2D SEISMIC DATA INTERPRETATION & FACIES ANALYSIS OF CHORGALI AND SAKESAR FORMATIONS, GUJAR KHAN AREA POTWAR SUB BASIN PAKISTAN

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CERTIFICATE

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بسم الله الرحمن الرحيم

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In the name of Allah, the most Beneficent, the most Merciful. All praises be to Almighty Allah, the Creator of universe. I bear witness that Holly Prophet Muhammad (PBUH) is the last messenger, whose life is a perfect model for the whole mankind till the Day of Judgment. Allah blessed me with knowledge related to the earth. I am enabled by Allah to complete my work. Without the blessings of Allah, I could not be able to complete my work as well as to be at such a place.

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ABSTRACT

The present study pertains to the interpretation, analysis and modeling of the productive zones for hydrocarbons from seismic and well log data. This was carried out by using SEG-Y seismic data of the lines GJN-09, GJN-11 and well log data (LAS format) of Rajian-01 well provided by the Directorate General of Petroleum Concession (DGPC). The area is a part of Potwar sub-basin. The area is important for its hydrocarbon (oil and gas) structural traps. Rajian oil field is located at the distance of 60 km in the South-East of Islamabad. The field was discovered in 1994 by OGDCL and came on regular production from 1994 till date.

The seismic interpretation of the study lines shows anticlinal structures bounded by thrust faults. The horizons were identified using formation tops from wells. Time and depth contour maps of the horizons of interest have been generated to understand the spatial geometry of the structures. Seismic structural model shows major thrust faults, which confirm the compressional tectonic regime in the study area. Analysis of Chorgali and Sakesar formations (which are the reservoirs in the study area) in terms of their facies was done by using density, resistivity and gamma ray logs run in Rajian-01 well and keeping in view the response from these logs, different facies present in these formations were identified.

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Chapter 01

Introduction

1.1 Introduction

The present study is base on the interpretation of seismic lines GJN-09 (Shot points 101 to 323) and GJN-11 (Shot points 101 to 348) of Rajian oil field located in Gujar Khan area. These lines are marked and interpreted using SMT Kingdom software. Along with the structural interpretation, among the formations traversed by Rajian -01 well, Sakesar Limestone and Chorgali Formation were selected to analyze them in terms of their facies contents using well logs data of Rajian -01 well.

1.2 Location and accessibility

The study area Gujar Khan is one of subdivisions of Rawalpindi district. It is 55 km Southeast of Islamabad. Gujar Khan is famous for its natural reserves of oil, natural gas and also being the heart of Potwar region. Gujar Khan is geographically located at latitude 33^{o} 15′ North of the equator and longitude 73^{o} 17′ East of prime meridian on the map of the world.

The seismic lines selected for study are of Rajian Oil field which was discovered by OGDCL in August 1994 and is still producing. Rajian oil field is located at a distance of 110 Km south-east of Islamabad. The Satellite image of the Gujar Khan area is shown in Fig 1.1.

Fig 1.1 Satellite image of Gujar Khan Area

1.3 Base map

A base map basically contains locations of concession boundaries, wells, Seismic survey points and other cultural data such as buildings and roads, with a geographic reference such as latitude and longitude or Universal Transverse Mercator (UTM) grid information. The base map of the study area has a scale of 1:150000 and is generated in SMT Kingdom. The base map contains a total of 6 lines and 2 wells (Rajian-01 & Rajian-03). Among these lines, the lines named as GJN-09 and GJN-11 have been interpreted. These lines are also highlighted by red color on the base map. Base Map of study area is shown in Fig 1.2.

1.4 Objectives of the Study

- Horizons marking.
- Geological interpretation of the area.
- Preparation of time and depth contour maps of Chorgali, Sakesar and Nammal formations & locating promising zones suitable for hydrocarbons.
- Facies analysis of Chorgali and Sakesar formations.

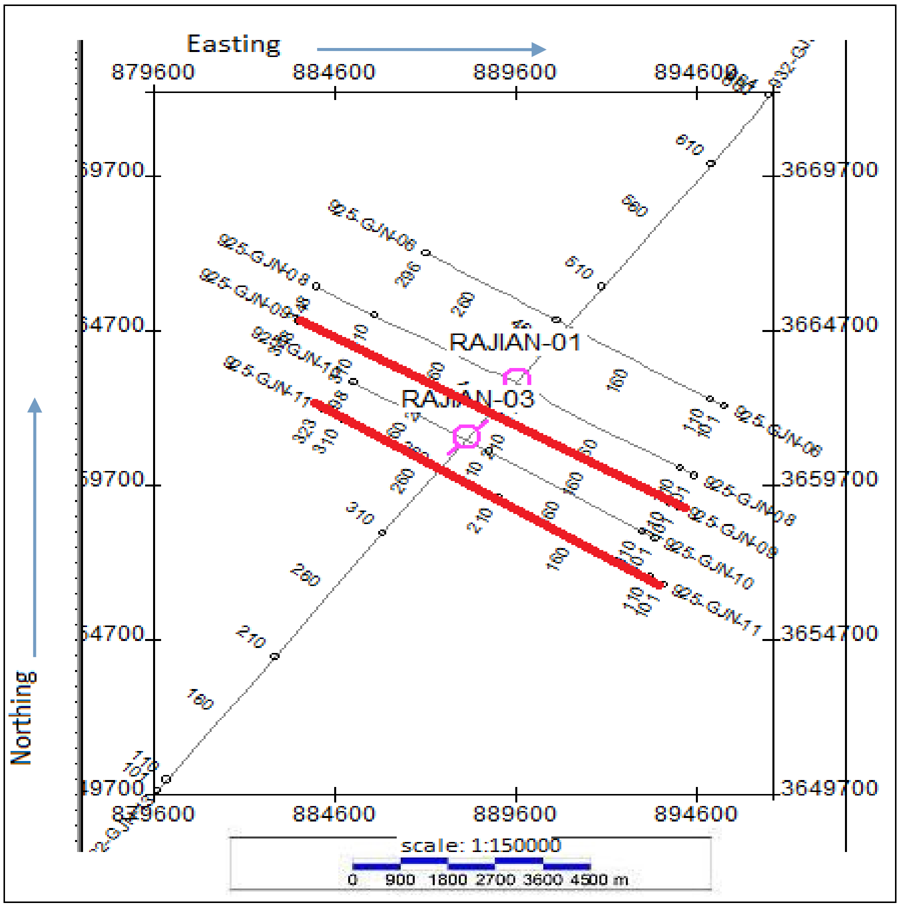

Fig 1.2 Base map of the Study area, Showing orientations of seismic lines. The highlighted Lines are interpreted (SMT Kingdom).

1.5 Methodology

- On the basis of provided seismic and well data we mark the reflectors of our interest and interpret faults on seismic section using interactive tools of SMT Kingdom.
- Time contour maps of Chorgali, Sakesar and Nammal Formations and then convert them into depth contour maps. These maps were also prepared in SMT Kingdom.
- We spatially analyze the structure present in the subsurface by looking at the marked lines and also time and depth contour maps.
- Facies of Chorgali and Sakesar formations were modeled by using well log responses from these formations using cross plot tool of SMT Kingdom.
- The logs employed for the purpose of facies analysis are Resistivity, Gamma ray and Density logs run in Rajian-01 well.

1.6 Short Introduction to Study Lines

The names, orientations and nature of the study lines along with the well located on these lines are given in table 1.1 below.

Line Name	**Orientation**	**Nature of line**	**Wells**
GJN-13	SW-NE	Strike	Rajian-03
GJN-06	SE-NW	Dip	
GJN-08	SE-NW	Dip	Rjian-01
GJN-09	SE-NW	Dip	
GJN-10	SE-NW	Dip	Rjian-03
GJN-11	SE-NW	Dip	

Chapter 02

GENERAL GEOLOGY

2.1 General Geology

The area under study is a part of the Potwar plateau where the topography is undulating and characterized by a series of parallel ridges and valleys. Mainly it consists of Duplexes and anticlinal structures bounded by thrust faults. Generally they trend in E-W direction. Geologically it forms part of the foreland zone of the NW Himalayan fold and thrust belt. This fore-land zone, comprising of Salt range, Potwar plateau/Kohat plateau and Hazara ranges is an area bounded by the Salt range thrust in the south and the Panjal-Khairabad fault in the north. At its eastern end is the nearly N-S running left lateral Jhelum fault (Kazmi & Jan, 1997).

2.2 Tectonic Setting

Gujar Khan area lies in northern Potwar basin. Tectonics in the Gujar Khan is thin skinned i.e. without significant involvement of basement. The Tectonic and Structural style of the area is governed by Himalayan orogeny which is due to the collision of the Indian plate with Asia, which is continuing at a rate of 5 mm/a and has produced a remarkable variety of active fold-and-thrust wedges within Pakistan. It is the tectonic activity which is responsible for fracture porosity of the reservoirs in the area although the matrix porosity is quite low (Kadri, 1995). These zones extend from the Kashmir fold-and-thrust belt in NE Pakistan, southwest ward through the Salt Range-Potwar Plateau fold belt, the Sulaiman fold belt and the Makran accretionary wedge. This collision between the Indian and Eurasian plats began during the middle to late Eocene in association with Late Cretaceous-Cenozoic spreading along the Carlsberg-southeast Indian Ocean Ridge. Sea-floor reconstruction indicates that about 2000 km of convergence has occurred between India and Eurasia since the collision began. In northern Pakistan, the Himalayan ranges are divided into four major subdivisions. North of the Main Karakoram thrust lie the Karakoram Range and HinduKush, terranes of Gondwanaland affinity sutured to Eurasia (Turan block) in the Late Triassic-Middle

Jurassic. South of the Main Karakoram thrust and north of the Main Mantle thrust lies the Kohistan block, a terrane believed to have been formed as an island arc, which docked with Eurasia in the Late Cretaceous to early Eocene. It is suggested that the Main Mantle Thrust locked approximately 15 Ma ago, subsequent to rapid uplift north of the fault between 30-15 Ma. During the early Miocene, deformation propagated southward near the Main Boundary thrust, where non metamorphosed lower Tertiary rocks are thrusted over Neogene molasses. In the latest phase in Pakistan, thrusting transferred to the Salt Range thrust, where deformation as young as 0.4 Ma has been documented. In the Lesser Himalaya of northern Pakistan (Hill Ranges), detachments at upper crustal levels occur along a series of south-verging thrust. The area is underlain by a gentle (1^0- 4^0) Northward dipping basement with an upward convexity, traversed by North dipping normal faults (Kazmi & Jan, 1997).

In terms of genesis and different geological histories Pakistan comprises of two main sedimentary basins. These two broad tectonic basins are Indus Basin and Baluchistan Basin which evolved during different geological episodes and were finally welded together during Cretaceous/Paleocene along Ornach nal/Chaman strike slip faults (Kadri, 1995). The study area belongs to Indus basin which is Bareilly discussed below.

2.2a Indus Basin

Indus Basin includes the area of 250000 Km^2 of South-East of Pakistan. It includes the Thar-Cholistan desert and Indus Plain. It has 80% of southeastern 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. Structurally Indus Basin is divided into two main parts:

i. Upper Indus Basin (in north)

ii. Lower Indus Basin (in south)

Lower Indus Basin is further divided into two parts;

a) Central Indus Basin (in north)

b) Southern Indus Basin (in south)

- **Upper Indus Basin**

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

a) Potwar sub Basin

b) Kohat sub basin

Since our study area lies in Potwar sub-basin so we will discuss only this ignoring Kohat sub-basin which is of no concern to us as for the study area is concerned.

a) Potwar sub basin

Potwar is a Fore-land fold and Thrust belt of Himalaya Orogeny that is bounded by Kala-Chita and Margalla Hills to the north, Indus River and Kohat Plateau in the west, Jhelum River and Hazara Kashmir Syntaxes in the east and Salt Range Formation in the south. Potwar Plateau has undulating topography. It is characterized by a series of parallel ridges and valleys, generally trend in the E-W direction. Geologically, it forms part of the foreland zone of the NW Himalayan Fold-and-Thrust belt. Structurally Potwar Basin is divided into North Potwar Deform Zone (NPDZ) in the north, Soan Syncline and Southern Potwar Deformed Zone (SPDZ) in the south. Potwar basin is covered by the molasses sediments ranging in age from Miocene to Pleistocene. Precambrian to Tertiary sequence is exposed along the ranges in south. The structure trend in the East-Potwar is long (NE-SW), continues and consisting of salt-cored anticlines separated by broad synclines. These structure are mostly bounded by hinterland and foreland verging faults, pop up zones are thought to be formed due to strike slip movement. The northern part is more intensely deformed called North Potwar Deformed Zone (NPDZ). South of NPDZ a broad asymmetric syncline, Soan Syncline exit, which is a major tectonic feature of Potwar. Its northern limb is more steeply dipping as compared to the southern limb; the southern limb is formed prior to north limb. From east to west structure become complicated due lack of lubrication in the basement and increased of internal deformation. Seismic, gravity and drill-hole data showed that Potwar underlies a gently north dipping basement (1-4 degree). (Kazmi &

Jan, 1997).

2.2b Stratigraphy of the Study Area

The Stratigraphy of the Salt Range and Potwar Plateau is well established from outcrops in the Salt Range. The stratigraphy in the NPDZ is not that well constrained due to lack of deep drilling. Surface outcrops along the MBT and seismic profile however, suggest the stratigraphy of NPDZ is similar to that of the Salt Rang and Potwar Plateau. Stratigraphic succession of the Potwar Basin is characterized by thick Infra-Cambrian evaporite deposits overlain by relatively thin stratigraphic succession of the Eocene to Cambrian.

The wells drilled in the study area traverses the following formations whose characteristics are discussed in the next few pages. The sequence is from older to younger.

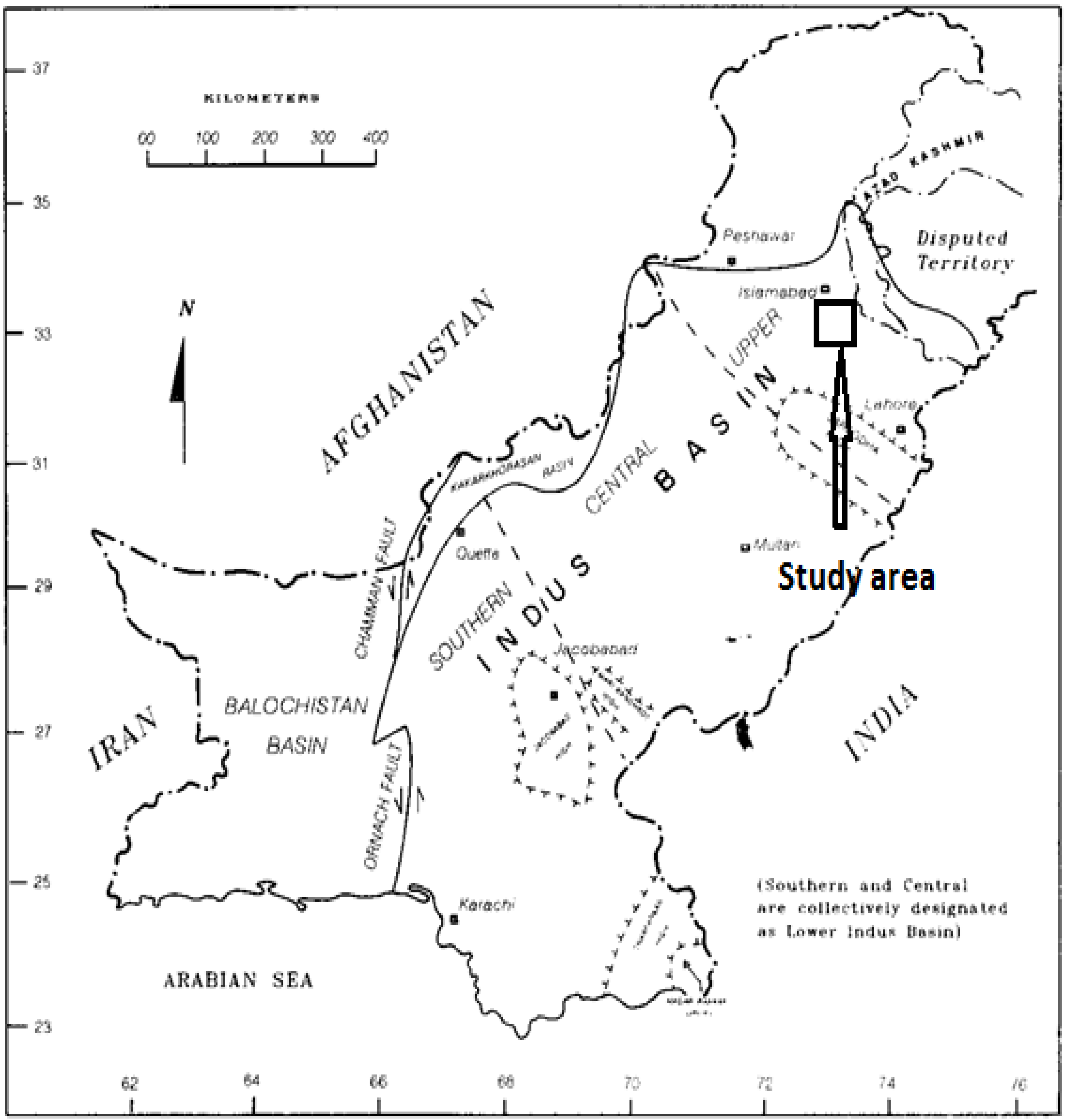

Fig 2.2 Sedimentary basins of Pakistan (After Abul Farah, et al 1984)

1) Khewra Sandstone:

The formation consists mainly of purple to brown fine grained sandstone. The sandstone is mostly thick bedded to massive. The upper contact with the Kussak formation is disconformable. The formation contains only few fossils recognized as Trilobites trails. The age of Khewra sandstone is almost certainly Cambrian.

2) Kussak Formation:

At the type locality the formation consists of greenish grey, glauconitic and micaceous sandstone, dolomite and siltstone. Formation is highly fossiliferous and contains the fauna like Neobolus, bots and Lingulella.

It is recognised in the subsurface in Potwar area. Its contact with the underlying Khewra sandstone is disconformable. It is overlain by Jutana formation conformably which is sandy dolomite. The change in lithology can be easily recognized by gamma ray log. Its age is late early Cambrian or early middle Cambrian.

3) Jutana Formation:

Lower part of formation consists of hard sandy dolomite in lower part of formation brecciated dolomite is also present. Formation is fossiliferous like Lingulella and Fuchsi etc. The lower contact with the Kussak formation is conformable and distinct. Upper contact with the overlying Baghanwala formation is also conformable. It can be recognised on electric logs by lower resistivity and high SP values as compared to overlying Baghanwala formation. Age of formation is late early Cambrian to early middle Cambrian.

4) Baghanwala Formation:

It is composed of red shale and clay. Sedimentary structures such as ripple marks and mud cracks are common in the formation. Presence of casts of salt pseudomorphs coupled with absence of fossils indicates lagoonal environment and arid climatic Conditions.

The contact of Baghanwala formation with the overlying Tobra formation is unconformable, whereas the lower contact with the Jutana formation is conformable.

The formation contains trace fossils. It is middle Cambrian in age.

5) Tobra Formation:

Tobra formation depicts a very mixed lithology in which the following three facies are recognised.

1. Tillitic facies
2. Fresh water facies with few or no boulders.
3. A complex facies of diamicite, sandstone and boulder bed.

Its lower contact with Cambrian rocks is disconformable. Its age is early Permian.

6) Dandot Formation:

Lithology of formation is sandstone with subordinate shales. It has gradational contact with the underlying Tobra formation and is terminated in sharp but conformable contact with overlying Warcha sandstone. It is fossiliferous and includes fauna of Eurydерma. Many species of Bryozoa and Ostrochoda have been reported. Its age is considered as early Permian due to fauna present.

7) Warcha Formation:

The formation consists of medium to coarse grained sandstone with conglomerates in place and has beds of shales. The sandstone is red and purple. It conformably overlies the Dandot formation. It is overlain by Sardhai formation with a transitional contact and the contact is placed at the top of highest massive sandstone bed.

On the basis of its Stratigraphic position with overlying and underlying early Permian rocks, the same early Permian age may also be assigned to it (Shah, 1977).

8) Sardhai Formation:

The formation is composed of bluish and greenish clay with some minor sandstone and siltstone beds. It also contains calcareous shales. Minor jarosite, chert and gypsum are found disseminated in the formation, with occasional calcareous beds in the upper part of it. It has lower transitional contact with Warcha sandstone and the upper contact with Amb formation is conformable. The formation is largely unfossiliferous. It is of Permian age.

9) Hangu Formation:

This formation consists of sandstone and shales. Color of sandstone is white, light gray and reddish brown fine to coarse grained and that of shales is gray. The formation is widely exposed and also present in the subsurface in Kohat - Potwar and Hazara areas. It is correlated with the lower parts of Dungan, Bara and Rakhshani formations of lower Indus basin.

It is conformably overlained by Lockhart Limestone. Fossils like foraminifers with some coral and gasteropods have been reported from the formation (Kadri, 1972). Its age is Paleocene.

10) Lockhart Limestone:

Lockhart Limestone is dark gray to black in Color. The limestone is well developed throughout the Kohat Potwar province. Lockhart Limestone is correlated with the Bara formation, the lower part of Dungan and Rakhshani formations of lower Indus basin. The formation conformably overlies and underlies the Hangu and Patala formations respectively. The formation abundantly includes foraminifers, mollusks, echinoids and Algae. It is assigned the age of Paleocene.

11) Patala Formation:

This formation consists of shales which are dark greenish grey in color. This is well exposed in Kohat Potwar and Hazara area and is encountered in subsurface in Potwar area. Throughout its extent Patala shales conformably overlies the Lockhart Limestone. The Formation is richly fossiliferous and contains foraminifers, mollusks and ostracodes. Its age is late Paleocene.

12) Nammal Formation:

This formation contains shale, marl and limestone throughout its extent. Its upper contact with Sakesar limestone and lower with Patala formation are transitional.

Abundant fossils mainly foraminifera and mollusks have been reported from the formation (Shah, 1977). On the basis of fossils the formation is given the Eocene age.

13) Sakesar Limestone:

Sakesar formation consists mainly of Limestone with subordinate marl. The lower contact with Nammal and upper with Chorghali formation is conformable. The formation has yielded rich fossil assemblage of foraminifers, mollusks and echinoids.
It is of Eocene age. This formation contains the most prominent limestone of Eocene age in salt and trans Indus ranges.

14) Chorgali Formation:

This formation composed of limestone and shales. It is of Eocene age. A fossil assemblage including foraminifers and mollusks has been reported by Davies and pinfold. In Khair-e-Murat range it is divided into two distinct units. The lower unit comprises of dolomitic limestone and shale. The upper part of formation composed mainly of shale with one thick bed of dark gray limestone.

15) Muree Formation:

Muree formation consists of dark red, purple and grey sandstone alternating with purple, red shales and conglomerates. Its age is early Miocene. Its upper contact is conformable/transitional with Kamlial formation and lower contact is erosional with Eocene formations.

16) Kamlial Formation:

This formation consists of purple, grey and dark red sandstone with subordinate interbeds of hard purple shale and conglomerates. It is a member of Rawalpindi group. Its thickness is 90 m at type locality Kamlial. Its upper and lower contacts are conformable. It is underlain by Muree formation. Its age is mid to late Miocene.

17) Chinji Formation:

Chinji formation consists of red clay with subordinate brown sandstone. Its age is late Miocene and is a member of Siwalik group of upper Indus basin. Its thickness is 750 m south of Chinji, Attock. The sandstone is fine to medium grained. The proportion of clay and sandstone is variable from place to place. It has conformable upper contact with Nagri and lower contact with Kamlial formation.

The generalized stratigraphic chart of Upper Indus basin is shown in Fig 2.3

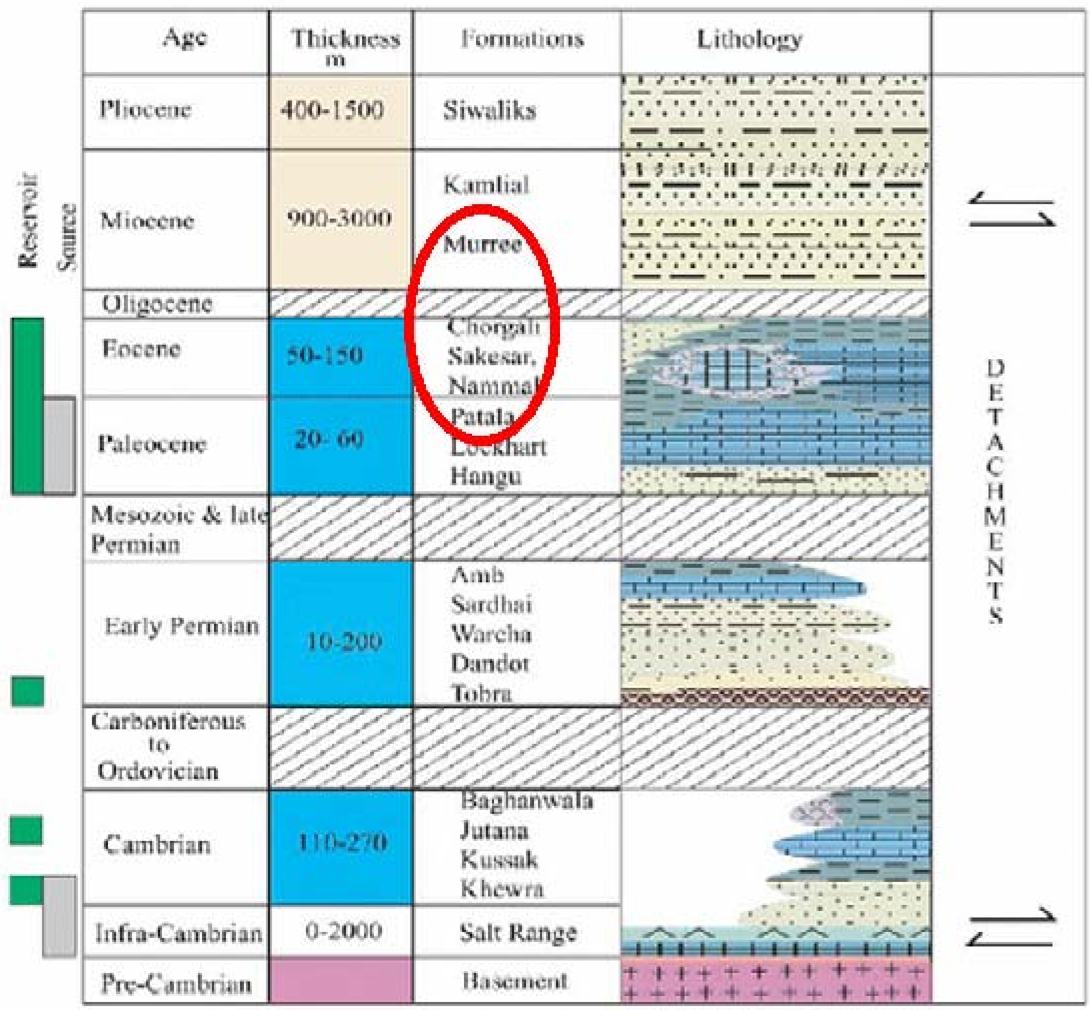

Fig 2.3 Stratigraphic chart of upper Indus basin, The Zone of our interest is encircled (Aamir & Siddiqui, 2006)

2.3 Petroleum Geology of Gujar Khan area

The study area Gujar Khan lies in Potwar sub-basin which is the oldest oil producing area of the world. In this area traditional oil bearing reservoirs belongs to early Eocene limestones. These are Chorgali and Sakesar Limestones. These limestones have very low matrix porosity and fractures have provided most of the voidage. The intensity and orientation of fractures is controlled by the structural style of the area which is governed by the Himalayan orogeny (Kadri, 1995). In Permian, shale of Dondot and Sardhai and Limestone and Black shale of Zaluch group has source potential of oil. Reservoir potential of Permian is also good, as Adhi oil filed in Tobra/Dandot/Warcha., Dhurnal oil field in Amb and Wargal while Dhulian Well in Permian sandy Limestone. Triassic unit of Potwar having versatility in the environment of deposition that reason that cannot act as a good source rock. Only the Khatkiara Member of Tredian Formation have good reservoir characteristic. In Jurassic the black clay and organic content of Data and some part of Shinawri Formation are believed to be good source rocks while Data is oil producing reservoir at Meyal, Toot and Dhulian oil field. Similarly Samana Suk Formation has also good reservoir characteristic. In Cretaceous Chichali Formation has good source potential due to abundance of organic material while Lumshiwal Formation is good reservoir having gas discovered in some area of Punjab Platform. In Paleocene Patala shale is major source in this region while the Paleocene reservoir is productive in all part of the Indus Basin like in Dhulian, Toot, Meyal and Missakeswal. Early Eocene carbonate are good source and reservoir rock, Sakesar and Chorgali having fractured Limestone have hydrocarbon potential in Adhi (PPL), Dhurnal (OXY), Dakhni (OGDCL), Missakeswal (OGDCL) and Rajian (OGDCL) etc. Rajian oil field was discovered in 1994 by OGDCL and is still producing. In Dhulian the Permian and Paleocene succession is quite thin. Carbonates of Chorgali and Sakesar Formations are major oil producing units in this area. Moreover the sandstone of Murree Formation has also good potential. Sakesar limestone is consisted of light gray, massive and partially dolomitized carbonated that locally contains the chert concentration. Paleocene Shales of Patala acts as a good source rock in the area under study. Chorgali Formation contains the creamy, yellow to yellow gray, silty, partially dolomitized and thin bedded limestone. Clay and shale of Murree Formation provides good vertical and lateral seal to these Eocene carbonates (Shami & Baig, 1998).

CHAPTER 03

Data Sets

3.1 Introduction

Seismic investigation starts in the field with the acquisition of seismic data. Seismic data is of two types i.e. seismic reflection data and seismic refraction data. However, seismic reflection data is used more frequently due to its wide application in the oil industry. For the investigation of study lines the data used consists of the following formats.

3.2 Data formats

The following data was issued by the Directorate General Petroleum concession (DGPC), Government of Pakistan upon the request of Chairman, Department of Earth Sciences, Q.A.U Islamabad.

- Seismic data in SEG-Y
- Well data in LAS format
- Navigation data

3.3 Source Parameters

A number of non-explosive and explosive energy sources have come into use for reflection prospecting. The various types used are as follows: Dynamite, Vibroseis, Land Air Gun and Geograph (Dropping of weight). The source used for the study area is Dynamite. A seismic source is activated in a localized region within which the sudden release of energy leads to a rapid stressing of the surrounding medium. Seismic sources are characterized by differing energy levels, time spans and frequency characteristics. Dynamite shooting collects the data of our dissertation. The energy source used to collect data for the lines under study is dynamite whose descriptions are given below.

- **Explosive (Dynamite)**

Explosive was formally the standard method used for the seismic emission on land. It is still employed to day in areas where its use is feasible. Dynamite charges from hundred grams to a few kg or buried in holes 3 to 5 meters deep and 10 to 15 cm in diameter at the base of the weathered zone. Several charges, horizontally spaced at intervals of a few meters are blasted simultaneously (Robinson & Coruh, 1988).The source Parameters of the study area given in table 3.1.

Advantages

- It is a powerful energy source
- It generates all the frequencies.

Disadvantages

Its major drawbacks are the storage and transport requirements and the cost of drilling stations.

Parameter	Description
Source	Dynamite
Charge pattern	1 hole
Average Size	15 kg
Average Shot depth	35 m
S.P interval	150 m

Table 3.1 Source Parameters of the study lines and their Descriptions

3.4 Receiver Parameters

The geophone signal, which is the electric current produced by ground vibrations is transmitted to the recording system by means of the seismic cable. Each geophone requires two wire conductors. Therefore, the number of conductors in the seismic cable depends on the number of geophones used in the survey. At regular intervals along the cable are “Takeout” points where a geophone can be connected to its pair of conductors (Robinson & Coruh, 1988).

Parameter	Description
Spread	2400-50-X-50-2400
Group interval	50 m
Geophone interval	1.52 m
Type of Geophone	OYO 10 Hz

Table 3.2 Seismic Receiver Parameters of the study lines and their Descriptions

3.5 Spread Configuration

In recording ground motions from reflected seismic waves it is customary to receive the signals with a large number of geophones (actually geophone groups) spread along a line extending from the shot point for a distance of thousands of feet. Each group transmits its data to the recording instruments on one information channel. An important reason for multiple-channel recording is the need to identify the reflections as such and separate them from ground motion due to other sources (Telford et al., 1990). The type of spread employed for the acquisition of the line of study is symmetric split spread. With the split spread an equal number of geophone groups are laid out on each side of the sources. All the geophone groups on either side of the source record the shot simultaneously.

The spread used for the lines under study is Split spread which is seismic recording with receiver positions extending along the seismic line in both directions from the source. “In a symmetrical split spread the live offset are the same in both directions, but different in an asymmetrical split spread”.

(Geophone spread) (Shot) (Geophone spread)

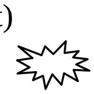

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Fig 3.1 Split Spread configuration

3.6 Common Depth Point (CDP) Profiling

"A setup by which reflections are recorded from the same subsurface point with different source-to-geophone offset is known as common-midpoint (CMP) or common-depth point (CDP) shooting". Each common-midpoint consists of two or more traces, the number of which determines the coverage or fold of the seismic record. For example, 2 traces for a common-depth point produces 2-fold or 200% coverage, 24 traces, 24-fold coverage. Fold of the lines GJN-09 and GJN-11 is 2400 %.

The advantage of CDP profiling is that quality of data can be enhanced by increasing multiplicity (fold) of seismic data. Seismic velocities can be determined during the phase of processing. Fold of seismic data can be determined by the formula.

$$\text{Fold} = N.\Delta G / 2\Delta S \quad \text{.. (Eq: 3.1)}$$

N = Number of traces recorded

ΔG = group interval

ΔS = short point interval.

3.7 Display Parameters

CDP profiling data from two-dimensional surveys are conventionally displayed as seismic sections, in which the individual stacked seismograms are plotted side by side, with their time axes arranged vertically. There are different methods of visualization of traces e.g. variable area, variable density, wiggly line etc. The display parameters of the lines under study are as follows:

Display amplitude : 10 DB
Polarity : Normal

3.8 Seismic Data Processing in General

Data processing is a sequence of operation, which are carried out according to the pre-defined program to extract useful information from a set of raw data as an input-output system (Al. Sadi, 1980). Processing may be schematically shown as.

Observational data ⇨ Processing system ⇨ Useful Information

3.8a Processing Sequence of the Study Lines

1) Edit/ Demultiplex
2) Preprocessor
3) Datum Statics Correction
4) Spherical Divergence Correction
5) Notch Filter (50 Hz)
6) Band Pass Filter
7) Zone Anomaly Process
8) Deconvolution before Stack
9) Band Pass Filter
10) Velocity Analysis
11) Auto Statics
12) Velocity Analysis
13) Normal Move out
14) Static and Dynamic Corrections
15) Stack (1600%)
16) Time invariant Filter
17) Random Noise attenuation
18) RMS Gain

3.8b General Processing Flow Chart

The block diagram shown in Fig 3.2 shows the steps usually carried out in a seismic processing sequence. This is a general flow chart and does not necessarily to be followed for the processing of every type of data.

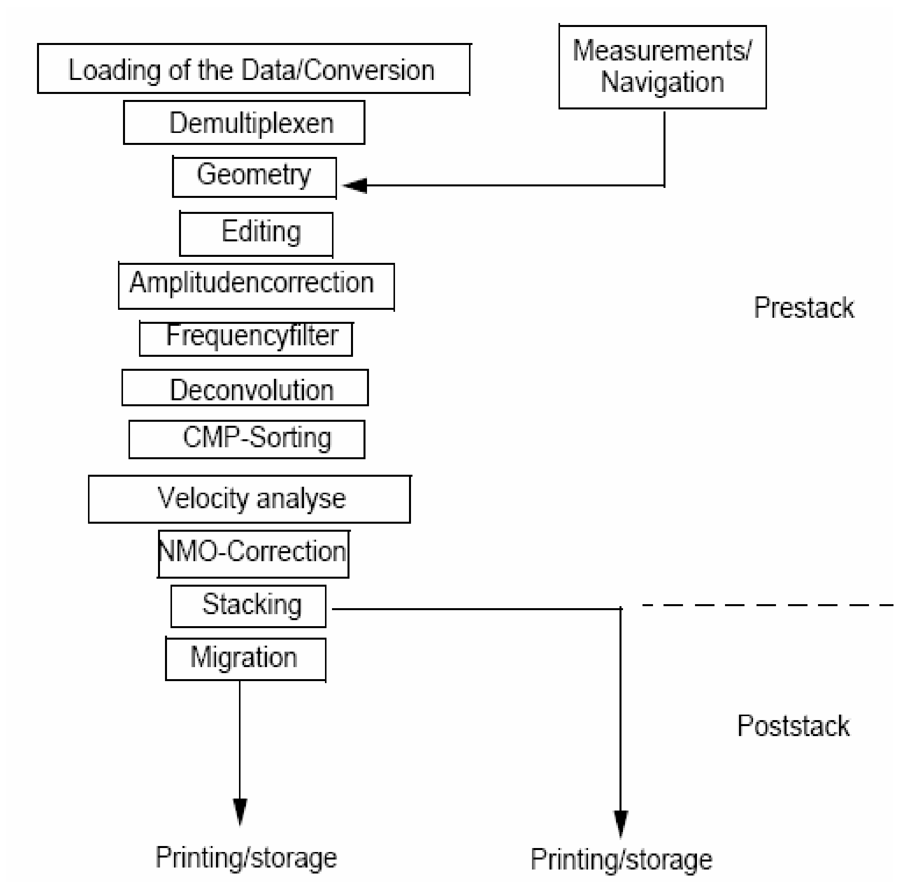

Fig 3.2 Block diagram showing the various stages of seismic processing (Khan, 2009)

Chapter 04

Interpretation

4.1 Introduction

Seismic interpretation is the transformation of seismic reflection data into a structural picture by the application of correlation of seismic reflectors with geological boundaries and their time-depth conversion (Dobrin & Savit, 1988).

This chapter is about the interpretation of provided seismic and well data. The main constituents of this chapter are as follows.

- Seismic Horizons and their depth provided in the data of Rajian-01 well.
- Seismic sections of lines GJN-09 and GJN-11, which are interpreted on the bases of provided well tops.
- Time Contour maps of Chorgali, Sakesar and Nammal formations in which contour interval is 0.05 sec.
- Depth contour maps of the above mentioned formations in which the contour interval is set as 100 m.
- Facies analysis of the reservoirs of the study area (i.e. Chorgali and Sakesar limestones) by using logs run in Rajian-01 well.

4.2 Seismic Horizons

The main task of interpretation is to identify various reflectors or horizons as interfaces between geological formations. This requires good structural and stratigraphic knowledge of the area (McQuillin et al. 1984). Thus interpretation involves marking of horizons and faults on the seismic section. The seismic data was provided in digital SEG-Y format which was loaded in kingdom software interpretation system. The prominent reflections that show continuity and can be traced across the seismic sections are marked. The seismic data is interpreted by correlating well information with the crossing seismic line and then from line to line at their tie points. Three reflectors are marked on the seismic section on the basis of continuity of the reflectors on the seismic section. Well tops are used in order to identify and name the horizons. Rajian-01 well lies on the seismic line GJN 08. The well tops are matched with the three seismic reflectors in time domain to identify the geologic formations. The Well information is given in table 4.1 below.

Well name : RAJIAN-01 **Elevation**: 546.6000 KB

Well type: Oil & Gas Exploratory

Formation	**Depth (m)**
Chinji	00
Kamlial	570
Murree	768
Chorgali	3306
Sakesar	3335
Nammal	3414
Patala	3425
Lockhart	3439
Hangu	3450
Sardhai	3460
Warcha	3473
Dandot	3477
Tobra	3484
Baghanwala	3490
Jutana	3505
Kussak	3537
Khewra sandstone	3623

Table 4.1 Geological Formations and their depths From Earth surface

4.3 Interpreted Time Sections

The time section gives the position and configuration of reflectors in time domain. We input the Shot Point numbers and time information in the kingdom software . The main reflectors marked on the seismic sections that are of interest are Chorgali, Sakesar and Nammal Formations. The interpreted time sections of line GJN-09 and GJN-11 are given in Figs 4.1, 4.2 and 4.3 respectively. In these sections, the horizon with red color is top of Chorgali, blue is top of Sakesar Limestone and green is top of Nammal formations. It is very difficult and time consuming to mark the horizons manually on hard seismic sections. The interactive tools in kingdom made it much easier and efficient to mark and manage the picked horizons data.

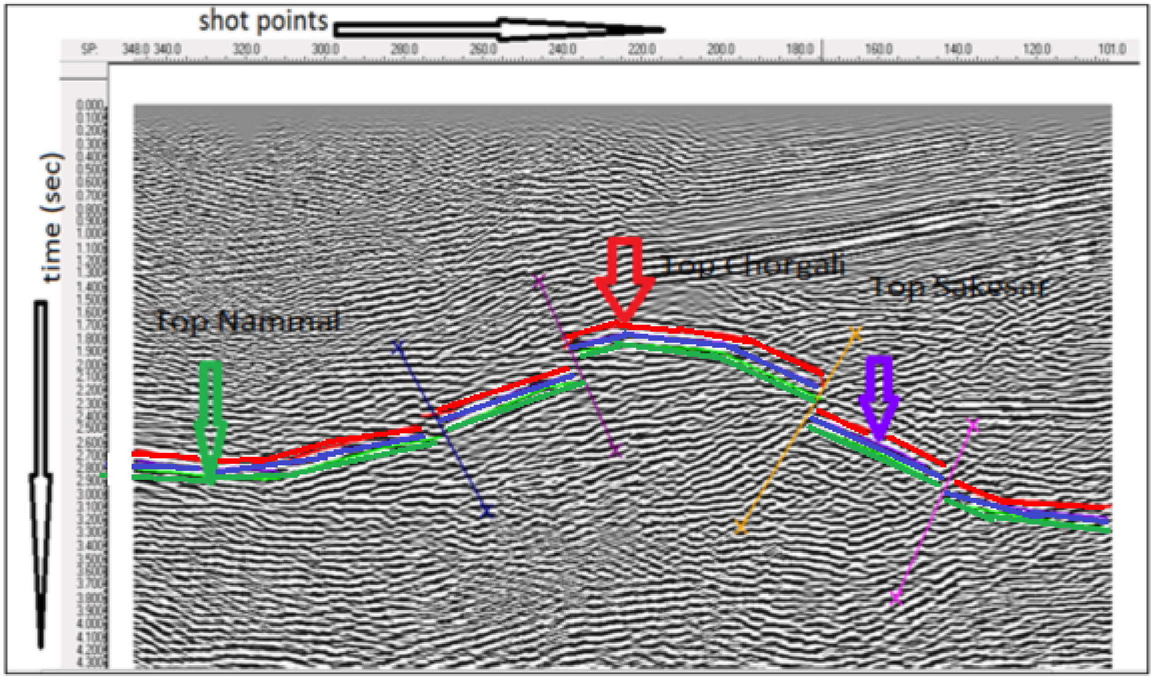

Fig 4.1 Seismic time Section of the line GJN-09 (SMT Kingdom)

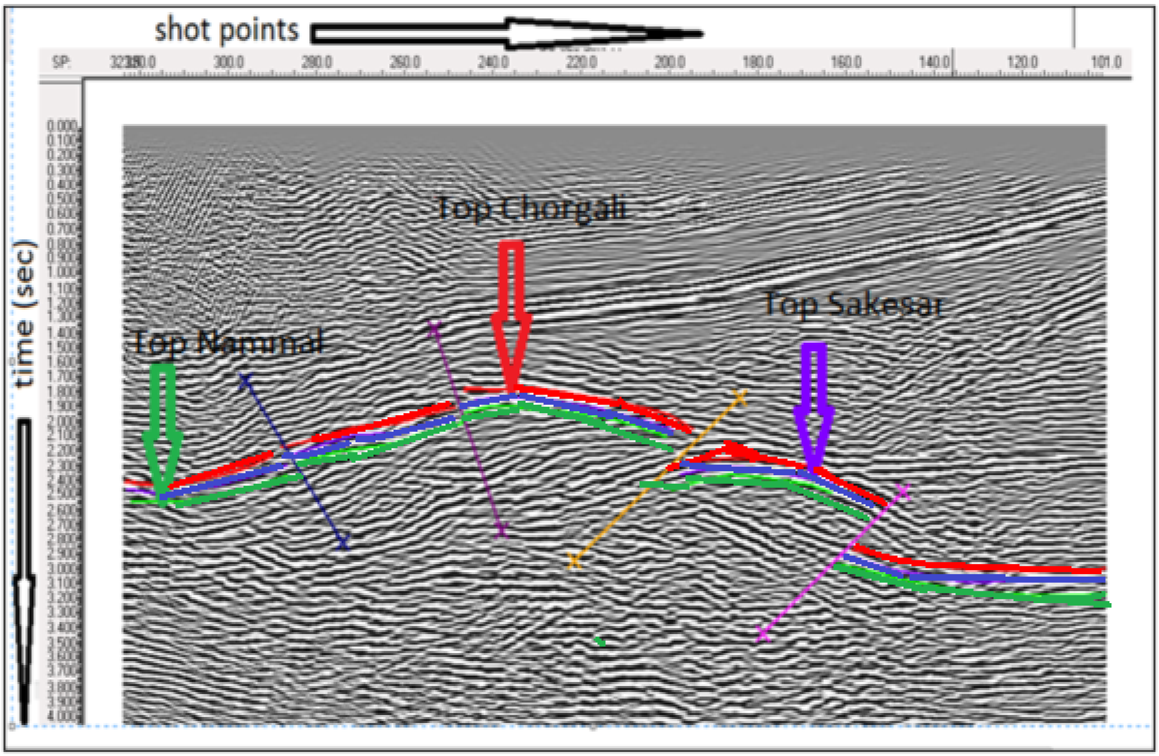

Fig 4.2 Seismic Section of line GJN-11 (SMT Kingdom)

4.4 Contour Maps

Contour maps are very important in seismic interpretation work flow because the results of seismic interpretation are usually displayed in map which shows the time or depth contours. Mapping is a 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 shows the three-dimensional view of Earth on a two dimensional surface. The spacing of the contour lines is a measure of the steepness of the slope; the closer the spacing the steeper the slope. A subsurface structural map shows relief on a subsurface horizon with contour lines that represent equal depth below a reference datum or two way time from the surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip and any faulting and folding. 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 SMT Kingdom software is used to generate the contour maps.

4.4a Time contour maps

Time contour Maps of Chorgali, Sakesar and Nammal Formations are posted on the base map (Figs 4.3, 4.4 & 4.5) along with wells and fault polygons. The pattern of Contour Maps confirms the sub-surface shape of the structure present there. The contour interval in time contour maps is set as 0.05 sec. Chorgali Formation is composed of limestone, it acts as a reservoir rock and its reflector is very prominent on the seismic, below it there exists Sakesar limestone. Time contour map of Chorgali formation shows 2D-variations with time. The hydrocarbons accumulate at those places where contour values are low. It is evident from the time contour map of Sakesar limestone that main structure lies in the center of faulted portion and it has maximum time as shown in scale. The closed contours indicate steep sloppy portion. The closed contour part can be considered as structural trap. Figs 4.3 to 4.5 shows time contour maps of Chorgali, Sakesar and Nammal formations.

4.4b Depth Contour Maps

Depth contour maps of Chorgali, Sakesar and Nammal formations are given in figs 4.6, 4.7 and 4.8 respectively. The contour interval is 100 meters. The depth contour maps also clarify the structure present in the subsurface.

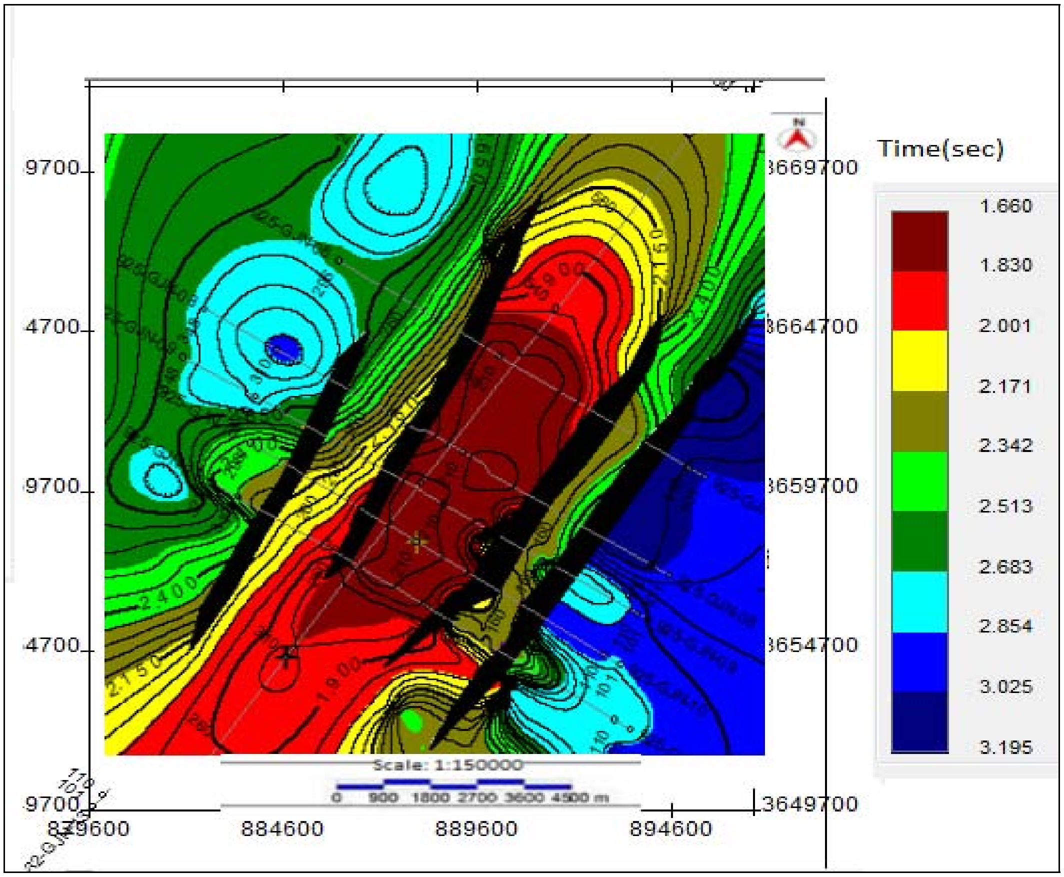

Fig 4.3 Time contour map of Chorgali formation(Contour interval = 0.05 sec)

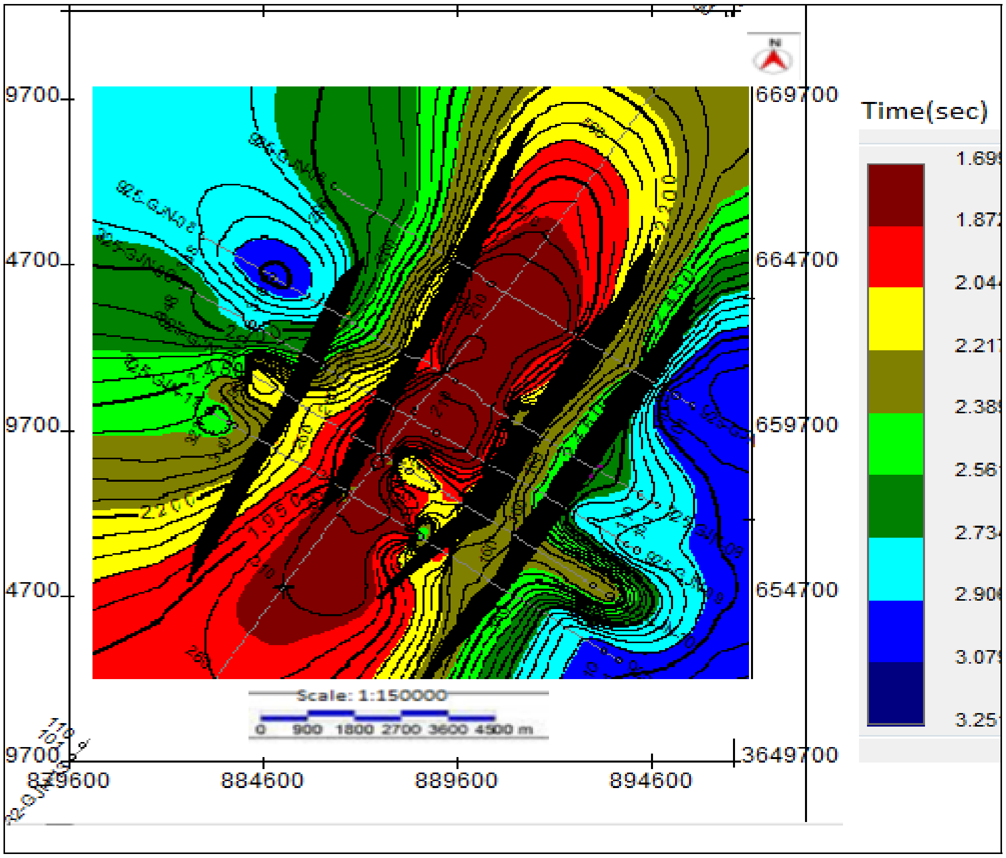

Fig 4.4 Time contour map of Sakesar limestone (contour interval = 0.05sec)

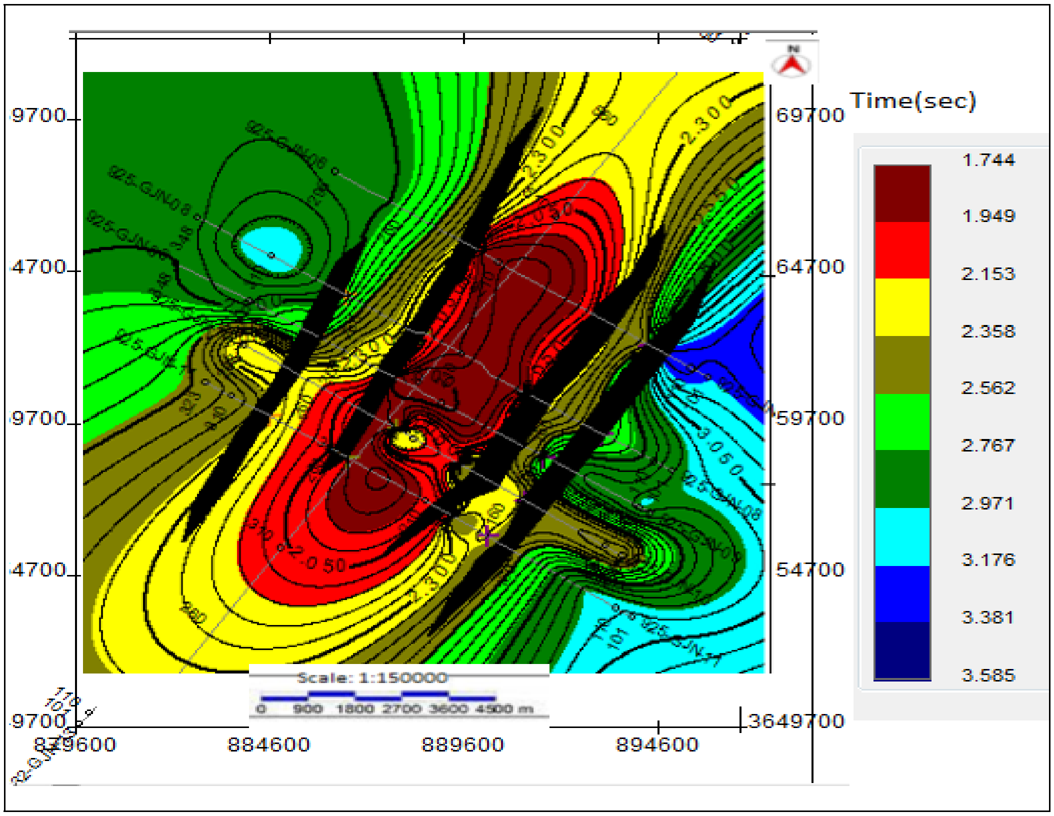

Fig 4.5 Time contour map of Nammal formation(Contour interval = 0.05 sec)

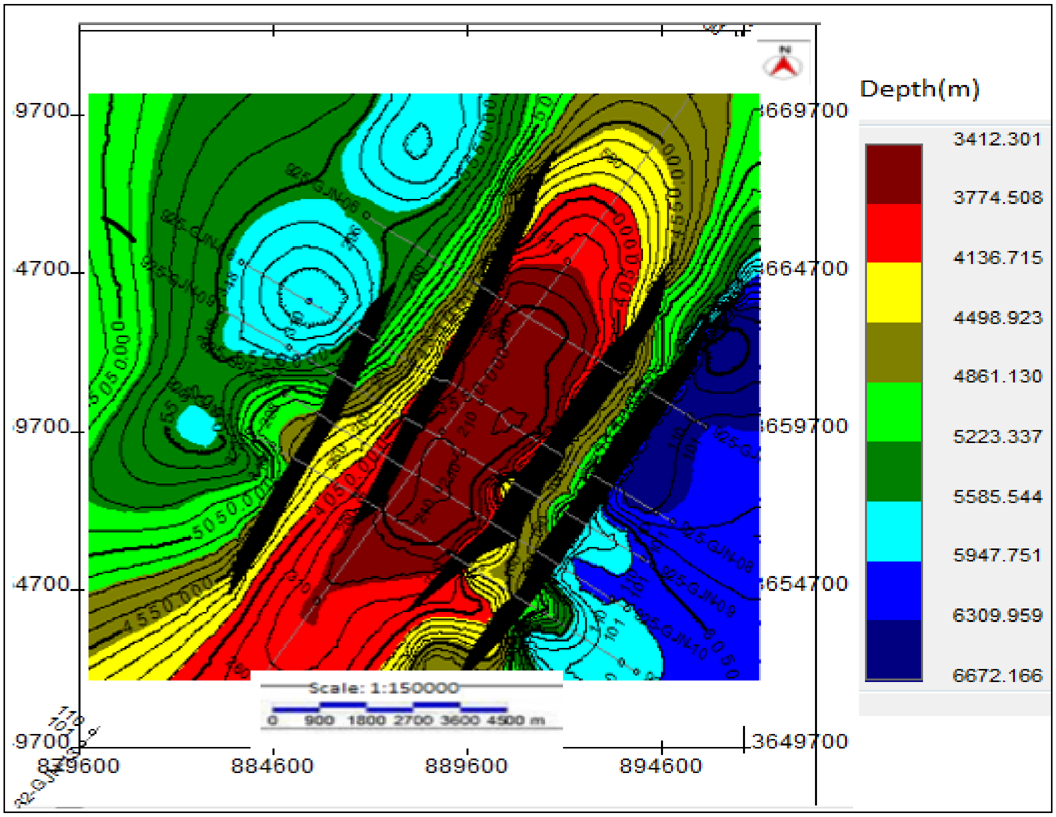

Fig 4.6 Depth Contour map of Chorgali formation(Contour interval = 100 m)

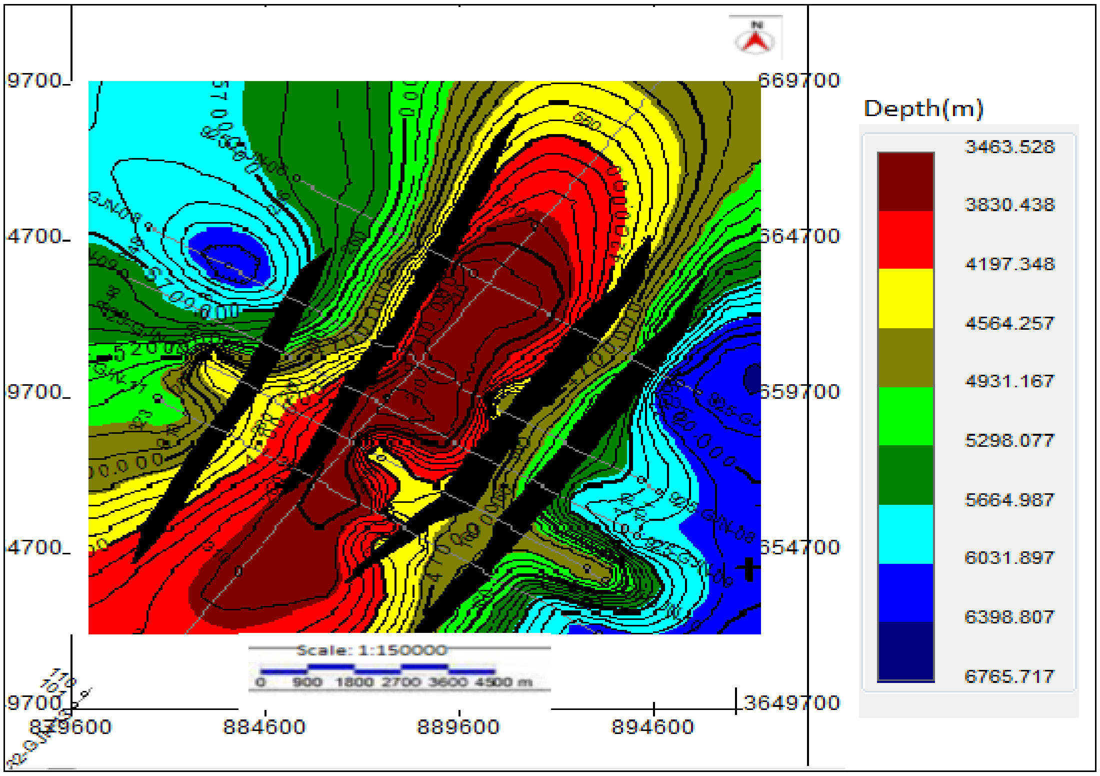

Fig 4.7 Depth Contour map of Sakesar Limestone (Contour interval = 100 m)

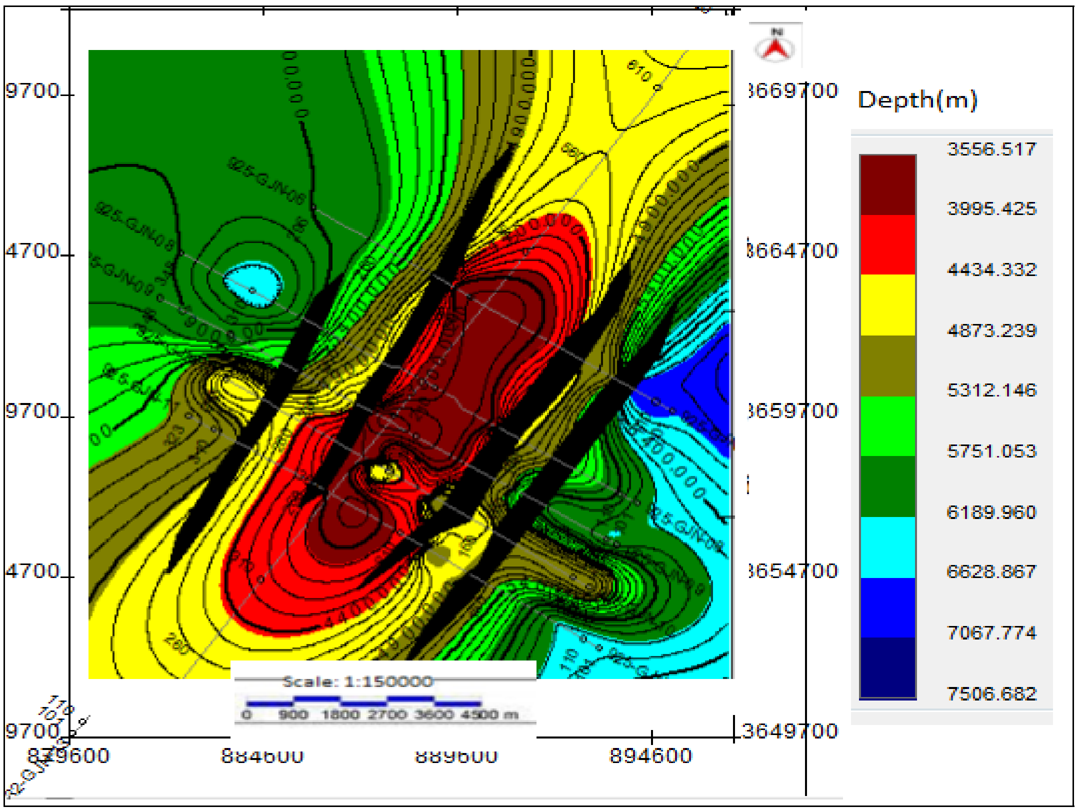

Fig 4.8 Depth Contour map of Nammal formation (Contour interval = 100 m)

4.5 Facies Analysis

Seismic facies analysis makes use of different seismic parameters in order to get other than structural information. A review is given of possibilities and usefulness of seismic facies analysis in oil exploration using gamma ray, density and resistivity logs.

A seismic facies unit can be defined as “A sedimentary unit which is different from adjacent units in its seismic characteristics”. Parameters that should be taken into consideration in the seismic facies analysis are as follows: reflection amplitude, dominant reflection frequency, reflection polarity, interval velocity, reflection continuity, reflection configuration, abundance of reflections, geometry of seismic facies unit and relationship with other units.

Interpretation of seismic facies data may be either direct or indirect. The purpose of the direct interpretation is to find out geological causes responsible for the seismic signature of a seismic facies unit. So, the direct interpretation may be aimed at predicting lithology, fluid content, porosity, relative age, overpressured shales, type of stratification, geometry of the geological body corresponding to the seismic facies unit and its geological setting. The indirect interpretation is intended to reach some conclusions on depositional processes and environments, sediment transport direction, and some aspects of geological evolution (transgression, regression, subsidence, uplift and erosion).

The results of the seismic facies analysis may be shown on seismic facies cross-sections and seismic facies maps. Depending on the available seismic and logging data and geological conditions in the area under consideration, the seismic facies maps may be of different types such as general seismic facies maps showing distribution of different seismic facies units, sand-shale ratio maps, direction of cross-bedding and paleo-transport maps.

In the available data we select the well named as Rajian 01 and from the main menu of “kingdom” we select the option “tools” and after proper method the following facies diagram was obtained. In fig 4.9, X-axis represents values of density log in gram/cm^3 which is the logging tool used to provide a continuous record of formation bulk density along the length of a borehole. Y-axis represents the values of resistivity logs in ohm-m. Z-axis represents the values of gamma ray logs in API units. The gamma ray log is an extremely useful tool for discrimination of different lithologies.

4.5a Log Observations in Chorgali Formation

The logs run in the Rajian-01 well indicate four different types of facies in the formation i.e. Dolomitic limestone, limestone, Shaly limestone and Shale. Dolomitic limestone is differentiated from limestone by its high resistivity values. Similarly Shaly limestone is differentiated from limestone and Dolomitic limestone by its high gamma ray values due to shaly content. Similarly density of Shaly limestone also falls due to addition of shales. The third facies identified is Shale which has low density, low resistivity and high gamma ray values as shown in Fig (4.9).

4.5b Data table

The following data table gives the values (in ranges) of the three logs for different facies as observed in the formation.

Facies	**Density(g/cc)**	**Resistivity (Ohm-m)**	**GR(API)**
Dolomite	2.5 - 2.7	48 - 930	08 – 23
Dolomitic limestone	2. 3- 2.7	11 - 24	11 – 50
Shaly limestone	2.3 - 2.6	1.7 - 10	24 – 62
Shale	2.1 - 2.3	0.4 - 4.3	43 - 84

Table 4.2 Observed Log values of different facies in Chorgali formation

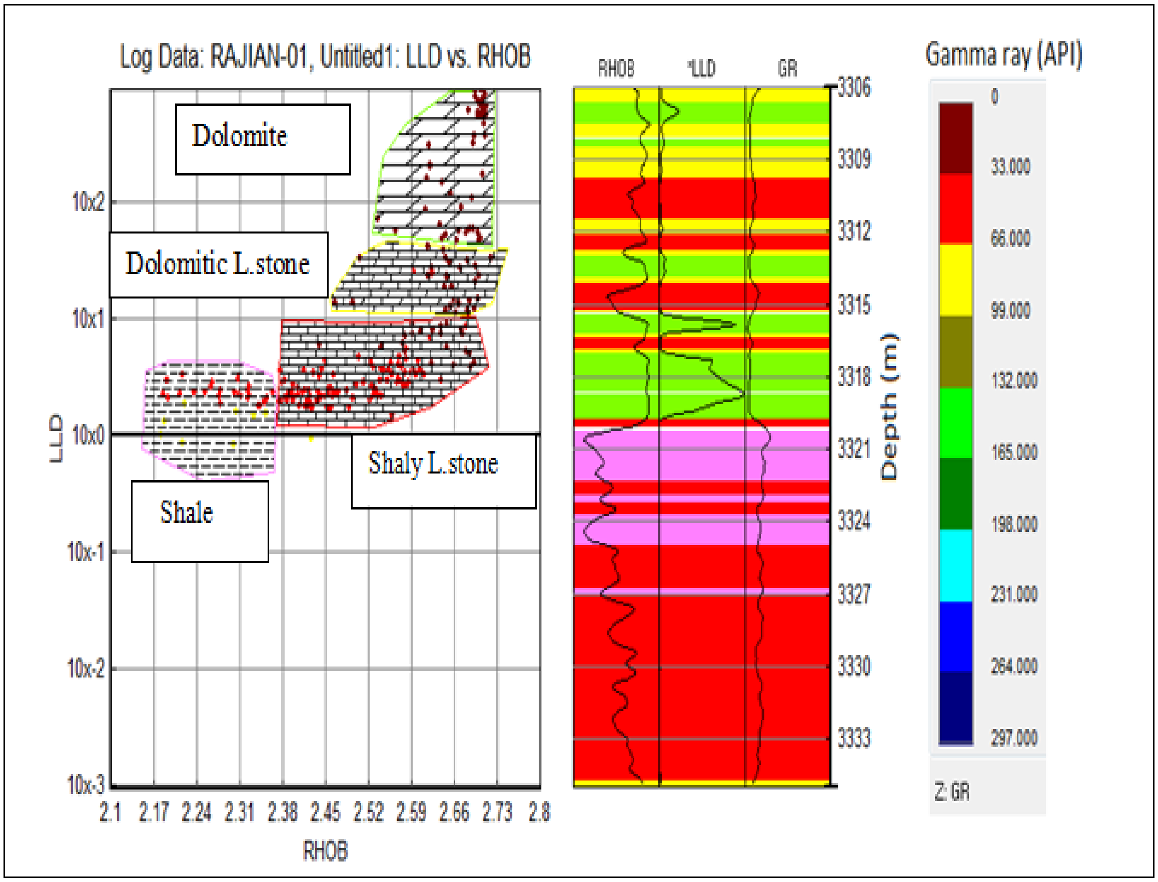

Fig 4.9 Facies analysis of Chorgali formation (SMT Kingdom)

4.5c Facies Analysis of Sakesar Formation

Sakesar formation is composed of Limestone, Cherty limestone and Marl facies respectively. This statement was concluded from the log responses of Sakesar formation as it is evident from the literature that limestone facies have low gamma ray values and is proved by the log run in the Rajian-01 well. Similarly the density values were also in accordance with the literature values. The limestone facies were differentiated from Cherty limestone by its high resistivity values. Cherty limestone has low resistivity values and thus can be differentiated from limestone. The third facies identified is Marl which has low density, very low resistivity and high gamma ray values as being radioactive. The Observations were taken from the following diagram.

The red color in the log chart shows limestone, green color shows Cherty limestone and pink color shows marl facies. The observed log response from the formation is shown in the table 4.3.

4.5d Data Table

The following table shows the numerical values of different logs run on the well.

Facies	**Density (gm/cc)**	**Resistivity (Ohm-m)**	**Gamma ray (API)**
Limestone	2.6-2.7	48-510	17-38
Cherty limestone	2.5-2.7	11-42	14-55
Marl	2.2-2.4	1.1-5	71-103

Table 4.3 Observed log values of different Facies in Sakesar Formation

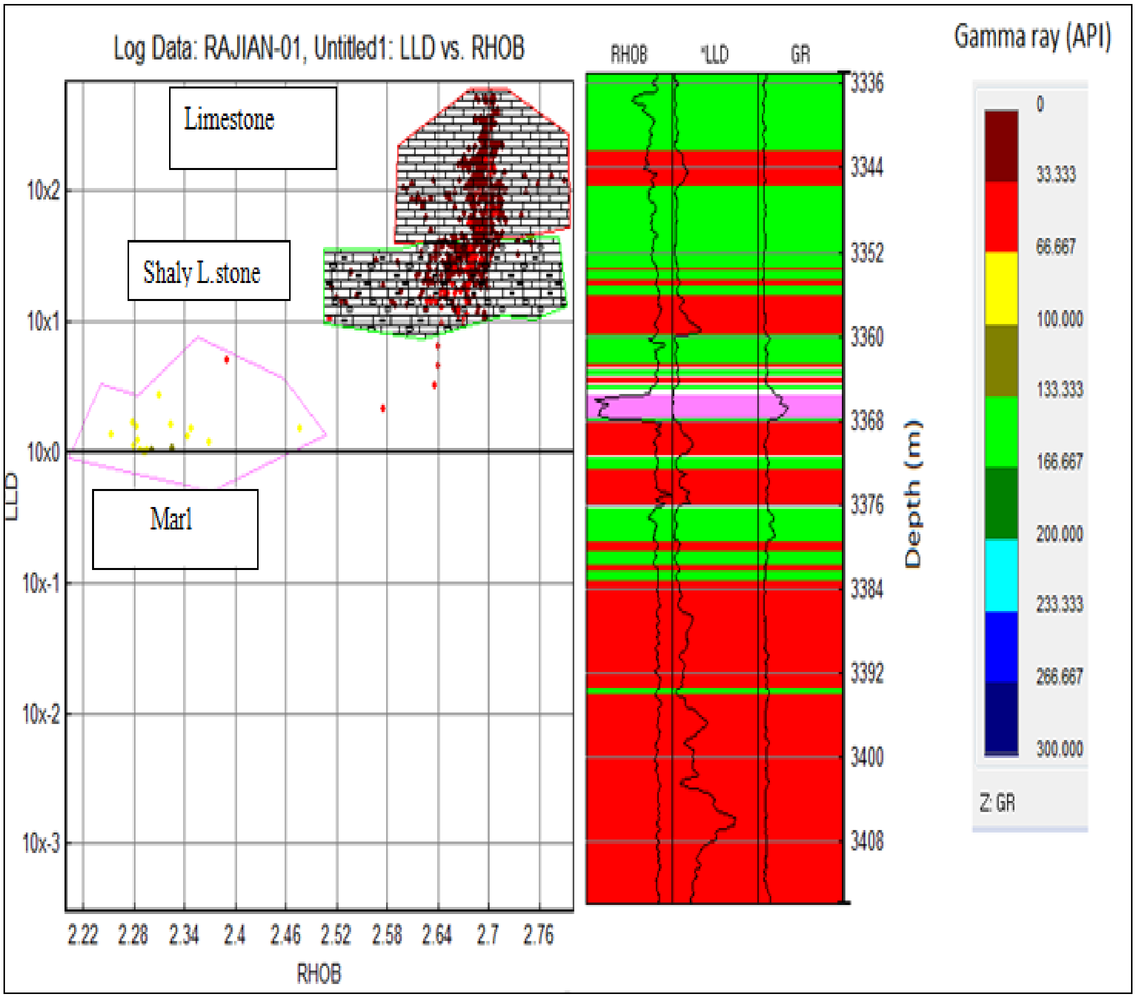

Fig 4.10 Facies Analysis of Sakesar formation (SMT Kingdom)

Conclusions

After interpreting Seismic lines 925-GJN-09 and 925-GJN-11 along with four other lines of Rajian field, we concluded that area is in compressional regime, so it has reverse faulting. These faults have given rise to Anticlinal structures bounded by faults which are considered to be suitable sites for accumulation of hydrocarbons. This anticline acts as a trap in the area. The time and depth contour maps of Chorgali, Sakesar and Nammal formations help us to confirm the presence of anticlinal structure in the area.

Using Density, Resistivity and Gamma ray logs which are usually used for lithological interpretations, different facies of Chorgali and Sakesar formations were modeled which are Dolomite, Dolomitic limestone, Shaly limestone and Shales in Chorgali formation and Limestone, Cherty limestone and Marl in Sakesar formation respectively.

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