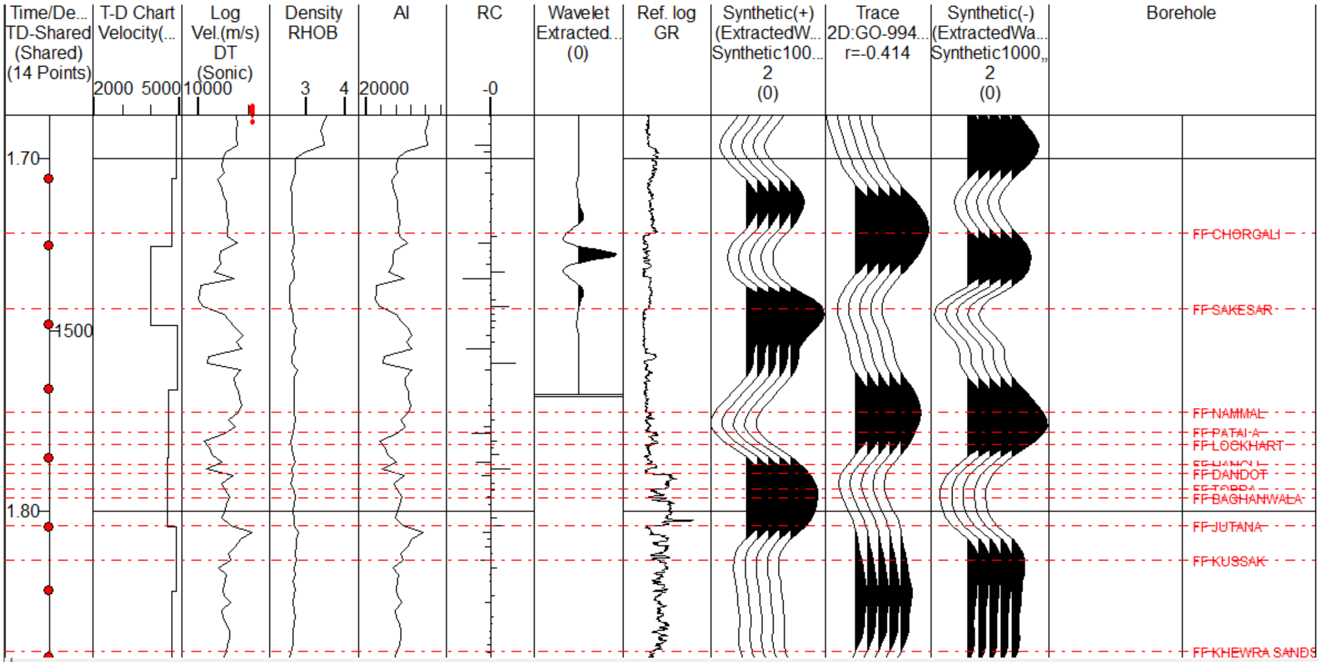

Figure 3.1 Synthetic seismogram generated by well to seismic tie.

The synthetic seismogram is shown in Figure 3.1. Synthetic seismogram is to confirm the position of subsurface reflectors. In above synthetic seismogram we can visualize the position of subsurface reflectors. Two formations Chorgali and Sakesar limestone are acting as reservoir in our study area. Red trace represents seismic data and black represent synthetic seismogram. We can see in diagram both negative and positive polarities are given, and we can see that polarity of our data is negative.

3.5 Fault picking:

Conventional seismic interpretations are the arts that require skills and thorough experience in Geology and Geophysics to be precise (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. Faults are marked 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.

The area under the study (MissaKeswal) lies in upper Indus basin. In further division of upper Indus basin, it lies in Potowar plateau. Since in potwar plateau we have compressional regime due to collision of INDIAN and EURASSIAN plate. So, in this area we have anticlines with associated reverse faulting.

3.6 Horizon picking:

Interpreting seismic sections, marking horizons, producing time and depth maps is a task which depends on interpreter's ability to pick and follow reflecting horizons (reflectors) across the area of study (Mc. Quillin et al., 1984). Reflectors usually correspond to horizon marking the boundary between rocks of markedly different lithology, but it does not always occur exactly at geological boundary of horizon which is sometimes important problem in seismic interpretations (Kemal et al., 1997). However 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.

3.7 Interpretation of dip line GNA-15

Seismic section of line is shown in Figure two horizons are marked on the line. MissaKeswal well is drilled on this line so synthetic seismogram is generated on this line. Synthetic seismogram shows the confirm position of formations encounters in the MissaKeswal well. By using synthetic the two horizons are marked on seismic section as shown in Figure 3.2.

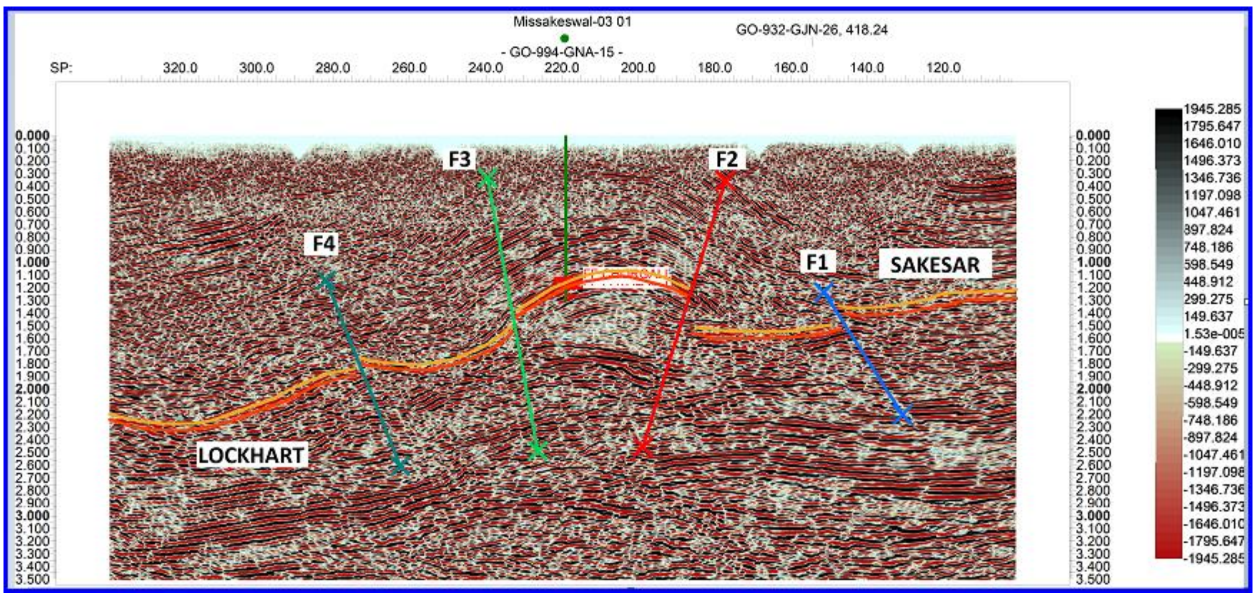

Figure 3.2: Anticline structure with associated reverse faults.

- SAKESAR(GOLD)
- LOCKHART (RED)

Four faults are marked on the section. An anticlinal structure with associated reverse faulting can be seen in the seismic section. Two reservoirs chorgali also known as bhadrar beds and sakesar limestone are shown in the section. The above Figure shows the petroleum play of the missakaswal area.

The seismic section of dip line is shown in the Figure. Two reservoirs are marked on the section as shown. Since Missakeswal well is drilled on line GNA-15 so when reservoirs are marked on this line, we have circles of same colour on line GNA-14,GNA-26. So, two horizons are marked on this line as shown in Figure 3.3 & 3.4 . The orientation of 994-GNA-15 and 994-GNA-14 is NW-SE direction. And orientation of strike line is 994-GNA-26 NE-SW direction.

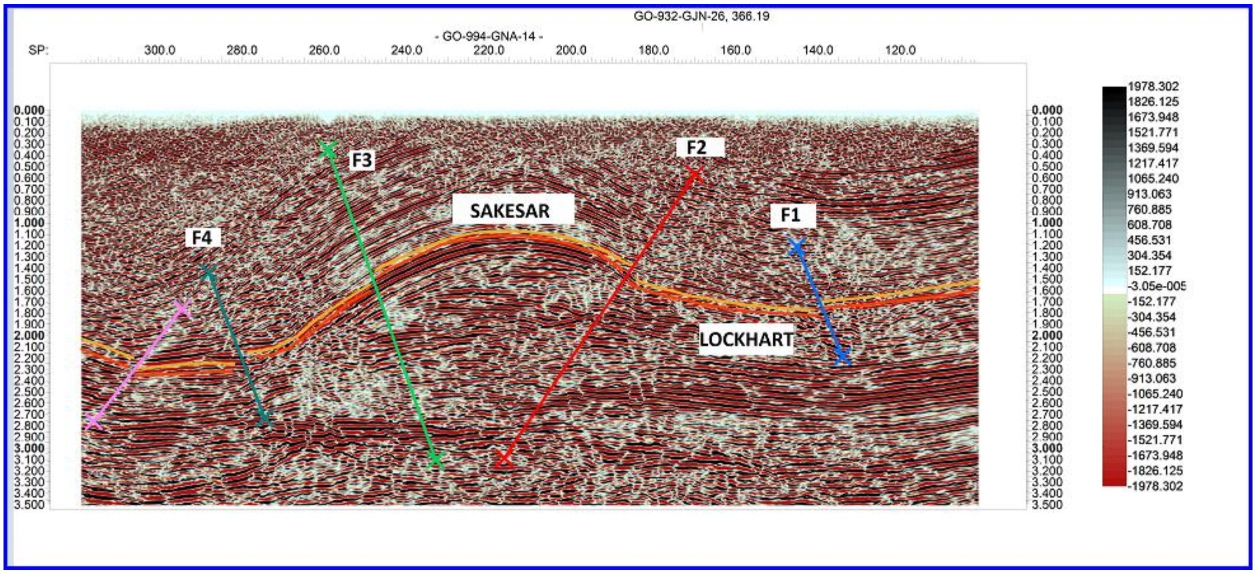

Figure 3.3: Anticline structure with associated reverse faults (994-GNA-14).

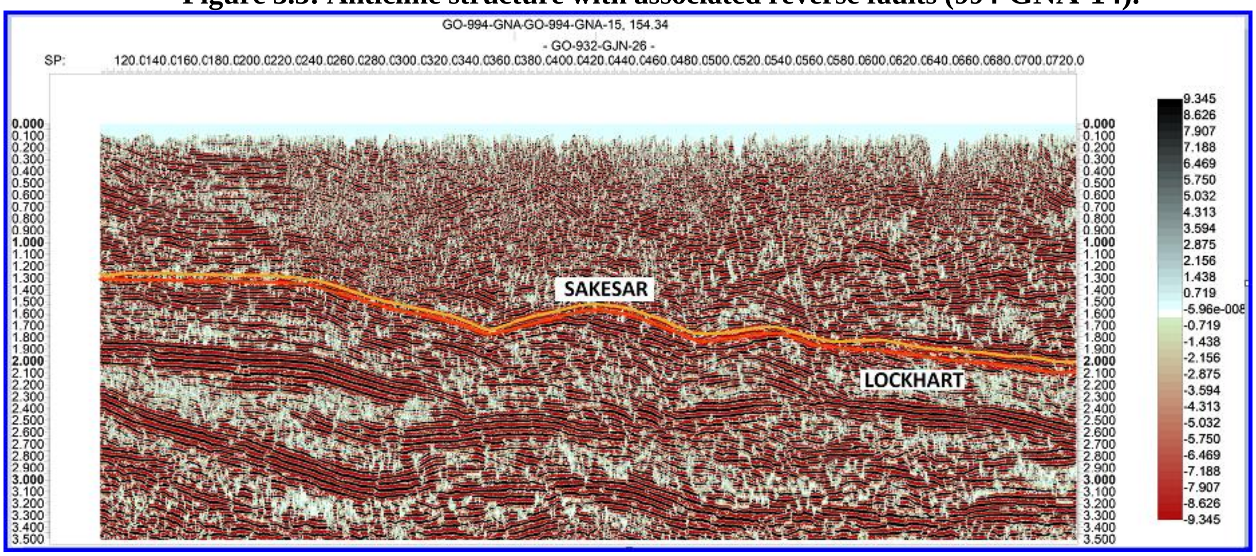

Figure 3.4: Strike Line (994-GNA-26).

3.8 Contour maps:

Contour maps show three-dimension earth in two-dimension surface. Contour maps show structural relief of the area. Since contour will join same reflection arrival time and hence defines the geometry of reflectors.

3.8.1 Fault Polygon:

Before generation of fault polygons, it is necessary to identify the faults and their lateral extent by looking at the available seismic data. If one finds that the same fault is present on all the dip lines, then all points (represented by a “x” sign by Kingdom software) can be manually joined to make a polygon. Construction of fault polygons are very important as far as time and depth contouring of a particular horizon is concerned. Any mapping software needs all faults to be converted into polygons prior to contouring. The reason is that if a fault is not converted into a polygon, the software doesn’t recognize it as a barrier or discontinuities, thus making any possible closures against faults represent a false picture of the subsurface Figure 3.4 formed at Sakesar level shows that after construction of fault polygons, the high and low areas on a particular horizon become obvious. Fault polygons are constructed for all marked horizons and these are oriented in NE-SW’ direction.

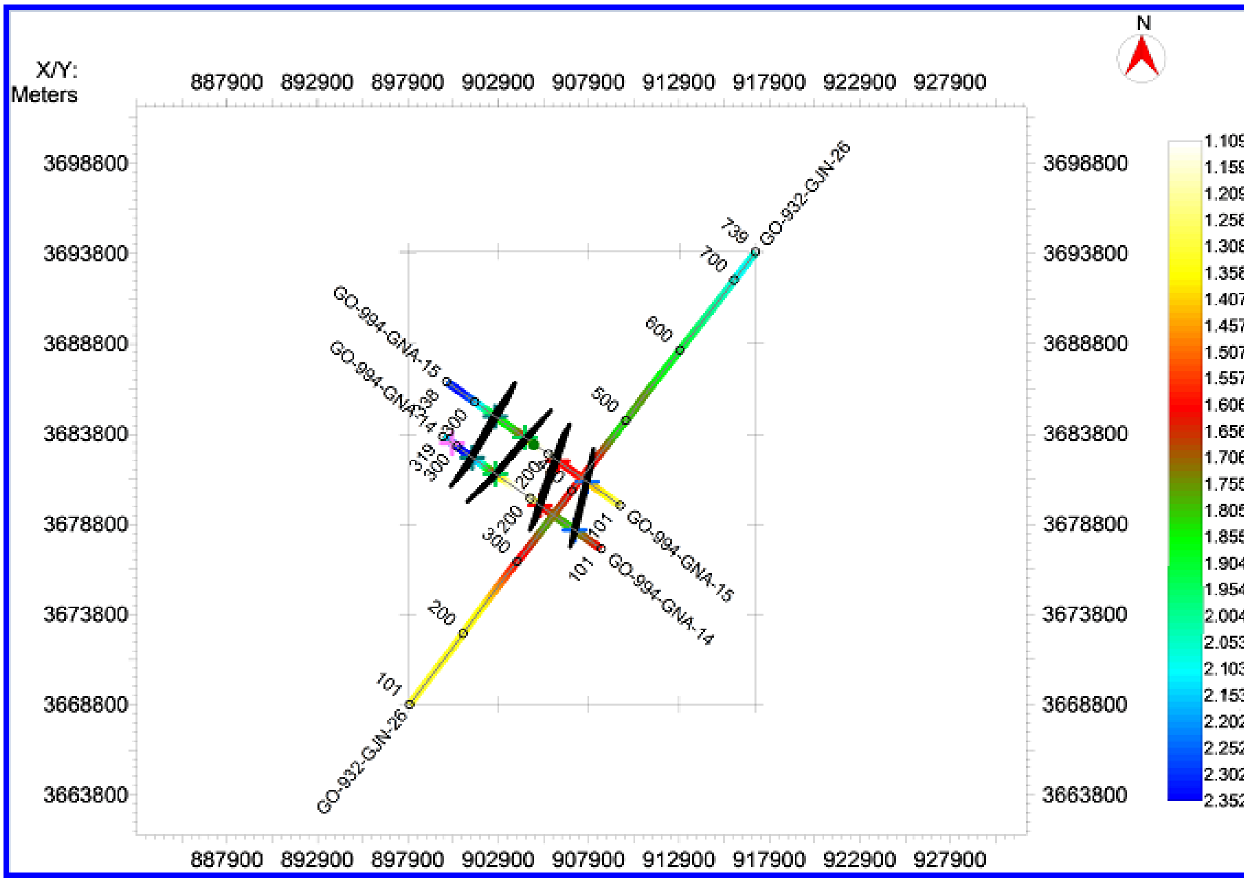

Figure 3.4 Fault Polygon of Sakesar formation (MissaKeswal 03).

3.9 Time contour map:

Time contour maps use the seismic data in time domain. Contour is a line joining the points of same elevation. On seismic section the time contours join the points which contains same reflection arrival time. Time contour map for Sakesar formation is shown in Figure 3.5.

The colour bar shows that at the top of anticline the reflection arrival time is less as compared to the limbs of anticline. In above contour map we can see that green colour shows anticline and in colour bar we can see that its reflection arrival time is less as compared to pink colour which shows limbs of anticline. Time contour map for Lockhart is shown in Figure 3.6.

Now when we place the second horizon on base map the following contour map was obtained.

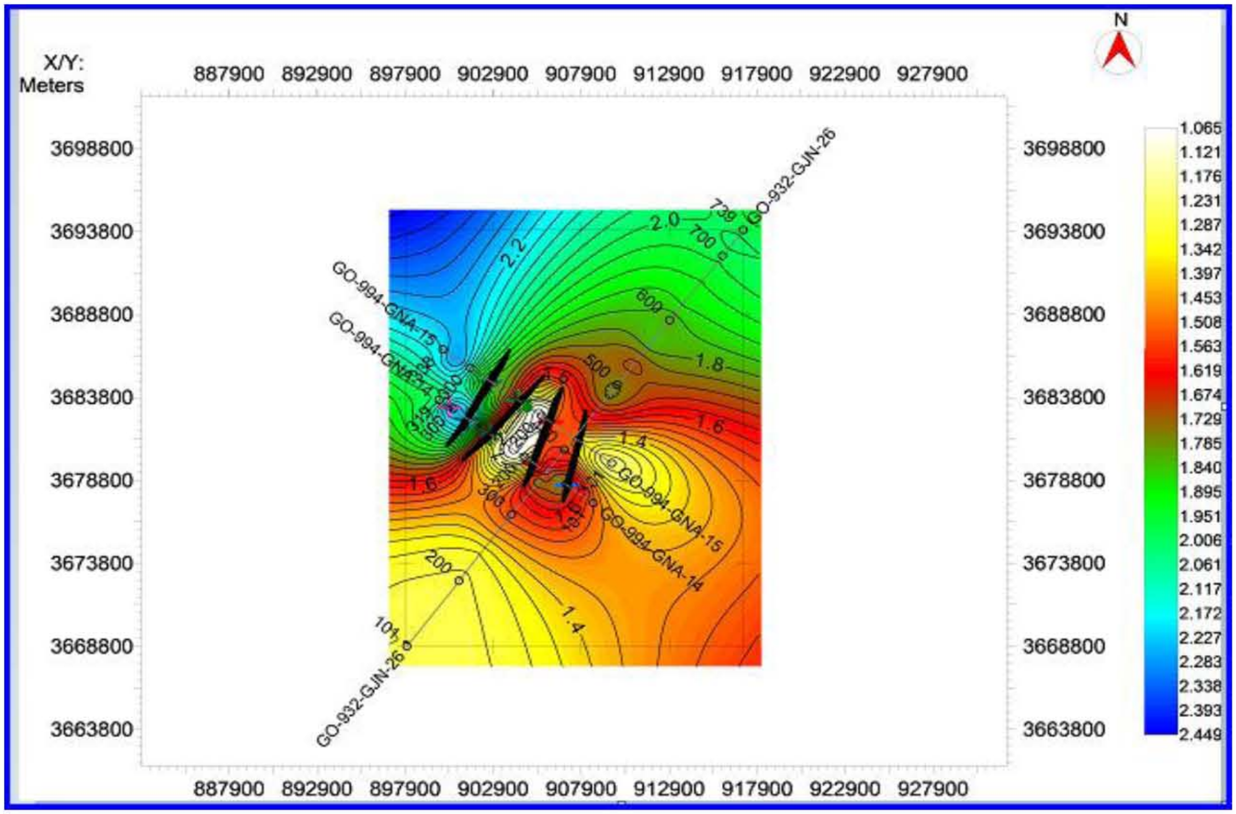

Figure 3.5: Time contour map of Sakesar formation

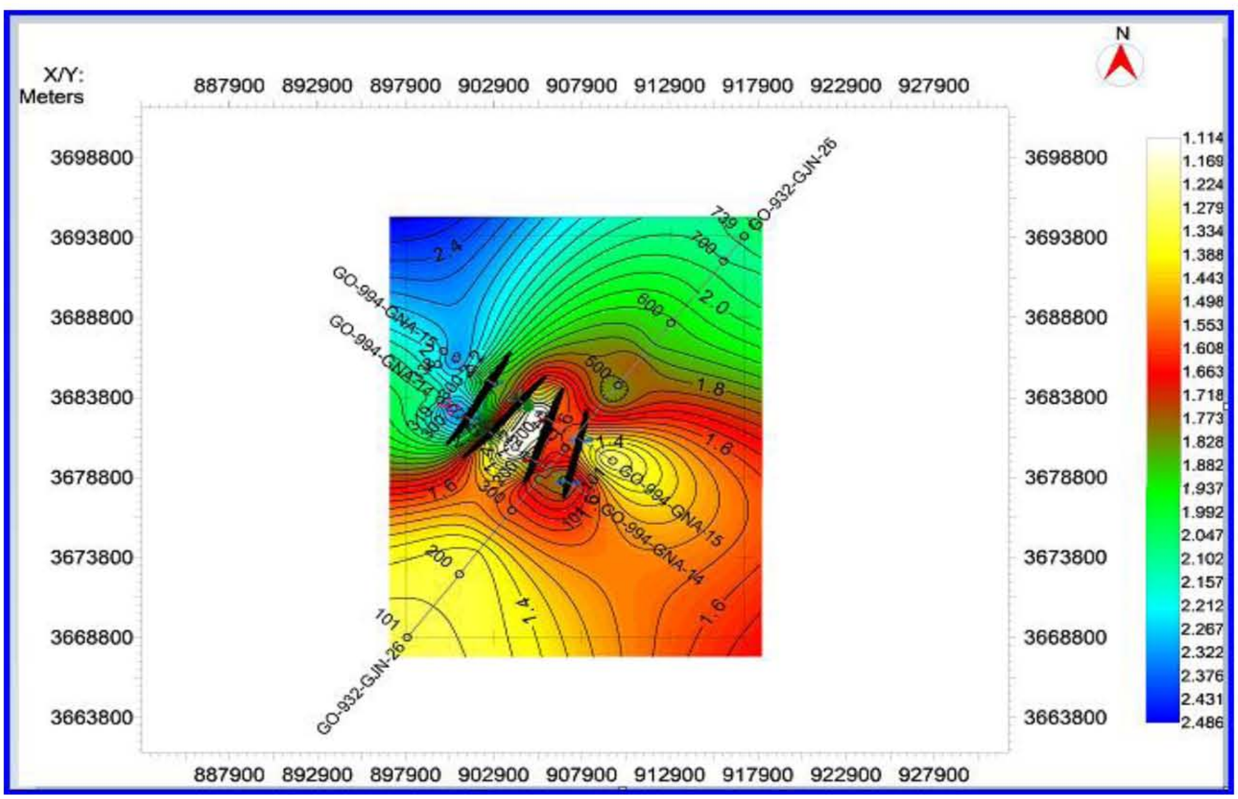

Figure 3.6: Time contour map of Lockhart Formation

3.10 Depth contour map:

The Depth contour map represents the horizon in units of depth i.e. meters. This gives a more accurate structure style of the horizon in the subsurface. Figure 3.7 below shows the depth contour maps for Sakesar Formation.

The contour interval is 200 m and the variations in the colour represent changes in the depth. The interpretation of the map suggests that there is an anticlinal pop-up structure at Centre and as we move towards periphery, the depth values increase progressively. The anticlinal structure is bounded by two main faults. These are reverse faults that are dipping towards each other from east and west. This dipping of the faults towards each other while bounding the anticlinal structure is the reason why our area of interest is called a 2-way fault bounded Anticlinal pop-up structure and is shown in Figure. Depth conversion is carried out using formula

$$s = \frac{v \times t}{2}$$

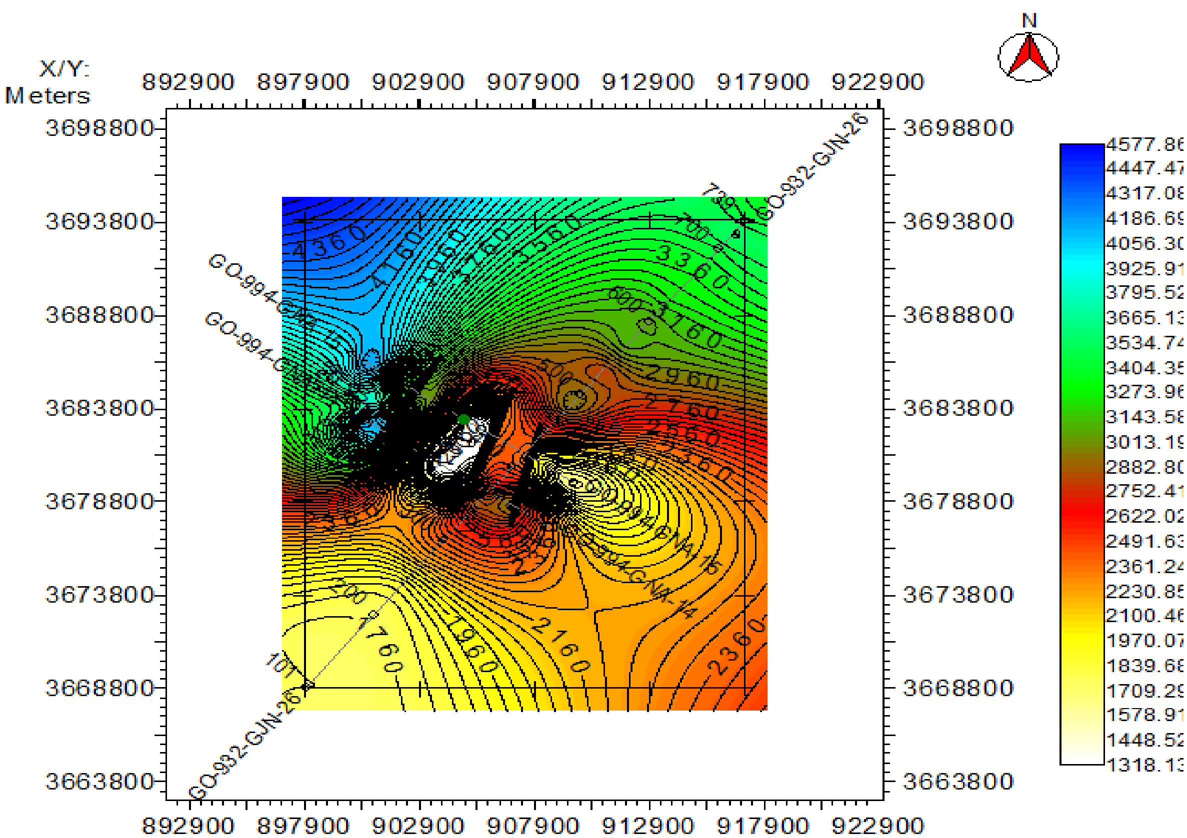

Figure 3.7: Depth contour map of Sakesar Formation

The contour interval is 7.5 m for lokhart Formation and the variations in the colour represent changes in the depth as shown in Figure 3.8. The structure of the formation is fault bounded anticline pop-up structure because away from the faults the depth values are increasing. While the faults are dipping towards each other from east and west.

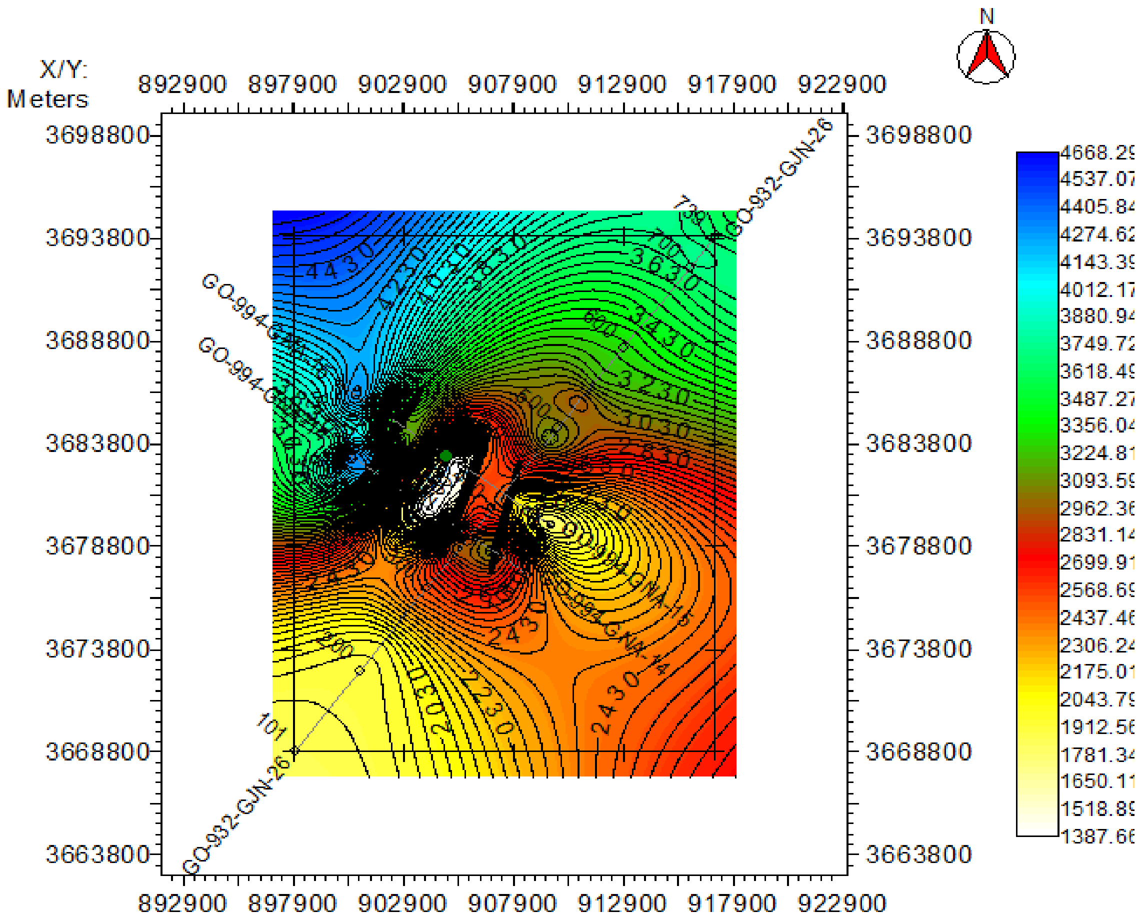

Figure 3.8: Depth contour map of Lockhart Formation

CHAPTER 4

PETROPHYSICAL WELL LOG ANALYSIS

4.1 PETROPHYSICAL ANALYSIS:

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

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

Different log curves are used in Petrophysics to locate a probable zone for hydrocarbon accumulation. Seismic interpretation gives us a structural trap by using Petrophysics we have located the productive zone in reservoir. We run logs in three tracks first track Spontaneous Potential(SP) ,Gamma ray (GR),CALIPER) for lithology identification, second track Micro Spherically Focused Log (MSFL), Laterelog Shallow (LLS), Laterelog Deep (LLD) for hydrocarbon versus water bearing zone and third track for Time (DT), Density Log (RHOB), Neutron Porosity Log(NPHI) for porosity. After we run these logs by using formulation, we calculate different properties essential for reservoir evaluation.

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

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

4.1.1 Classification of geophysical well logs:

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

a) Lithology track

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

Gamma ray (GR)

Spontaneous Potential log (SP)

b) Gamma ray log.

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

c) Spontaneous potential log.

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

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

d) Caliper log.

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

e) Porosity log.

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

Porosity log contains

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

f) Sonic log.

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

- Porosity (using interval transit. Time)
- Lithology identification (with Neutron and/or Density).

- Synthetic seismograms (with Density).
- Mechanical properties of formation with (Density).
- Abnormal formation pressures detection.

g) Density log.

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

h) Neutron log.

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

i) Electrical resistivity log

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

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

j) Laterelog deep.

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

k) Laterolog shallow.

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

The following wire-line logs of MISSAKESWAL-03 allotted by DGPC was used for petrophysical analysis.

MISSAKESWAL -03 allotted by DGPC:

- Resistivity log
- Gamma Ray log
- Density log

- Neutron log
- Sp log (spontaneous log) Sonic log

Logs used

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

4.2 Log curves:

The log information of MISSAKESWAL -03x was accessible in Logging ASCII Standard (LAS) format. All the parameters (hydrocarbon saturation, water saturation, volume of shale and porosities) are calculated by using information given in header and LAS file. (Figure 4.1) shows the different log curves.

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

4.2.1 SCALE USED FR THE DIFFERENT LOGS TRACK:

No	Log Name	Abbreviation	Scale	Unit
1	Gamma Ray	GR	0-200	API
2	Sonic Log	DT	140-40	µsec/ft
3	Caliper Log	Cali	6-16	Inches
4	Density Log	Rhob	1.95-2.95	Gm/m3
5	Neutron Log	Nphi	0.45- (-0.15)	PU
6	Later Log Deep	LLd	0.20-2000	Ώm
7	Later Log Shallow	LLs	0.20-2000	Ώm

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

I. ZONE OF INTEREST:

On the basis of the single log we cannot give the information about the productive zone we correlate the different logs and get the results. We marked the zone of interest from 2145-2161 m. Because there was low value of Gr which is clear cut condition that it is reservoir zone. Now in 2nd track we run the LLD, LLS, these are resistivity log now their cross over is also the clear cut indication of the formation contain some high resistivity fluid i.e. hydrocarbon. Similarly, in the track three the crossover of density and neutron logs is also showing that this is hydro carbon bearing zone. Also calculated effective and average porosity are greater than other zone and hydrocarbon saturation is greater than water saturation as shown in Figure 4.1

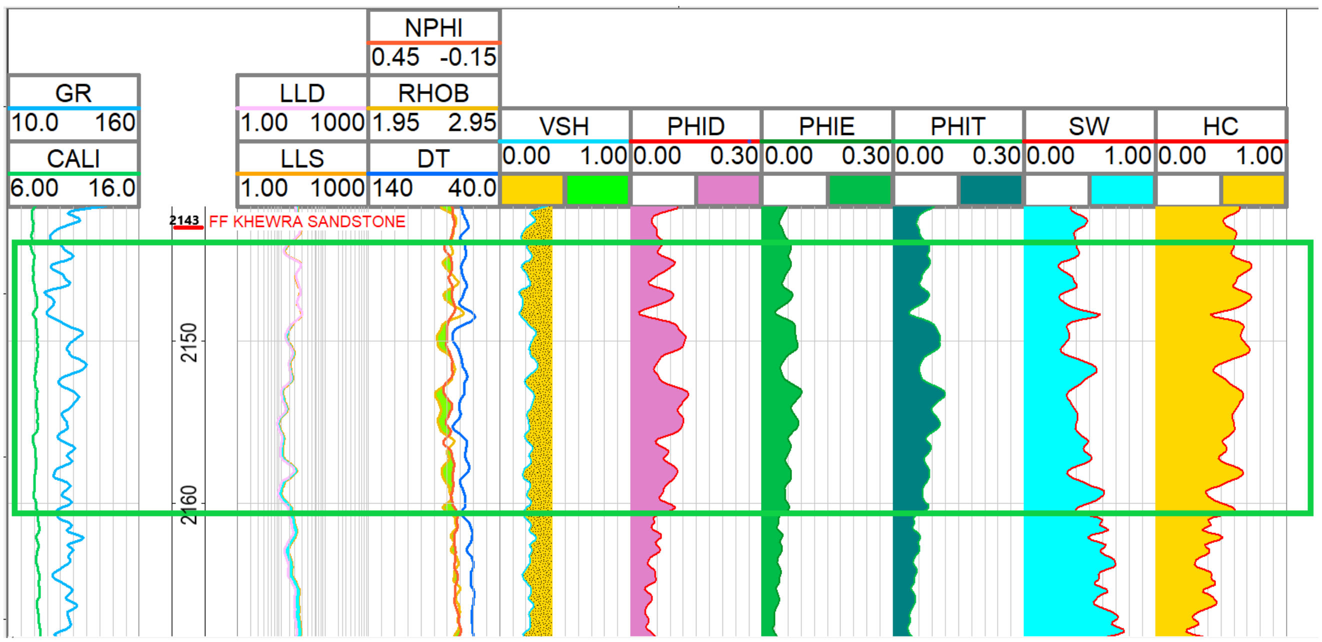

Figure 4.1 Well log interpretation of Missakeswal-03 by IHS kingdom.

Zones	**Starting Depth(m)**	**Ending Depth(m)**	**Thickness(m)**
Khewra Sandstone	2145	2161	16
Volume of Shale	**Porosity**	**Water Saturation**	**HC Potential**
21.75%	6.40%	39.57%	60.43%

Figure 4.2 Zone of interest interpretation of Missakeswal-03 by IHS kingdom.

4.3 CALCULATION OF ROCK PROPERTIES:

Many of the rock properties can be derived using geophysical well logs. We have calculated the following properties using the different equations which are given in below Table 4.2

NO	PROPERTIES	MATHMATICAL FORMULAS
1	Volume of shale (VSH)	VSH=(GR-GRCLN)(GRSHL-GRCLN
2	Density of porosity (PHID)	PHID=(RHOMA-RHOB)(RHOMA-RHOF)
3	Sonic porosity (PORS)	PORS=(DLT-DLTM)(DLTF-DLTM)
4	Total porosity (PHIT)	PHIT=(DPHI+NPHI)2.0
5	Effective porosity (PHIE)	PHIE=(DPHI+NPHI)/2.0*(1-VSH)
6	Static spontaneous potential (SSP)	SSP=SP(CLEAN)-SP(SHALE)
7	Resistivity of mud filtrate	$R_{mf2}=\frac{(ST+6.77)\times R_{MF1}}{(FT+6.77)}$
8	Formation Temperature (FT)	$\frac{(BHT-SST)}{TD}{}_{x}FD$
9	Saturation of Water (S_w)	$S_W=\frac{\sqrt{F\times R_W}}{\sqrt{R_t}}$
10	Hydrocarbon Saturation(HS)	HS=1-Sw

Table 4.2 Different equations for calculating rock properties (Altaf et al., 2018)

a) Volume of Shale:

The volume of shale is calculated using the Gamma ray (GR) log. This log is used to measure the natural radio activity of the formation. Hence it provides the concentration of the radioactive material present in the formation, hence it is very useful in order to identify the lithology. The value of the gamma ray is low in the carbonate and in sandstone while it is having higher value in the shale. The reason is that the concentration of the radioactive material is larger in the shale as compared to sand and the carbonates.

$$Vsh = \frac{GR_{log} - Gr_{dean}}{GR_{shale} - Gr_{clean}}$$

Calculation of Porosity:

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

c) Average Porosity

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

$$\Phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

d) Effective Porosity.

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

$$\emptyset_{Effective} = \emptyset_{Total} - (V_{Shale} \times \emptyset_{Shale})$$

e) Resistivity of formation water (Rw)

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

Step 1: The values of the surface temperature (ST), maximum recorded temperature (BHT), and the resistivity of the mud filtrate (RMF1) from the well headers, the very first step is to find the (SSP) static spontaneous potential from the relation given in the table 4.2 from (Rider, 1999).

Step 2: Formation temperature is calculated using the using the relation which is given in the table 4.2 by (Rider, 1999).

Step 3: In this step the resistivity of the mud filtrate is calculated using the relation given in the table 4.2.

Step 4: In step 4 the resistivity of the mud equivalent (Rmfeq) is calculated by the equation given in the table 4.2.

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

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

CHAPTER 5
SEISMIC ATTRIBUTE ANALYSIS

5.1 Introduction

The goal of seismic attribute analysis is to improve the spatial prediction of geomechanical rock properties and petrophysical in the whole reservoir. The primary of this analysis is to discover the linear and more often non-linear relation between the seismic trace and production indicants, such as lithology, in-situ stresses fluids and geomechanical properties.

Attribute volumes are carefully studied to ascertain that noise and other irregularities are not transmitted, which is achieved by well logging conditioning and reservoir-focused seismic studies.this holds particular importance in the analysis of anisotropic fractured rocks. Petrophysical studies achieved by the well logs and core cuttings is the first step in the attribute analysis while the second step is forward modelling which is employed to identify primary controls on production.

Independent seismic attributes come up with clues for many elusive properties; however, the real improvement in predictive accuracy and authenticity of results generates from combining multiple seismic attributes and then solving the non-linear relationship between the seismic attributes and reservoir properties .Anefficient seismic attribute is either directly sensitive to the in demand geologic feature or reservoir property of interest, or allows deeper insight into the structural or depositional environment and thereby empowers us to find out some features of interest. Seismic traces are composite responses to geological factors such as lithology, fluid saturations and geomechanical properties. Unscrambling the effect each rock property has on the seismic trace and reckona seismic attribute or a good combination of attributes which is capable of predicting that property is a backbone of the reservoir characterization procedure workflow. The better geologic interpretation and prediction of production indicators aid in the identification of preferential drilling locations and completion practices.

Tanner, 1969, described the concept of complex traces while the idea of Hilbert Transform and complex trace build the foundation of most of the seismic attributes. In complex trace analysis actual seismic trace is carefully weighed as the real component $f(t)$, while its Hilbert transformed

(90 degrees phase shifted) version is the quadrature trace which is the conjugate or imaginary component*h(t)*. A complex traceis defined as

$$F\ (t) = f\ (t) + ih\ (t)$$

Where:

*F (*t) =complex trace

f (t) = seismic trace

h (t) = Hilbert's transform 90 phase shift of *f (t)*

5.2 Classification of Seismic Attributes

Seismic attributes are properties of our recorded data that can be measured, such as amplitude, dip, phase , frequency and polarity. Attributes can be measured over a time window and may be measured for a single trace, on a set of traces or on a surface interpreted from seismic data.

An attribute is quantified as the derivative of a seismic measurement. The different attributes of horizon and formation are the different ways of presenting and analyzing a limited amount of basic information which is essentially derived from time, amplitude, frequency and attenuation (Fig 5.1).

Assuming a broad generalization, it can be suggested that time derived attributes provide information about structural features, amplitude derived attributes provide knowledge about stratigraphic and reservoir characterization while frequency attributes are assumed to be related to direct hydrocarbon detection .

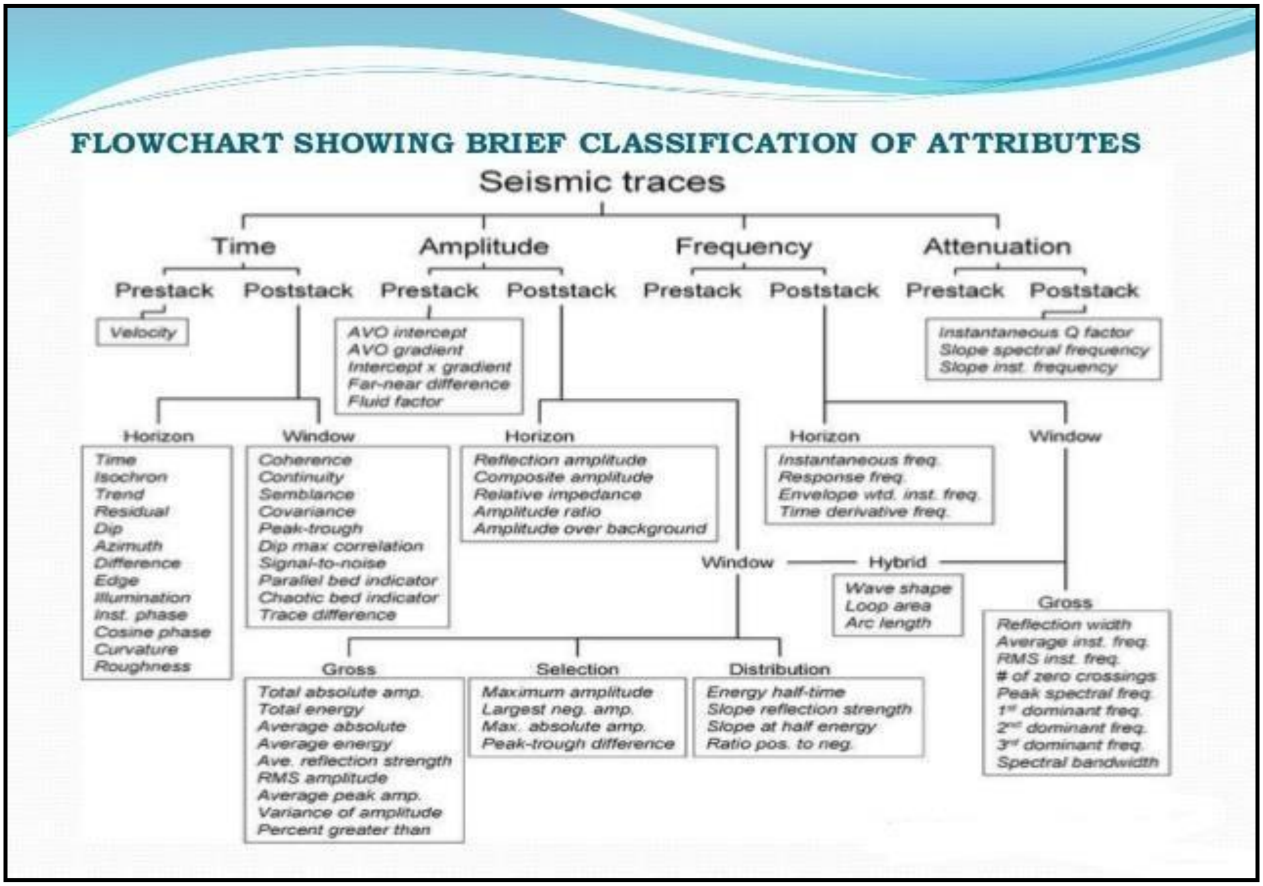

Fig 5.1 Classification of seismic attributes (M.T. Taner, F.Koehlar, and R.E. Sheriff, 1979)

5.3 Seismic Attributes

As mentioned earlier seismic, attributes are used to unravel the seismic features of interest. We used standard (horizons and trace based) post-stack attributes to analyze the reflector characteristics, which cannot be easily observed on the seismic sections. In this study Post-Stack tool of Kingdom software is used to extract a suite of post-stack seismic attributes from 2D seismic data.

5.3.1 Instantaneous Attributes

The Instantaneous Attributes are worked out for each sample of the input trace in an independent manner. The basis for the calculation of most instantaneous attributes is that of the seismic signal is considered as complex trace consisting of the real part f(t), and imaginary part h(t), first is the

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signal recorded by the geophone, second part can be computed as the Hilbert transform of the real part.(M.T. Taner, F.Koehlar, and R.E. Sheriff, 1979).

In general, whether in time or depth domain, the complex trace can be expressed as

F(z) = f(z) + ih(z),

wherez stands for either time or depth.

Instantaneous Attributes calculated for time and depth.

5.3.2 Instantaneous Phase

Average instantaneous phase describes the angle between the rotating vector and a real axis as a function of time. Itis limited to the range of -180 to +180.The attribute is useful to analysethe lateral bedding continuity, fluid content, pinchout, channel fans and depositional environments. The attribute is also helpful to distinguish the payable and non-able zones especially when the amplitude attributes are biased due to tuning effect .

Projected uses:

- It correlates phase component and wave propagation.
- Phase velocity can be calculated through this attribute.
- Its not always best to show discontinuity but the reverse case is true for continuity and sequence boundaries.
- It doesn’t contain any amplitude information, so all events (weather of our interest or not) are shown.
- It can be used in the calculation of frequency/wavenumber and acceleration.

Instantaneous phase attributes successfully aided in depicting lateral continuity of all horizons. Since it doesn’t have any amplitude information so all the events can be seen on the section which has been removed during the processing of seismic data by different kinds of amplitude filtering. Furthermore, it shows discontinuities across the section thus leading to the confirmation of right fault interpretation on the section.

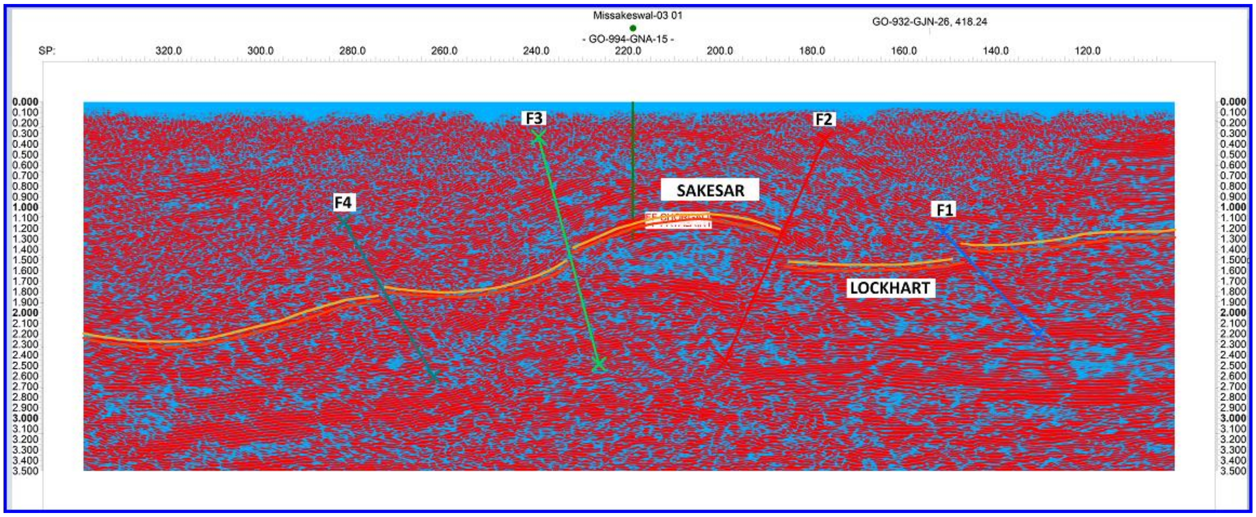

Fig 6.2 Instantaneous phase attribute applied on line

Instantaneous phase attributes successfully aided in depicting lateral continuity of all horizons. Since it doesn’t have any amplitude information so all the events can be seen on the section which has been removed during the processing of seismic data by different kinds of amplitude filtering. Furthermore, it shows discontinuities across the section thus leading to the confirmation of right fault interpretation on the section.

Similarly for Average Energy

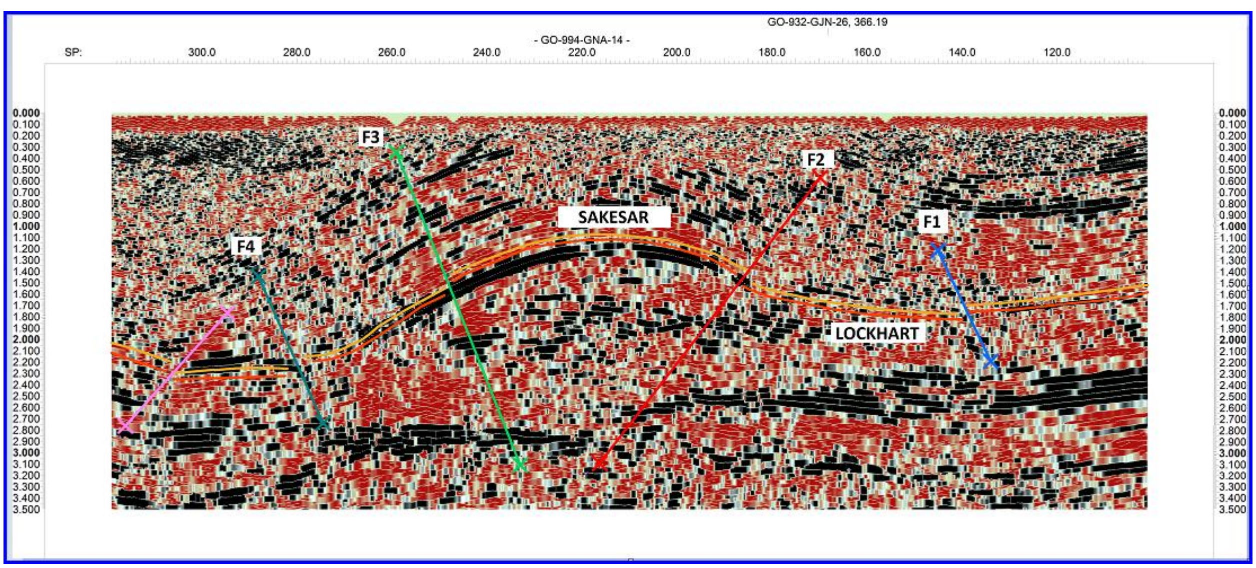

Fig 5.2 Average Energy attribute applied on line

5.4 Trace Envelope

Trace envelope also called the Reflection strength(Instantaneous amplitude), represents the total Instantaneous energy of the complex trace.Itis computed as the modulus of the complex trace. The formula is given below;

$$A(t) = \sqrt{f^2(t) + h^2(t)} = |F(t)|$$

Or

$$\text{Reflection strength} = \sqrt{(\text{real trace})^2 + (\text{quadrature trace})^2}$$

From above formula,it is evident that value of reflection strength is always positive. Trace envelope attribute is independent of phase due to which it is more suitable to investigate the amplitude anomalies in greater detail.

- Represent the acoustic impedance contrast.
- Major changes in lithology.
- Bright spots.
- Spatial correlation of porosity and other lithologic variations.
- Gas accumulation zones.
- Sequence boundaries, and thus major changes or depositional environments.
- Local changes as a clue of faulting.
- Thin-bed tuning effects.
- Unconformities.

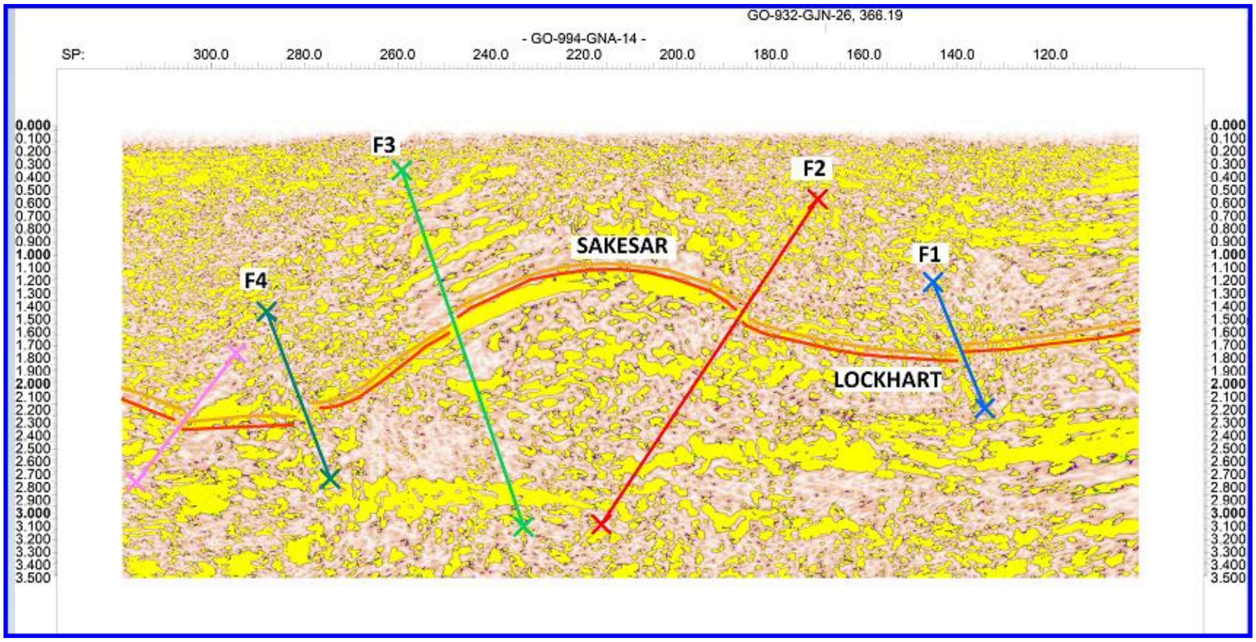

Fig 5.4 Trace envelope attribute applied on line

From Fig 5.4 it is evident that trace envelope attribute successfully predicted impedance contrasts which is a clue to lithological changes across the Sakesar (shown by gold color), and Lockhart (shown by red color) .

Conclusions:

The 2D seismic and Petrophysical study of MissaKeswal can be concluded as follows.

- The MissaKeswal area is one of the intensely deformed regions of Northeastern Potwar of Punjab, Pakistan.
- The Petrophysical analysis was also helpful in determining the reservoir's net pay and the interpretation of well logs indicates that the shales can act as an effective cap rock due to enormous volume especially if the fault plane has smeared its 25% volume.
- The high porosity and Hydrocarbon saturation in both Formations indicate that the carbonates of each formation can act as a reservoir.
- The pay zone is 16m thick in Khewra sandstone Limestone Formation.
- The popup structure interpreted on seismic sections and time depth maps reflects the possibility of structural traps for hydrocarbon reservoirs of the area.
- The high porosity, hydrocarbon saturation and thickness of pay zone interpreted on well logs favor Khewra sandstone Formation as effective reservoir, Sakesar and chorgali formation act as reservoir according to the literature of the area.

References:

- Aamir, M., & Siddiqui, M. M. (2006). Interpretation and visualization of thrust sheets in a triangle zone in eastern Potwar, Pakistan. *The Leading Edge*, *25*(1), 24-37.
- Altaf Mehmood, 2d seismic survey of Balkassar area, Department Of Earth Sciences, QAU, Pakistan. (2018)
- Bannert, D,(1995). Geology of Pakistan (F.H. Bender & H.A. Raza,Eds). Stuttgart, Germany: Borntraeger.
- Dobrin and Savit (1988) "Practical Seismic Interpretation" IHRDC publisher, Boston.
- Dobrin and Savit.,1988, Geophysical Exploration, Hafner Publishing Co.
- Elsevier, Miall, A. D. (1977). A review of the braided-river depositional environment. *Earth-Science Reviews*, *13*(1), 1-62.
- Harry Williams, book Historical Geology 2004.

- Harry Williams, book Historical Geology 2004.

- Hasany, S. T., & Saleem, U. (2012). An integrated subsurface geological and engineering study of Meyal field, Potwar plateau, Pakistan. *Search and Discovery Article*, *20151*, 1-41.
- Kadri, I. B. (1995). *Petroleum geology of Pakistan*. Pakistan Petroleum Limited.
- Kazmi, I.B.Qadri (1995) "Petroleum geology of Pakistan" PPL Pakistan.
- M.T. Taner, F.Koehlar, and R.E. Sheriff, 1979,Geophysics; Complex Seismic Trace Analysis; 44(6), 1041 (1979).
- McQuillin, R., Bacon. M., and Barcaly, W., 1984 an introduction to seismic interpretation, Graham and Trotman.
- Mughal, Mustafa, S., Khan, M. A., Khan, M. R., Sousa, L. M., Hameed, F., M. S., & Niaz, A. (2016). Building stone evaluation—A case study of the sub-Himalayas, Muzaffarabad region, Azad Kashmir, Pakistan. *Engineering geology*, *209*, 56-69.
- Muhammad Kashif, 2D seismic survey of Missa Kaswal area, Department of Earth Sciences, QAU, Pakistan. (2007)
- Porth, H., & Raza, H. A. (1990). On the Geology and Hydrocarbon Prospects of Sulaiman Province, Indus Basin, Pakistan. Hydrocarbon Development Institute of Pakistan/Federal Institute of Geoscience and Natural Resources. *Unpublished Report*.
- Rider, M., Goodall, T., & Dodson, T. (1999). A pre-development turbidite reservoir evaluation using FMS electrical images. *Geological Society, London, Special Publications*, *159*(1), 123-137.

- Shami, Baig, Zahid, M., Khan, A., ur Rashid, M., Saboor, A., & Ahmad, S. (2014). Structural interpretation of Joya Mair oil field, south Potwar, Upper Indus Basin, Pakistan, using 2D seismic data and petrophysical analysis. *Journal of Himalayan Earth Sciences*, *47*(1), 73.