2D Seismic Reflection Data Interpretation of Meyal Area Integrated with Reservoir Characterization by using Wireline Data and Seismic Attribute Analysis

BY

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“With The Name of ALLAH, the Most Gracious & the Most Merciful”

And look at the mountain how they are set! And at the earth how it is spread out

(AL-QURAN)

CERTIFICATE

This dissertation submitted by **SHAHZEB ALI KHAN** son of **HASHIM ALI KHAN**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.

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ABSTRACT

The present study pertains to the structural and stratigraphic interpretation, attributes analysis, and petrophysical analysis using seismic and well logs data of Meyal area. The data used for this study consists of Seg–Y data and well logs data of Meyal area provided by the Department of Earth Sciences Quaid-i-Azam University Islamabad. Meyal area lays in the eastern Potwar is known for its hydrocarbon (oil and gas) structural traps. Meyal oil field is located in Eastern Potwar of Pakistan.

The Seismic lines were acquired and processed by POL. For interpretation of these seismic lines three reflectors and reverse faults were marked by using the interactive tools of Kingdom software. In this way time section were obtained. After time to depth conversion the true structural geometry was obtained in the form of depth sections. The marked horizons were identified using formation tops from wells and their depths were confirmed through correlation with synthetic seismogram from Density log (RHOB) and Sonic log. After generating fault polygons, time grids and depth grids of marked horizons were prepared. From time and depth grids time and depth contour maps of the horizons of interest were generated to understand the spatial geometry of the structures and the nature of geological structures as identified by the seismic section of the area. Three dimensional surfaces are also generated to further confirm these anticlinal structures. Reverse faulting as identified on seismic sections confirmed compressional tectonic regime in the study area resulting due to Indian Eurasian plate’s collision. The seismic interpretation of these lines showed pop-up structures and snaked head bounded by reverse faulting. These pop-up structures were favorable places for hydrocarbons accumulation and extraction.

Seismic attributes analysis of seismic section helps in identifying the different lithological boundaries and further confirmed the structural and stratigraphic interpretation and petroleum play of the study area. The Petrophysical analysis of Meyal-05 and Meyal-08 for the selected zones of the interest showed reservoir quality of different formations.

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CHAPTER 1: INTRODUCTION

1 INTRODUCTION

1.1 INTRODUCTION TO STUDY AREA

Pakistan has high potential of hydrocarbons in its northern (like Potwar, Kohat) and southern (like 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. The Potwar sub basin is dominated by the structural traps and mostly seismic data is incorporated for the delineation of these structures. From seismic we generate the model that is representative of geological model of the earth. Now limited seismic data and complex tectonic conditions create the difficulty in interpreting the seismic data(Amir and Siddiqui, 2006).

This study pertains to investigate the 2D seismic interpretation of given seismic reflection data of Meyal area situated in North Potwar sub-basin, Upper Indus basin. The seismic lines selected for studying were acquired by Pakistan Oilfield Limited (POL) in the Meyal Block which is situated in Potwar sub basin.

In Pakistan the first oil well was drilled near oil seepage at Kundal in the Potwar basin in 1866. Since then in spite of a low number of wells drilled, several oilfields have been discovered. Yet the Potwar basin still has not acquired the status of a mature basin as all of its potential reservoirs either have not been reached or tested. Main production has been from Paleogene carbonate and Jurassic clastic reservoirs. The oldest reservoirs of Cambrian and Permian ages have been found in the "thrusted anticlinal play" of Adhi, JoyaMair, Dhurnal, Balkassar, ChakNaurang, Missa-Keswal, Rajian, and Kal oil fields. The northern part of Potwar plateau is known as North Potwar Deformed Zone is more intensively deformed. It is characterized by east-west, tight and complex folds overturned to the south and sheared by steep-angle faults. In its eastern part the strike abruptly changes to northeast and the structures comprise tightly folded anticlines and broad synclines. In central and western Potwar, the thrust wedge has been transported southward as adherent slab with little deformation and less than 1km of shortening between NPDZ and salt range. In eastern Potwar, in contrast, the deformation has shortened the crust to 24 km(Amir and Siddiqui, 2006).

1.2 LOCATION OF THE STUDY AREA

Geographically the study area is situated inPotowar basin, which lies in the northern part of upper Indus basin. In the south of Meyal area KalarKhar is present, in the east city of Chakwal and in west city of Talagang. The area is now easily approachable due to construction of Lahore Islamabad Motorway. The study area Meyal lies between latitude 33°, 11', 00" N to 33°, 22', 00" N and longitude 71°, 59', 00" E to 72°, 18', 00" E.

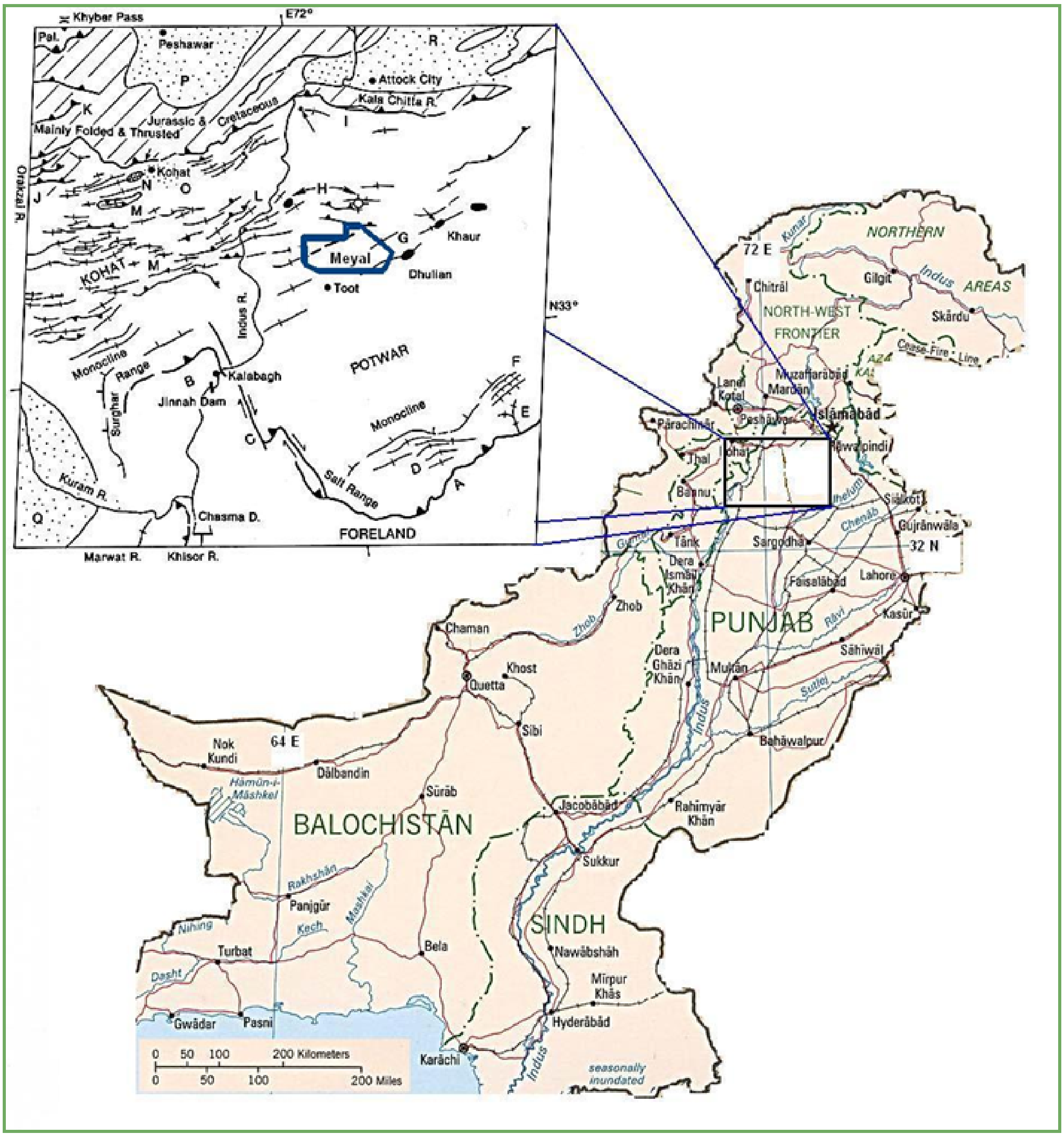


Figure 1.1: Geographic location of study area in Potwar plateau and zoomed structural map of Meyal area(Amir and Siddiqui, 2006).

Geologically Meyal block lies in the northern part of Potwar shown in (Figure 1.1) where the structural trend is northeast-southwest as compared with the dominant east-west trend of northern Potwar. The Meyal block lies in the northern part of Potwar sub-basin. The Indus River and the Jhelum and Soan rivers are passing on its western and eastern sides respectively. The Kalachitta-Margalla Ranges are in the north and the Salt Range is in the south. 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(Ghazi et al., 2014).

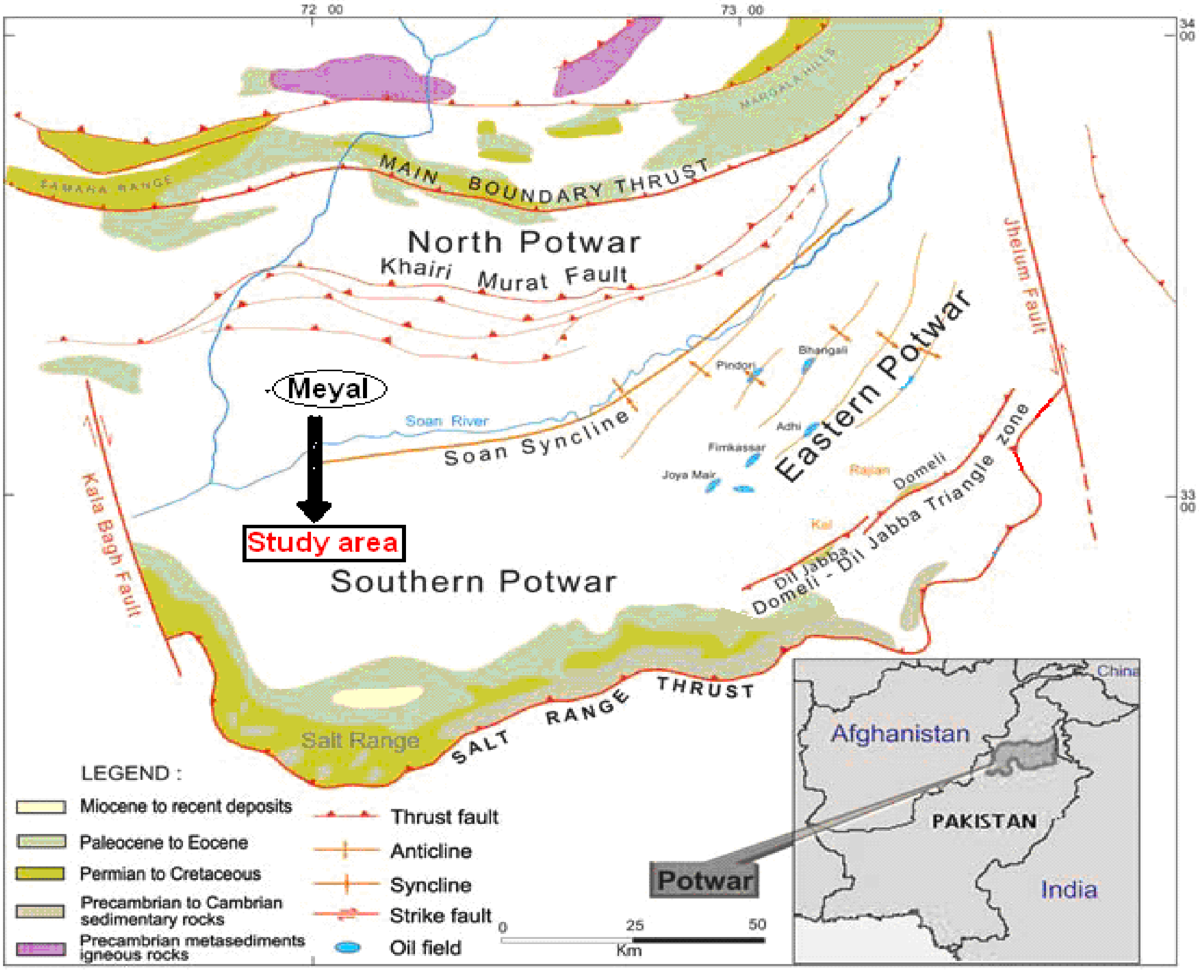


Figure 1.2: Geological location of study area with Meyal block highlighted (Ghazi et al., 2014).

1.3 PREVIOUS WORK OF STUDY AREA

The Burma Oil Company was the first to acquire Meyal concession in 1916, and they drilled three wells, but unfortunately they were all dry, till 1924. Later the area was granted to Attock Oil Company and they drilled their first well during 1942 to 1944 which was abandoned. They drilled second well at the same site and abandoned due to the fact that the well had crossed the thrust entering downthrown block at 8000 ft. Their third well was to be abandoned at 8100ft due to mechanical problems. Seventeen (17) wells have been drilled till to-date in Meyal Concession area. Oil has been discovered in Eocene (Chorgali / Sakesar

Formations), Paleocene (Ranikot/ Lockhart Formations) and Jurassic (Datta Formation) (Sajjad et al., 2005).

The very first well of POL in the concession (POL Well – 1), was initially drilled on Nov. 2, 1967 and drilled to TD 13489 ft (Dhak Pass Fm) in November, 1968 and oil discovery from Chorgali and Sakesar Formations was made. Well – 2 was drilled down to 13600 ft, in Dhak Pass Fm, and completed as a dual producer, but produced from Paleocene only and ceased production in 1980. Well – 3 were drilled down to 12719 ft in SakesarFm and produced oil/gas from Chorgali / Sakesar Fm.

Well – 5 was drilled down to 14100 ft in Triassic and the well-produced from Lockhart Formation. Jurassic sands were tested tight. Wells 4, 7, and 9 were drilled down to 12640 ft (Sakesar), 14211 ft and 12849 ft (Ranikot) respectively and all produced from Chorgali – Sakesar Formations. Well – 10 was drilled down to 14121 ft (Triassic) and produced from Jurassic only. Well – 11 was drilled to 2860 ft (Chinji Formation). The deepest well in the concession is Well - 13, which was drilled down to 14506 ft (Chhidru Formation) and produced oil/gas from Jurassic sands.

Wells 14, 15 and 16 were drilled to 13028 ft (Sakesar), 13953 ft (Nammal) and 13195 ft (Sakesar) respectively. Wells 14 and 16 produced oil/gas from Chorgali/Sakesar Formations whereas Well – 15 didn’t flow hence the well was completed as water injector.

POL wells 6, 8, 12, and 17 are currently producing oil and gas. Well – 6 was drilled down to 13424 ft (Jurassic sandstone), initially completed as dual producer from Paleocene and Jurassic, but production from Jurassic was ceased later in 1982 and currently producing from Paleocene. Well – 12 (W/O) was deepened down to 13622 ft (Triassic) and producing oil/gas from Chorgali/Sakesar. Well – 8 is producing from Eocene/Jurassic. Meyal – 17 was the last well drilled down to 13660 ft in Jurassic and now producing from Paleocene(Sajjad et al., 2005).

1.4 SEISMIC REFLECTION DATA

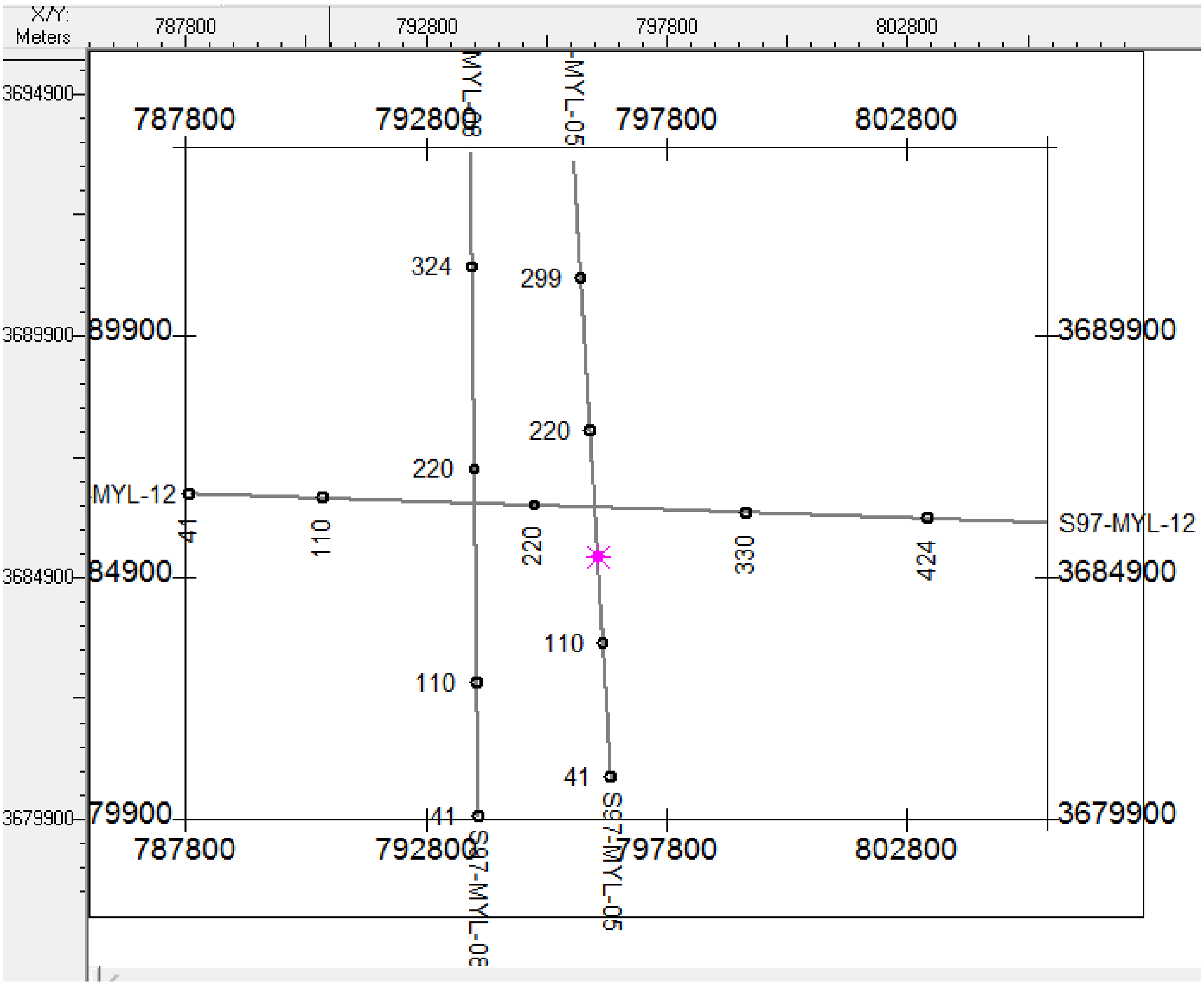
The seismic reflection data of the study area was obtained by Directorate General of petroleum concession (DGPC) Pakistan in digital format .This data was acquired and processed by POL. The trend of the seismic dip and strike lines in SE-NW and SW-NE respectively. The seismic reflection data are given below in table (1.1)

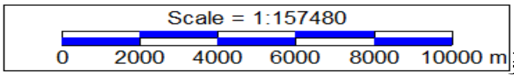
Table 1: Seismic reflection data used for base map

LINE NAME	NATURE	LINE ORIENTATION	WELLS
97-MYL-01	Dip Line	S-N	
97-MYL-02	Dip Line	S-N	
97-MYL-03	Dip Line	S-N	
97-MYL-04	Dip Line	S-N	
97-MYL-05	Dip Line	S-N	
97-MYL-06	Dip Line	S-N	MEYAL-08P
97-MYL-07	Dip Line	S-N	MEYAL-01,17
97-MYL-08	Dip Line	S-N	
97-MYL-09	Dip Line	S-N	MEYAL-1A
97-MYL-10	Dip Line	S-N	MEYAL-14
97-MYL-11	Dip Line	S-N	
97-MYL-12	Strike Line	W-E	13, 10P
97-MYL-13	Strike Line	W-E	MEYAL-16

1.5 BASE MAP

The base map is important component of interpretation, as it shows different position of each seismic strike and dip line. For a Geophysicist a Base map is that which shows the orientations of seismic lines and specify points at which seismic data were acquired or simply a map which consist of number of dip and strike lines on which seismic survey is being carried out . A base map typically includes location of lease and concession boundaries, wells, seismic survey points and other cultural data such as buildings and roads with geographic reference such as latitude and longitude. Geophysicist typically use shot points maps, which show the orientation of seismic lines and shot points at which seismic data were required , to display interpretation of seismic data(Coffeen, 1986).





gure 1.3: Base-map of study area and Seismic lines with relative scale.

1.6 SCALE OF BASE-MAP

The scale of base-map used is 1:157480. Scale is important in order to understand the area.

1.7 WORKFLOW ANALYSIS

The Interpretation was carried forward using different techniques and steps with each step involve different processes which were performed using the software tools. Simplified workflow used in the dissertation is given in figure 1.5, which provides the complete picture depicting how the dissertation has been carried.

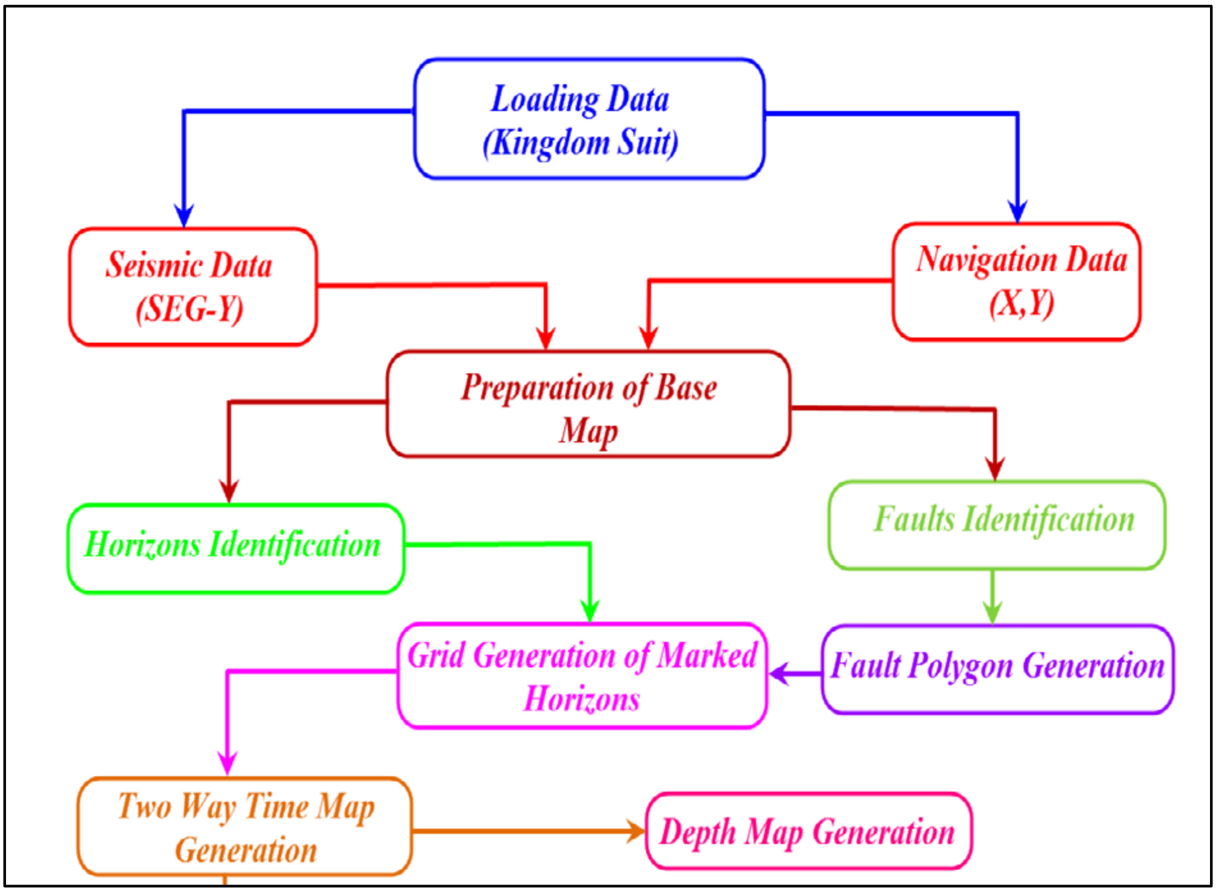


Figure 1.5: Work flow analysis of seismic interpretation.

1.8 OBJECTIVES

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

- Structural and stratigraphic interpretation to find out the structural traps and horizons of interest.
- Rockphysics of reservoir formations to confirm their lithologies.
- Seismic attribute analysis to confirm the interpretation.
- 1 D forward modelling to confirm the marked horizons.
- Petrophysical analysis of reservoir formations to identify their prospect zones.

CHAPTER 2:
GEOLOGY AND TECTONICS OF THE STUDY AREA

2 INTRODUCTION TO THE GEOLOGY OF THE AREA

Geological information plays fundamental role in seismic survey. As the same velocity effect can be produce from the formations of different lithology and vice versa. Information about the position and penetration of local fault and the presence of the unconformities between the rocks is very important for interpretation point of view. Area under study is composed of very complex tectonic that is directly related to the regional movement of plates. Since northward movement of Indian plate yield the Mariana type subduction that resulted in the formation of Kohistan Island Arc that accreted with the Eurasian Plate followed by the accretion of Indian Plate along the southern margin. This yield the north dipping subduction zone that result in the formation complex tectonic feature and crystalline rocks. Deformation as result of plate tectonic in these areas is episodic (Kazmi& Jan, 1997).

2.1 REGIONAL SETTINGS

The Indian Ocean and the Himalayas, two of the most pronounced global features surrounded the Indo-Pakistan subcontinent, have a common origin. Both are the product of the geodynamic processes of sea-floor spreading, continental drift and collision tectonics. A plate of the earth’s crust carrying the Indo-Pakistan landmass rifted away from the super continent Gondwanaland followed by the extensive sea-floor spreading and the opening up of the Indian Ocean.Propelled by the geodynamic forces the Indian plate traveled 5000 Km northward and eventually collided with Eurasia.Thesubduction of the northern margin of the Indian plate finally closed the Neotythes and the Indian Ocean assumed its present widespread expanse.This collision formed the Himalayas and the adjacent mountain ranges(Yeats and Lawrence, 1984; Najman, 2006).

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(Yeats and Lawrence, 1984).

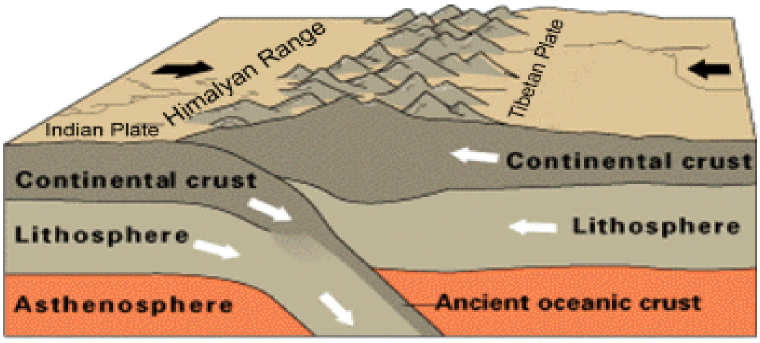


Figure 2.1: Subduction of Indian plate and formation of Himalaya(Yeats and Lawrence, 1984)

2.2 NORTHWARD DRIFT OF INDIA AND THE OPENING OFINDIAN OCEAN

The Indo-Pakistan subcontinent separated from the Gondwana motherland about 130 million years ago. Its location within Gondwana in relation to Africa, Antarctica and Australia is uncertain. Various authors have placed in different positions. It has been estimated that between 130 m.y. and 80 m.y. India moved northward at a rate of 3 to 5 cm/year (Jhonson et al., 1976).

The vast distance (5,000 Km) between the matching set of anomalies 21 and 32 shows that from 80 m.y. ago India moved at an average rate of about 16 cm/year relative to Australia and Antarctica Before anomaly 22 (50 m.y.) this rate of movement varied between 15 and 25 cm/year(Powell, 1979).

This movement was facilitated by transform faulting in the Proto-Owen fracture zone and extensive sea-floor spreading along Mid Oceanic Ridge. It is noteworthy that extensive extrusion of Daccan Trap Basalts occurred between 65-60 million years ago during the fast northward drift of India.

2.3 POTWAR SUB-BASIN

Triangle zone plays are common in the Potwar area of Pakistan. The PotwarBasin is one of the oldest oil provinces. It is located in the western foothills of the Himalayas in northern Pakistan. It includes the Potwar Plateau, the SaltRange, and the Jhelum Plain. The Khairi Murat thrust-Dhurnal back thrust triangle zone in the northern Potwar deformed zone (NPDZ) and the JoyaMair triangle zone in the southern Potwar platform zone (SPPZ) are also well documented today. These tectonic settings hold several billion barrels of reserves, and significant amounts of hydrocarbons are being produced. This is the regional triangle zone in the eastern edge of Potwar which is the result of large, regionally extensive convergent thrust sheets structurally. Geologically, it forms part of the foreland zone of the NW Himalayan Fold-and-Thrust belt. The Trans-IndusRanges in south of the Kohat sub-Basin exposed sediments from Cambrian to Pliocene age (Kadri, 1995).

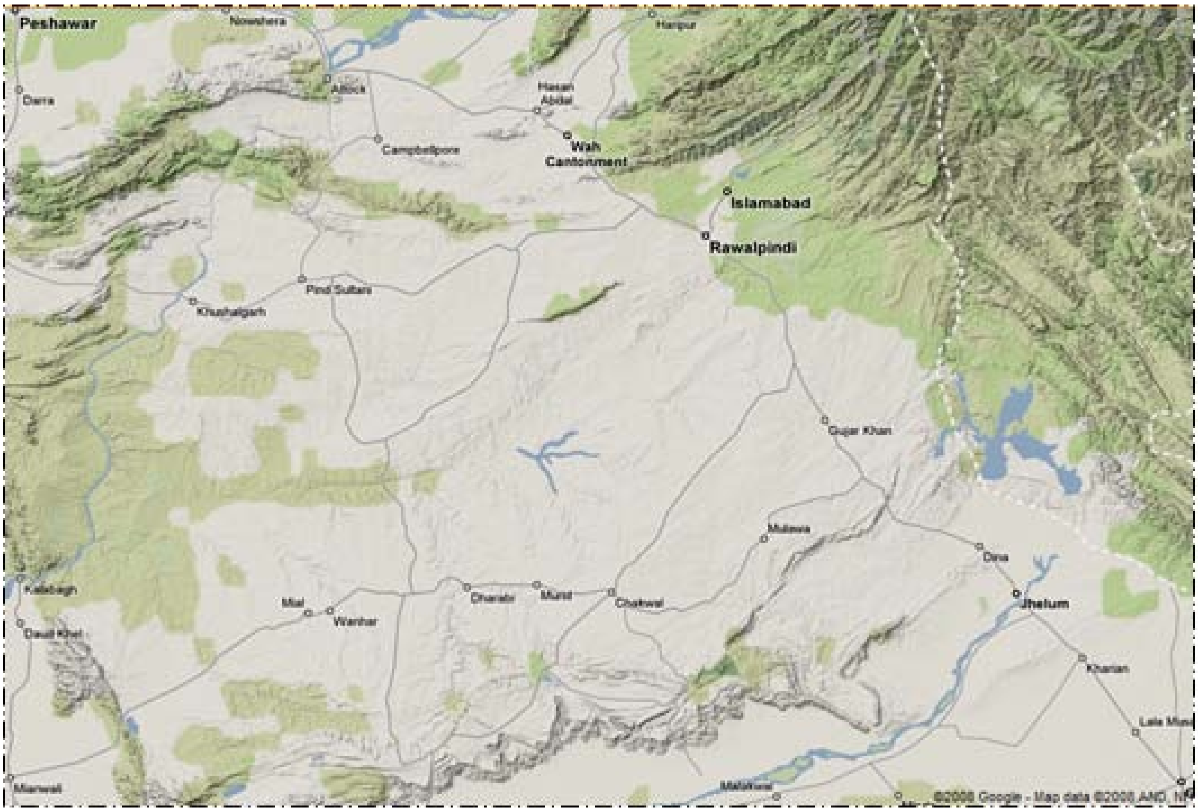


Figure 2.2: Potwar Sub Basin (Ghazi et al., 2015)

The potwar sub basin is divided into two zones due to the amount of deformation in both the zones. They are:

- North Potawar deformed Zone
- South Potwardeformed Zone

2.3.1 North Potwar Deformed Zone (NPDZ)

The NPDZ is more intensely deformed than the southern part. It is a belt of Neogene deformation, extending southward from the MBT to the Soansyncline.Formation outcrops and faults are generally east-northeast trending, approximately perpendicular to the tectonic transport direction. The highly dissected NPDZ is an area of wide synclines, compressed folds and closely spaced imbricate thrusts. The deformation style of NPDZ abruptly changes from east to west. The eastern NPDZ represents a buried thrust front with the development of foreland syncline on the back of Dhurnal Fault, passive roof duplex (triangle zone) and hinterland dipping imbricate stack farther north (Kemal et al., 1991).

While the western NPDZ which is characterized by compressed and faulted anticlines separated by large synclines, representing the emergent thrust. The NPDZ is followed to the south by asymmetrical wide and broad Scan syncline, with a gently northward dipping southern flank along the salt range and a steeply dipping northern limb along NPDZ(Kemal et al., 1991).

2.3.2 STRUCTURAL STYLE OF POTWAR SUB BASIN

The structural style of the central eastern and western parts of Potwar Plateau shows a marked difference. In the central western parts of Potwar Plateau, the deformation appears to have occurred by south-verging thrusting, whereas in the eastern part the deformation is mainly in northeast-southwest direction with tight and occasionally overturned anticlines separated by broad synclines. This difference may be related to lesser amount/thickness of salt in the lnfra-Cambrian in the eastern areas and very low dip of the basement (˚1 -1.5˚) as compared to Central Potwar (2˚-3˚). Overturned anticlines separated by broad synclines. This difference may be related to lesser amount/thickness of salt in the lnfra-Cambrian in the eastern areas and very low dip of the basement (˚1 -1.5˚) as compared to Central Potwar (2˚-3˚). Based on the seismic interpretation, the structures in Potwar area may be divided into: Pop-up anticlines, Snake-head anticlines, Salt cored anticlines and Triangle zones (Moghal et al., 2003).

2.3.3 MAJOR FAULTS IN POTWAR BASIN

As Potwar represents the southern margin of the Himalayan collisional zone, a variety of faults and folds exist in this area. Some of the major faults of the area are given as:

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

2.3.4 MAJOR FOLDS IN POTWAR BASIN

Besides major faults, other structures present in the area include several anticlinal andsynclinal features which are given as follows:

- Soan Syncline
- ChakNaurang Anticline
- Adhi-Gungril Anticlines
- JoyaMair Anticline
- Mahesian Anticline
- Tanwin-Banis Anticline
- Dhurnal Anticline

CHAPTER 3
STRATIGRAPHY AND PETROLEUM GEOLOGY

3 INTRODUCTION TO THE PEROLEUM GEOLOGY OF THE AREA

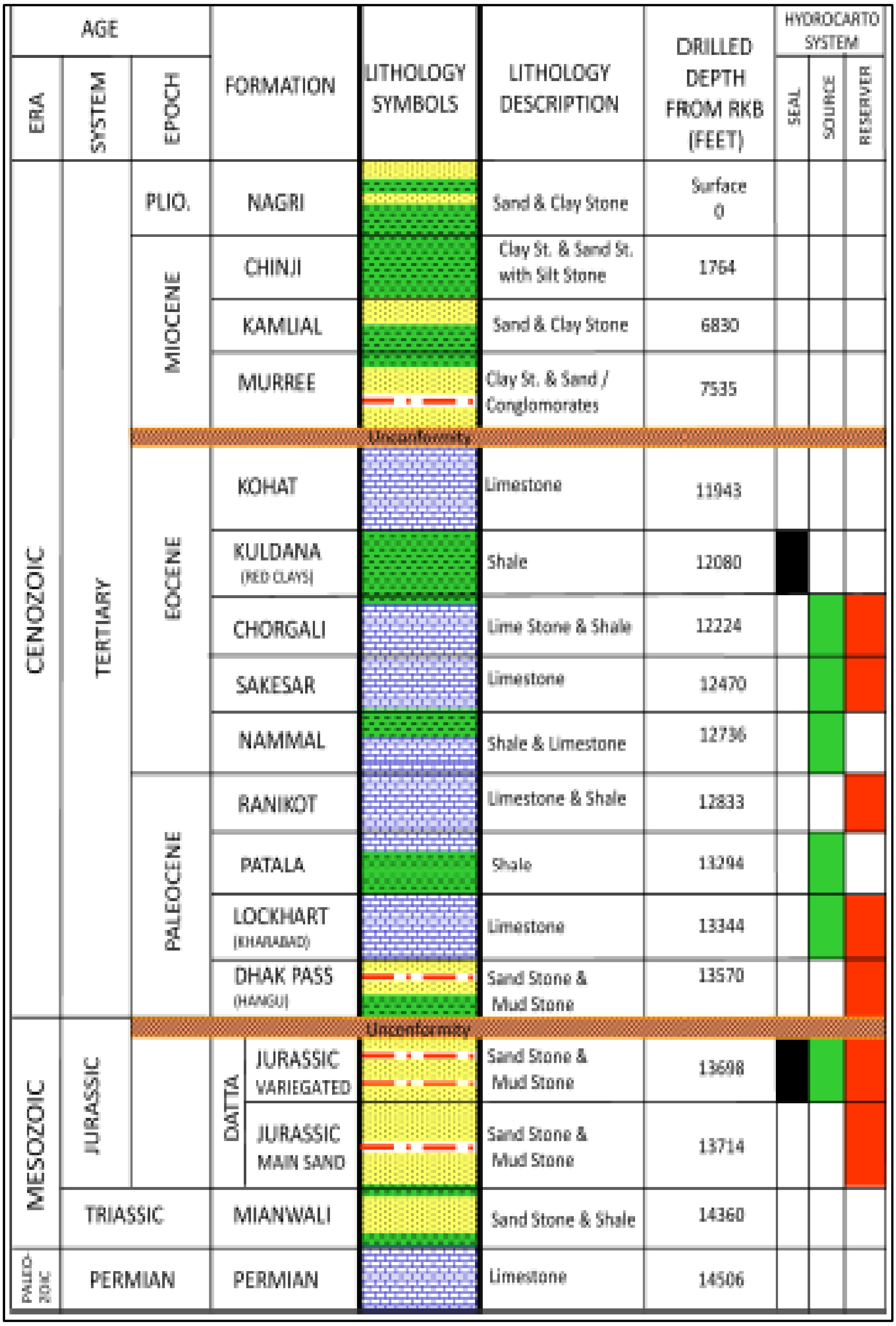
In Meyal area, the Salt Range Formation is overlain by the Cambrian to Eocene platform sequence. It is generally similar to the rest of Peninsular India. In Salt Range PotwarForland Basin(**SRPFB**), the Early to Middle Cambrian Jehlum Group lies on the Eocambrian Salt Range Formation (Gee, 1934).

The Jehlum Group includes Cambrian Khewra and Kussak Formations which is shown in Table 2.1. These were deposited in littoral to shallow marine environments. The basin was uplifted during Ordovician to Carboniferous; therefore no sediments were deposited in SRPFB. The Jehlum Group is disconformably overlain by the Permian Nilawahan Group. It includes the Tobra, Dandot, Warcha and Sardahi Formations. The Late Permian Zaluch Group was eroded or not deposited in the area. The Late Permian to Cretaceous rocks from west to east in the basin is eroded due to significant pre-Paleocene tectonic uplift in SRPFB (Shami and Baig, 2003).

The early Paleocene marine transgression resulted thick deposition of the Paleocene to Eocene carbonate-shale sequence. It includes the Lockhart, Patala, Sakesar and Chorgali Formations. The carbonates of these formations form the principal reservoirs for the accumulation of oil in the area. Hangu Formation is not identified in this part of SRPFB, which is eroded after deposition and can be identified on outcrop representing residual environments of deposition (Shami and Baig, 2003).

The upper part of the stratigraphic section comprises of the Miocene to Pleistocene non-marine molasses deposits.These include rocks of the Rawalpindi Group (Murree, Kamlial). On top of these are Siwaliks that include Chinji, Nagri, DhokPathan and Soan formations.

The transgressivemolasse sediments represent the erosional products of the southward advancing Himalayan thrust sheets. The molasses sediments in the southern SRPFB lie on the lower Eocene carbonates. The significant part of these sediments in depth fall in the zone of oil window, serving as a regional over pressured cap (seal) rock over the reservoir rocks in northern SRPFB (Shami and Baig, 2003).



AGE			FORMATION		LITHOLOGY SYMBOLS	LITHOLOGY DESCRIPTION	DRILLED DEPTH FROM RKB (FEET)	HYDROCARTO SYSTEM		
ERA	SYSTEM	EPOCH						SEAL	SOURCE	RESERVER
CENOZOIC	TERTIARY	PLIO.	NAGRI			Sand & Clay Stone	Surface 0			
		MIOCENE	CHINJI			Clay St. & Sand St. with Silt Stone	1764			
			KAMLIAL			Sand & Clay Stone	6830			
			MURREE			Clay St. & Sand / Conglomorates	7535			
					Unconformity					
		EOCENE	KOHAT			Limestone	11943			
			KULDANA (RED CLAYS)			Shale	12080	■		
			CHORGALI			Lime Stone & Shale	12224		🟩	🟥
			SAKESAR			Limestone	12470		🟩	🟥
			NAMMAL			Shale & Limestone	12736		🟩	
		PALEOCENE	RANIKOT			Limestone & Shale	12833			🟥
			PATALA			Shale	13294		🟩	
			LOCKHART (KHARABAD)			Limestone	13344		🟩	🟥
			DHAK PASS (HANGU)			Sand Stone & Mud Stone	13570			🟥
					Unconformity					
MESOZOIC	JURASSIC		DATTA	JURASSIC VARIEGATED		Sand Stone & Mud Stone	13698	■	🟩	🟥
				JURASSIC MAIN SAND		Sand Stone & Mud Stone	13714			🟥
	TRIASSIC		MIANWALI			Sand Stone & Shale	14360			
PALEO-ZOIC	PERMIAN		PERMIAN			Limestone	14506			

Figure 3.1: Stratigraphic column of Potwar (Hasany and Saleem, 2001).

3.1 PETROLEUM GEOLOGY

The Kohat-Potwar depression has several features that makes it a favourable site for hydrocarbon accumulations. Located on a continental margin, the depression is filled with thick deposits of sedimentary rocks, including potential source reservoir and cap rock. 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 (Khanetal., 1986).

The sedimentary rocks are deformed during thin-skinned Himalayan tectonics, forming the structural traps for hydrocarbons. The SRPFB is structurally favourable site for hydrocarbon accumulation (Coward &Buttler, 1985).

Simple and translated fault-propagation folds form important structural traps in fold and thrust belts. The most important traps in fault propagation folds are in the crests of major anticlines.

These fault traps may be present along back limb thrusts, between imbricates in the forelimbs and in upturned beds in the footwall. Secondary traps may also be present within major thrust sheets, particularly at the leading edge of the thrust sheet and above footwall ramps (Gee, 1934).

3.2 HYDROCARBON POTENTIAL

The SRPFB belongs to the category of extra continental down warp basins, this account for 48% of the world known petroleum. It has several features suitable for hydrocarbon accumulation including continental margin, thick marine sedimentary sequence, potential source and reservoir and cap rocks. The thick overburden of 3047 m of molasses provides burial depth and optimum geothermal gradient for oil formation. The SRPFB with an average geothermal gradient of 2°C/100 m is producing oil from the depth of 2750-5200 m. The presence of an optimal combination of source, reservoir and trap within the oil window resulted oil and gas accumulation in JoyaMair, Toot, Meyal and Dhulianoilfields (Shami and Baig, 2003).

3.2.1 RESERVOIR ROCKS

The Cambrian, Permian, Jurassic, Paleocene and Eocene reservoirs are producing oil in SRPFB. The fractured carbonates of the Sakesar and Chorgali Formations are the major oil producing reservoirs in JoyaMair area. In Meyal, Chorgali and Datta Formations are major oil producing reservoirs. The Sakesar limestone is light yellow gray, massive and partly dolomitized and locally contains chert concretions. The Chorgali Formation is creamy yellow to yellow gray, silty, partly dolomitic and thin bedded limestone. The Datta Formation is dominantly sandstone (Sajjad et al., 2005).

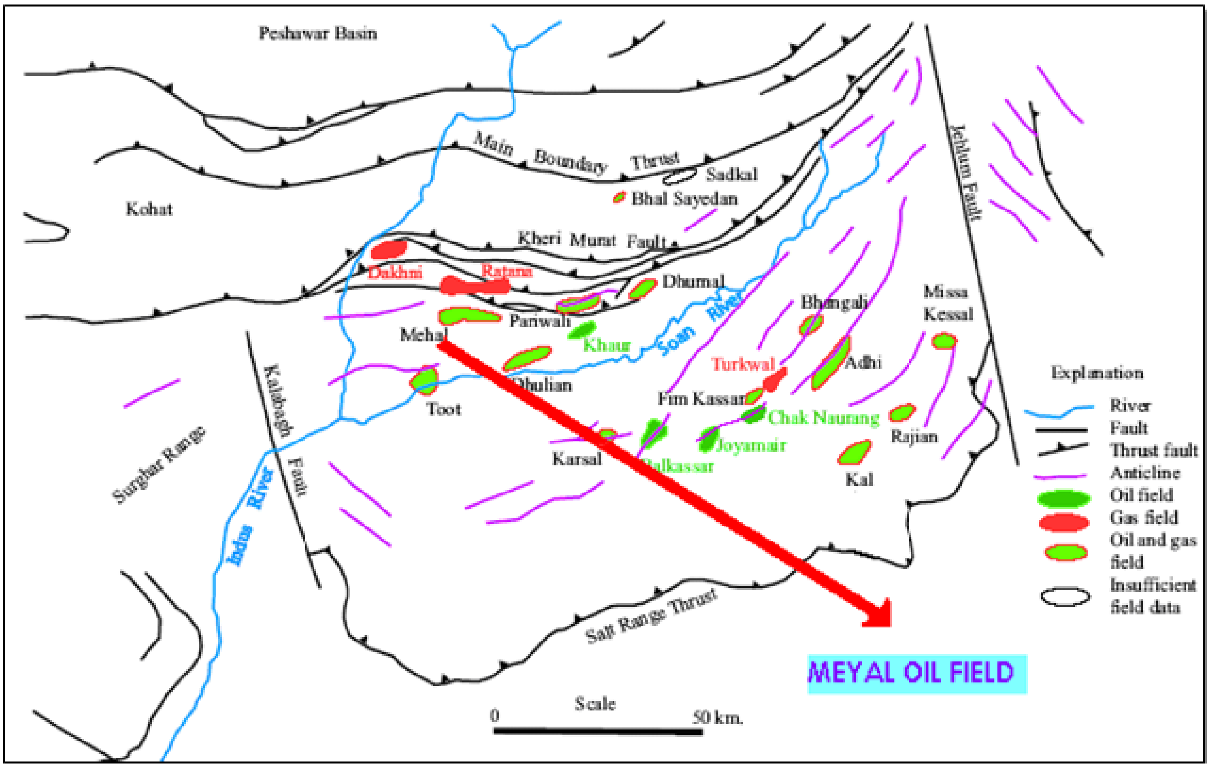


Figure 3.2: Shows the oil gas field of PotwarPaleatu (Shah et al., 2004)

Core analysis from Meyal, Dhulian and Balkassar oilfields shows that the primary porosity is less than 1% in the Chorgali and Sakesarlimestones. The fracture porosity is relatively higher in wells of northwestern Potwar because the rocks deformed several times during the Himalayan orogeny. The fracture sets trend eastwest, northeast-southwest and northwest-southeast. The fractures develop parallel, oblique and perpendicular to the fold axes of anticlines (Shami and Baig, 2003).

3.2.2 SOURCE ROCKS

The gray shales of the Mianwali, Datta and Patala Formations are potential source rocks in SRPFB. The oil shales of the Eocambrian Salt Range Formation include 27% to 36% total organic content (TOC) in isolated pockets of shales, and are considered as the source rock in SRPFB (Shami and Baig, 2003).

3.2.3 CAP ROCKS

The Kuldana Formation acts as cap for the reservoirs of Chorgali and Sakesarlimestones in SRPFB. The clays and shales of the Murree Formation also provide efficient vertical and lateral seal to Eocene reservoirs in SRPFB where ever it is in contact. The following Oil & Gas field is present in Upper Indus Basin that accounts for large supply of energy in Pakistan.

Age	Formations	Lithology	Oil&Gas Field	Production
Eocene/Paleocene	Lockhart/ Sakesar/ Chorgali	Limestone& Shale	Dhurnal, Balkassar& Meyal	Oil
Jurassic	Data & Samana Suk	Sandstone & Limestone	Dhulian, Toot & Meyal	Oil
Permian	TobraNilawahan & Zaulch Group	Conglomerate& Limestone	Adhi& Dhurnal	Oil
Cambrian	Khewra- Sandstone	Sandstone	Adhi& MissaKeswal	Gas

Figure 3.3: Hydrocarbon significance of different rock units in the study area (modified after Kadri, 1995)

Some major structural traps are Horst and Graben structures, Pop-up structures, Anticlines, faults, etc. while stratigraphic traps are pinch out structures, truncated type and the main trap making element in stratigraphic trap is some variation in lithology or stratigraphy.

CHAPTER 4:
SEISMIC INTERPRETATION OF MEYAL AREA

4 INTRODUCTION

4.1 SEISMIC DATA INTERPRETATION

Interpretation is a technique or tool by which we try to transform the whole seismic information into structural or stratigraphical model of the earth. Since the seismic section is the representative of the geological model of the earth, by interpretation, we try to locate the zone of final anomaly. The test of good interpretation is consistency than correctness. Not only a good interpretation be consistent with all the seismic data, it also important to know all about the area, including gravity and magnetic data, well information, surface geology as well as geologic and physical concept (Sheriff, 1999).

The Seismic data interpretation is the method of determining information about the subsurface of earth from seismic data. It may determine general information about an area, locate prospects for drilling exploratory wells or guide development of an already discovered field (Coffeen, 1986). According to Badley (1985), such reflections and unconformities are to be mapped on seismic section, which fully describe the geology and hydrocarbon potential of the area. If the horizon of interest is not prominent and it is difficult in tracing it over the whole area, it is advisable to pick additional horizons above and/or below the target horizon. This helps in understanding the trend and behavior of the target horizon in the zones where its quality is not good enough to be picked with confidence. Final objective of interpretation is conversion of seismic section into a geological section which provides a somewhat realistic subsurface picture of that area, both structurally as well as stratigraphically (Badley, 1985).

An interpreter of seismic data may have good hold in both geology and geophysics. It is the ingenuity and in-depth understanding of an interpreter to extract geologic significance from aggregate of many minor observations. For example, down dip thinning of the reflection might be result from normal increase velocity with depth or thinning of the sediments or flow of the shale or salt may develop illusory structure in the deeper horizon (Sheriff, 1999).

Main purpose of the reflection is to reveal as clear as possible the structure and stratigraphy of the subsurface. Geologic meaning of the reflection is the indication of the boundaries where there is change in the acoustic impedance; to distinguish the different horizons with the seismic data we correlate the well information with the seismic data. Structure and estimate of the depositional environment, seismic velocity, seismic stratigraphy and the lithology is identified by using the best available seismic data (Dobrin&Savit, 1988).

There are two main approaches for the interpretations of a seismic section are:

- Stratigraphical Analysis
- Structural Analysis

4.1.1 STRATIGRAPHICAL ANALYSIS

Stratigraphy 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 the both stratigraphy change and hydrocarbon depositional environment . The amplitude, velocity, frequency or the change in wave shape indicates hydrocarbon accumulation. Unconformities are marked by drainage pattern that help to develop the depositional environment. Reef, lenses, unconformity are example of stratigraphy traps (Sheriff, 1999).

4.1.2 STRUCTURAL ANALYSIS

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's, 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 (Sheriff, 1999).

Seismic section can predict the structure that scale up to few tens of kilometers. A fault with throw less than ¼ of the wavelength of seismic wave will difficult to pick in the seismic section (Badley, 1985). The study area lies in intense compressional regime, so general structure are thrusts related Pop-up structures. A thrust fault develops under high pressure system and to develop, it required high pressure under the thrust plane.

Over all several faults are marked on the seismic section which indicates the complexity of study area. These are marked on observing the sudden change in the position of the reflectors and distortion or disappearance of the reflection below the faults. All the faults are not basement rooted that gives some indication of thin skin tectonic involvement in the study area but the normal faulting is present in basement (Badley, 1985).

4.2 MARKING OF SEISMIC HORIZONS

Primary task of interpretation is the identification of various horizons as an interface between geological formations. For this purpose, good structural as well as stratigraphic knowledge of the area is required.(McQuillin et al., 1984). Thus during interpretation process, I mark both, the horizons and faults on the seismic section Three horizons are picked on the basis of available information. The horizons are named on basis of well tops of the well Meyal-01, Meyal-17, Meyal-09, Meyal-10 and Meyal-16.

The interpreted seismic section of the line 97-MYL-05 is shown in figure 4.1. Total three seismic horizons namely, Chorgali, Sakesar and Nammal of Eocene age are marked. Along these seismic horizons, faults are also marked as shown in figure 4.1. This seismic section shows a pop-up structure bounded by thrust faulting. These pop-up structures may be suitable place for the accumulation of the hydrocabons. Thurst faulting and pop-up structure show that the study area is dominated by compressional forces.

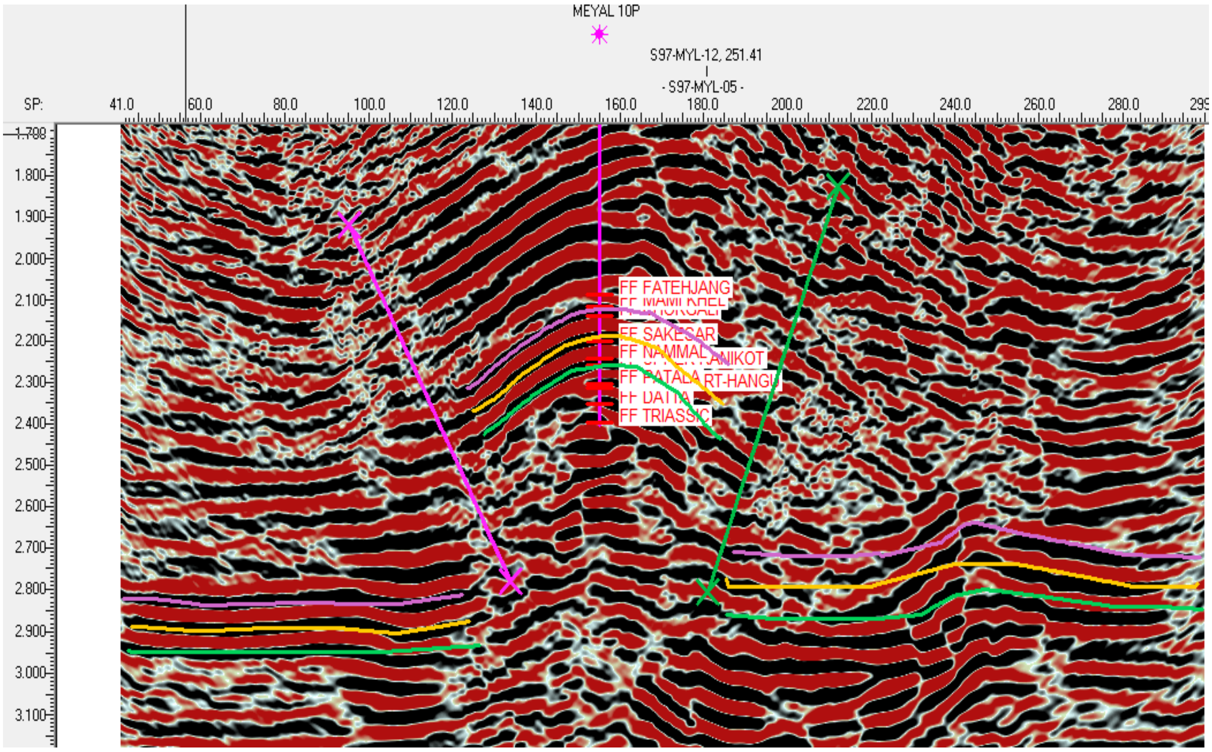


Figure 4.1: Interpreted seismic section of line 97-MYL-05 showing horizons and faults.

The interpreted seismic section of the line 97-MYL-08is shown in figure 4.2. Total three seismic horizons namely, Chorgali(Purple), Sakesar(Yellow) and Nammal(Green) of Eocene age are marked. Along these seismic horizons,faults are also picked as shown in Figure 4.2. This seismic section shows a pop-up structure bounded by thrust faulting. These pop-up structures may be suitable place for the accumulation of the hydrocarbons. Thrust faulting and pop-up structures show that the study area is dominated by compressional forces.

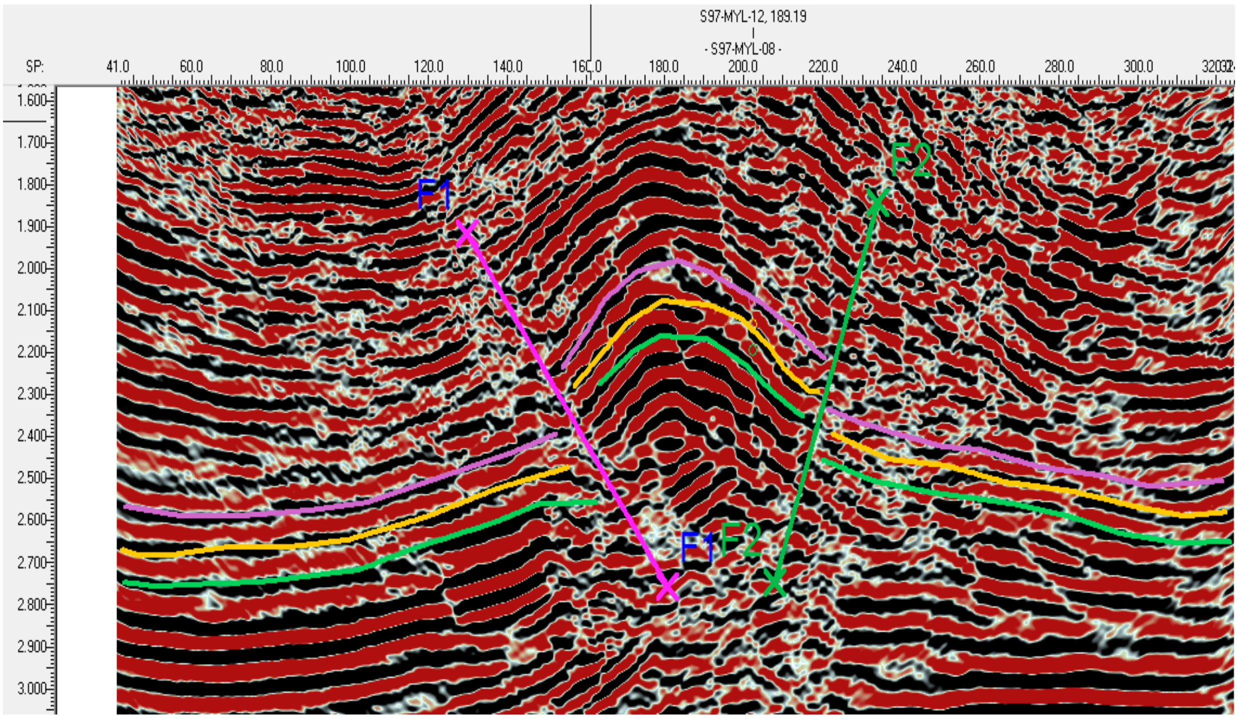


Figure 4.2: Interpreted seismic section of line 97-MYL-08 showing horizons and faults.

The interpreted seismic section of the line 97-MYL-12 is shown in figure 4.3. Total three seismic horizons namely, Chorgali, Sakesar and Nammal(purple, yellow and green respectively) of Eocene age are marked. This seismic section shows a gentle anticlinal fold. It is a strike line so faults are not clearly shown on this line.

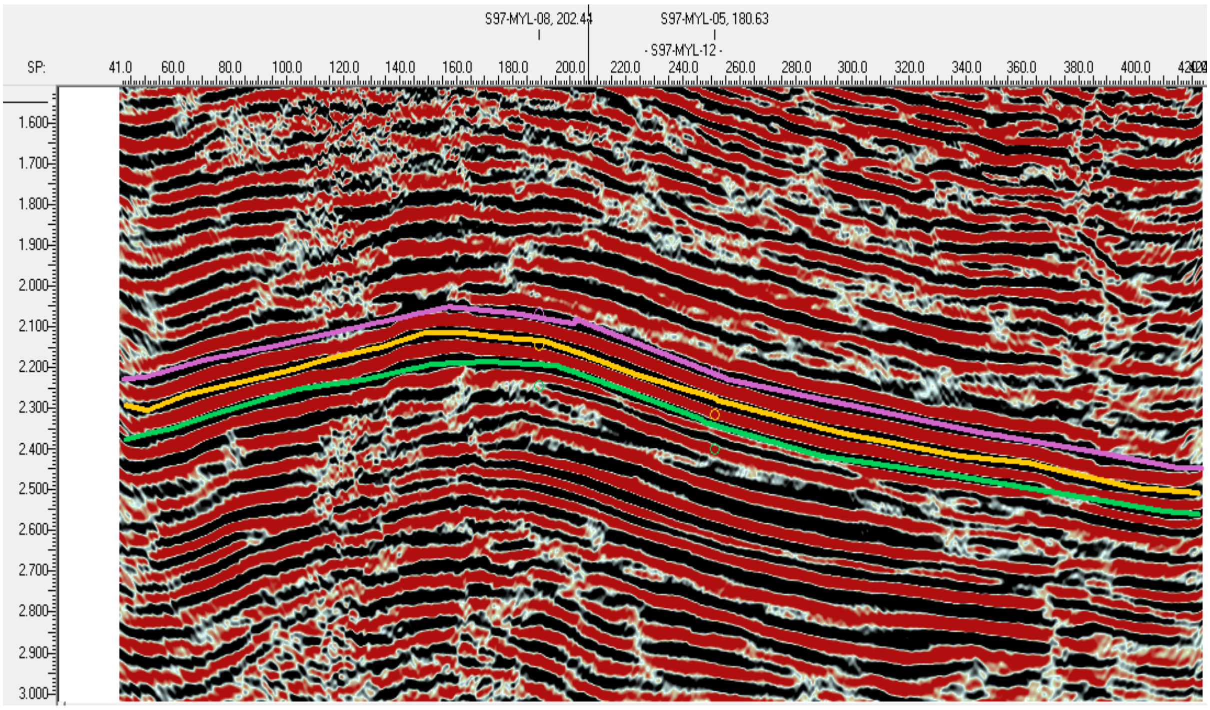


Figure 4.3: Interpreted seismic section of line 97-MYL-12 showing horizons

4.3 FAULT POLYGONS GENERATION

A fault polygon represents the lateral extent of dip faults or strike faults having same trend. Fault polygons show the sub-surface discontinuities by displacing the contours. To generate fault polygons it is necessary to identify the faults and their lateral extent by looking at the available seismic data. If one finds that the same fault is present on all the dip lines, then all points on base map can be manually joined to make a polygon. After construction of fault polygons, the high and low areas on a particular horizon become obvious. Moreover, the associated color bar helps in giving information about the dip directions on a fault polygon if dip symbols are not drawn. Fault polygons are constructed for all marked horizons and these are oriented in E-W direction. Figure 4.4 shows polygon of Chorgali formation. At Chorgali level twofault polygons are generated.

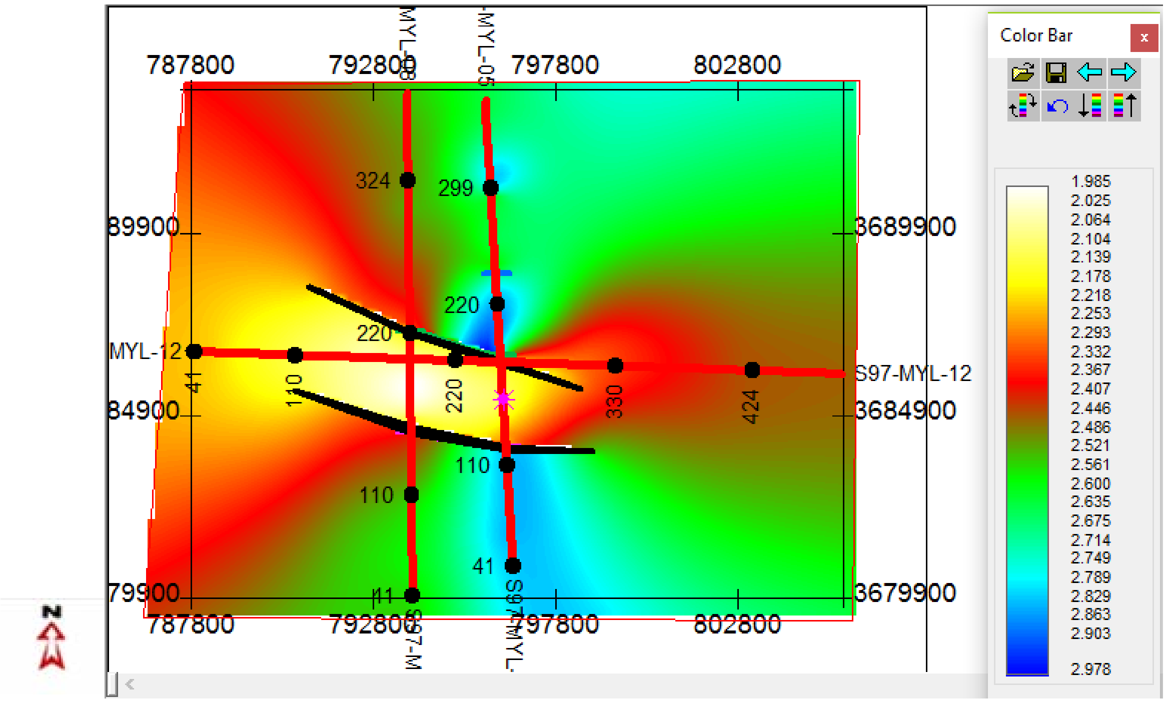


Figure 4.4: Fault polygons constructed at Chorgali level.

4.4 CONTOUR MAPS

The result of seismic interpretation is 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 spacing of the contour lines is a measure of the steepness of the slope; the closer the spacing the steeper the slope. A subsurface structural map shows relief on a subsurface horizon with contour lines that represent equal depth below a reference datum or two way time from the surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip and any faulting and folding. The interpreted seismic data is contoured for producing seismic maps which provide a three-dimensional picture of the various layers within an area which is circumscribed by intersecting shooting lines. The picked times for each reflector are exported along with the navigation data in the form of an XYZ file to be used for contouring. The Kingdom software is used to generate the contour maps.

4.5 TIME AND DEPTH CONTOUR MAPS OF CHORGALI FORMATION

Chorgali formation is one of the main reservoir formations in Meyal area. This formation has both Oil & Gas content and is mainly composed of limestone with some shaly content. Chorgali time & depth contours maps shown in figure 4.5 and figure 4.6 plotted on the seismic base map along with well locations and fault polygons. Fault polygons make pop-up structures which are suitable for hydrocarbon accumulation. Contour interval in time & depth contour maps is set as 30 milliseconds and 50 meters respectively.

Two way time contour map of Chorgali formation is shown in figure 4.5. Time variation is mentioned through the color bar from (1.985 to 2.987 sec). Dark red colored portion (1.949 to 2.092 sec) is showing the shallowest part while blue colored portion (2.749 to 2.238 sec) is showing deeper part of the formation.Yellowcolor from (1.985 to 2.218 sec) is showing highest (peak) point and it is the most favorable area for hydrocarbon extraction. The pop-up structures are bounded by two major faults.

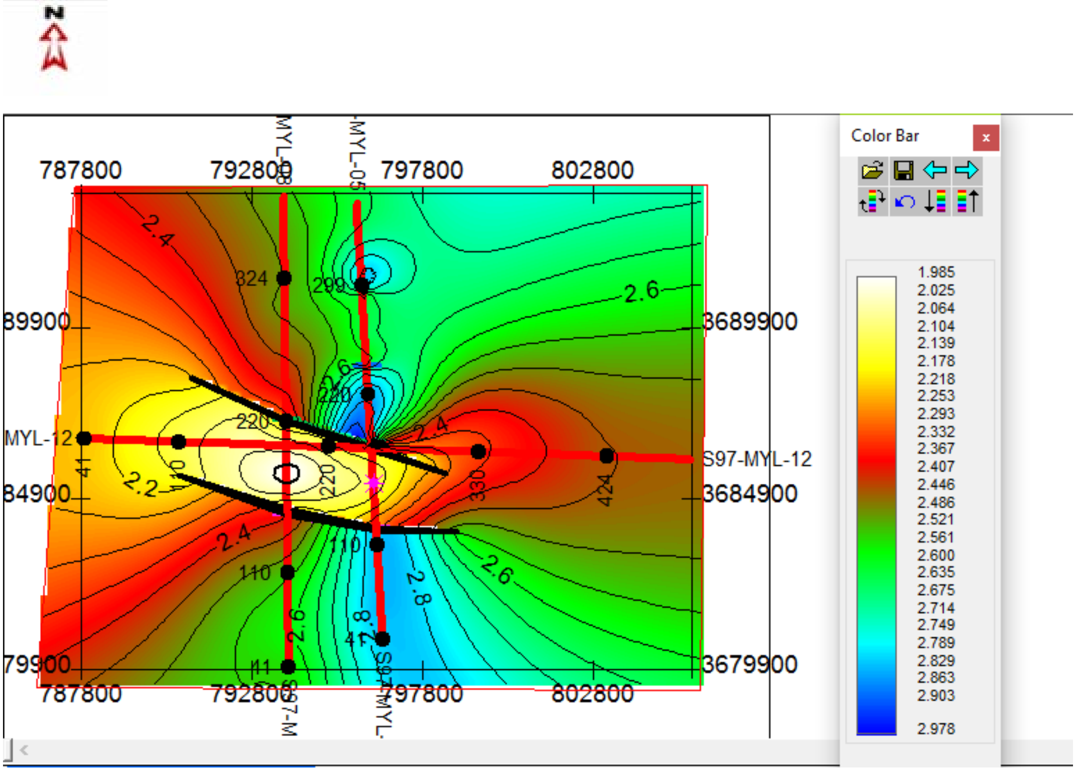


Figure 4.5: Time Contour map of Chorgali formation at Eocene level.

Depth contour map of Chorgali formation is shown in figure 4.6 Depth variation is shown by the color bar from top 3204 m to bottom 4806 m. Dark red colored portion (3390 to 3640 m) is showing the shallowest part while blue color (5384 to 5634 m) is showing deepest part of the formation. Dark red color from (3204 to 4806 m) is showing highest point. This highest point is the pop up structure and it is the most favorable area for hydrocarbon extraction from Chorgali formation.

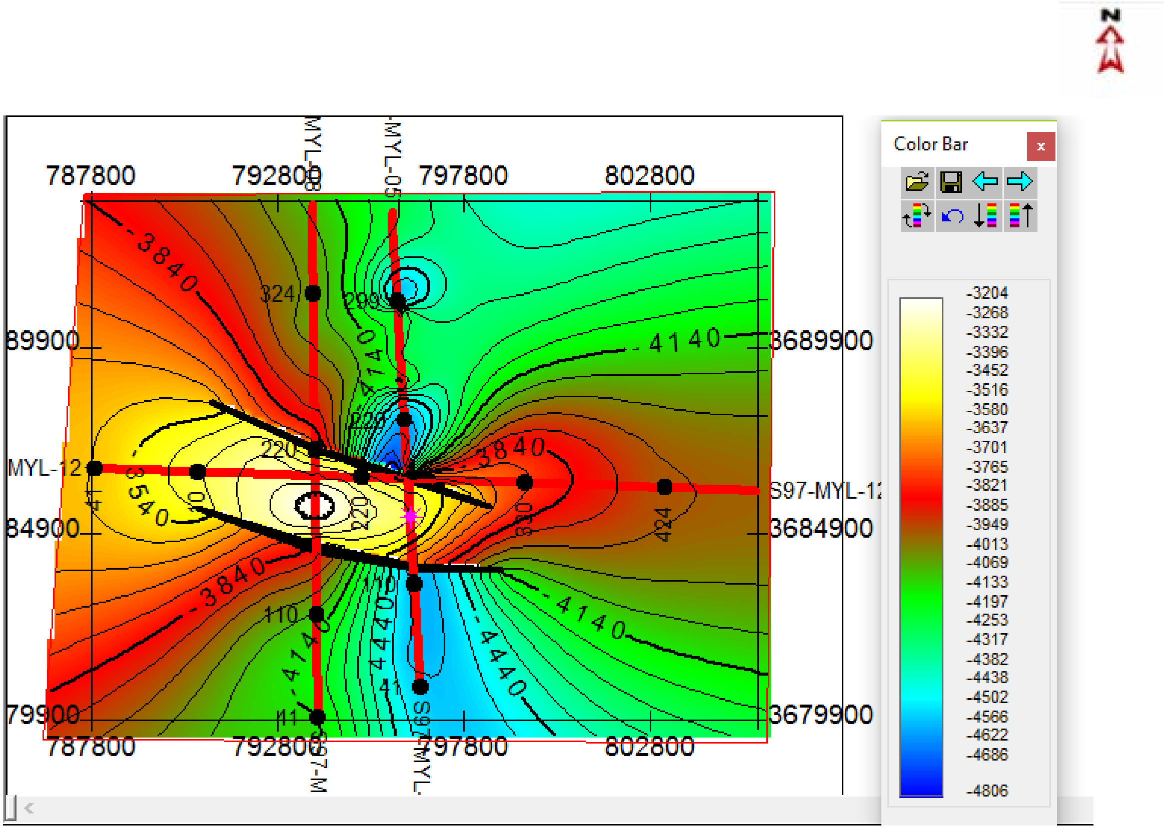


Figure 4.6: Depth Contour map of Chorgali formation at Eocene level.

4.6 TIME AND DEPTH CONTOUR MAPS OF SAKESAR FORMATION

Sakesar formation is also one of the main reservoir formations second in Meyal area. Time & depth contours maps of Sakesar formation are shown in figure 4.7and figure 4.8. Sakesar formation lies below Chorgali formation in all seismic sections. Fault polygons of Sakesar formation are similar to Chorgali formation which indicates the presence of same faults on both formations. Contour interval in time & depth contour maps is 30 milliseconds and 50 meters respectively.

Time contour map of Sakesar formation is shown in figure 4.7. Time variation is shown through the color bar from (2.076 to 3.066 sec). Yellow colored portion from (2.076 to 2.308 sec) shows the shallowest part while blue colored portion from (2.878 to 3.066 sec) shows deepest part of formation. The shallowest point known as pop up structure and it is the most favorable area for hydrocarbon extraction from Sakesar formation.

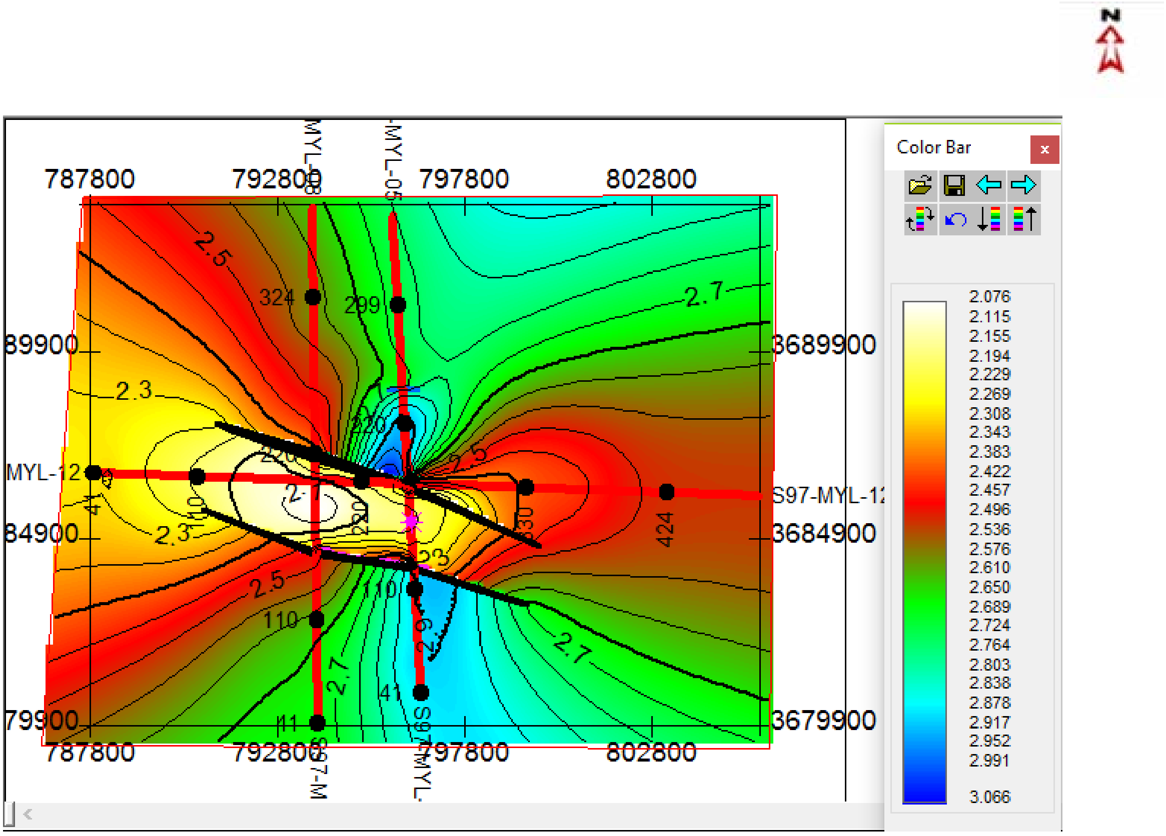


Figure 4.7: Time Contour map of Sakesar formation at Eocene level

Depth contour map of Sakesar formation is shown in figure 4.8. Depth variation is shown through the color bar from top 3314 m to bottom 4895 m. Yellow colored portion from (3314 to 3695 m) shows the shallowest part while blue colored portion from (4657 to 4895 m) shows deepest part of the Sakesar formation. Yellowshows highest point known as pop up structure. These pop up structures are the most favorable traps for hydrocarbon extraction from Sakesar formation.

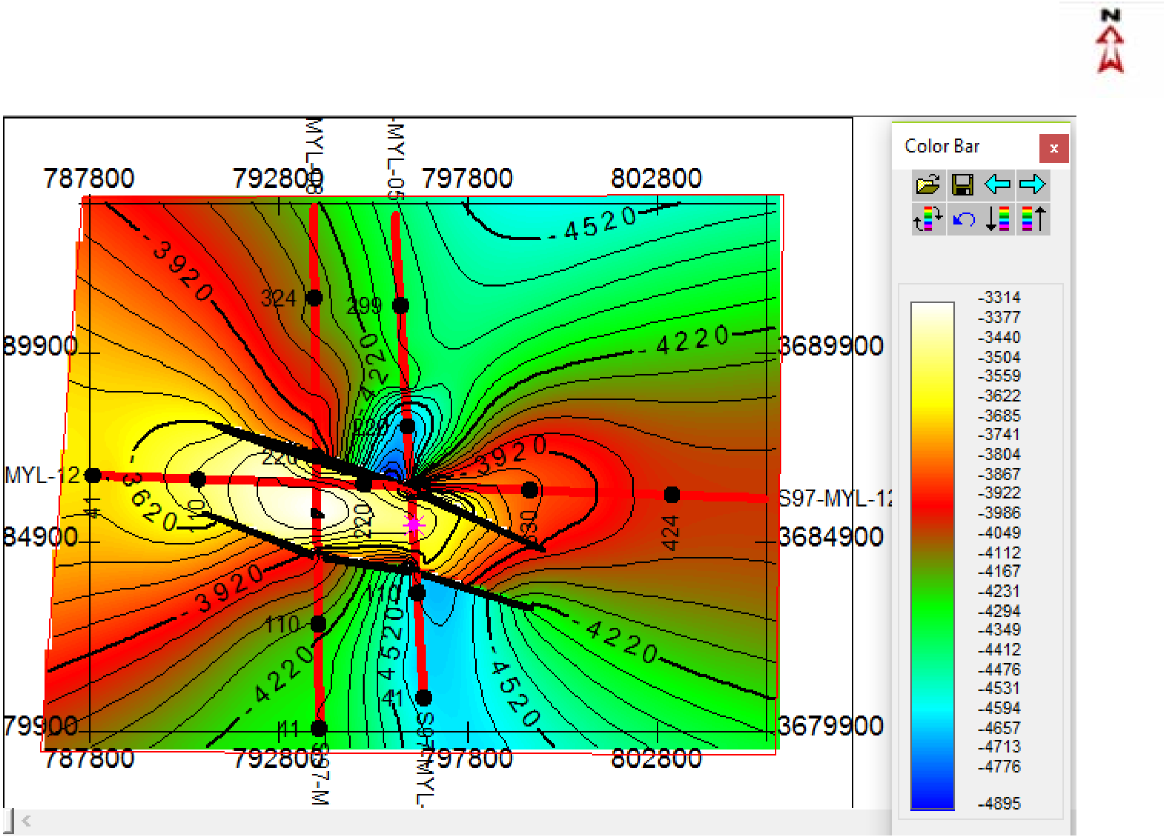


Figure 4.8: Depth Contour map of Sakesar formation at Eocene level.

CHAPTER 5
SEISMIC ATTRIBUTES AND 1 D FORWARD MODELLING

5 SEISMIC ATTRIBUTES

A Seismic attribute can be defined as, anything or any information which can be obtained from seismic data is called as seismic attribute. It can be obtained either by direct measurements or by logical or experience based reasoning. Seismic attributes have come a long way since their introduction in the early 1970's and have become an integral part of seismic interpretation projects. Today, they are being used widely for lithological and petrophysical prediction of reservoirs. Various methodologies have been developed for their application to broader hydrocarbon exploration and development decision making (Chopra and Marfurt, 2006).

5.1 TYPES OF SEISMIC ATTRIBUTES

The default attribute of Seismic data is Amplitude. From the early days of seismic prospecting, Geoscientists used to draw conclusions about subsurface geology and drilling locations primarily from this single seismic data attribute. Attribute computations decompose seismic data into constituent attributes. There are no rules governing how attributes are computed. Any quantity calculated from seismic data can be considered an attribute. Seismic Attributes can be classified in a number of ways as discussed below.

a. Seismic Data Domain based Classification
  I. Pre-Stack Attributes
  II. Post-Stack Attributes

b. Computational Characteristics based Classification
  I. Instantaneous Attributes Interval / Window Attributes Trace to Trace Attributes

c. Information Characteristics based Classification
  I. Time-derived attributes
  II. Amplitude-derived attributes
  III. Frequency-derived attributes

5.1.1 ENVELOPE OF TRACE (REFLECTION STRENGTH / INSTANTANEOUS AMPLITUDE)

Envelop of a trace, also called as reflection strength, represents the total instantaneous energy of the complex trace which is independent of the phase and is computed as the modulus of the complex trace. The Hilbert Transform of the real seismic trace is generates an imaginary trace and using both these traces the envelope trace is computed.

This attribute is computed for seismic line 97-MYL-05 shown in figure 5.1, to see the major changes in lithologies. Even negative reflection coefficients such as limestone formation overlaid on clayey formation would generate a positive response in this attribute. A thick (yellow) package indicates the maximum reflection strength corresponding to the source, reservoir and seal rocks. It also shows spatial patterns representing changes in the limestone thickness and breakage due to the faults.

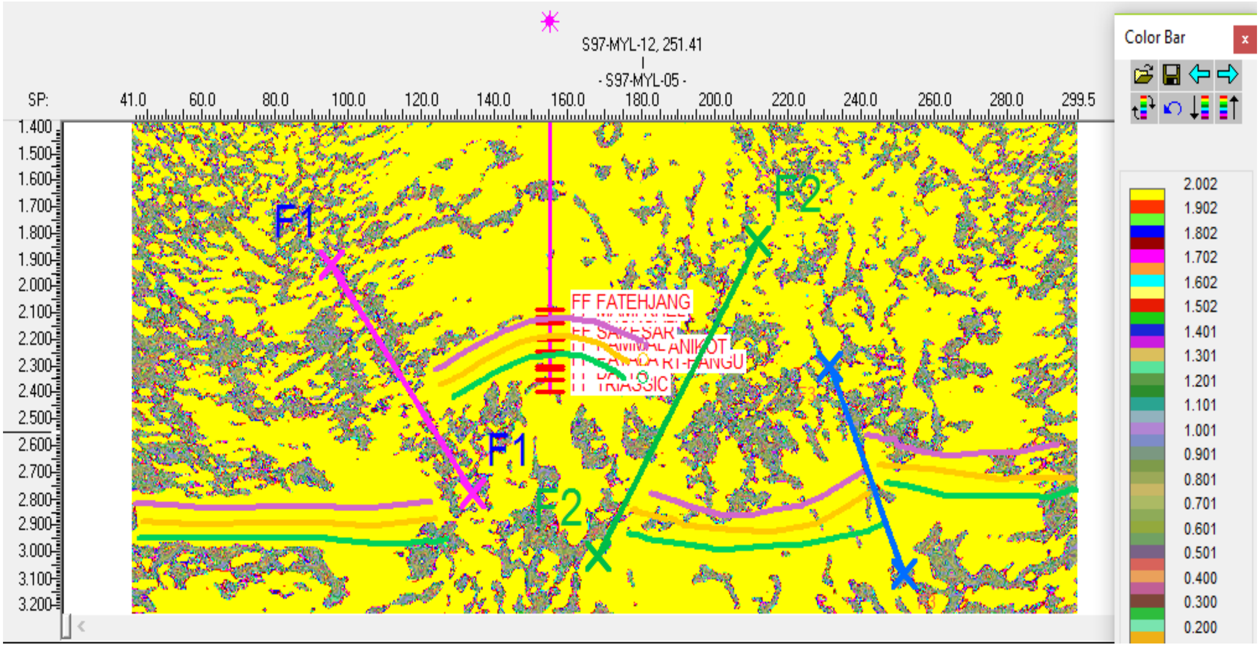


Figure 5.1 Envelop attribute map calculated for seismic line 97-MYL-05.

5.1.2 INSTANTANEOUS PHASE

The phase information is independent of trace amplitudes and relates to the propagation of phase of the seismic wave front. Since, most of the time, wave fronts are defined as lines of constant phase, the phase attribute is also a physical attribute and can be effectively used as a discriminator for geometrical shape classifications. It is computed from real and imaginary traces. It can be used to highlight interface in sections with high decay of amplitudes and even highlight deeper horizons which are not visible in the normal amplitude sections. It can be observed in comparison to amplitude based sections that the instantaneous phase shows much deeper horizons. Figure 5.2 shows instantaneous phase attribute for seismic line 97-MYL-05

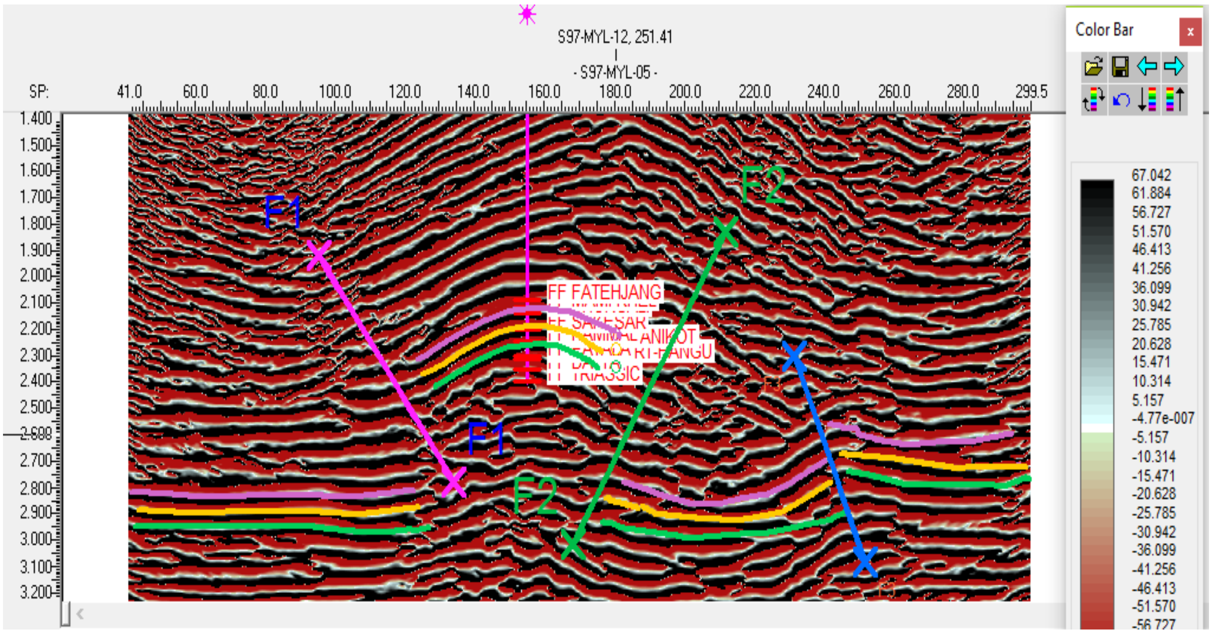


Figure5.2 Instantaneous phase attribute calculated for seismic line 97-MYL-05.

5.2 ONE DIMENSIONAL FORWARD SEISMIC MODELLING

An artificial seismic reflection record, prepared from velocity log data and density log data by

convolving the reflectivity function derived from digitized acoustic and density logs with the wavelet derived from seismic data is called as “Synthetic Seismogram”. Synthetic seismogram is an artificial model of the Earth that is used to mark the different geological horizon on the seismic section. It is direct one-dimensional model of acoustic energy traveling through different layers of Earth. The synthetic seismogram can be of great value to the interpreter and it is best presented by splicing it to an interpreted seismic section through the well location. Synthetic seismogram of Meyal-01 well are generated. In this procedure the petrophysical logs; Sonic (DT) and Bulk Density (RHOB), which provide the velocity and density information of subsurface layers respectively, are used. The DT is a delay time log and its inverse gives the velocity. These logs are acquired in the borehole. We use this velocity and density data to compute a series of reflection coefficients called reflectivity series. Then a source Ricker wavelet with a dominant frequency of 35 Hz is generated. The reflectivity series is convolved with the source wavelet to get a synthetic seismogram. In this case we have performed the convolution with only one reflectivity series (1D), thus only one seismic trace is generated. Graphically we plot multiple copies to display it in the form of a stack section. The synthetic seismogram vertical units are meters or feet and it can be converted into time units by using its own velocity information. Synthetic seismogram is matched with the seismic section at the well point to correlate the succession of reflectors. It may also be used to calibrate our seismic velocities.

Synthetic seismogram= Reflection coefficient * Source Wavelet

The parameters used for the generation of synthetic seismogram are given below:

- Type of wavelet: Ricker
- Frequency: 90 Hz
- Sampling Rate: 2 Milliseconds
- Phase: Zero Phases
- Number of traces: 40

One dimensional forward seismic model of Meyal-01 well is shown in figure 5.4. Meyal-01 well has eight formations encountered during drilling. These are also confirmed by one dimensional forward seismic model as shown in figure 5.4. For correlation calliper and gamma ray logs are used. Black wiggles represent the stratigraphic reflectors. Chorgali and Sakessar formations have also strong reflection in this well.

Sonic log and density log were used to find out acoustic impedance. From acoustic impedance reflection coefficient series was determined. This reflection coefficient series then convolved with theoretically calculated wavelet known as “Ricker Wavelet”. After convolving reflection coefficient series with Ricker wavelet one dimensional forward seismic model of Meyal-01 well was obtained.

Figure 5.3: Synthetic seismogram of Meyall-01 well.

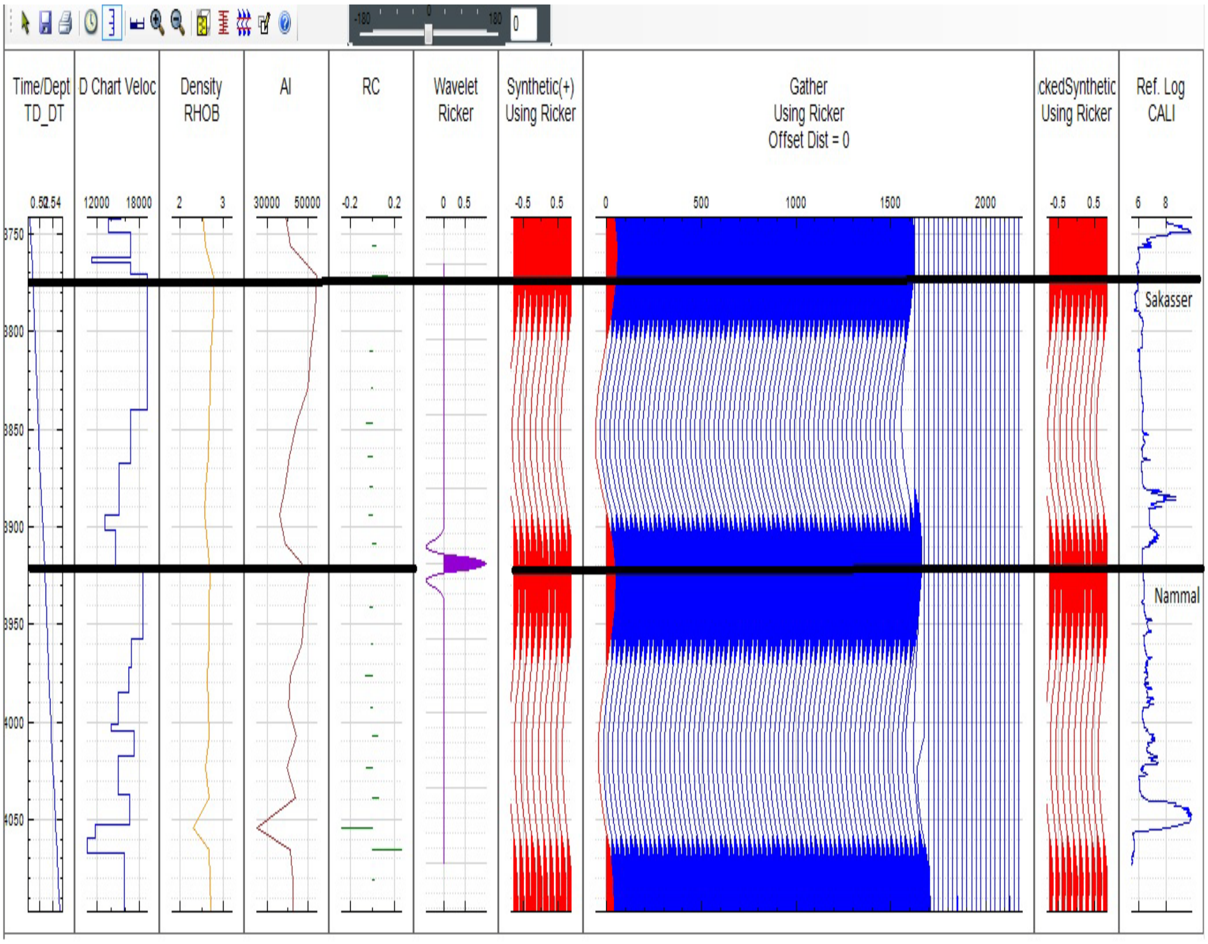


Figure 5.4: One dimensional forward seismic model of Meyal-01

CHAPTER 6
PETROPHYSICAL ANALYSIS

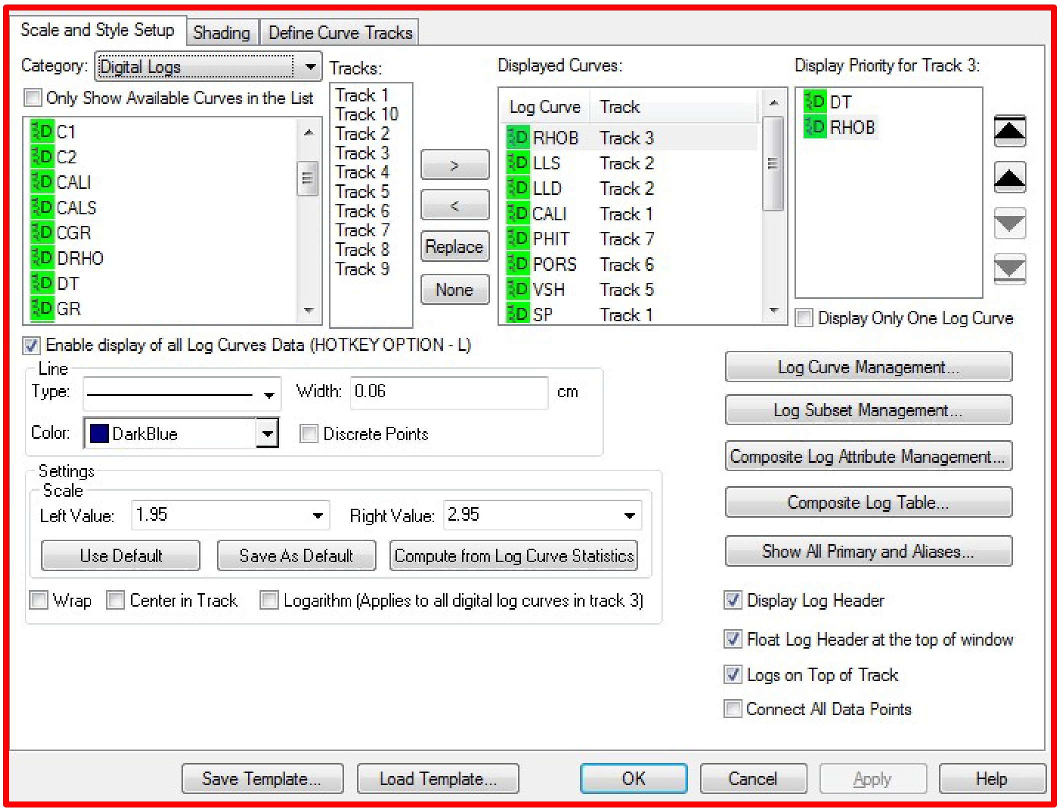
6. INTRODUCTION

Petrophysics is one technique used for the reservoir characterization. This study facilitates in identification and quantification of fluid in a reservoir (Aamir et al., 2014). Knowledge of reservoir physical properties like volume of shale, porosity, and water and hydrocarbon saturation is needed to define accurately probable zones of hydrocarbons. The integration of petrophysics along with the rock physics enables the geologists and geophysicists to understand the risks and opportunities in the area. Petrophysics is apprehensive with using well measurements to subsidize reservoir depiction (Daniel, 2003). Petrophysics uses all kinds of logs, core data and production data and integrates all relevant information. Thus purpose of petrophysics is to obtain physical properties such as volume of shale, porosity, water saturation and permeability, which are related to production parameters. Petrophysics is more concerned with using well bore measurements to contribute to reservoir description (Asquith et al., 2004).

6.1 DATA SET

Data set The pertophysical analysis has been carried out for reservoir characterization of Meyal area. For this purpose the data of the drilled boreholes, Myl-9P . The log curves of these boreholes are used i.e. Gamma ray (GR), Sonic log (DT), Latero log deep (LLD),), Latero log shallow (LLS), Neutron log, Density log (RHOB), and Photoelectric effect (PEF) etc. For pertophysical analysis in Fig (6.2) the following parameters are determined on the basis of these log curves.

The integration of petrophysics along with the rock physics enables the geologists and geophysicists to understand the risks and opportunities in the area. Petrophysics is apprehensive with using well measurements to subsidize reservoir depiction (Daniel, 2003).



Category: Digital Logs

☐ Only Show Available Curves in the List

C1
C2
CALI
CALS
CGR
DRHO
DT
GR

Tracks:
Track 1
Track 10
Track 2
Track 3
Track 4
Track 5
Track 6
Track 7
Track 8
Track 9

Displayed Curves:

Log Curve	Track
RHOB	Track 3
LLS	Track 2
LLD	Track 2
CALI	Track 1
PHIT	Track 7
PORS	Track 6
VSH	Track 5
SP	Track 1

Display Priority for Track 3:
DT
RHOB

☐ Display Only One Log Curve

☑ Enable display of all Log Curves Data (HOTKEY OPTION - L)

Line
Type:
Width: 0.06 cm
Color: DarkBlue
☐ Discrete Points

Settings
Scale
Left Value: 1.95
Right Value: 2.95

☐ Wrap ☐ Center in Track ☐ Logarithm (Applies to all digital log curves in track 3)

☑ Display Log Header
☑ Float Log Header at the top of window
☑ Logs on Top of Track
☐ Connect All Data Points

Fig 6-1 Represent types of log curves by using Kingdom software

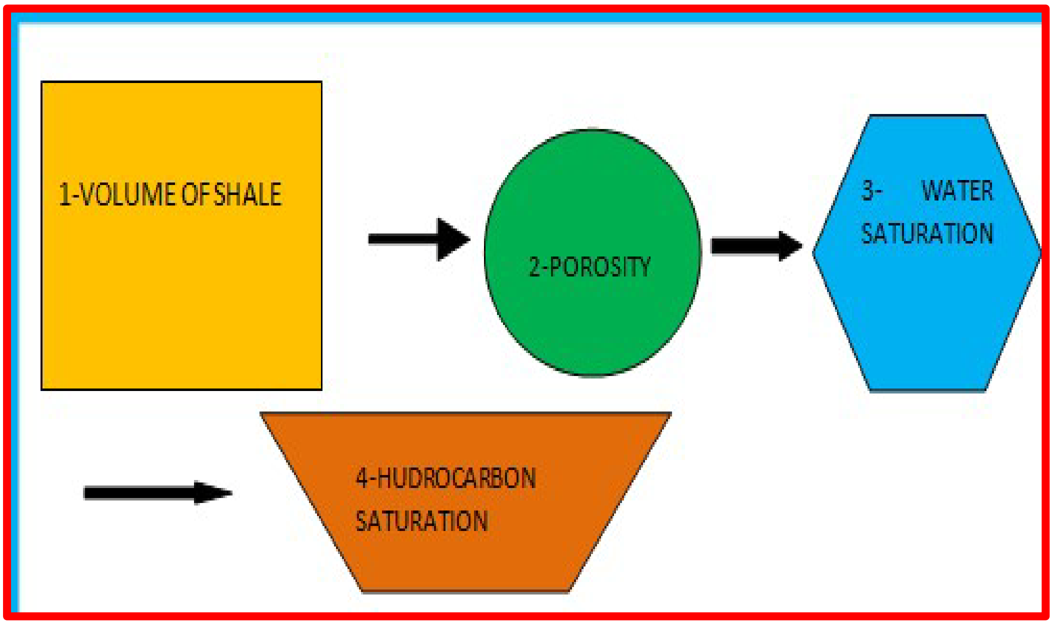


Fig 6-2 Petrophysical parameters on the basis of log curves

6.2WORK FLOW CHART FOR PETROPHYSICAL INTERPRETATION OF MYL-9P

Petrophysical interpretation is carried out by making use of SMT Kingdom software. Raw log curve are loaded and step by step different rock properties are calculated. Number of mathematical equations and Schlumberger charts has been involved in calculations. Workflow is illustrated inFig (6-3). Raw log curves have been used for the petrophysical analysis of Myl15P having reservoir in Chrogali and Sakesar of Eocene age. In study area, A and B interval is most productive. Top and bottom depth of A interval represent the depth Chorgali Formation having more interest zone for hydrocarbon is defined for petrophysical analysis. Also the zones of importance are defined within the reservoir for more specific interpretation of reservoir.

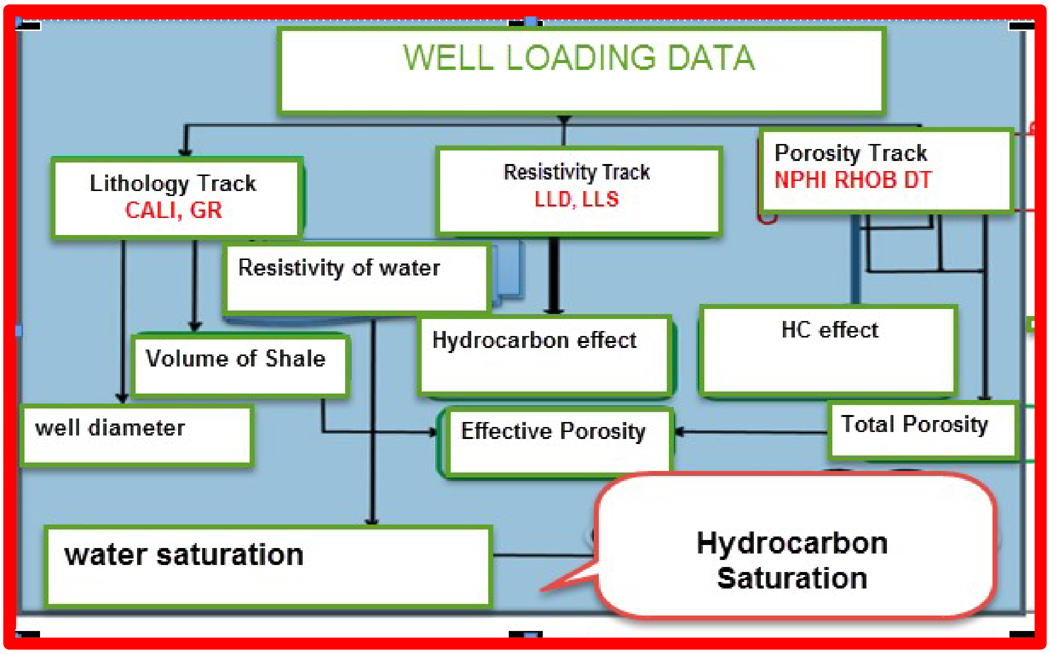


Fig 6-3 Petro physical interpretation

6.3CLASSIFICATION 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.

6.3.1LITHOLOGY TRACK

In lithologies track the following two logs are displayed which are explained as follow.

- Gamma ray (GR)

- Spontaneous Potential log (SP)

6.3.2 GAMMA RAY (GR)

This log is actually a measurement of the natural radioactivity of the formation. Gamma radiations are emitted in the form of electromagnetic energy called photon. When photon collides with electrons, some energy is transferred to electron called Compton scattering. These scattered radiations reached the detector and are counted after absorption of gamma rays from natural radioactive source present within the layer. These emissions are counted and displayed as count per second which is termed as gamma ray log. This log is very important and used for various purpose for lithology indicator.

6.3.3CALIPER LOG (CALI)

Caliper log use to measure the borehole size. This log give us help to identify the cavity washouts and break outs. Hence this log is also called the quality check for other logs. Because if any where there is say wash out then in front of the wash out the porosity and resistivity log will not give the correct reading. Hence caliper log is very important in pertophysical logs. (Asquith and Gibson, 2004).

6.4POROSITY LOG TRACK

Porosity logs measure the percentage of pore volume in a bulk volume of rock. These logs are also helpful to provide data to distinguish between oil and gas and, in combination with resistivity measurements, calculate water saturation.

6.4.1POROSITY LOG INCLUDE

- Density log (RHOB)
- Neutron log (NPHI)

6.4.2DENSITY LOG

Gamma rays collide with electrons in formation and scattered gamma rays (Compton scattering) received at detector and counted as indicator of formation density. An increase in counting rate causes a decrease in bulk density of formation and vice versa.

Bulk density from the density log is considered to be sum of density of fluid times its relative volume plus density of matrix time its relative volume. However, density log separately and also along with other logs used to achieve various goals (Tittman and Wahal, 1965).

6.4.3NEUTRON LOG (NPHI)

This is the porosity log which measure concentration of hydrogen ions in the formation. Neutron is continuously emitted from a chemical source in neutron logging tool. When these neutron collide with nuclei in the formation and results in loss of some energy. Hydrogen atom has same mass as that of neutron, maximum loss of energy occurs when neutron collide with hydrogen atom. Hydrogen is usually indication of presence of fluids in pores, so energy loss is related to the formation porosity.

In shale free formation (clean formation), this log measures the liquid filled porosity where the porosity is filled by water or oil. Neutron porosity will be very low when pores in the formation are filled with gas instead of oil or water. This occurs because there is less concentration of ions (hydrogen) in the gas as compared to water and oil. This decreasing of neutron porosity due to presences of gas called as gas effect (Asquith and Gibson, 2004).

6.5ELECTRICAL RESISTIVITY LOG TRACK

Basically there are different types of electrical Resistivity Logs. But in my work I have only two logs available in my data which are simply explained as follow.

These logs measure the subsurface electrical resistivity. This helps to differentiate between formations filled with salty waters and those filled with hydrocarbons. Resistivity and porosity measurements are used to calculate water saturation. Resistivity logs includes.

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

6.5.1LATEROLOG DEEP (LLD)

Later log is used for deep investigation of the undisturbed zone (Uninvaded zone) and it is called Later log 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 has deep penetration as compared to the (LLS).

6.5.2LATEROLOG SHALLOW (LLS)

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

Log Name	**Abbreviation**	**Scale**	**Unit**
Gamma Ray Log	**GR**	0------------300	**API**
Caliper Log	CALI	6-------------16	**INCHES**
Density Log	ROHB	1.95---------2.95	Gm/Cm^3
Neutron Log	NPHI	0.45---------(-0.15)	PU
Sonic Log	DT	140……..40	μ(sec)/ft
Laterolog Deep	**LLD**	1--------------1000	Ωm
Laterolog Shallow	LLS	1…………1000	Ωm

Table 6-1 Scale used for the different logs track in SMT kingdom for petrophysics (Slb.com)

6.6CALCULATION OF ROCK PROPERTIES

Many of the rock properties can be derived from geophysical well logs. I have calculated the following properties using the different equations which are given in below Table 6.2

6.7PETROPHYSICAL INTERPRETATION OF MYL-9P

Petrophysical analysis of Myal-9P is concluded on the basis of behavior of different log curves. As a first indicator of lithology, GR log is very useful as it suggests where shale may be predictable. For the higher values of GR, higher will be the percentage of shale. So due to this reason, clean zone or shale free zone is defined easily.

Properties		**Mathematical Formulas**
1	Volume of Shale	$VSH=(GR-GRCLN)/(GRSHL-GRCLN)$
2	Density porosity	$PHID=(RHOMA-RHOB)/(RHOMA-RHOF)$
3	Sonic porosity	$PORS=(DLT-DLTM)/(DLTF-DLTM)$
4	Total porosity	$PHIT=(DPHI+NPHI)/2.0$
5	Effective porosity	$PHIE=((DPHI+NPHI)/2.0)*(1-VSH)$
6	Static spontaneous potential	$SSP=SP(CLEAN)-SP(SHALE)$
8	Formation temperature	$FT=(BHT-ST)/TD)\times FD$
9	Saturation of water SH= 1-Sw	$Sw=\frac{\sqrt[n]{F\times Rw}}{\sqrt[n]{Rt}}$
10	Hydrocarbon saturation	$HC=1-SW$
11	P-wave velocity	$V_P=1/DT$
12	S-wave velocity	$Vs=Vp/1.9$
13	Poisson Ratio	$K=\rho\ (Vp^2-4/3Vs^2)$

Table 6-2 Equation used for calculating the rock properties

Where there is low value of the shale we can say that this is the zone in the reservoir where the hydrocarbon can be present, but not confirm. Basically to confirm the types and amount of hydrocarbon we go towards the integrative results of other logs that give a comprehensive report about the hydrocarbon and water present in that zone.

The principal use of resistivity logs is to detect and quantify hydrocarbon. That is, resistivity logs are used to give the volume of oil/gas in a particular reservoir, or, in petrophysical terms, to define the water saturation (Sw). When Sw is not 100%, then hydrocarbons are present there. Higher values of resistivity usually indicate the presence of hydrocarbons or fresh water. If separation between If separation between LLD and LLS is reported, that is quite possibly a hydrocarbon zone as value of LLD is much higher in case of oil or gas. Density in the study field mainly varies from 2 to 2.7 g/cm^3. Considering all the above factors, A interval is interpreted and few petrophysical properties are quantified. Which are given in the above Table (6.2).

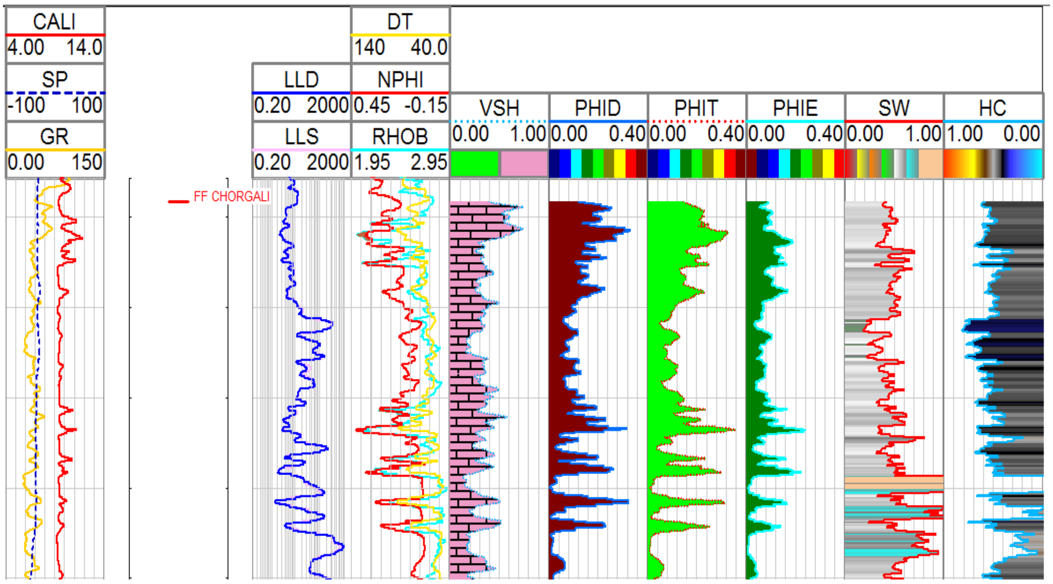


Fig 6.4 Different logs and their values of well Meyal 9p.

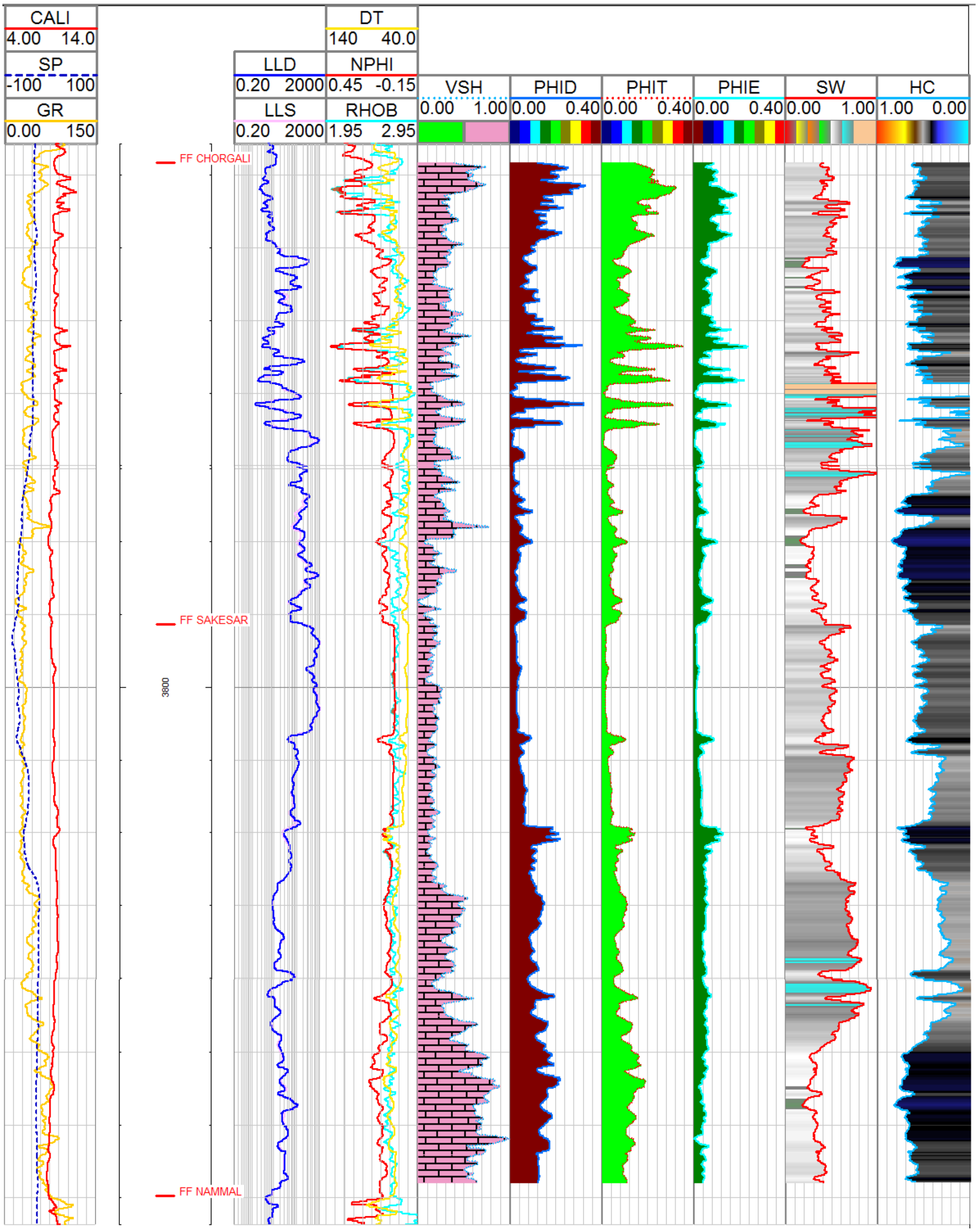
6.7.1INTERPRETAION OF ZONE A (3850-3900m)

Depth range of zone A interval varies from (3850-3900m) in well Myl-9P . It consist of alternate layers of shale and limestone. Shale volume for zone is 16% and water saturation is 48%. A prominent zone is marked through the well section in Fig (6.5), where high net pay is expected. LLD and LLS separation is observed. This zone bears relatively low values of GR, resistivity and high porosity the detail of this zone is explained below.

6.8INTERPRETATION OF ZONE OF INTEREST

Main zone of interest are marked. Depth range of Zone of interest varies from 3850-3900m at Sakesar Formation and well Myal-9P. Shale volume for whole depth range is less than 40%. Effective porosity is about at zone A is 9-12% and hydrocarbon potential of 55.%. This is only one pay zone in where high net pay is expected. This zone bear relatively low values of GR, high resistivity and high porosity. The figure of zone of interest is shown in the following page.

We can’t calculate the rock properties from single velocity value because for this purpose we need velocities at each point using semblance chart.



Zone A

Fig 6.5 Zone of Interest of the Reservoir of well 9-P

CONCLUSION

- It is concluded that by knowing the geology of the study area and the stratigraphic sequence presents in different wells confirms the marked reflector in the seismic section Chorgali and Sakesar of Eocene age, act as reservoir characteristics.
- The interpreted seismic sections show pop up anticlinal structure and thrust/reverse faulting are dominated in study area due compressional tectonic forces.
- Structures are confirmed in time to depth conversion gives the true subsurface image.
- Time and depth contour map show the presences of anticlinal structure are indicated by the seismic section of the study area. These structures are further confirmed by the 3D Visulation in time .
- These anticlinal structures are the common structural trap in the study area and are more favorable zone for the hydrocarbon accumulation.
- Seismic attributes analysis also helps in identifying the lithologies.
- Petrophysical interpretation of MYL-9P, In which Chorgali and Sakesar formation confirm the reservoir zones and they are the most favorable areas for hydrocarbon production and accumulation.

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