2-D SEISMIC INTERPRETATION OF KADANWARI AREA, KHAIRPUR DISTRICT, SINDH, PAKISTAN

Submitted By

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ACKNOWLEDGEMENT

All praises to **Almighty Allah**, the most beneficent and the most merciful. We thank Allah on bestowing the mercy upon us and made us to complete our thesis.

We would like to thank **Mr. Tahir Maqsood** who supervised us. His allegiance to our thesis is a great honor for us. Without him, this thesis would be still dwindling without knowing the main objective and purpose of thesis. He provided us the true intuitive techniques that help us to learn and to do work on thesis. His advice, knowledge and guidance were pivotal for completion of our thesis.

We would also like to thanks **DR. M. Zafar** and **Mr. Mohsin Munir** for cooperating and guiding in thesis procedure and checked the thesis, reviewed our work and made numerous corrections in our manuscript.

Adnan, Fida and Razi.

ABSTRACT

This dissertation involves the study of 2D seismic interpretation of area lies in the Kadanwari Gas discovery which is located in Lower Indus Basin, Pakistan. The key objective includes the delineation of subsurface structure suitable for Hydrocarbon accumulation. This part of the basin has well known exploration history from 1989 to 1992. The well and the seismic data reveals presence of Mesozoic-Cenozoic sedimentary cover which has been involved through extensional and then transtensional episodes of Indo-Pakistani plate related to Cretaceous rifting and drifting, the present work reveals presence of structure style which shows the geometry of negative flower structures.

The seismic lines for this dissertation were provided by LMK Resources by permission of Directorate General of Petroleum Concession (DGPC). A total of 11 seismic lines for seismic interpretation in which 6 horizons were picked by well correlation. The fault trend is marked according to the regional geology and the effect of regional geology on the study area was analyzed. Three Reflectors (Yellow, Green and Purple) represented by Pirkoh, Lower Goru E sand and Albian Aptian Formation are marked by check shot survey of the available Kadanwari well -1 and its reflection prominence. Two way travel time from seismic section were used to create time contour maps of Pirkoh, Lower Goru E sandstone and Albian-Aptian. Finally constructions of contour maps provided the structural highs suitable for accumulation of hydrocarbon were identified

Chapter-1

INTRODUCTION

The study area is located in Kadanwari, Khairpur district of Sindh Province, Pakistan and occupies Sargarh depression in Lower Indus Basin. Sargarh depression is structural low, North East of which is Mari Kandhkot High and Khairpur-Jacobabad High is in west, Thar slope is on south and Delhi Aravalli range is in the East (fig 1). The study area is gas prone and has structural as well as stratigraphic traps. The study area shows negative flower structure due to transtensional activity in the Cretaceous formations which reveals that the area was subjected to the rifting and drifting.

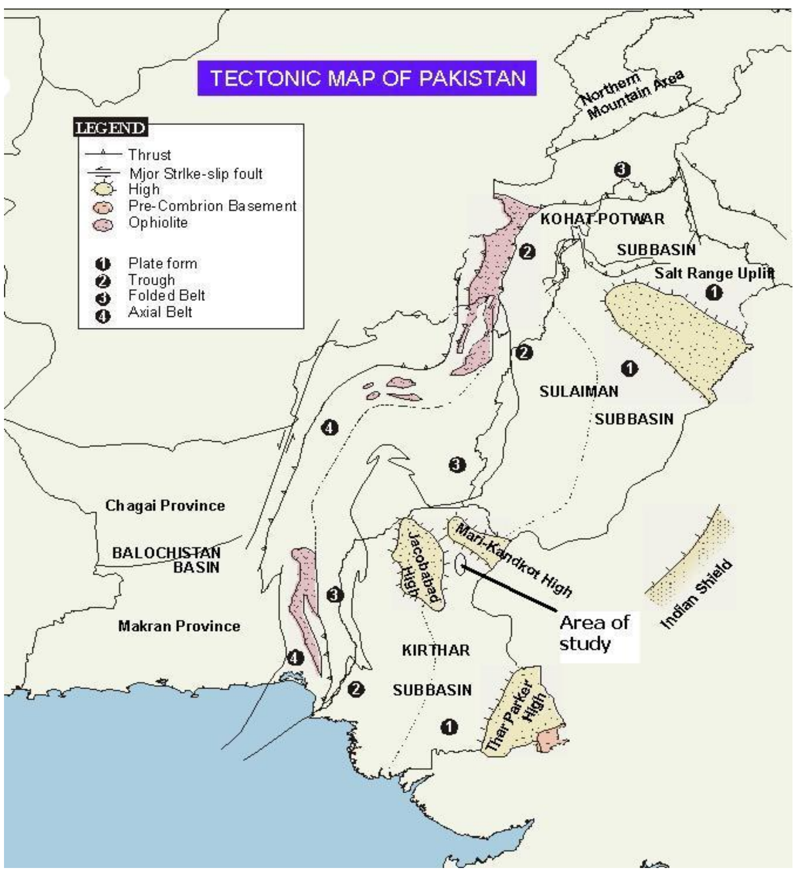

Figure 1: Tectonic map of Pakistan

1.1 Purpose and Scope:

This study is originated for the completion of BS degree during the Academic year of 2010.This dissertation is aimed to achieve an understanding of 2D seismic interpretation of Kadanwari area using well and seismic data of ENI. Through this thesis, understanding of seismic-well data correlation and subsurface structure was developed. The main purpose of this dissertation is to find out structural traps suitable for hydrocarbon accumulation.

1.2 LOCATION AND ACCESS:

Our study area is situated 27° 18′ 00″ to 27° 00′ 00″ North Latitude and 69° 06′ 00″ to 69° 21′00″ East Longitude. The study area is located 69 km away from Khairpur City, 287 Km from Hyderabad and 432 km from Karachi. It is located in northern Sindh Province and is bounded on North by Shikarpur and Sukkur, on East by India, on South by Sanghar and Nawabshah and on West by Larkana and Naushahro Feroz. (fig 2)

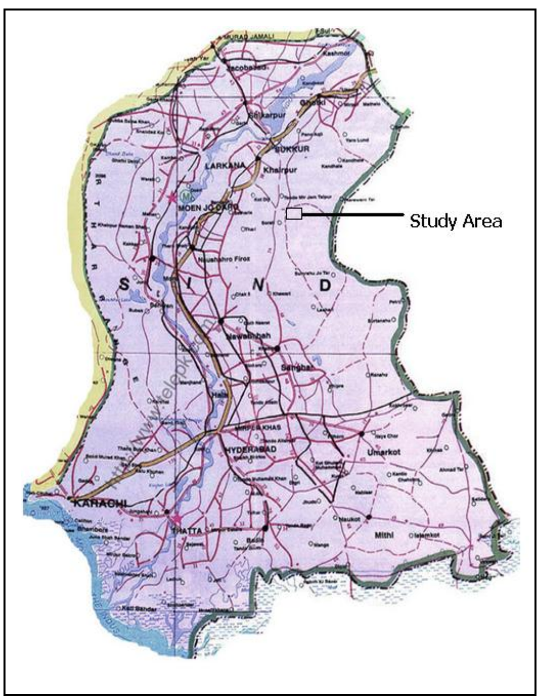

Figure 2: Road access to the study area.

1.3 PHYSIOGRAPHY AND CLIMATE:

The study area lies in Thar region which forms part of the biggest desert of the Pakistan. The Tharparkar district is mostly desert and consist of barren tracts of sand dunes covered with thorny bushes. The ridges are irregular and roughly parallel, that they often enclosed sheltered valleys, above which they rise to a height of some 46 meters. The extraordinary salinity of the subsoil and consequent shortage of potable water renders many tracts quite uninhabitable. (fig 3)

Figure 3: Sand dunes in study area

The study area has a tropical desert climate. In summer, it is extremely hot during the day, but nights are remarkably cooler. April, May and June are the hottest months during the day; December, January and February are the coldest months. The mean maximum and minimum temperature during this period are 28°C and 9°C, respectively.

There are wide fluctuations in the amount of rainfall from year to year and the yearly average for some areas is as low as 100 mm. Most of the rain falls between July and September, during the south-west monsoon, and is often concentrated in a period of two to three days.

1.4 EXPLORATION HISTORY:

Approximately 3300 kms of seismic data has been acquired and two exploration wells have been drilled. Initial exploration began in 1973 with the acquisition of 12 fold Vibroseis data by Amoca over the northern part of the area.

However, the main phase of the exploration activity began in 1987, when Lasmo conducted a 60 fold, reconnaissance Vibroseis survey over the Tajjal License. Following the acquisition of infill surveys in 1988, the Kadanwari-1 gas discovery was drilled in 1989. This was followed by the successful Gorwar-1 (1990), Kadanwari-3 (1991) and Kadanwari-4 (1991).

Chapter-2
REGIONAL SETTING

Study area is a part of Lower Indus basin located on northwest margin of Indo-Pakistan Plate. The basin is bounded by Ornach-Nal Fault in West and Arravalli Range in East, while it extends to South in the offshore region. The Mari High and the sulieman fold belt are feature present in the North shown in fig 4.

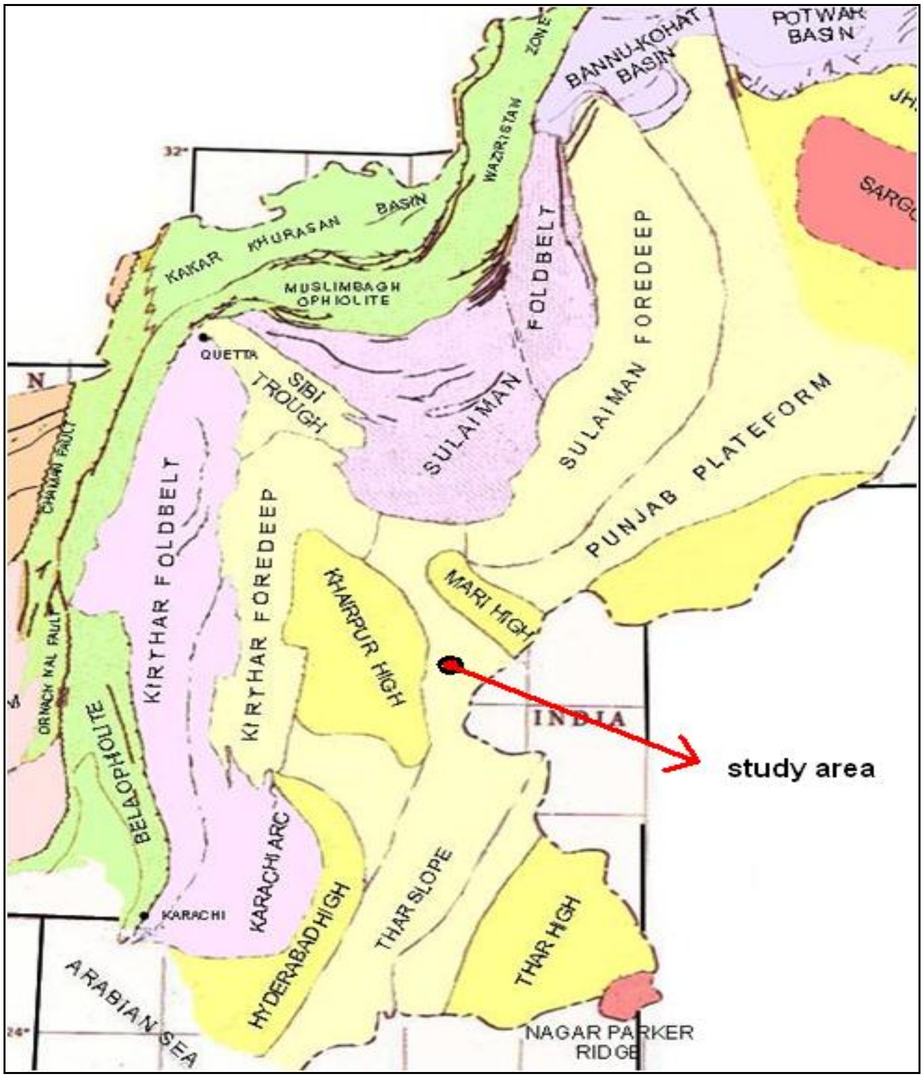

Figure 4: Tectonic map of Lower Indus Basin

The Lower Indus basin has been subdivided into a platform region in East which is juxtaposed by the kirthar foldbelt in West. The major broad structural feature present in the near vicinity of the study area includes Mari High in the north, Khairpur High in the west and Thar slope in the South. The study area occupies a part of Sargarh Depresion which straddles a continental crust at base from the Indian Shield and is overlain by thick Pre-Cambrian, Paleozoic, Mesozoic and Cenozoic sedimentary cover.

This sedimentary cover is deformed into extensional and transtensional features generally trending NNW. The structural styles preserved is the result of Mesozoic rifting and subsequent drifting of Indo-Pakistan plate from Madagascar and Seychelles Mascarene plateau.

2.1 TECTONIC HISTORY AND STRUCTURAL STYLES:

The basinal history of the study area is related to rifting and breakup of Gondwana in the Jurassic Period. In the Cretaceous, East Gondwana (India-Antarctica- Australia) separated from the West Gondwana (Africa-South America). The Indian Plate separated from East Gondwana in Aptian Time (120 Ma). Jurassic or earlier extensional tectonics and failed rifting along the Indus River contributed to a postulated deep-seated shear zone and horst-and-graben regime and later, a division of the greater Indus Basin into three sub basins at the Mari-Kandhkot and Sargodha structural highs (fig. 5) (Kemal and others, 1992; Zaigham and Mallick, 2000). During Early Cretaceous time the Indian plate drifted northward, entering warmer latitudes (fig. 6). On the western shelf, marine shales, limestones, and near shore sandstones of the Lower Cretaceous Sembar and Goru Formations were deposited over a regional erosional surface on the Sulaiman Limestone Group.

Northward plate movement continued during the latest Cretaceous, and a transform fault became active along the Ninety-East Ridge (fig. 7). Rifting between Madagascar and the Seychelles initiated formation of Mascarene Basin.

Extensional faulting occurred or was reactivated as the western part of the Indian plate sheared southward relative to the main plate (Kemal and others, 1992). Counter-clockwise rotation of the Indian plate was initiated, and the Seychelles portion of the Indian plate began to break away (Waples and Hegarty, 1999). Cretaceous time also brought to western India intense volcanism, expulsion of the Deccan Trap basalts, and further rifting, which began and then failed, leaving the Cambay and Kutch Grabens just south of the Lower Indus Basin floored with the Deccan Trap basalts (Biswas and Deshpande, 1983). The rifting event in the Cambay and Kutch areas may be tectonically related to the extensional faulting and shear zone that was developing in the southern Indus Basin area (Sarwar, oral commun. 2001).

Oblique convergence of the Indo-Pakistan plate with the Afghan and other microplates resulted in wrench faulting and development or reactivation of regional arches such as the Jacobabad and Sargodha Highs in the Indus Basin (Kemal and others, 1992) (fig. 6).

The regional base Tertiary Unconformity is due to thermal doming associated with the separation of the Seychelles and Madagascar from India. After the Paleocene, there a continuing oblique convergence of India and Asia throughout Tertiary time and the collision of India with Asia caused a westward tilting of the entire region.

The Jacobabad-Khairpur High on which the study area is located, developed by domal uplifting in during the Early Cretaceous and later on along deep seated faults in the Late Cretaceous and Paleocene. During Eocene time there was submergence and by Oligocene it was uplifted again and then leveled by molasses deposition in Miocene to recent time in the newly developed alluvial fans of a major river system due to the uplift of the Himalayas. (Fig 9 - 10).

The presence of Jurassic rocks in the area show deposition during rifting. The drifting of East Gondwana began in the Early Cretaceous and with continued deposition on the marginal slopes of the northward drifting Indian plate till early the Tertiary. The collision of India and Asia took place in phases at the end of Cretaceous and the Tethys became closed during the Paleocene-Eocene. The spur of the Tethys is now marked by exposure of ophiolites along the axial belts.

The study area has been evolved through above mentioned tectonic events and as a result the stratigraphic units from Pre-Camb-Mesozoic and Paleogene have been deformed by more than one episode. The structural style prevailed in the area show transtensional features which have been developed after the extensional stage.

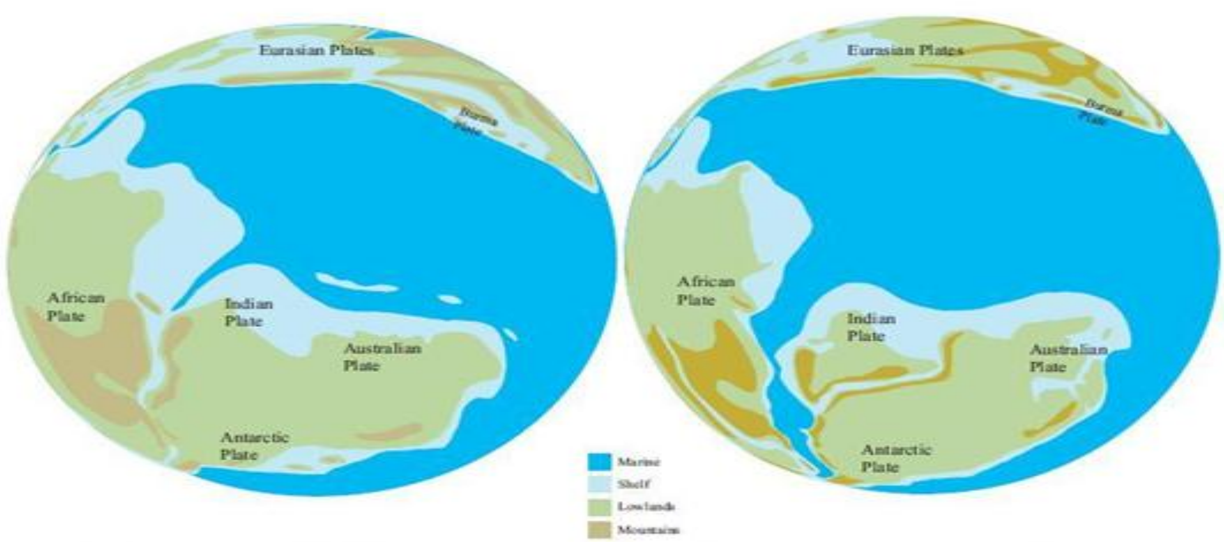

Figure 5 Middle Jurassic (approximately 166 Ma). Perspective lat 20°S., long 68°E. (modified from Scotese and others, 1988).

Figure 6 Early Cretaceous (approximately 130 Ma). Perspective lat 20°S., long 68°E. (modified from Scotese and others, 1988).

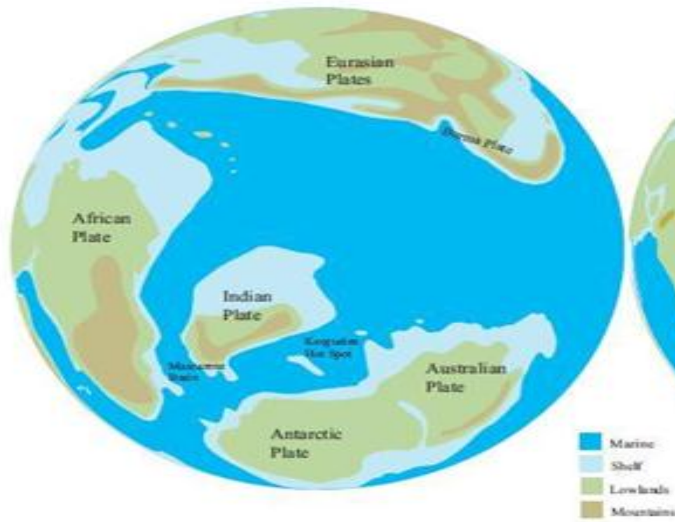

Figure 7 Late Cretaceous (approximately 94 Ma). Perspective lat 20°S., long 68°E. (modified from Scotese and others, 1988).

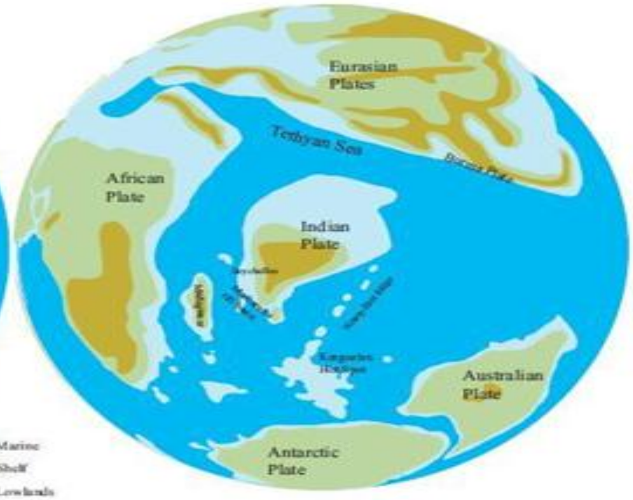

Figure 8 Latest Cretaceous (approximately 69 Ma). Perspective lat 20°S., long 68°E. (modified from Scotese and others, 1988).

Figure 9 Middle Eocene (approximately 50 Ma). Perspective lat 20°S., long 68°E. (modified from Scotese and others, 1988).

Figure 10 Late Oligocene Epoch (approximately 27 Ma). Perspective lat 20°S., long 68°E. (modified from Scotese and others, 1988).

2.2 STRATIGRAPHY:

2.2.1 Pre-Mesozoic:

The study area comprises Pre Cambrian, Paleozoic, Mesozoic and Cenozoic rocks which has been drilled and are reported from the outcrops in the west. The Pre-Cambrian-Paleozoic section has been drilled only in the east of Lower Indus basin. Generally this section represents more or less same rock units present in the other parts of Indus basin. The recent work is more focused to Mesozoic and Cenozoic section and is supported by well data (Gorwar-1), therefore we are taking into account detail description of the stratigraphy.

2.2.2 Mesozoic:

Triassic:

2.2.2.1 Wulgai Formation:

Age: Early to late Triassic

Contact: The lower contact with Marvi basalt is unconformable.

Environment: Deep Marine.

Lithology: It has 3 members

- Shale, marl and limestone member
- Shale, limestone and sandstone member
- Clay, shale, mudstone and sandstone.

Beneath the Wulgai formation, the lithology up to salt range has been encountered in Marvi-1 well. No stratigraphic report of this well is available. The Permian Marvi basalt found in the Marvi-1 well is named after it because no volcanic rock is reported in whole in Indus basin of this age.

Jurassic:

2.2.2.2 Shirinab Formation:

Age: Early to Middle Jurassic

Contact: The lower contact with Wulgai Formation is conformable.

Environment: Marine.

Lithology: It has 3 members.

- Spingwar member
- Loralai member
- Anjira member.

It is composed of limestone and shale intercalation. Shale is light grey, grey, dark gray, greenish grey, slightly indurated to well indurated, splintery, sub fissile, flaky, blocky, at places silty, pyritic. Slightly non-calcareous and limestone is dark color, medium to hard and occasionally soft, locally marly, chalky and fossiliferous.

2.2.2.3 Chiltan Formation:

Age: Middle to Late Jurassic

Contact: The lower contact with Shirinab Formation is confirmable.

Environment: Shallow marine.

Lithology: Massive dark limestone, Pisolitic limestone, oolitic, reefoid and shally.

Limestone is off white, whitish grey, cream, yellowish brown, medium hard to hard, occasionally soft, crypto crystalline, locally marly, chalky and fossiliferous.

Cretaceous:

2.2.2.4 Sember Formation:

Age: Early Cretaceous

Contact: The lower contact with Chiltan Formation is confirmable.

Environment: Deep marine.

Lithology: Shale with subordinate sandstone.

Sember has black silty shale with black siltstone & nodular rusty argillaceous L.S. Glauconite also present.At base pyritic & phosphitic nodules & sandy shale also formed.

2.2.2.5 Lower Goru Formation:

Age: Cretaceous

Contact: The lower contact with Sembar Formation was not penetrated

Environment: Shallow marine - deltaic deposits.

Lithology: Sandstone with subordinate shale, marl, siltstone and rare Limestone

Sandstone is white, off white, creamy, dirty white, light grey, grey, brownish white, pinkish white, translucent to transparent, friable, medium hard, locally loose, occasionally hard to very hard, fine to medium grained, occasionally very fine grained, at places coarse to very coarse grained, sub angular to sub rounded, moderately to poorly sorted and poorly to fairly cemented, micaceous, glauconitic, occasionally pyritic, at places argillaceous, and slightly to non-calcareous. Shale is light grey, grey, dark grey, light greenish grey, soft to moderately indurated, in places well indurated, splintery, sub fissile, blocky, occasionally pyritic, Non calcareous.

Marl is ash grey, grey, whitish grey, soft to firm, occasionally medium hard, arenaceous, pasty, sticky, soluble, hydrophilic, and pyritic. Siltstone is light grey, whitish grey, brownish grey, medium hard, at places hard, pyritic, micaceous, locally grading to very fine grained sandstone, and calcareous. Limestone is mudstone, off white, white, light brown, soft to medium hard, cryptocrystalline.

On the basis of relative proportions of different lithologies, the formation can be subdivided into following four sections. In Gorwar well Lower Goru formation found at depth of 2545 meters and its thickness is 1075 meters.

2.2.2.5.1 Upper Sand, Shale and Marl Sequence

Lithology: Shale with subordinate siltstone, sandstone, marl and rare limestone. Shale is light grey, grey, dark gray, greenish grey, slightly indurated to well indurated, splintery, sub fissile, flaky, blocky, at places silty, pyritic. Slightly to non-calcareous.

Sandstone is white, dirty white, light grey, brownish white, translucent to transparent, friable, medium hard, locally fine to very fine grained, at places medium grained, sub angular to sub rounded, moderately to poorly sorted and cemented, calcareous, micaceous, glauconitic, at places argillaceous and grading to siltstone, occasionally pyritic, visual porosity poor to fair with occasional to no hydrocarbon shows. Siltstone is whitish grey, light grey, dirty white, medium hard, blocky, very highly argillaceous, pyritic, micaceous and calcareous. Marl is Whitish grey ash grey; light grey, soft to firm, arenaceous, rarely moderately indurated, pasty, sticky, soluble and hydrophilic. Limestone is off white, white, light brown, soft to medium hard, cryptocrystalline, pyritic and argillaceous. E sand is more or less part of the upper sand.

2.2.2.5.2 Basal Sands (Lower Goru Formation)

Lithology: Sandstone with interbedded shale.

Sandstone is brownish white, white, transparent to translucent, generally friable, medium hard, medium to fine grained, occasionally coarse grained, sub angular to sub rounded, moderately sorted and poorly to moderately cemented, fairly argillaceous matrix, at places micaceous and calcareous. Visual porosity is 10-12%. Fluorescence: direct is dull yellow; scattered, patchy and poor, indirect is white, milky white streaming cut.

Shale is grey to dark, grey, soft to firm, occasionally medium hard, sub fissile, locally fissile, locally silty, at places pyritic and calcareous. Albian sand is more or less part of Basal sands.

2.2.2.5.3 Talhar Shale (Lower Goru Formation)

Age: Cretaceous

Lithology: Shale with thin bands of siltstone

Shale is dark grey, brownish grey, blackish grey, occasionally greenish grey, firm, moderately indurated, blocky, silty, locally highly silty, pyritic, rarely micaceous and pyritic and slightly calcareous.

Siltstone: is grey, light grey, medium, blocky, locally grading to very fine grained sandstone, rarely glauconitic, slightly calcareous.

2.2.2.5.4 Massive Sandstone (Lower Goru Formation)

Age: Cretaceous.

Lithology: Sandstone with subordinate shale and siltstone.

Sandstone is off white, brownish white, dirty white, light grey, medium hard to hard, rarely friable, occasionally very hard, fine to medium grained, at places coarse to very coarse grained, in places is very fine grained, sub angular to sub rounded, moderately sorted, moderately to fairly cemented with calcareous/siliceous material, locally argillaceous and pyritic, calcareous to non-calcareous. Visual porosity is poor to fair. At different intervals direct fluorescence is pale yellow, scattered and spotted and indirect is milky white, yellowish white, slow-moderate streaming to residual ring.

Shale is dark grey, brownish grey, greenish grey, firm, moderately to well indurated, splintery, blocky, sub fissile, silty, rarely micaceous and pyritic, and rarely glauconitic and slightly to non-calcareous.

Siltstone is brownish grey, dirty white, medium hard to hard, locally grading to very fine grained sandstone, glauconitic and pyritic, rarely micaceous.

2.2.2.6 Upper Goru Formation:

Age:	Cretaceous
Contact:	The lower contact with Lower Goru Formation is conformable
Environment:	Marine, transitional, sub-littoral.
Lithology:	Marl with subordinate shale.

Marl is whitish grey, light grey, brownish grey, soft to firm, occasionally medium hard, pasty, sticky, soluble, hydrophilic, locally silty, at places pyritic.

Shale is light grey, light greenish grey, soft to moderately indurated, blocky, splintery, silty, pyritic, and slightly calcareous.

In Gorwar well thickness of upper Goru is 543.5 and it found at depth of 2001 meters.

2.2.3 Paleocene

2.2.3.1 Khadro Formation:

Age: Paleocene

Contact: The lower contact with Parh Formation is unconformable.

Environment: Marine.

Lithology: Basalt and Sandstone with interbedded Clay/Claystone.

Basalt of Khadro Formation is dark grey, occasionally light greenish grey, hard, compact, and porphyritic, sub vitreous.

Sandstone is white, transparent, friable, and occasionally medium hard, medium to course grained, at places very coarse grained, sub angular to sub rounded, moderately sorted and poorly cemented, slightly calcareous.

Clay/claystone is earthy brown, brick red, reddish brown, and soft, sticky, hydrophilic, partly moderately indurated, and silty, non-calcareous.

On the basis of relative proportions of different lithologies, the formation can be subdivided into following two sections.

The upper section from 1571m to 1587m consists of basalt with subordinate clay/claystone. The lower section, from 1587m to 1650m comprises mainly sandstone with subordinate interbeds of clay/claystone.

After the depth of 1522 meters in Gorwar Well Khadro formation comes where its thickness is 479.5 meters.

2.2.3.2 Ranikot Formation (Lakhra and Bara Formation)

Age: Paleocene

Contact: The lower contact with the Khadro Formation is conformable.

Environment: Continental - Shallow marine (mixed facies).

Lithology: Sandstone, shale with interbeds of clay/claystone and limestone.

Sandstone is white, transparent, occasionally translucent, rarely pink, loose to friable, medium to course grained, occasionally very coarse grained, sub-angular to sub-rounded, moderately to poorly sorted, poorly cemented, at places argillaceous and slightly to non-calcareous.

Shale is grey, dark grey, black, occasionally brownish grey, soft to moderately indurated, partly well indurated, splintery, blocky, sub fissile to sub fissile, locally pyritic, rarely silty and slightly calcareous.

Limestone is off white, whitish grey, cream, yellowish brown, medium hard to hard, occasionally soft, crypto crystalline, locally marly, chalky and fossiliferous.

Clay/claystone is reddish brown, brick red, grey, soft, pasty, sticky, soluble and hydrophilic, occasionally silty and slightly too non calcareous.

On the basis of relative proportions of different lithologies, the formation can be subdivided into following two sections.

The upper section from 1163m to 1295m consists of shale with subordinate interbeds of clay / claystone with sandstone. The middle section, from 1295m to 1340m comprises limestone streaks of sandstone with thin bands of shale. The lower portion, from 1340 to 1571 m, comprises of sandstone with alternations of clay / claystone.

Ranikot Formation was drilled in Gorwar well at depth of 1345 meters and its thickness is 177 meters.

2.2.4 Eocene

2.2.4.1 Laki Formation (Sui Main Limestone and Shale)

Age : Eocene

Thickness : 545 meters approximately.

Contact : The lower contact with Ranikot Formation is unconformable.

Environment : Shallow marine.

Lithology : Limestone with interbeds of marl and shale.

Limestone is white, off white, cream, and grayish white, soft to medium hard, rarely hard, crypto-crystalline, in places marly, chalky, and argillaceous, rarely fossiliferous.

Marl is dirty white, milky white, light grey, whitish grey, soft, pasty, sticky, soluble, hydrophilic and lumpy.

Shale is dark grey, greenish grey, occasionally brownish grey, soft to moderately indurated, partly well indurated, splintery, occasionally blocky, sub fissile, rarely pyritic and locally silty and slightly calcareous.

On the basis of relative proportions of different lithologies, the formation can be subdivided into following sections.

The upper section from 618m to 960 m consists of limestone with subordinate interbeds of marl and shale. The middle section from 960 m to 1100m comprises shale with intercalations of limestone and marl. The lower portion from 1100 to 1163 m comprises limestone with minor marl.

2.2.5 Post Eocene

2.2.5.1 Siwalik:

Age: Post Eocene.

Contact: The lower contact with the Laki Formation is unconformable.

Environment: Alluvial.

Lithology: Sandstone with streaks of Clay/Claystone

Sandstone is white, multicolored, loose, friable, medium to coarse grained, at places fine grained, sub-angular to sub-rounded, moderately to poorly sorted, rarely pyritic, micaceous and slightly to non-calcareous.

Clay/claystone is khaki, earthy brown, yellowish brown, pinkish grey, reddish brown, soft, sticky, pasty, soluble, hydrophilic and calcareous.

Conglomerate is yellowish white, dark yellow; cream, off white, medium hard to hard, compact, embedded in clay matrix.

Siwaliks were drilled in Gorwar well 1 where its thickness is 293.3 meters and top comes at depth of 7.8 meters.

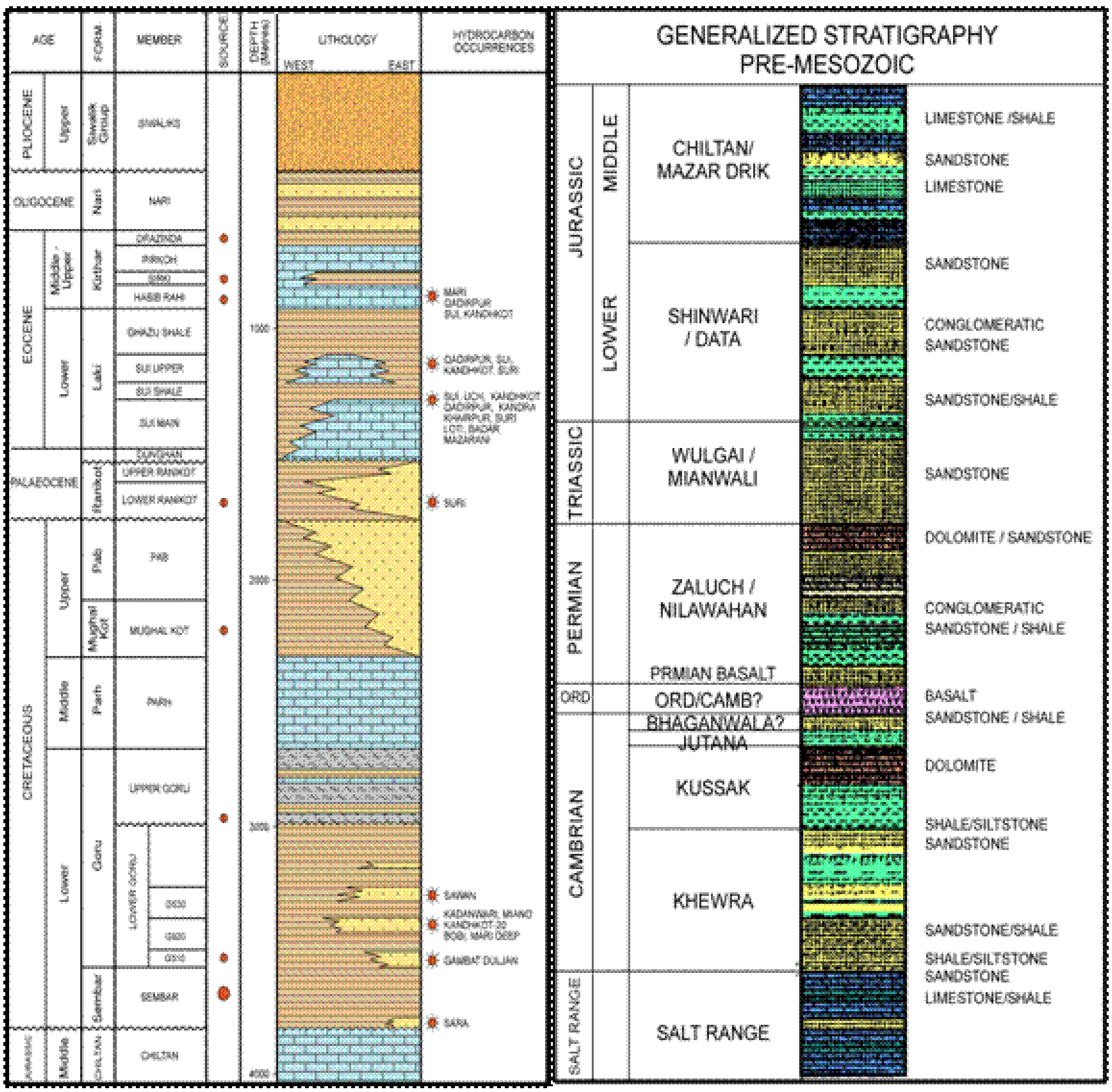

FIGURE 11: Generalized Stratigraphy of Study Area.

2.3 Hydrocarbon potential in Lower Indus Basin:

Lower Goru and Sembar formations are considered as potential reservoir rock in Lower Cretaceous siliciclastics of Lower Indus Basin. Lower Goru sandstone is the reservoir rock in the study area. The presence of gas in the study area signifies the possibility of oil from the Early Cretaceous Sembar, which acts as a source rock as well as reservoir. All producing well in the study area are of type 3-Kerogen source rock.

The shale unit of Sembar and Upper Goru provides the regional seal for Cretaceous Lower Goru reservoir rock.

2.3.1 Source Rocks:

The Early Cretaceous marks Northward movement of the Indian Plate when Sembar Formation was being deposited in an environment of shallow sea with influx of detrital material coming from Indian Shield. Due to relative quiescence during this period the Sembar Formation is widespread in the basin and occurs virtually throughout the Lower Indus Basin.

Shales of Sembar and Lower Goru Formations have been established as main source rocks in Lower and Middle Indus basin (Raza et al, 1989 & 1990; Saqi and Jamil. 2000) and are believed to be main source of dry gas in the study area; however carbonates and shales of deeper horizon may also act as source. The geothermal gradient in the region ranges from 2.0c/100m to 4.0 c/100m (Khan and Raza, 1986). The gas window is in the range of 2625m to 5250m, compatible with depth range of Sembar, Lower Goru and deeper horizons source rocks at various structural positions, created due to rifting. Lower Goru and upper Goru act as Source rock as well as cap rock in area of study.

2.3.2 Reservoir Rocks.

The most prospective reservoirs in this region are cretaceous sandstones (Sembar-Goru and Pab sandstones), Paleocene Ranikot formation sandstones and Eocene Sui Main limestone.

The principle reservoirs are deltaic and shallow-marine sandstones in the lower part of the Goru in the Lower Indus Basin. Potential reservoirs are as thick as 400m. The depth of these reservoirs is about 2400 meter according to the formation tops data of Gorwar well.

2.3.3 Seals:

The known seals in the system are composed of shales, which are interbedded with sands and overlying the reservoirs. In producing fields, thin shale beds of variable thickness are effective seals. Additional seals that may be effective include impermeable seals above truncation traps, faults, and updip facies changes. The Upper Goru shale and interbedded shales of Sui Main Limestone are acting as a seal in study area.

2.3.4 Traps:

The traps in study area are mainly structural, caused by extension followed by transtensional events. These provide the significant trapping system along tilted fault blocks and negative flower structures. But the most prominent traps are associated with transtensional products (Negative flower structures) forming closures in the forms of Highs.

Chapter-3

Seismic Acquisition and Processing

3. Seismic Acquisition:

3.1 Seismic Acquisition Basics:

Seismic Acquisition is a process of acquiring data from field; it may be onshore (on surface of earth) or offshore (in ocean). In acquisition elastic waves are produced through source and response of the earth is recorded with the help of receivers. The result of elastic waves is reflector where difference of velocity and density occur known as acoustic impedance.

3.1.1 Seismic waves:

Seismic Waves are messengers that convey information about the earth's interior. There are two types of the seismic waves.

3.1.1.1 Body Waves:

Seismic wave's moves through the body of substance these are dived into P and S the most basic kinds of seismic wave's .In P waves pulse moves through a rock layer, particles vibrate back and forth in the direction of wave motion, whereas in S waves they move perpendicular to the direction of the motion of particles. In nature Vp > Vs, these waves are experienced near to the surface of the earth (fig. 12).

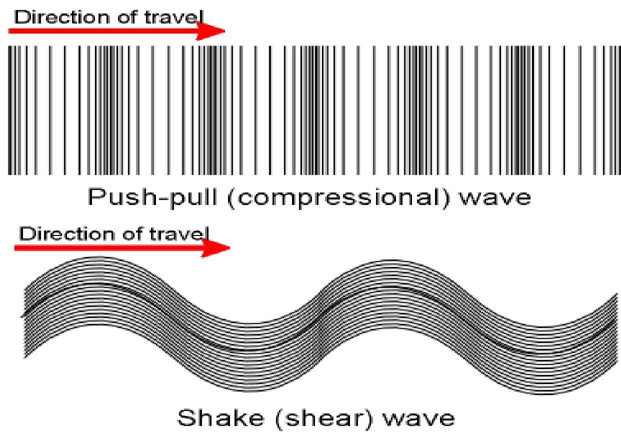

Figure 12: Direction of wave motion.

3.1.1.2 Surface Waves:

These waves move along the boundaries of the rocks and divided into two types. Rayleigh waves involve ground movement in vertical plane aligned with the path of the wave. Second type of surface wave is Love waves that cause horizontal ground movement perpendicular to the path of the wave. Vibration of these waves increases with time and are slower than the direct waves.

3.1.2 Rays and Wave Fronts:

Waves produced at a point inside a mass of rock are just like the ripples made by tossing a pebble into a quiet pond. Each wave moves away from the point of impact in an ever-expanding circle. The circle at outer edge of an advancing wave marks the wave front. Lines drawn outward are rays that show directions along which the wave is advancing.

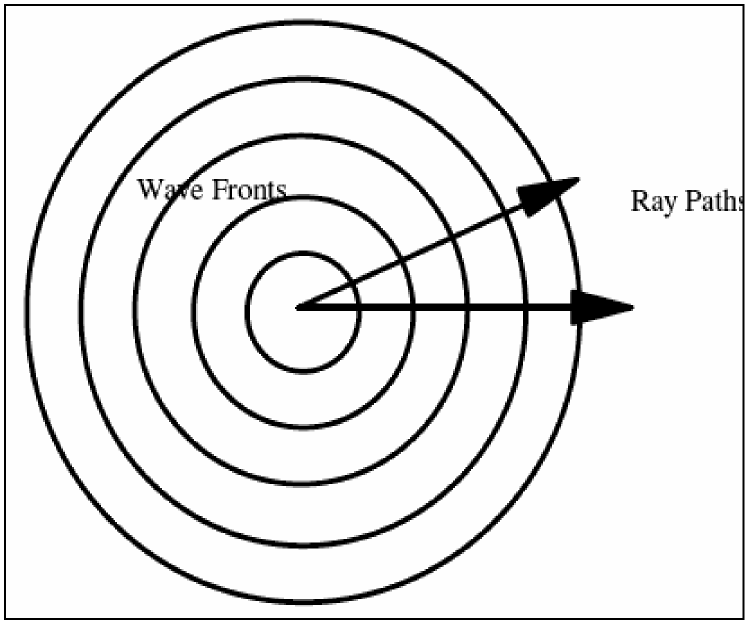

Figure 13: Wave fronts

3.1.3 Wave Conversion:

When a wave reached at the boundary of the two substances where there is difference of velocity and density called acoustic impedance it divided into reflected and refracted wave. The wave which bounce is called reflected and the wave which passes away is called refracted. The original wave that hit the boundary is Incident wave. The amounts of the wave that will reflect or refract depend upon the coefficient of reflectivity, coefficient of transmission and acoustic impedance.

3.1.4 SEISMIC METHODS:

3.1.4.1 SEISMIC REFRACTION METHOD:

Seismic refraction is a geophysical principle governed by Snell's Law. Used in the fields of engineering geology, geotechnical engineering and exploration geophysics, seismic refraction traverses (seismic lines) are performed using a seismograph(s) and/or geophone(s), in an array and an energy source. The seismic refraction method utilizes the refraction of seismic waves on geologic layers and rock/soil units in order to characterize the subsurface geological conditions and geologic structure.

The methods depend on the fact that seismic waves have differing velocities in different types of soil (or rock): in addition, the waves are refracted when they cross the boundary between different types (or conditions) of soil or rock. The methods enable the general soil types and the approximate depth to strata boundaries, or to bedrock, to be determined.

a: P-Wave Refraction (Compression Wave Refraction):

P-wave refraction evaluates the compression wave generated by the seismic source located at a known distance from the array. The wave is generated by vertically striking a plate with a sledgehammer, shooting a seismic shotgun in to the ground, or detonating an explosive charge in the ground. Since the compression wave is the fastest of the seismic waves, it is sometimes referred to as the primary wave and is usually more-readily identifiable within the seismic recording as compared to the other seismic waves.

b: S-Wave Refraction (Shear Wave Refraction):

S-wave refraction evaluates the shear wave generated by the seismic source located at a known distance from the array. The wave is generated by horizontally striking an object on the ground surface to induce the shear wave. Since the shear wave is the second fastest wave, it is sometimes referred to as the secondary wave. When compared to the compression wave, the shear wave is approximately one-half the velocity depending on the medium.

3.1.4.2 SEISMIC REFLECTION METHOD:

Geological layers can be mapped using the seismic reflection method. This can be done using either an S or Shear wave source or a Primary or Compressional wave seismic source. Compressional wave sources range from a simple hammer and base plate, to black powder and conventional explosive sources, to vibrators. For relatively shallow investigations, a hammer and base plate, weight drop, and black powder sources can be used. The actual depth of investigation depends on the geology and site conditions, but can be 50 m and deeper. For deeper investigations, a small vibrator can be used. Seismic sources, producing either vibrations or impulses can be used for seismic reflection surveys. Special processing techniques are applied to the vibrational sources to make the resulting data compatible with impulse sources.

Seismic reflection involves using a surface seismic source to create a seismic wave, which then travels into the subsurface. At interfaces that have an impedance contrast (related to velocity and density), a portion of these waves is reflected back to the ground surface, and a portion is transmitted through the interface. Geophones on the ground surface record these reflections. The signals at two geophones are illustrated to the right of the ray path diagram given below. The reflection from the interface between layers 1 and 2 arrives first at geophone 1. A short time after this arrival, the same interface provides a reflection that arrives at geophone 2. Sometime later, the reflection from the boundary between layers 2 and 3 arrives at geophone 2.

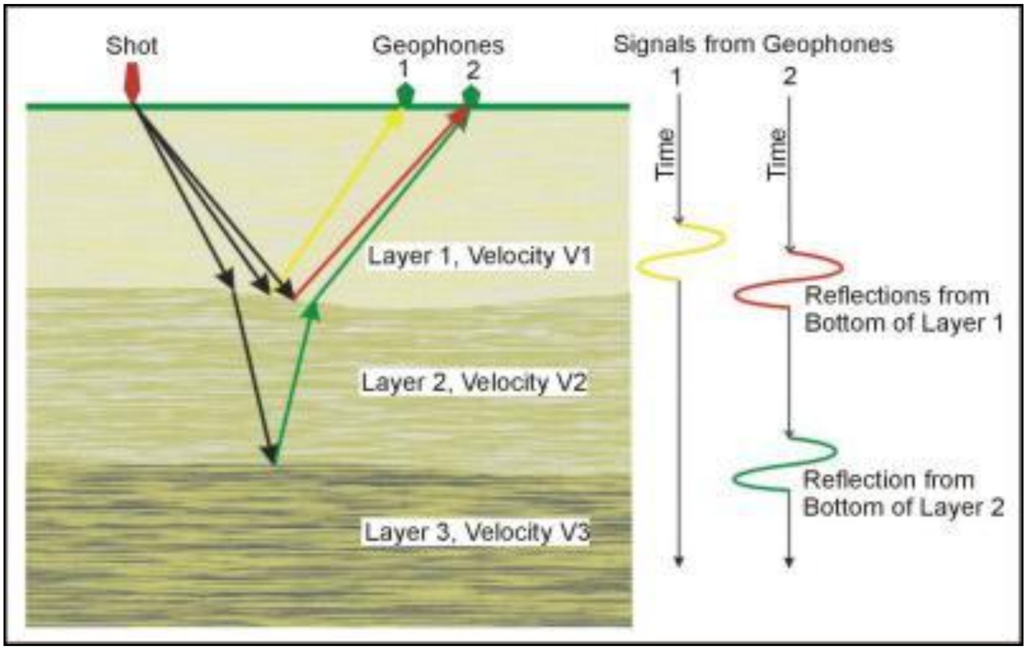

Figure 14: Two way travel path of seismic waves.

3.1.5 Basic Seismic Laws:

3.1.5.1 Law of Reflection:

Law of Reflection is one of the simplest rules in science. It states that when an object bounces off a flat surface, the angle it at which it hits the surface will be equal to the angle at which it bounces away.

The angles are named this way:

- The angle at which the object hits the flat surface is called the angle of incidence (I).
- The angle at which it rebounds from the flat surface is called the angle of reflection (R).

Both angles are measured from the path of the object to the normal line, which is a line perpendicular to the surface at the point of impact.

Incident ray, reflected ray and normal to the reflecting interface at the point of incidence are coplanar.

3.1.5.2 Snell's Law:

It is mathematical description of the refraction or physical change in direction of a wave front as it travels from one medium to another medium with a change in velocity and particle conversion and reflection of P wave to S wave at interface of two medium. It is named after a Dutch mathematician.

3.1.5.3 Format's Principle:

The path taken by light ray from one point to another is that which takes minimum time (or maximum time in relative cases). It is named after French mathematician.

3.1.5.4 Huygens Principle:

This Principle states that every point on wave front can be considered as a source of new secondary wave front. The wave front at any latter time is the surface tangent to the new spherical waves.

3.1.6 Types of Seismic Velocities:

1. P Wave Velocity.
2. Average Velocity.
3. RMS (Root Mean Square) Velocity.
4. Interval Velocity.
5. Dix Interval Velocity.
6. Stacking Velocity.
7. Migration Velocity.

3.1.7 Factors Effects Seismic Velocity:

1. Fluid Content
2. Pressure and temperature.
3. Density and Elasticity.
4. Porosity
5. Packing of Grains
6. Compaction and Cementation of Strata
7. Age of Rocks / Lithologies.
8. Depth of strata.

3.1.8 Basic Instruments:

3.1.8.1 Source:

In seismic Acquisition Source is used to generate the seismic waves. There are two types of the sources, explosive (dynamite) and non-explosive (vibroseis), used in field. Vibroseis is truck which generates the vibrations. Dynamite is explosive material which is generating vibration inside the earth. Due to explosive material it is used in subsurface by drilling a hole, depth of hole depend upon the thickness of the weathering layer, size of charge depend upon the area complexity and structure in the area and depth of the target horizon.

3.1.8.2 Receiver:

Instrument used for receiving the reflected seismic waves, also called Geophone, detector, or seismometer. It is in direct contact with the earth which converts the motion of the earth into electrical signal. These signals constitute the input into an instrumental system the end product of which is the presentation of sub surface geological information in visible form on seismic section.

3.2 Acquisition Parameters in Study Area:

The area of study lies in Kadanwari and seismic section studied are following with general detail of acquisition parameters used are given below.

Seismic Lines are shown in table 2

1-	TJ 89 – 512	Dip Line.
2-	TJ 89 - 518	Dip Line.
3-	TJ 89 – 520	Dip Line.
4-	TJ 89 – 526	Dip Line.
5-	TJ 89-503	Strike Line.

Table 2: Seismic lines used.

3.2.1 General Acquisition Parameters Used in Seismic Sections:

Detail of seismic section used, source and receiver's parameter is given in table 3.

Acquisition Parameters	**TJ 89-503**	**TJ 89 – 518**
Date recorded	DEC 1989	NOV 1989
Crew	SSL	SSL
Instrument	SERCEL SN 348	SERCEL SN 348
Format	SEG – B	SEG – B
Coverage	12000%	6000%
Sample Rate	4.0 MSEC	4.0 MSEC
Record Length	6.0 SEC	6.0 SEC
SOURCE INFORMATION		
SOURCE	VIBROSEIS	VIBROSEIS
NO OF SWEEPS PER STATION	04	04
SWEEP FREQUENCY	15 – 80 HZ	15 – 80 HZ
SWEEP LENGTH	10 SEC	10 SEC
V.P INTEVAL	25 M	50 M

RECEIVER INFORMATION		
NUMBER OF CHANNELS	240	120
GROUP INTERVAL	25 M	50
GEOPHONES PER GROUP	24 (04 STRINGS OF 06 GEOPHONES)	36 (4 STRINGS OF (GEOPHONES EACH)
GEOPHONE SPACING	4.17 M	
TYPES OF SPREAD	SYMMETRIC SPLIT SPREAD	
NEAR OFFSET	+/- 62.5 M	
FAR OFFSET	+/- 3037.5 M	

Table 3: Detail of Seismic lines, source and receiver.

3.3 Seismic Processing:

It is based on the sequence of computer programs, each designed to achieve one step along the path from field tape to record section. Reduce the seismic data by removing the noise, unwanted information, and enhanced the signal, wanted information. There are two types of noise recorded on geophones.

3.3.1 Coherent Noises:

Noise which is co-relatable from one trace to next is called coherent noise such as Ground roll (composed of Rayleigh waves & Love waves) refractions, multiples, side sweeps, are examples of Coherent noise.

3.3.2 Ambient /Incoherent Noise:

It is noise which is random in nature, also refers as unpredictable. Examples include wind, a running factory, and busy road, and distant storm, human or animal activity. As main purpose of the processing is to suppress the noise and enhance the signal for which different filters are used

3.3.3 Filters:

Filters are computer programmers which are used to cut down the unwanted signals or noises. Types of filters are **High cut Filter used** to cut the high frequency and pass the low frequency. It is also called low pass filter. **Low cut Filter** it is used to cut the low frequencies and pass high frequencies. It is also called the high pass filter. **Band pass filter** it allows passing a specific range of frequency and cutting frequencies above and below that range. **Notch Filter** it is used for removing the effect of high extension wires on specific geophones cause the noise. It frequency ranges from 50-60 HZ.

3.3.4 Processing sequence Applied on sections is as fallow:

I. **Transcription:** Process to transform the data from field format to industrial format, SEG Y to ProMax. Format.

II. **Editing:** Editing of the bad traces, due to disturbance or tilt of the geophones (not properly installed).

III. **True Amplitude Recovery:** Application of the Automatic Gain Control to recover the loss of amplitude due to spherical divergence.

IV. **Statics:** In statics two types of the correction are applied weathering and elevation. In weathering loss of amplitude due to loss unconsolidated material in upper surface of Earth is removed whereas in elevation ups and downs on earth surface which cause delay of reflection on some Geophones is adjusted by selecting a datum.

V. **Deconvolution:** This correction is applied for removing the effect of earth filter on a spike which elongated by earth and cover important deeper information.

VI. **Velocity Analysis:** This process is applied for the application of NMO during staking process.

VII. **NMO:** Normal Move out correction this process remove the hyperbolic form in TX graph due to delay in arrival time of reflectors caused by horizontal offset of geophones.

VIII. **Stack:** Process of adding that reflection that share the same CMP on surface of earth or CDP in subsurface but have different source and receiver pairs.

IX. **Migration:** Migration is applied for three purposes:

1. Repositioning
2. Refocusing
3. To collapse diffraction

Chapter-4
Interpretation

4.1 Data Base:

The following seismic data including seismic lines and well data of study area are provided for interpretation. The names of the seismic lines and wells data are given below:

Seismic Lines	**Well Data**
TJ89-512 - 13.95 Km	Gorwar-1
TJ89-518 - 17.47 Km	Kadanwari-1 (For check shotdata)
TJ89-520 – 17.34 Km	
TJ89-526 - 12.31 Km	
TJ89-503 – 34.11 Km	

Total distance of 95.18 Km on seismic lines were used for the interpretation.

4.2 Data Quality:

To carry out this study, 11 seismic lines of 90 fold 2D seismic data from LMK Resources by the permission of Directorate General of Petroleum Concession (DGPC) were acquired. Among these 11 lines, data of four dip lines (TJ89-512, TJ89-518, TJ89-520 and TJ89-526) and a strike line (TJ89-503) were used. Check shot and well data of Kadanwari-1 and Gorwar-1 was also obtained. Check shot of the well helped in picking the reflector of the desired formation. A base map of study area was also obtained.

The data quality was fair to good and processing parameters were applied properly. Few seismic lines showed smiley structures at depth depicting the poor migration of the data. The data stacking was also done properly, and data was in paper form, not digital one.

4.3 Misties:

Misties occur when character of the reflector on the strike line does not match with character of the same reflector on the dip line. They may be due to several reasons including difference of processing techniques on different sections, difference in the scale of sections, resolution or magnification issues, difference of datum line. Misties causes the difference of two way travel time of the same reflector on different sections. Misties were removed by adding or subtracting the differences in two way travel time. The sections studied were marked with 20 to 30 milliseconds of misties due to different processing techniques used, poor data quality and due to magnification issues. These misties were removed by adding or subtracting the travel time according to situation.

4.4 Horizon Correlation:

On the time sections, horizons were marked by picking of continuous reflectors running across the sections. Subsurface structural changes or abrupt lithological changes cause great difficulty in marking the continuous reflector because they tend to mix up or break down, the presence of different types of noises was also a problem, such noises causes the distortion of the signal. Therefore, in order to decide that whether the sequence continues towards the upper horizon or the lower, a broader view of the interpreter, knowledge about the area and the considerable experience would help in marking a correct pick.

From check shot data, the velocity and depth of the horizon was obtained by using the formula:

$$S = VT \quad \rightarrow \quad T = S/V$$

The calculated travel time for each horizon was one way, which was converted into two way travel time after multiplying by 2. This time is compared with time of horizon picked on seismic section. This whole exercise was done by keeping in mind mean sea level, NMO datum, height of the rig and Kelly bushing from the surface. These things can cause the difference in the time measured from check shot and seismic section.

4.5 Subsurface Structural Geometry:

The subsurface of study area characterizes deformation related to extensional and transtensional episodes which has been restricted up to a level of Paleocene. The 2-D seismic data interpretation show negative flower structures underlain by Eocene strata which appeared undisturbed and generally form a westward dipping monocline. (fig. 15,16,17,18)

Interpretation of 2-D seismic data show presence of faults and intervening blocks, the faults were picked at the lateral discontinuity of seismic marker on one seismic section and then correlated laterally to next dataset for identification of trend. During the correlation of faults from one line to another the dip of the fault plane was a key tool to establish a fault across the whole data set.

The interpretation of existing seismic data from pre-Jurassic to Albian level show high angle fault geometry which seems to corresponds with the master fault of a negative flower structure, from where the splay faults branch out to shallow level (Post Albian - Paleocene) as seem on seismic lines TJ89-512, 518, 520 & 526, (fig 15,16,17,18). The throw of the fault varies from deeper to shallow level and thus reveals a differential movement of each block and reactivation due to stress and accommodation space. These appear to be a significant throw of master fault and associated splays at the level of post Albian – Cenomanian, which suggests the provision of more accommodation space caused by the shear movement. The key structural trend appears to be NW-SE in direction. The intervening fault blocks appears to form highs and lows in the study area as show by seismic lines TJ89-512, 518, 520 & 526, (fig. 15,161,17,18).

The timing of this structural deformation relates to extensional and transtensional history of Indo-Pakistani plate when separated from Madagascar and Mascarine plateau.

Fault associated structural closure is responsible for trapping of oil and gas in Cretaceous Goru formation sandstone.

4.5.1 Description of TJ89-512:

Figure 15 shows the seismic section of the TJ89-512 which reveals more than one negative flower structure in study area. The horizons are marked by the well data as well as on the reflectors matching of the horizons. The extensional followed by transtensional period is clear in the horizon of Purple, orange, green and red color respectively which unveils that during Cretaceous, Indian plate was in phase of rifting and drifting. The negative flower structure is found in the horizon of Lower Goru formation of late Cretaceous age. The fault system evolves from the Chiltan formation and continues till the Sui Main Limestone (SML).

4.5.2 Description of TJ89-518:

Figure 16 showing the seismic chart TJ89-518 which possesses intricate negative flower systems which are associated with transtensional fault system. The fault pattern in Albian-Aptian is markedly high angle and in upright direction whiles the fault in the shallower horizon of E sand and Top Lower Goru shows marked negative flower structure. The fault throws are of significant amount. The maximum thrown of fault was observed in Albian-Aptian of 0.1second. The dips of faults are mostly in northwest direction. No well has been drilled on this seismic line.

4.5.3 Description of TJ89-520:

Figure 17 showing the seismic chart of TJ89-520 that reveals negative flower structure. The extensional episode followed by transtensional is visible in the Albian-Aptian, E sandstone and Top lower Goru horizons. The Pirkoh horizon is recognized by its reflection clarity. The horizon doesn't have any fault and is dipping in north east direction. The faults are very significant in Cretaceous age horizon in which the Albian-Aptian, E sand and Top Lower Goru formation is included. There are very high angle faults in the Albian Aptian horizon while in the E sand and Top Lower Goru they are low angle which shows negative flower pattern. The shallowest point marked is at SP 140 of 380ms and deepest point is of 520 ms at SP 430. The throw of fault is also remarkable and highest throw is noted to of 0.3 seconds. The average throw is of 10ms. The highest throw in the Albian- Aptian is observed at SP 265 of 15ms while the higest throw in E sand horizon is observed to be of 20ms at SP 228.

4.5.4 Description of TJ89-526:

Figure 18 is about the seismic line TJ89-526 which shows the transtensional fault trend dipping in northwest direction. The horizons are marked by the well data of Kadanwari-1 as well as on the reflector matching of the horizons picked. The limestone of Pirkoh shows good reflection proving the identity of limestone while the reflection of E sand and Albian Aptian is marked weak as compare to Pirkoh horizon reflections. The faults systems are generated from Chiltan formation and the faults are markedly upright and high angle with very low tilt observed in it. In Albian Aptian horizon the faults are in very upright direction and the maximum throw is of 10ms. The deepest point is at SP 210 of 2210ms while shallowest point is of 2180ms at SP 305.

4.6 Compilation of TWT Maps

The primary job of seismic interpretation is to mark the reflectors. Once confirmed through well data correlation, then the structures are marked on section and faults continuity is observed. This provides the detail of a fault trend. The fault is marked by keeping in mind the regional geology of the area.

First faults are marked on the selected horizon. The top most yellow reflector of Pirkoh did not show any fault, it had reflector continuity throughout all the seismic lines cutting the strike line of TJ89-503.

Most faults were seen in the Green and Purple reflector. Green Reflector is E sands of Lower Goru and Purple Reflector is believed to be the Albian Aptian sands according to the check shot and well data.

After marking the faults on reflectors and generating fault trend, travel time was picked after every 20 vibroseis point and along the fault, time of downthrown and up thrown block was also picked. Where the reflector appeared to be horizontal straight, lowest and highest point on the reflector are picked and then used interpolation method to avoid the repetition of the value which cause problem during contouring.

After plotting the value of maximum and minimum time of reflector and marking fault on the specific vibroseis point on the base map, it helped in constructing the fault trend on base map and provides the significant identity of the highs and lows of the structure. Then contouring were started in which the value of equal time joined and finally the structural highs and lows in horst section were defined. This aided us in recognizing the structural closure and trap mechanism due to transtensional faults.

4.6.1 TWT contour Map Top Pirkoh Level

This map was compiled from the horizon pick at the level of Eocene which is a consistent and higher amplitude reflector in seismic data. This reflection is not intercepted by any pre-Eocene Faults thus indicating culmination of transtensional stress regime (fig. 19).

The Pirkoh limestone has a sharp continuous reflection index which signifies the presence of limestone. The Pirkoh is dipping in the East direction with no marked fault observed which reveals the shape of monocline. The highest point is 310ms at VP 110 and lowest point is 520ms at VP 370. The elevation difference between VP 110 and VP 370 is 210ms. The contour interval was 10ms.

4.6.2 TWT Contour Map of E Sand Level

The E sand map was prepared for the horizon marker in green color which is one of the reflectors at upper sands of Lower Goru This horizon is intercepted by number of transtensional faults which can be regarded as a splay of negative flower.

The map shows that the structural trend is aligned to NW in direction where highs and lows are bounded by the faults.

The shallowest point was found at 265 VP of 1800ms and deepest at 160 VP of 1900ms. The throw of faults system was not more than 10ms. The maximum throw was measured at 230 VP with throw of 15 milliseconds.

Highs are mostly associated with fault system. The structural high marked on the horst on line TJ89-524 at VP 300 is very close to the well Kadanwari-1 that has been drilled. 5 highs and 4 lows have been identified in this horizon. The highs on horst have closures that are associated with the fault system (fig. 20).

Description of leads:

1: Lead-1

Lead 1 is located on horst block and evident by seismic line TJ89-518 and TJ89-520, between VP 330 to VP 360 and between VP 305 to 360 respectively (fig. 20). This leads is bounded by a NE and SW trending fault. The last closing contour is of 1640 millisecond and lead is terminating against fault.

2: Lead-2

This lead is observed on structural horst block and evident by seismic line TJ89-520, between VP 390 to VP 338 (fig. 20). This leads is bounded by a NE and SW trending fault. The shallowest TWT value is 1640 millisecond while the last closing contour is of 1660 millisecond.

3: Lead-3

Lead 3 is found on structural horst block and can be seen on seismic line TJ89-524, between VP 305 to 315 (fig. 20). It is bounded by a NE and SW trending fault. The shallowest TWT value is 1630 millisecond.

4: Lead-4

This lead is located on horst block and evident by seismic line TJ89-520, between VP 265 to 279 (fig. 20). This leads is bounded by a NW and SE trending fault. The shallowest TWT value is 1640 millisecond.

5: Lead-5

It is created on structural horst block and can be observed on seismic line TJ89-520, between VP 140 to 100 (fig. 20). This leads is bounded by a

NW to SE trending fault. The shallowest TWT value is 1630 millisecond while the last closing contour is of 1690 millisecond.

6: Lead-6

Lead 6 is situated on horst block and marked on seismic line TJ89-518, between VP 210 to 219 (fig. 20). It is bounded by a NE and SW trending fault. The shallowest TWT value is 1650 millisecond while the last closing contour is of 1670 millisecond.

4.6.3 TWT Contour Map of Albian Aptian Level:

This map was compiled at the reflector shown in purple color on 2D seismic data set. The mapping reveals structural trend of transtensional block system bounded by faults aligned to NW in direction. The higher blocks appeared to form horst in relation to other blocks.

The highest point on horst is marked on SP 250 of 1730ms while lowest point is marked on SP 148 is 2230ms. The mapping delineated 6 highs along the horst blocks that are closely located to high angle master fault (fig. 21).

Albian Aptian is highly disturbed by faults therefore we found complex contour pattern which terminate against the faults and provides lows and highs as potential leads.

Description of leads:

1: Lead-1

This lead is located on horst block and evident by seismic line TJ89-518, between VP 310 to 355 (fig 21). This leads is bounded by a NW and SE trending fault. The shallowest TWT value is 2170 millisecond.

2: Lead-2 and Lead-3

The lead-2 is formed on horst block whereas lead-3 is on graben block and can be seen on seismic line TJ89-524.Lead-2 is between VP 320 to 340 and lead-3 is between VP 258 to 320 (fig 21). These leads are bounded by same NW and SE trending fault.

3: Lead-4

This lead is situated on horst block and can be observed on seismic line TJ89-522, between VP 180 to 217(fig 21). It is bounded by a NW and SE trending fault. The shallowest TWT value is 2170 millisecond.

4: Lead-5 and Lead-6

The lead-4 is found on horst block whereas lead-5 is on graben block and can be verified from seismic line TJ89-522. Where Lead-4 is between VP 240 to 290 and lead-5 is between VP 290 to 310 (fig 21). Both leads are bounded by same NW and SE trending fault.

Chapter-5
Results and Conclusion

After studying regional geology of the area and interpreting the seismic lines of study area, following conclusions are drawn:

- Geologically, area is in extensional regime followed by the transtensional fault movement, negative flower structure is clearly evident in the Cretaceous sediments of study area.
- During interpretation, it was observed that horizon of Jurassic age in seismic section has very vertical fault system and very sharp breakages in deeper horizon while in the shallow horizon of Cretaceous, the faults are tilted and produce negative flower structure.
- In the shallow horizon of Pirkoh, the structural discontinuity is not found and the reflector is very sharp due to limestone, continuous and monoclinal structure.
- The contouring of 3 horizons (Pirkoh, E sands and Albian-Aptian) was done and highs and lows were found. Fault trends were also marked and the highs are mostly associated with fault system.
- The E sands are disturbed by the fault system due to which the highs and lows are formed. Most of the highs associated with fault system have potential for the hydrocarbon accumulation.
- The Albian-Aptian horizon is also highly disturbed and 3 fault blocks are identified. The highs terminating against fault system can be the potential hydrocarbon accumulation.
- On contour map of Albian sands and E sands at VP 300 of line TJ 89-524 a high is formed which can be a potential lead, where a successful well Kadanwari 1 has been drilled that is producing gas.

5.1 Recommendations

- If more 2D or 3D data is acquired and interpreted in study area then there is possibility of hydrocarbon exploration in places where leads are found on Two Way Travel Time Map of Albian sands and E sands.
- On one of the leads on TJ 89-524 Kadanwari 1 well has drilled, it is on the limbs of lead found on map; if it is moved towards the apex of the lead then there may be the chances of increase in production.

Chapter-6
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