2D SEISMIC INTERPRETATION OF SANGHAR AREA, LOWER INDUS BASIN, PAKISTAN

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ABSTRACT

This dissertation holds the study of interpretation of 2D seismic data of the concerned seismic lines of Sanghar area in Lower Indus Basin. The purpose of 2D seismic interpretation of Sanghar is to evaluate the area to estimate the potential for discovery of hydrocarbons. The location of the well is between 25.8577° N, 69.4785° E. The data issued included seismic lines, base map, navigation files and well tops. Reflector and faults were marked on the seismic lines and contours have been made which confirms the structures marked on seismic lines.

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CHAPTER 1

INTRODUCTION

1.1 General introduction

Pakistan's sedimentary basins cover an area of 827,000 km² that expanses from Karakorum Mountains in the north to the Arabian Sea in the south. The first exploration well in the region was drilled near Kundal in 1866, just seven years after the Drake well in Pennsylvania. To date, 384 exploration wells have been in Pakistan resulting in 45 oil and 55 gas discoveries, thus generating a highly favorable success ratio of 1:4. The drilling density in Pakistan is one well/1000 km². Pakistan has proven oil reserves of around 500 million barrels of oil, whereas proven gas reserves are about 31 trillion cubic feet. However, Pakistan's resource potential is estimated to be 40 billion barrels of oil and 200 trillion cubic feet of gas (Ahmed, 1995).

The sedimentary area of Pakistan is occupied by two vast basins, namely Indus Basin and Baluchistan Basin. Oil was first discovered in the Indus Basin in 1915 at Khaur and since then all oil and gas discoveries have been confined to two regions of Indus Basin the Potwar Plateau in the Upper Indus Basin and Lower Indus Basin in Sindh province (Ahmed, 1995).

Potwar Plateau is foreland fold-belt that is thrusted outward (southward) over the Punjab Plains. Crude oil is produced from thrusted, salt-cored anticlines that owe their origin to the compressional tectonics of the Himalayan orogeny during Miocene-Pliocene time. Traditionally, oil has been produced from fractured carbonates of Paleocene and Eocene age, but additional oil is also being obtained from Mesozoic sandstones and Paleozoic carbonates and sandstones (Ahmed, 1995).

The first oil discovery outside the Potwar Plateau was made in the Lower Indus Basin at Khaskeli by Union Texas. This discovery dispelled the long held brief that the southern half of Indus Basin was mainly a gas prone region. To date, more than 50 crude oil and gas/condensate discoveries have been made in this region by Union Texas and Oil and Gas Development Company (OGDCL). Lower Indus Basin now contributes more than 50% of the total production of Pakistan. The producing reservoirs are Upper Cretaceous shallow-marine sandstones, which are sourced by Lower Cretaceous/Upper Jurassic organic shales. Hydrocarbons are trapped in the tilted fault blocks, which formed during the Cretaceous rifting but were later modified by Cenozoic wrench movements. The study area incarnate in the Lower Indus Basin in district Sanghar designated as Bobi field (Ahmed, 1995).

1.2 Introduction to study area

Sanghar district is one of the largest districts in the Sindh province of Pakistan bounded by India on the east. It is located on the middle of Sindh province. The province of Sindh forms the Lower Indus basin and lies between 23°-30° north and 66°-71° east. Sindh is located on the western corner of South Asia, bordering the Iranian plateau in the west. Geographically it is the third largest province of Pakistan, Stretching about 579 km from north to south and 442 km (extreme) or 281 km (average) from east to west, with an area of 140,915 km^2 (54,408 mi^2) of Pakistan territory**.** Sindh is bounded by the Thar Desert to the east, the Kirthar Mountains to the west, and the Arabian Sea in the south. In the centre is a fertile plain around the Indus River (Siddiqui, 2007).

District Sanghar is an agricultural district except the large part of taluka Khipro and some part of taluka Sanghar, One third of the area is desert while rest is fertile land. The soil is sandy with hard clay loams.

Bobi Gas Condensate Field is located about 25 km south of Sanghar and 85 km north-east of Hyderabad city in Sindh province. It was discovered by OGDCL in May, 1988. Satellite view of Bobi field is given in (fig 1.1). Total of 8 wells were drilled up to 1991 out of which 2 wells i.e. Bobi N-1 and Bobi-5 are non-producers. Bobi well 01 was the first exploratory well drilled and completed as gas/condensate producer in May 1988 (Bobi well 01 is purposed well for study in this desertion) (OGDCL, 2010).

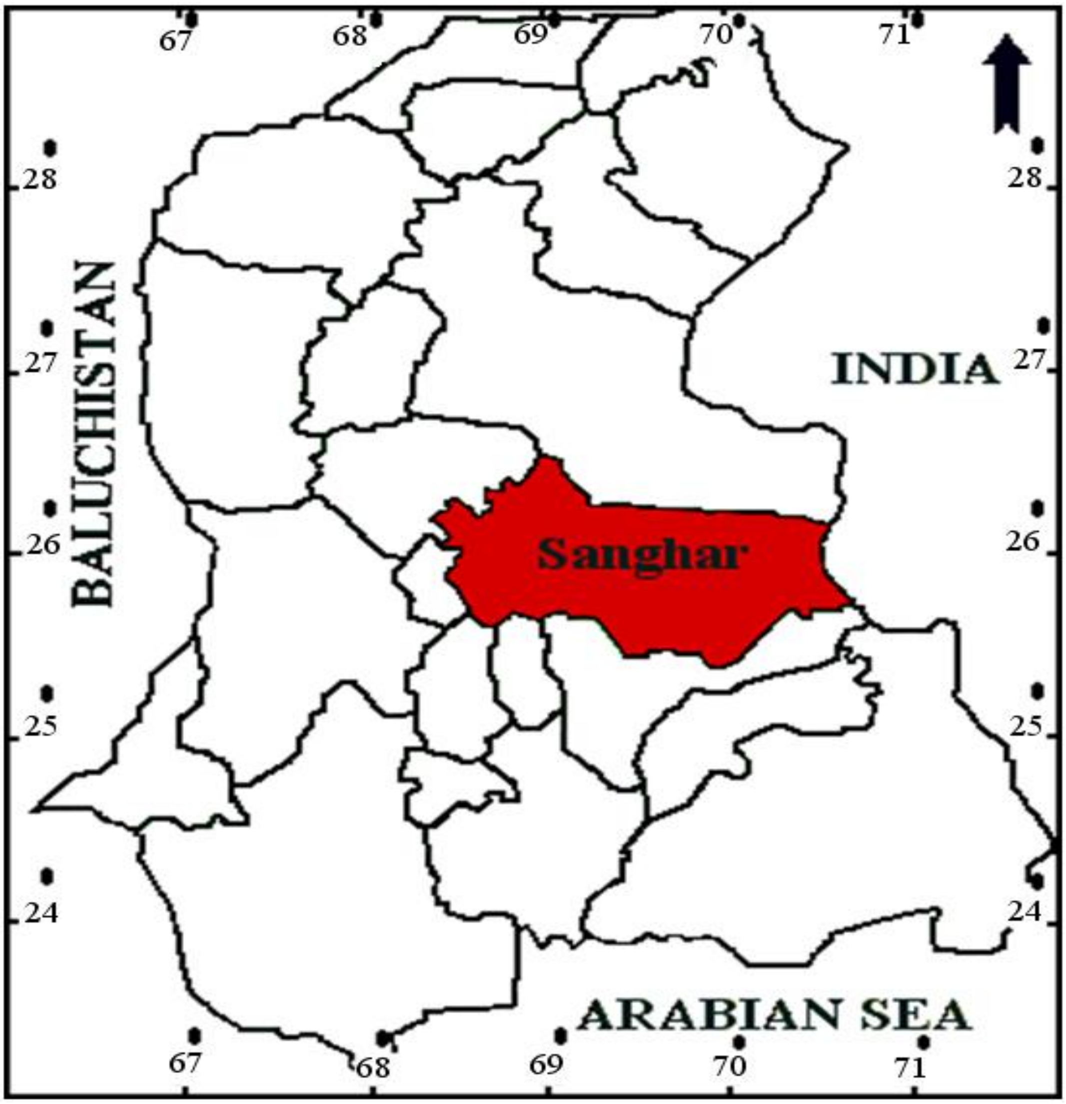


Figure 1.1 Location map of Sanghar area within Sindh

1.3 Objectives of the research

The main purpose of the study is as follows:

1) To get the basic idea of seismic interpretation for the delineation of subsurface target horizon in the study area.
2) To understand the geological and structural setting of the area.
3) To understand the petroleum system, identify the possible source and reservoir mechanism.

Five available seismic lines are used. However, a complete and reliable picture of the subsurface could not be obtained on the basis of these five lines. To have a better understanding, available literature was also taken in to consideration.

1.4 Data obtained

The given dissertation is carried out in order to study the 2d structural interpretation. To carry out this exercise, seismic data which we obtained consist of five seismic sections and a well named Bobi-01.Data were obtained from Land Mark Resources (LMKR) by the permission of directorate general of petroleum concession (DGPC). Out of these, there are one strike lines and four dip lines. Line 896-SGR-379 is strike lines. Lines 944-SGR-206, 896-SGR-375, 947-SGR-222, 896-SGR-397 are dip lines.

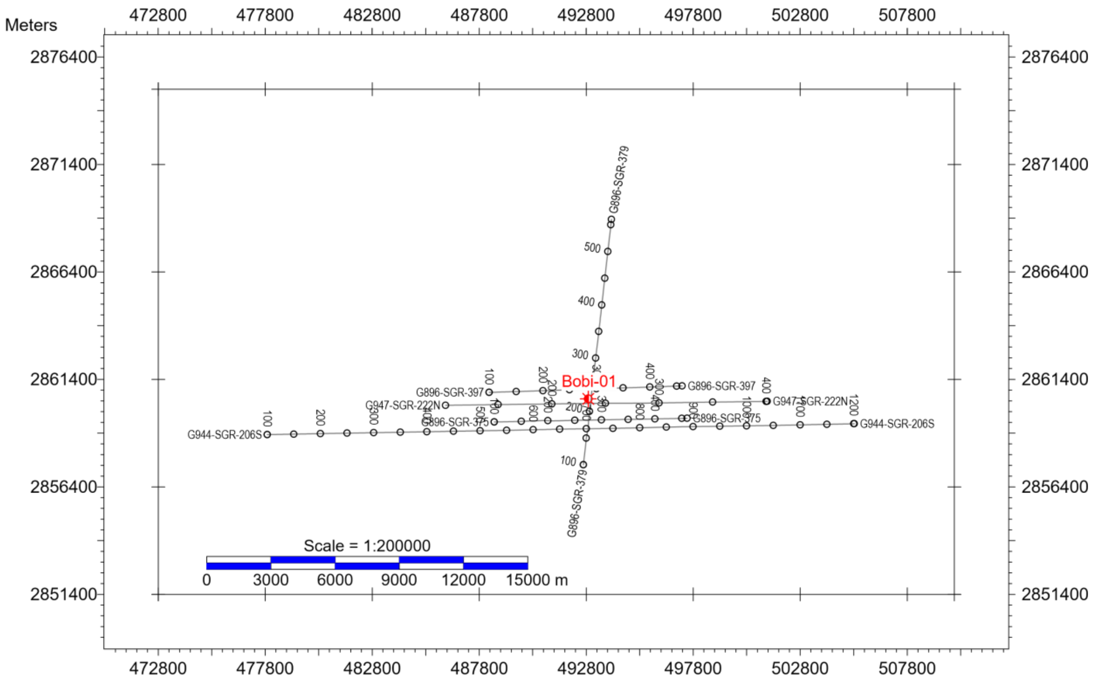


Figure 1.2 Base map of study area (Bobi 01 well).

CHAPTER 2

REGIONAL GEOLOGY OF THE AREA

2.1 Geological setting

Pakistan lies along part of the tertiary convergence zone between greater India Eurasia and straddles the subducting margin of Arabian plate beneath the Makran coast line. Greater India was a part of the Gondwana continental mass prior to Triassic times. After the break down of Gondwana (Australia, Arabia, South America and Antarctica) and separation of India from other continental masses at about 210 Ma and later from Madagascar at about 84 Ma, it continued its north-eastward drift with different speeds. It is possible that Kohistan Arc was formed in association with an easterly extension of the same active margin system. Arc-arc collision between Kohistan and southern Eurasia has been placed between 100 and 90 Ma (Kazmi and Jan, 1997).

The separation of India from Seychelles micro-continental block began in the Late Cretaceous and was eventually assisted by the advent of the Indian Ocean plume which gave rise to the Deccan Traps flood basalts (66 Ma). The counter clockwise rotation of the Indian plate relative to Africa about a pole north of Madagascar during Early Eocene was coincident with reduction of its velocity from 130-150 mm/y to 40-60 mm/y. Finally collision between the Indian and Eurasian continental crusts occurred in the Late Eocene. The continued under-thrusting of Indian plate since Cretaceous produced the spectacular mountain ranges of the Himalaya as a chain of fold and thrust belts as thick sheets of sediments thrusted over the Indian shield. The collision in the west is oblique along a transpressional fault zone, known as Cha/Ornach- Nal Transform Zone, which marks the western plate boundary (Kazmi and Jan, 1997).

2.2 Basin development

The geologic history of basin development is subdivided into cycles using three parameters basin forming tectonics, depositional sequences and basin modifying tectonics. All of these factors play their role in basin evaluation of Pakistan. The sedimentary sequences reflect paleo-geographic environments of these basins.

Pakistan has two major sedimentary basins, the Indus Basin and Baluchistan Basin Indus Basin is further divided into following basins.

(1) Upper Indus Basin.

(2) Middle Indus Basin.

(3) Lower Indus Basin.

CHAPTER 3
TECTONICS OF THE STUDY AREA

3.1 Regional tectonics

The rifting between India and Madagascar only affected the Lower Indus Basin margin and signaled the start of separate basin history for the Middle/Upper and Lower Indus Basin areas. Syn-sedimentary normal faulting produced thickness variation and condensation near highs throughout the Early Eocene. The cessation of this initial-rifting produced a repeat of the initial flexure phase tectonic style, which was first seen in the early Triassic over the whole continental margin. Thermal subsidence produced deepening water culminating in widespread pelagic sedimentation (Kazmi and Jan, 1997).

In the Lower Indus Basin, continued thermal subsidence produced over 1500m of early Paleocene sandstones. Marine sedimentation persisted throughout the Tertiary, with little influence from the full-scale collision of Indian and Eurasian in the north. The major influence to the offshore area was the uplift, which accompanied the collision. The greater art of the southeastern Lower Indus Basin continued to be uplifted to the present day since Late Tertiary. Towards the end of Pliocene, the Indus Basin was filled with sediment (Kazmi and Jan, 1997).

This basin is located just south of Sukkur Rift, a divide between Central and Southern Indus basins. It comprises the following main units.

(1) Thar Platform

(2) Karachi Trough

(3) Kirthar Foredeep

(4) Kirthar Fold Belt

(5) Offshore Indus

3.1.1 Thar Platform

It is a gently sloping monocline analogous to Punjab platform controlled by basement topography. The sedimentary wedge thins towards the Indian shield whose surface expressions are present in the form of Nagar Parkar high. It is bounded in the east by Indian shield, merges into Kirthar and Karachi trough in the west and is bounded in the north by Mari-Bugti inner folded zone. The Platform marks very good development of Early/Middle Cretaceous sands (Goru), which are the reservoirs for all the oil/gas fields in this region (Qadri, 1995).

3.1.2 Karachi Trough

It is an embayment opening up in to the Arabian Sea. The trough is characterized by thick Early Cretaceous sediments and also marks the last stages of marine sedimentation. It contains a large number of narrow chains like anticlines, some of which contains gas fields. The Early Middle and Late Cretaceous rocks are well preserved in the area. It has been a trough throughout the geological history. The Upper Cretaceous is marked by westward pro gradation of a marine delta. The most interesting feature of Karachi trough is the reportedly continued deposition across the Cretaceous/Tertiary (K/T) boundary wherein Korara Shales were deposited, the basal part of which represents Danian sediments. Elsewhere in Pakistan, a break in deposition marked by laterites, bauxites, coal etc. is a common feature across the K/T boundary (Qadri, 1995).

3.1.3 Kirthar Foredeep

It trends north south, which has received the sediments aggregating a thickness of over 15,000 m. It has a faulted eastern boundary with Thar platform. It is inferred that the sedimentation has been continuous in this depression. From the correlation of Mari, Khairpur and Mazarani wells it appears that the Upper Cretaceous would be missing in the area. Paleocene seems to be very well developed in the depression but is missing from Khairpur – Jacobabad high area. This depression, like Suleiman depression, is the area of great potential for the maturation of source rocks (Qadri, 1995).

3.1.4 Kirthar foldbelt

A north-south trending tectonic feature that is similar to Suleiman foldbelt in structural style and stratigraphic equivalence. Rocks from Triassic to Recent were deposited in this region. The configuration of the Kirthar foldbelt also marks the closing of Oligocene- Miocene seas. The western part of the Kirthar foldbelt adjoining the Baluchistan Basin, which marks the western edge of the Indus Basin, is severely disturbed. This western margin is associated with hydrothermal activities, which resulted in the formation of economic mineral deposits of Baryte, Fluorite, Lead, Zinc and Manganese (Qadri, 1995).

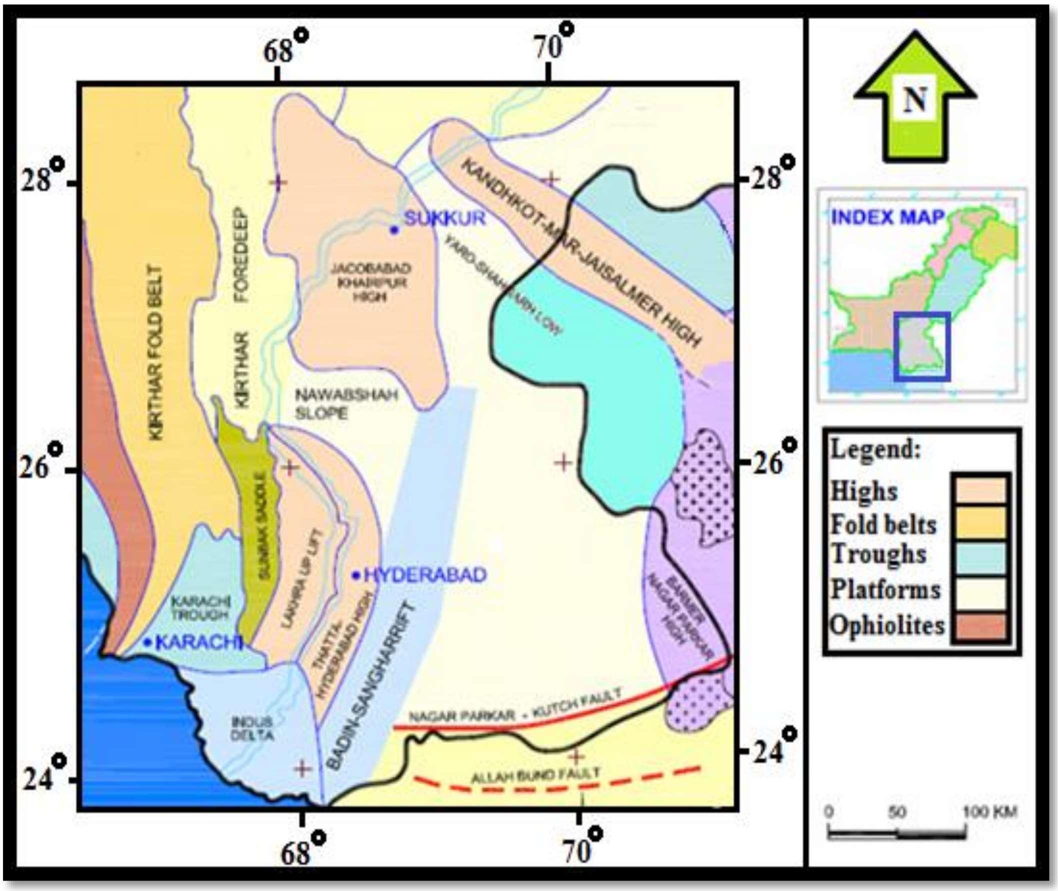


Figure 3.1 Map of the geological divisions of Lower Indus Basin (Annual report PEL. 2011).

3.1.5 Offshore Indus

It forms the part of passive continental margin and appears to have gone through two distinct phases of geological history (Cretaceous-Eocene and Oligocene to recent). Sedimentation in offshore Indus region started from Cretaceous time. However deltaic and submarine fan sedimentation has occurred since Middle Oligocene time with the inception of Proto-Indus system. Offshore Indus is divided into Platform and depression along a hinge line in close proximity and parallel to 670E longitudes. Offshore platform is divided into Karachi trough and the Thar platforms deltaic area by a line, which divides Karachi trough from Thar slope onshore (Qadri, 1995).

CHAPTER 4
STRATIGRAPHY OF THE STUDY AREA

4.1 Stratigraphic column of study area

Table 4.1 Generalized stratigraphic sequence of Lower Indus Basin (Annual report PEL, 2011)

Age	Group	Formations	Lithology
Paleocene	Ranikot group	Lakhra	Limestone, sandstone and minor shale.
		Bara	Sandstone interbeded with shale and thin beds of Limestone and clay
		Khadro	Sandstone with interbeded clay and thin beds of basalt.
Unconformity			
Cretaceous		Pab sandstone	Sandstone
		Fort monro	Limestone, shale
		Mugalkot	Mudstone, shale
		Parh limestone	Limestone, marl, shale, chalk
		Upper Goru	Marl with minor shale and limestone
Early Cretaceous		Lower Goru	Shale with subordinate sandstone, marl, siltstone and rare limestone
		Sembar	Shale, limestone

4.1.1 Jurassic sequence in Southern Indus Basin

The advent of Jurassic is marked by the break in deposition. Rifting and break-up of Gondwana continued during Jurassic. In Southern Indus Basin, submergence of platform produced deep water sedimentation of Shirinab and Chiltan Formations (Qadri, 1995).

4.1.1.1 Shirinab Formation

This is widely developed in Kirthar and Suleiman province. It consists of inter-bedded limestone and shale which grade into low lying Wulgai Formation. The Formation is divided into three members (Spingwar, Loralai, Anjira) based on level of shale. Limestone is generally medium to thin bedded (Qadri, 1995).

4.1.1.2 Chiltan Formation

It is massive, thick bedded, dark limestone. It contains pisolitic limestone beds locally. Upper contact with Mazar Dirk Formation is gradational. At places it is organic rich and seems to have generated hydrocarbons. There are some indications of the development of 10 to 12 percent porosity (Qadri, 1995).

4.1.2 Cretaceous sequence in Southern Indus Basin

The greater India broke up from eastern Gondwanaland some 120 Ma years ago at the time when Sembar and Goru Formations were being deposited. The whole cretaceous therefore, represents shallow seas while northern floor of the southern arm of the Tethys was subducting beneath Iran-Afghanistan micro-continent (Qadri, 1995).

4.1.2.1 Pab Sandstone

It is light grey to light tan to brown, quartzose, fine to coarse grained, hard to soft sandstone. It is occasionally conglomeratic and generally cross-bedded. It is considered to be deposited under shallow water environment characteristic of the MoghalKot Formation deposition. In the MoghalKot Formation seepage area, most of oil seeps are from Pab Formation. It also forms petroleum reservoirs at Pirkoh, Loti, Dhodak and Rodho fields. It is considered to have no source potential (Qadri, 1995).

4.1.2.2 Parh Limestone

Although Parh Limestone occurs widely throughout the Indus Basin, erosional truncation has limited the formation distribution to an area lesser than Goru and Sembar Formations. Like in Badin platform area it is only present in southern portion and that too in the form of thin layer. No oil or gas shows have been found in the Parh limestone in the subsurface and no surface seeps are known (Qadri, 1995).

4.1.2.3 Goru Formation

The sands of Goru Formation are the most important entity in the Southern Indus Basin from the petroleum reservoir point of view. The thickest Goru Formation sedimentation occurs within the Karachi embayment. On the wells west of Badin platform, Goru is partially penetrated about 2,360 m (Qadri, 1995).

Based on its lithological content, Goru Formation has been divided into upper and lower portions, with sand being rarer in upper portion. Upper portion is predominantly shale while the lower portion is the sandy member. This lower portion (Lower Goru) is the most important reservoir in Southern Indus Basin. It contains all the hydrocarbons in Sindh Monocline (Qadri, 1995).

The wells drilled in Badin area exhibit a lateral facies change from east to west, from producible sand/shale sequence in Lower Goru to non-reservoir sand/shale facies, which in turn is entirely represented by shale’s further west (Qadri, 1995).

4.1.2.4 Sembar Formation

The Sembar Formation is composed mainly of clastic rocks, primarily shale’s, sandstones and siltstones with minor limestone. Characteristically, the formation in outcrop consists of black silty shale with nodular black siltstone and limestone beds (Qadri, 1995).

Sembar Formation thins eastwards against the Indian shield and the cutch positive areas. Possibly most of thinning is due to erosional truncation. It is suspected that thinning due to onlap may also have occurred (Qadri, 1995).

Numerous good source rock determinations as well as gas and oil shows have been reported from the Sembar Formation and it is believed to be the source of hydrocarbons in Badin platform fields. Potential reservoirs occur within the sandstones of the formation. The chances of Sembar-sourced oil migration into the underlying Jurassic formations against faults also appear to be relatively favorable (Qadri, 1995).

The thickest sediments of Sembar Formation are deposited in Suleiman lobe area (1000 m). In Karachi embayment the Sembar Formation is over 760 m in thickness while in Badin platform, thickness is around 650 m (Qadri, 1995).

4.1.3 Cretaceous Tertiary Unconformity

The end of Mesozoic is marked by regression of sea in most of Pakistan but in Central and Southern Indus basins, there are numerous indications which suggest very little gap between Cretaceous and Paleocene sedimentation.

4.1.4 Paleocene sequence in Southern Indus Basin

The end of Cretaceous and the advent of Tertiary is marked by northward journey of Indian plate which accelerated 16cm/yr during Paleocene. The collision of Indian and Eurasian plates resulted in emergence of numerous local areas in Lower Indus Basin. This basin is therefore marked by various phases of transgression and regression. Early Paleocene transgression deposited Khadro Formation in negative areas while other areas did not receive terrestrial sediments. Therefore, in Southern Indus basin the rocks of Paleocene age are almost entirely of marine origin (Qadri, 1995).

In early Paleocene, as a result of east-west compression and north-south tension and counter clockwise rotation of Indian plate, Thoelitic basalts extruded and covered the older weathered formations. Evidence of this is found in base of Khadro Formation which contains basaltic inflows. This phenomenon is restricted to southern Kirthar region and Badin platform (Qadri, 1995).

CHAPTER 5
PETROLEUM GEOLOGY

5.1 Source rocks

Beginning of the Cretaceous marks the worldwide rising of the sea level, which made the organic life flourish. Furthermore basin wide anoxia caused preservation of organic matter. Time and temperature conditions were also favorable to turn this preserved organic matter into hydrocarbons. Shale sequences in Sembar and Lower Goru formations (Lower Cretaceous) are known to be source rocks as shown in (fig 5.1). Cretaceous shale's of Sembar, Goru and MoghalKot formations are both widespread and thick. They contain abundant organic matter and generally exhibit good source rock characteristics. Moreover most of the underlying Cretaceous rocks lie within oil window. Source rock analysis of some samples from Cretaceous shale's indicates that they are fairly mature for hydrocarbon generation. This shale's are thick enough to give rise to huge hydrocarbon reserves in potential and producing reservoirs. The major component of Badin oil is believed to have sourced from Sembar shale's. This oil was generated on platform and migrated up dip which is proved by oil source correlation and source rock typing (Qadri, 1995).

5.2 Reservoir rocks

The basal sands of Lower Goru Formation are the main objective in this prospect. These sands are hydrocarbon producer in Bobi, Jakhro, Chak-5 Dim-01 and Chak-5 Dim south 01. MoghalKot Formation exhibits good reservoir characteristics in Jandran. The Lower Goru sands with porosity in range 5 to 30 percent constitute the reservoir in the oil and gas fields discovered in the Badin Platform/ Sindh Monocline area. These include the oilfields of Khaskheli, Laghari, Dhabi, Nari, Mazari, South Mazari, Makhdumpur, TandoAlam, Bobi and gas fields of Kadanwari and Miano. MoghalKot Formation and Parh Limestone show good potential for the development of secondary porosity in limestone. Texture of Pab Sandstone indicates good signs of primary porosity and potential for the development of secondary porosity. The porosity in Pab Sandstone, in discovered fields ranges from 5 to 15 percent. The famous MoghalKot oil seepage occurs in the basal outcrops of Pab Sandstone which is another indication of hydrocarbon generation and its migration through permeable Pab Sandstone. Other Cretaceous rocks with reservoir potential are possible reef and fore reef facies of Parh Limestone and delta and submarine fan facies of MoghalKot Formation.(Qadri, 1995).

5.3 Cap rocks

The thick sequence of shale and marl of Upper Goru Formation serves as cap rock for underlying Lower Goru reservoir.

5.4 Traps

The oil and gas fields discovered to date are structural traps, except two. The Jurassic of Dhulian field in the Upper Indus Basin is structural-stratigraphic, while Bari oil field in the Lower Indus Basin is a classic stratigraphic trap of Sand "B" of the Lower Goru upper sand unit (Qadri, 1995).

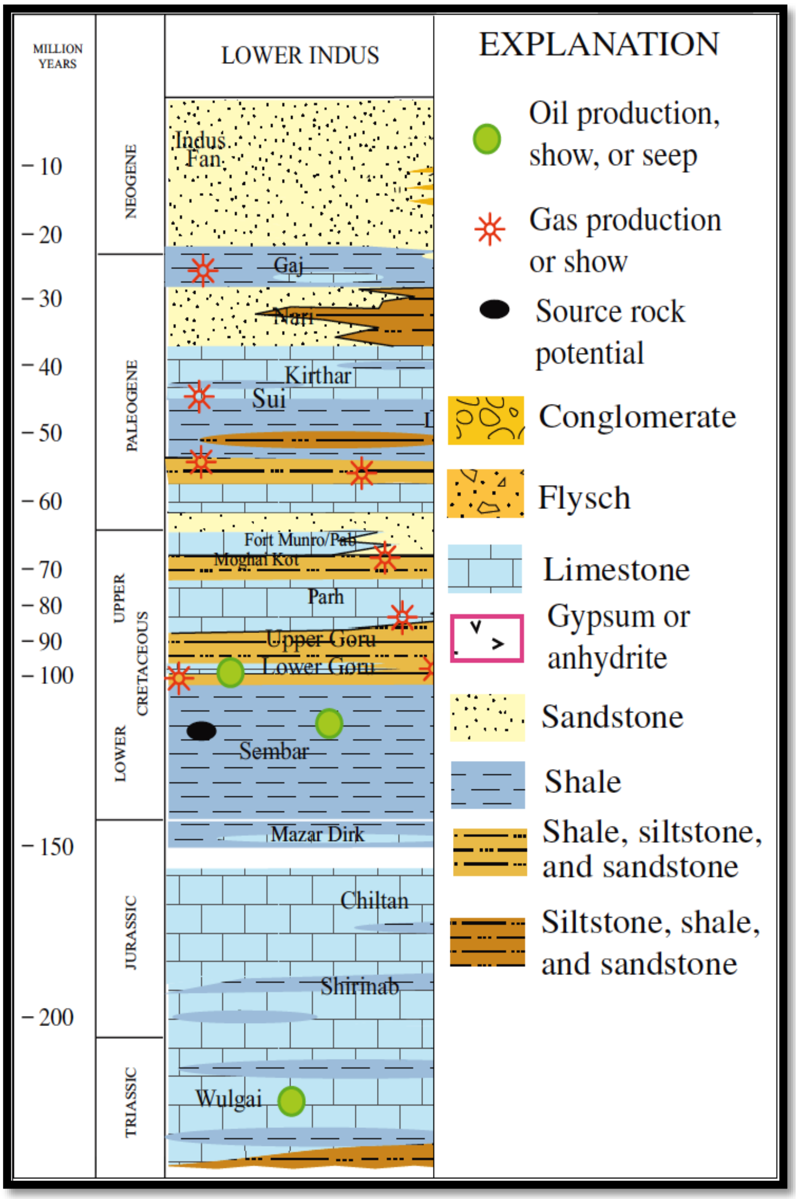


Figure 3.2.Petroleum geology and stratigraphy of Lower Indus Basin (Wandrey et al., 2004).

CHAPTER 6

SEISMIC DATA ACQUISITION AND PROCESSING

6.1 Seismic data acquisition

In the seismic data acquisition surveys, reflections from different sedimentary layers are considered as primary signal. Almost all other types of events are commonly regarded as noise. The aim of the entire recording system and field layouts are essentially designed to improve signal to noise ratio. The basic field activity in seismic surveying is the collection of seismograms. The acquisition of seismograms is accomplished by using the system consisting of three main components. (Rehman, 1988)

1) Input devices
2) Design of detectors array
3) Recording system

6.1.1 Input devices

Input devices are used to produce vibration in earth. Different kinds of input sources are used for land and marine survey. These input sources include explosive as well as non-explosive energy sources for land and marine surveys different devices are used.

Land energy sources

1) **Dynamite**

This is the most common energy source used in seismic prospecting. Normally it is exploded inside a drilled hole at a depth raging from few meters to several tens of meters. The amount of charge per shot point depends on whether it is a single hole or a pattern shooting as a rough estimate the charge weight is 10-50 Kg of dynamite.

2) Geograph

This method is also known as Thumper, involves dropping a weight of about 3 tons from a height of about on the ground.

3) Dinoseis

In this method, the weight is power driven against the ground surface. The impact energy is generating by exploding a gas mixture (propane and oxygen) contained in a chamber.

4) Geoflux

The seismic source consists of an explosive cord, which is buried in the ground at a shallow depth. It is laid down by a hydraulically operated plough, which is especially designed for the purpose.

5) Vibrosies

This method is based on the use of a mechanical vibrator. This is hydraulically driven to exert a force of an oscillating magnitude. (Al-sadi, 1980).

6.1.2 Design of detectors array

Whatever the method (reflecting or refraction), advice for generating and detecting seismic pulses is essentially needed. The seismic disturbance beginning from the source and traveling along different paths is detected on reaching the ground surface by an array of geophones. A geophone is a type of microphone device to listen to the minute to the minute ground vibrating (as small as 10-10m) of the earth. (Al-sadi, 1980).

6.1.3 Field layouts

Virtually all routine seismic work consist of continuous profiling, that is the cables and shot point are arranged so that there are no gaps in the data other than those due to the fact that the geophone groups are spaced at intervals rather than continuously. Conventional coverage implies that each reflecting point is sampled only once except at the ends of each profiles, these ends points are sampled again with the adjacent spread so as to reduce the like hood of errors in the following an account form one record to the next. This contrast to CDP or redundant coverage where each reflecting point is sampled more than once.

6.1.4 Spread types

By spread we mean the relative location of the shot points and the several spread type are used such as:

1) Split spread
2) End –on spread
3) Cross-spread
4) In-time offset spread
5) Split-dip spread with shot gap
6) Broad side T spread (Robinson and Couth, 1988)

6.1.5 Conventional acquisition versus CDP'S acquisition

Conventional techniques of data acquisition have been replaced by-CDP technique, in which the shooting patterns and acquisition layouts are used to cut down the field. Conventional techniques being single fold coverage, continuous subsurface coverage but signal to noise ratio is affected by the presence of multiples and ground role, (Yilmaz, 1988)

Conversely, CDP shooting infect offers cancellation of coherent and random noise and problem, because in CDP stacking, the summing of all traces (from different sources and different receivers) related to the same reflection point in the subsurface, reduces significantly the effect. So increase in fold improves signal to noise ratio (SNR) (Rehman, 1988).

6.1.6 CDP shooting

Mayne introduced in 1963, the CDP techniques which is basically defining the signals associated with a given reflection point but recorded at different shots and geophone position.

CDP data acquisition involves an and spread with an inline offset sources such that CDP shooting yields greater number of shot point per unit distance along the line causing repletion twice during shooing, there would be two seismic traces corresponding to that point, so it admits 2-fold acquisition or it can be designed as 200% data.

The data fold can be evaluated from the following relation

$$F = N\Delta\ Y/2\Delta$$

Where

N = Number of recording channels

ΔY = Geophone interval

ΔX = shot interval

Seismic data for dissertation i.e. acquired objectively for H-C, exploration by applying CDP shooting scheme. The CDP principal breaks down in the presence of dip because the CDP then no longer directly underlines the shot-detector midpoint. This is improved by migration.

6.1.7 Fold

The fold CDP-scheme is the number of traces in a CDP gathers, i.e. repetition of reflection point, and can be determined by the relation;

Fold = N/2n

Where:

N= Number of geophone arrays along a spread

n= number of geophone arrays spacing by which spread is moved forward

Source located at station-18, geophone at station-36 received reflection from the same CDP at the source at station-6 received at station-42. The set of 24 traces with different offsets, which are reflected from the same reflection point, is called CDP gather, which represents the best possible data set for computing velocity from the NMO effect. With accurate velocity information, the move- out can be removed from each a trace of a CDP-gather to produce a CDP- stack in which reflected arrivals is enhance greatly, stacking process actually attenuates or practically suppresses the long – path multiples that have significantly different move outs from the primary reflections, the theoretical improvements in S/N ratio stacking of “n” traces in CDP

(n) however, later data processing brings remarkable improvements in the seismic section.

6.2 Recording parameters

1) Source

Energy source	Dynamite
SP-interval	50m
Format	SEG-B

2) Tools

Instrument	SN-388-HR
Sampling rate	2-MS
No. of channels	96
Coverage	4800%
Aliasing	125H
Notch Filter	Out

3) Geophones

Geophones Type	MARK L-10
Geophones Code	031205
Geophones Frequency	20HZ
Geophones interval	5.0 M

4) Scales

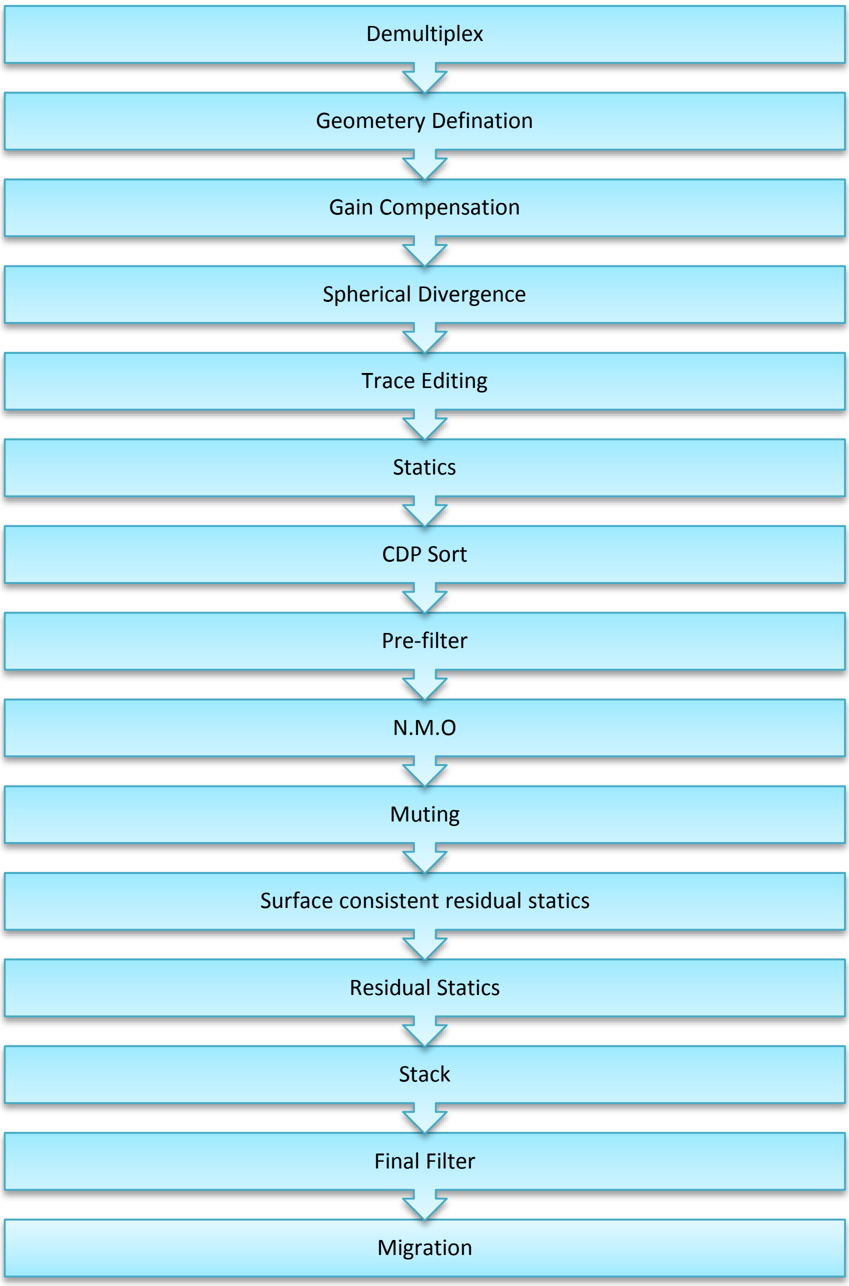
Horizontal	24.0 TPI
Vertical	2.5 INS. / Sec

5) Display parameters

Display Gain	None
Polarity	Normal
Display set	Migrate316

6.3 PROCESSING SEQUENCE

The processing sequence is as follows:



CHAPTER 7

SEISMIC DATA INTERPRETATION

7.1 Introduction

The basic field activity in seismic surveying is the collections of seismograms which may be defined as analogue or digital time series that register the amplitude of ground motion as a function of time during the passage of seismic wave train.

The acquisition of seismogram involves conversion of the seismic ground motion into electrical signals, amplification and filtering of the signal and their registration on a chart recorder and / or tape recorder. Acquisition essentially comprises a source pattern, a detection spread and digital recording instruments (Kearey et al., 2002).

Seismic interpretation is a process in which seismic data is interpreted to determine geological structures, subsurface horizons are contoured and further depth conversion is carried out by applying some suitable velocities. The seismic reflection interpretation usually consists of calculating the positions and identifying geologically concealed interfaces or sharp transition zones from seismic pulses returned to ground surface by reflection. The influence of varying geological conditions is eliminated along the profile to transform the irregular travel times into acceptable subsurface model. This is very important for confident estimation of depth and geometry of the bed rock or target horizon (Dobrin and Savit, 1988).

7.2 Interpretation steps

The methodology adopted for interpretation consists of following points:

1) Marking reflectors on the seismic section
2) Generating time sections
3) Time to depth conversion
4) Restoration of depth section
5) Time contour mapping
6) Velocity contour mapping
7) Depth contour mapping
8) Generation of subsurface structural model

7.2.1 Interpretation of given seismic lines

Material provided for the study comprised of seismic sections, having four dip lines in east-west direction, two strike lines in north-south direction, and well logs of Bobi 01 well and base map.

1) Seismic sections of acquired lines:

   a) Strike lines:

      896-SGR-379

   b) Dip lines:

      944-SGR-206

      896-SGR-397

      947-SGR-222

      896-SGR-375

2) Well logs of Bobi 01well

   Gamma ray log, neutron log, density log, self-potential log, laterolog shallow, laterolog deep, microspherically focused log and well tops.

3) Base map

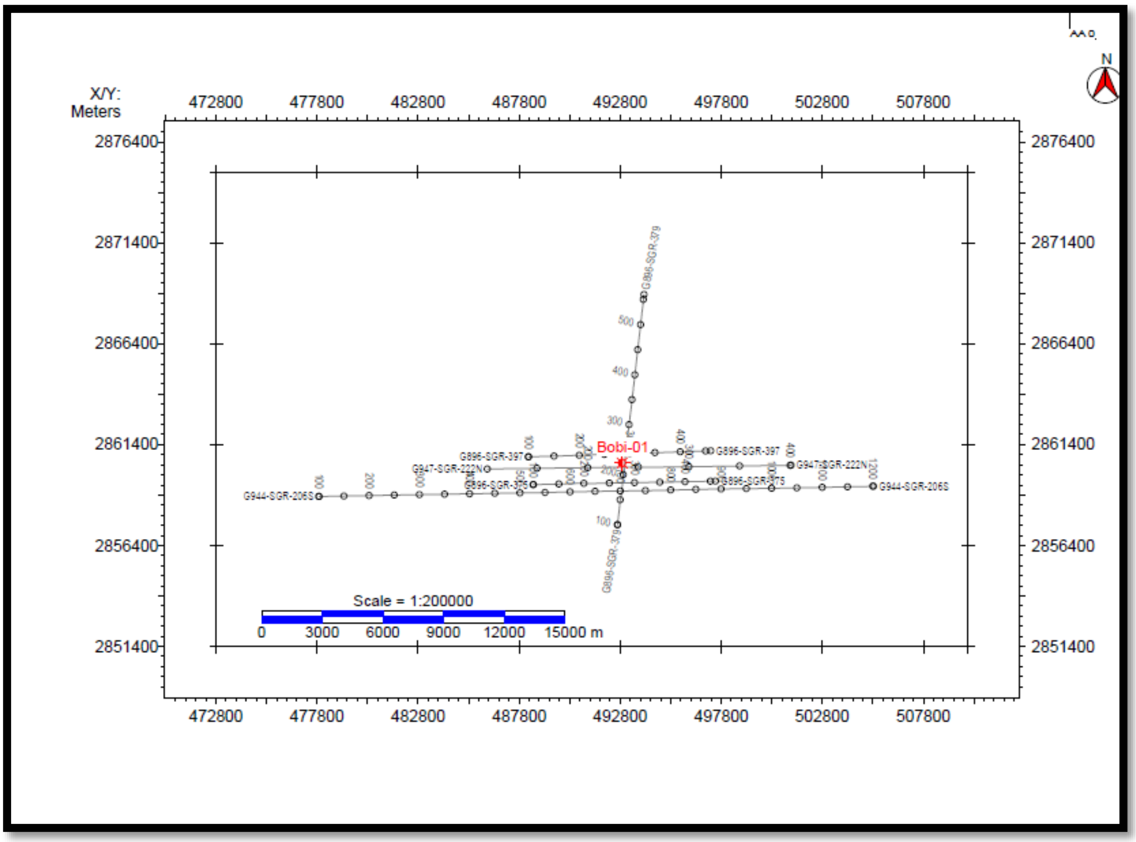


Figure 7.1 Base map of study area (Bobi 01 well).

7.2.2 Use of velocity window

The velocity window which is used very above the control shot point is solved, as the well lies on the 316 shot point (which served as control point), it contain in column time in millisecond while in second column the Vrms velocities. The Vrms velocities are multiplied with time column which is one way travel time to get the depth from relationship S=VT, this one way travel time obtained by dividing the time by 2000 as the time was in millisecond. So new column will give the depth of each time during the recording of seismic waves traveling under the subsurface, this is also called as velocity analysis.

7.2.3 Time depth chart

As the velocity windows are solved, this can be further solved by plotting on graph paper with depth on vertical axis while time on horizontal axis. The depth chart is then plotted on the graph paper with all the velocity windows which were available in the 26 seismic section of control line, in this fashion time for desired horizons is picked and marked (Fig. 7.2).

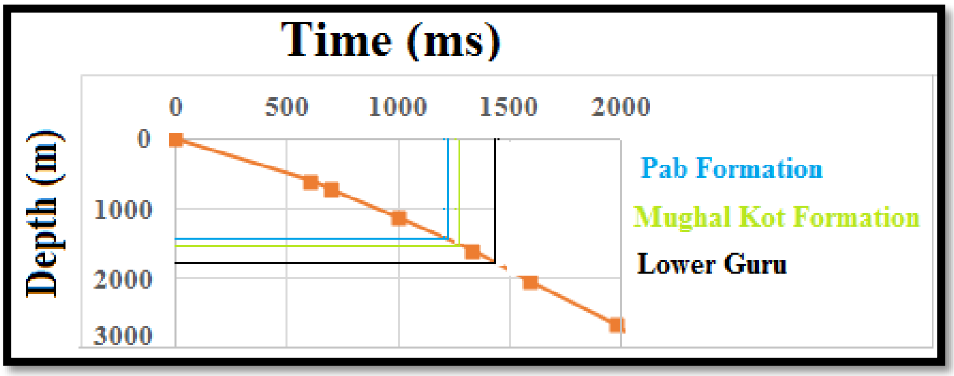


Figure 7.2 Time depth chart of different formations

7.2.4 Identification of horizons

The first step in interpretation of a processed seismic section is to pick up the best seismic reflections on the seismic section. Before marking reflectors on the seismic sections the root mean square velocity values from velocity windows on the seismic sections were solved using Dix equation to generate a velocity profile that gives values of velocity after the time interval of 1 msec.

Well data provided four well tops and their depths which are as follows:

Table7.1 Formation mark on seismic line.

S. no.	Formation Top	Depth (m)	Time (sec)
1	Pab Formation	1455	1.2
2	Moghal Kot Formation	1530	1.28
3	Lower Goru Formation	2900	1.4

7.2.5 Identification of faults

The next step in the seismic interpretation is identification of faults. Faults are the broken reflectors in the seismic section, which continues after slight distortion in the pattern of the horizon. The study is the part of the extensional regime therefore normal faults making horst and graben structures were present.

Figures 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 show interpreted seismic sections of lines 896-SGR-379, 896-SGR-397, 944-SGR-206, 896-SGR-375 and 947-SGR-222 respectively. In these figures vertical scale of all sections is time in seconds and horizontal scale measures shot points according to line of acquisition. Location of seismic line on the base map is shown on lower right corner of each figure and is highlighted red. Location of well is also shown on the base map.

7.2.6 Tying of strike lines with dip lines

As the horizons are marked and tied by using loop time, first, the marked horizons on control line which is dip line by nature by using the well tops information. Then control lines was used to mark the horizons on all the dip and strike lines because it intersected them at particular station which further helped in tying up with other dip lines. Point to be remembered that transferring the pick between lines, always maintained, the vertical time scale of two seismic lines are coinciding with each other.

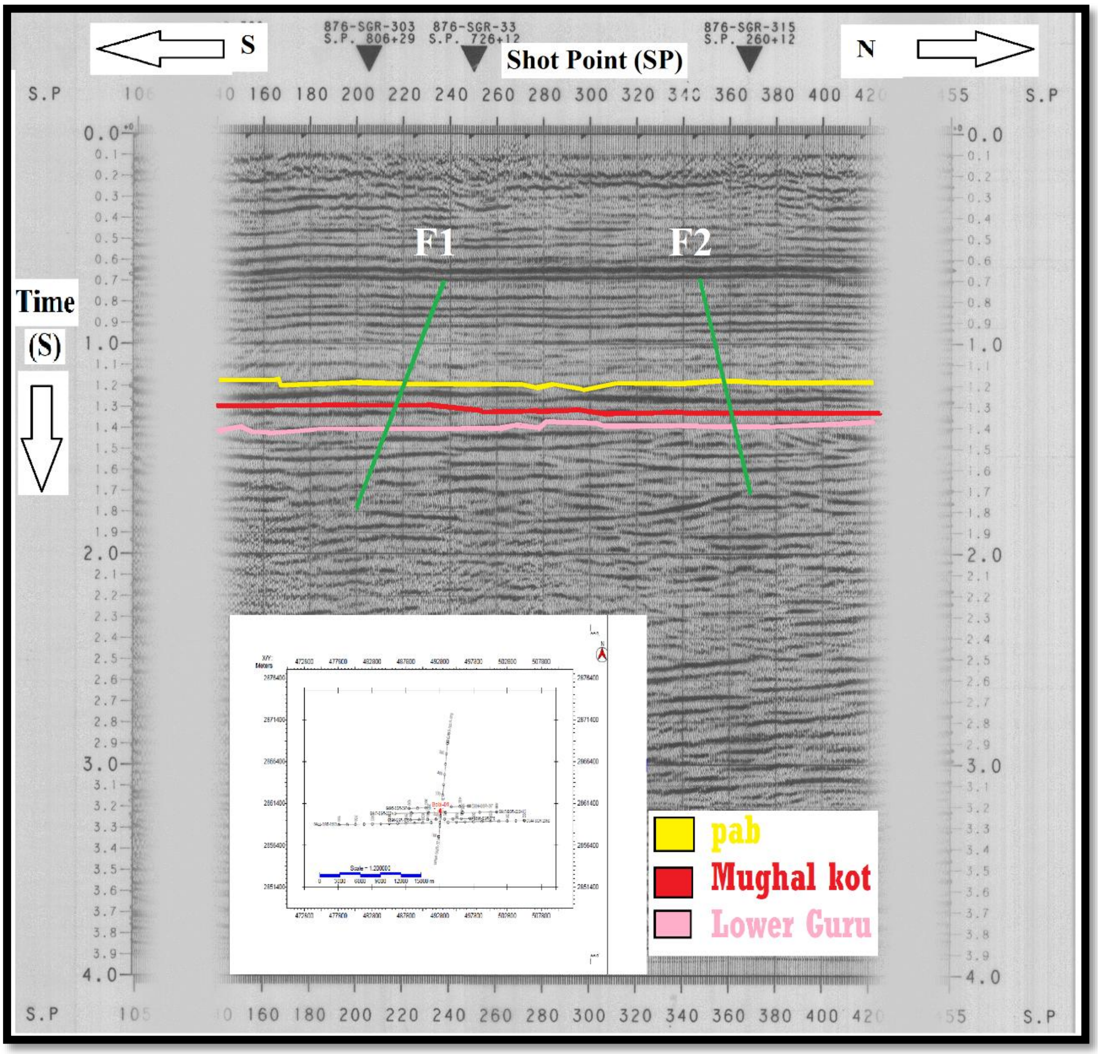


Figure 7.3 Interprated seismic section of strike line 896-SGR-375.

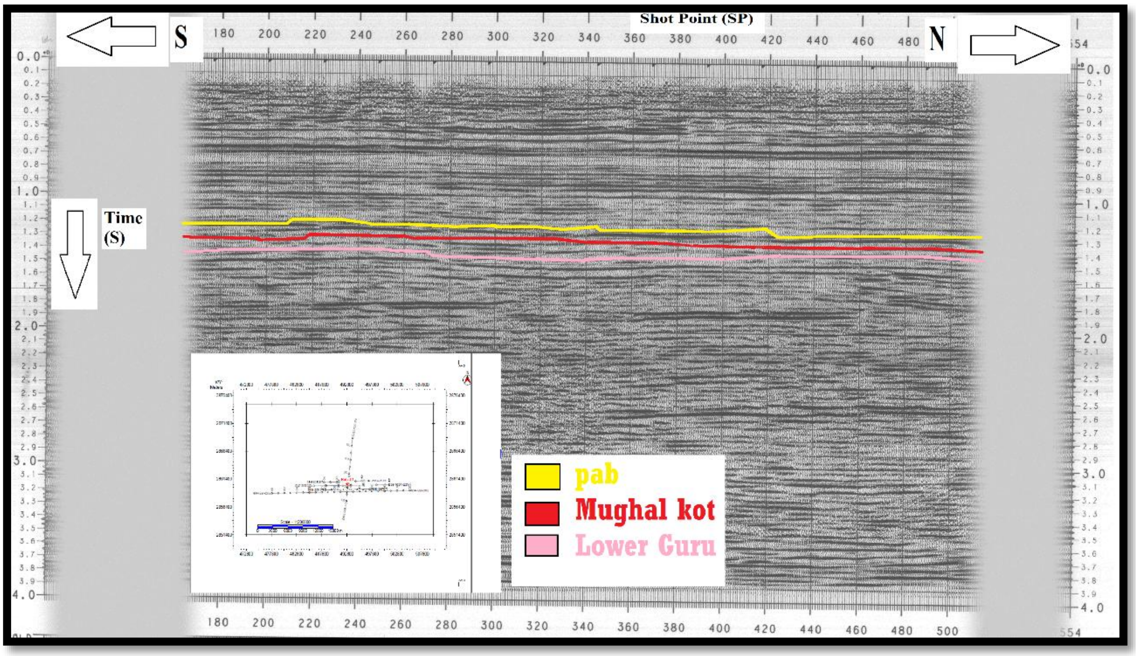


Figure 7.4 Interprated seismic section of strike line 896-SGR-379.

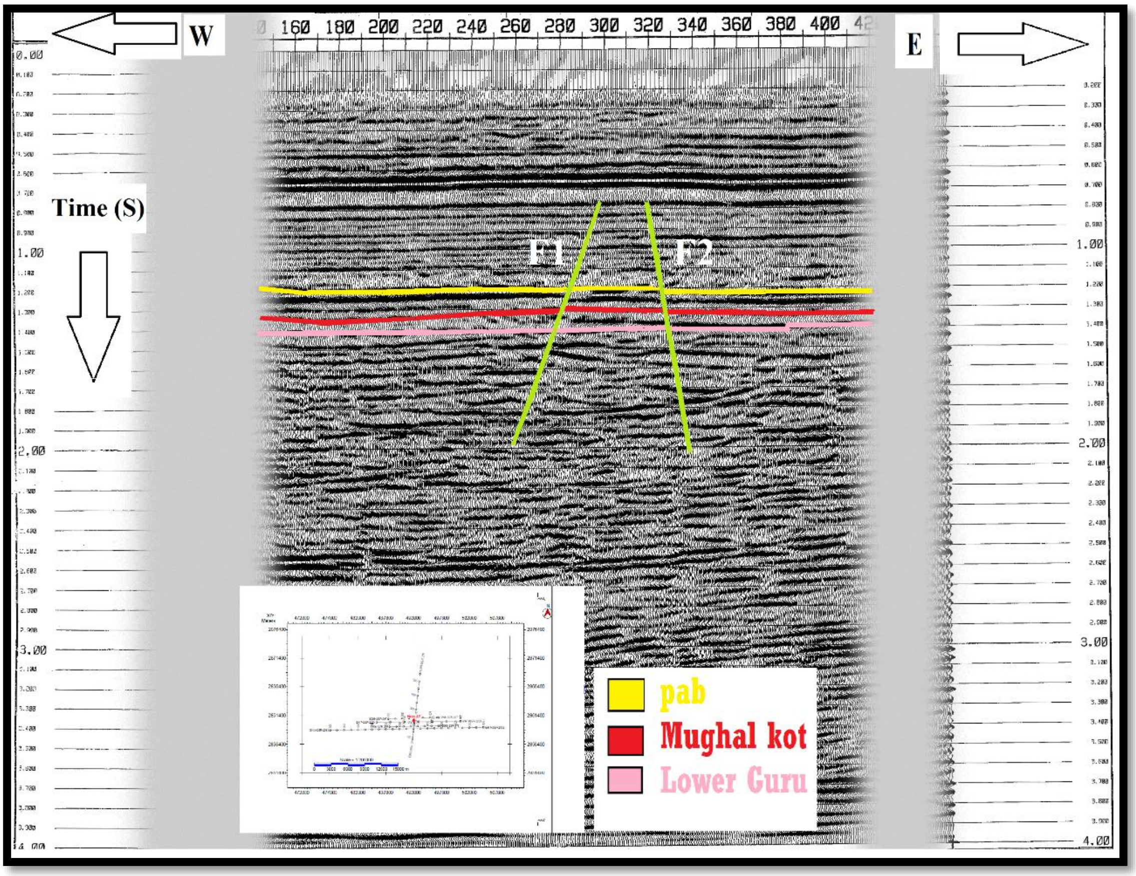


Figure 7.5 Interprated seismic section of dip line 896-SGR-397.

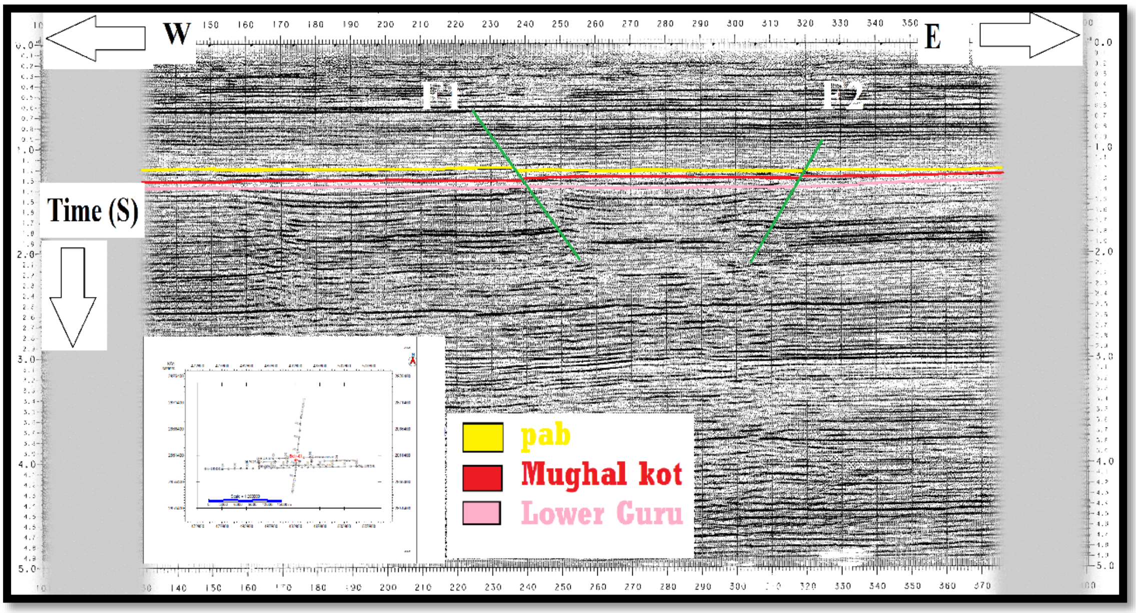


Figure 7.6 Interprated seismic section of dip line 947-SGR-222.

7.2.7 TWT contour maps

Contour map is line showing the same parameters on a 2D map. Here, the contours are made with the help of the time values, which is time of the wave to reflect back from prominent strata due to acoustic impendence contrast. For each reflector, the contours of the time are generated on a map, taking the values of reflectors time picking on the line. TWT contours represent contour lines having the same time values, these values represent the time consumed by the seismic wave from source to travel in the sub surface, strike and reflect back to the surface.

They are plotted on map where latitude and longitude values of each shot point are given. A time grid for each horizons generated which is represented by different color showing the marked horizons. In interpretation, the reflectors of interest are the Pab Formation, Mughal Kot Formation and Lower Goru Formation; following are the reflector time contours maps of the lines 896-SGR-206, 896-SGR-375, 947-SGR-222, 896-SGR-397 and 896-SGR-379 in Sanghar area.

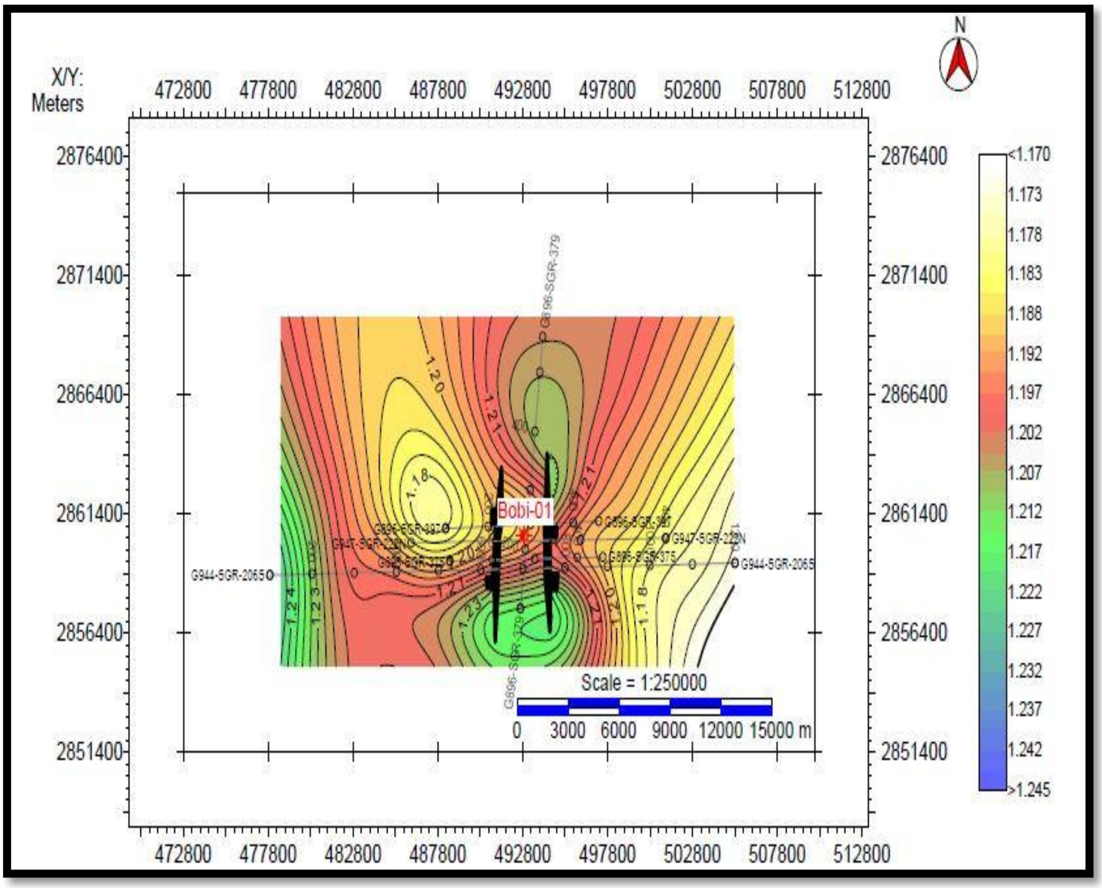


Figure 7.6 Time Contour map of Pab Formation.

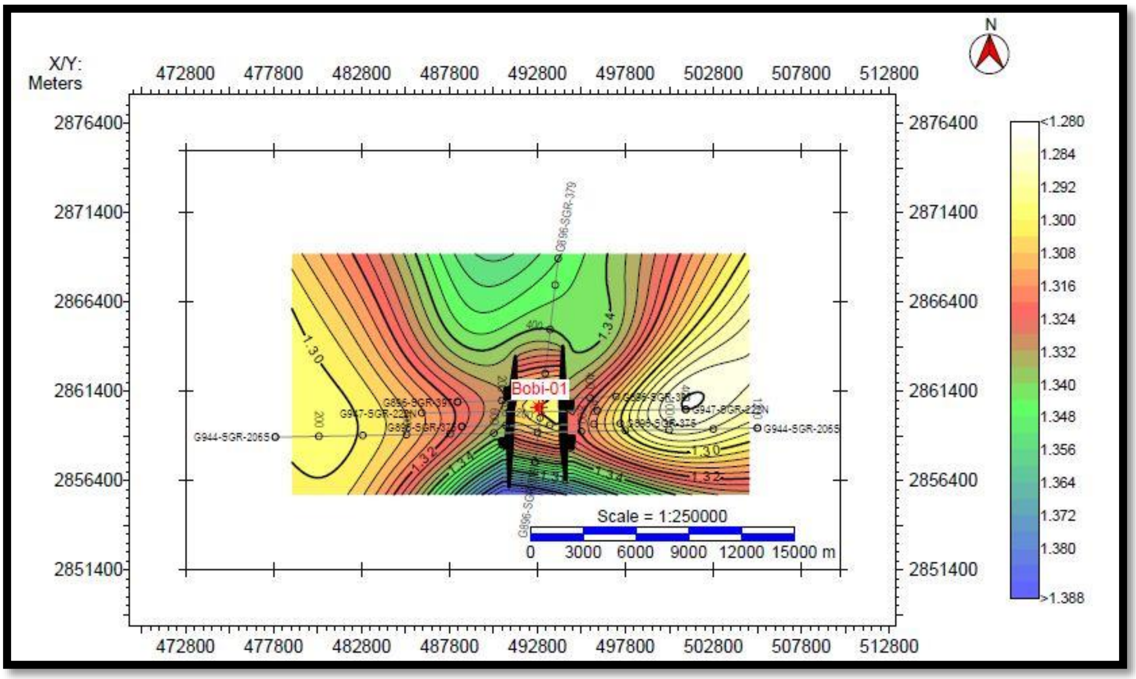


Figure 7.7 Time contour map of Mughal Kot Formation

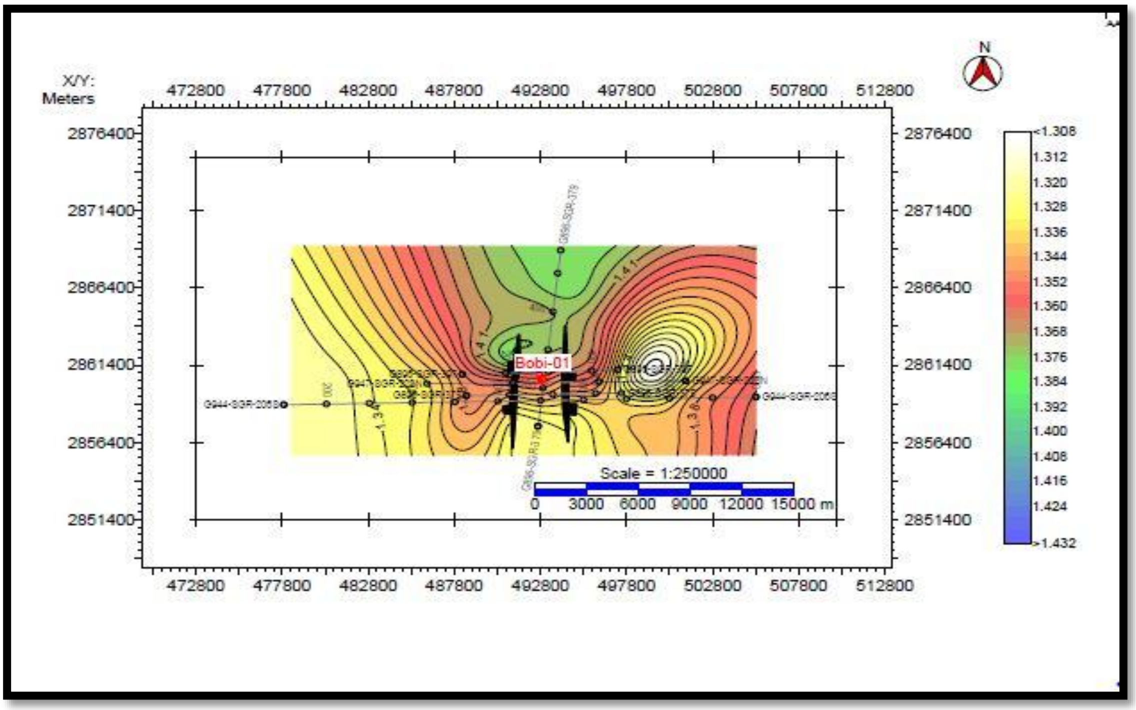


Figure 7.8 Time contour map of Lower Goru Formation.

7.2.8 Velocity contour maps

Velocity contour maps represent the horizons in units of velocity (m/s). The interpretation of velocity contour map is similar to that done for time contour map except that in case of velocity contour map, the units are in meter per second instead of millisecond and velocity will be displayed instead of time.

The velocity contour maps are generated with the help of the reflection time values and the velocity values 944-SGR-206, 896-SGR-379, 947-SGR-222 and 896-SGR-397 lines in Sanghar area. These reflectors of interest are the Pab Formation, Mughal Kot Formation and Lower Goru Formation.

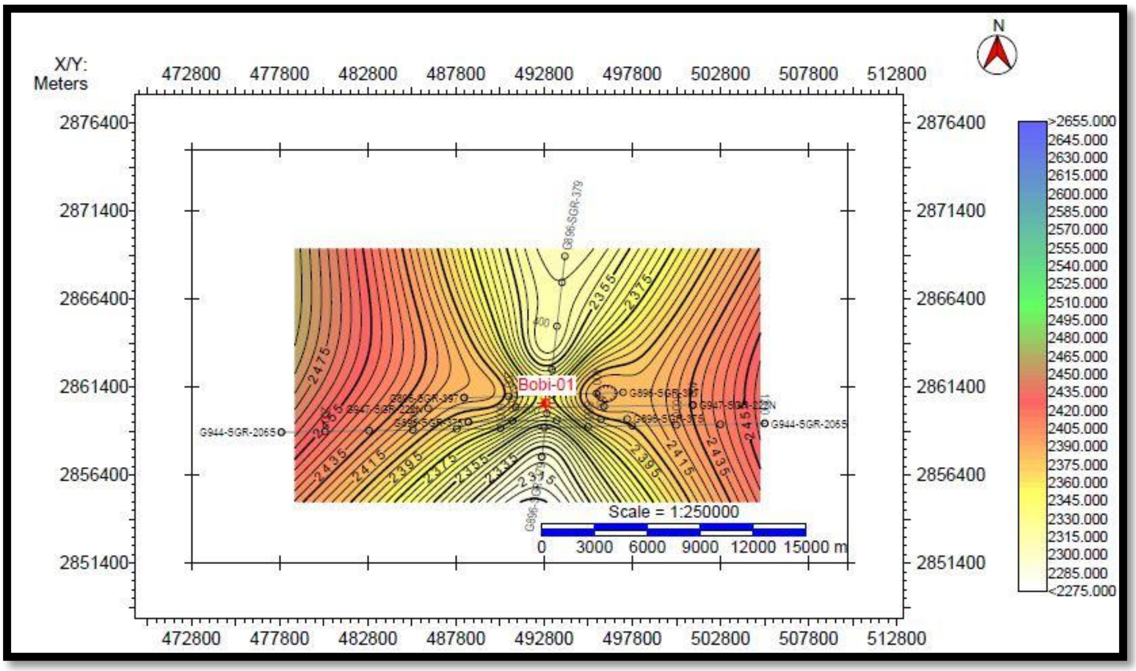


Figure 7.9 Velocity contour map of Pab Formation

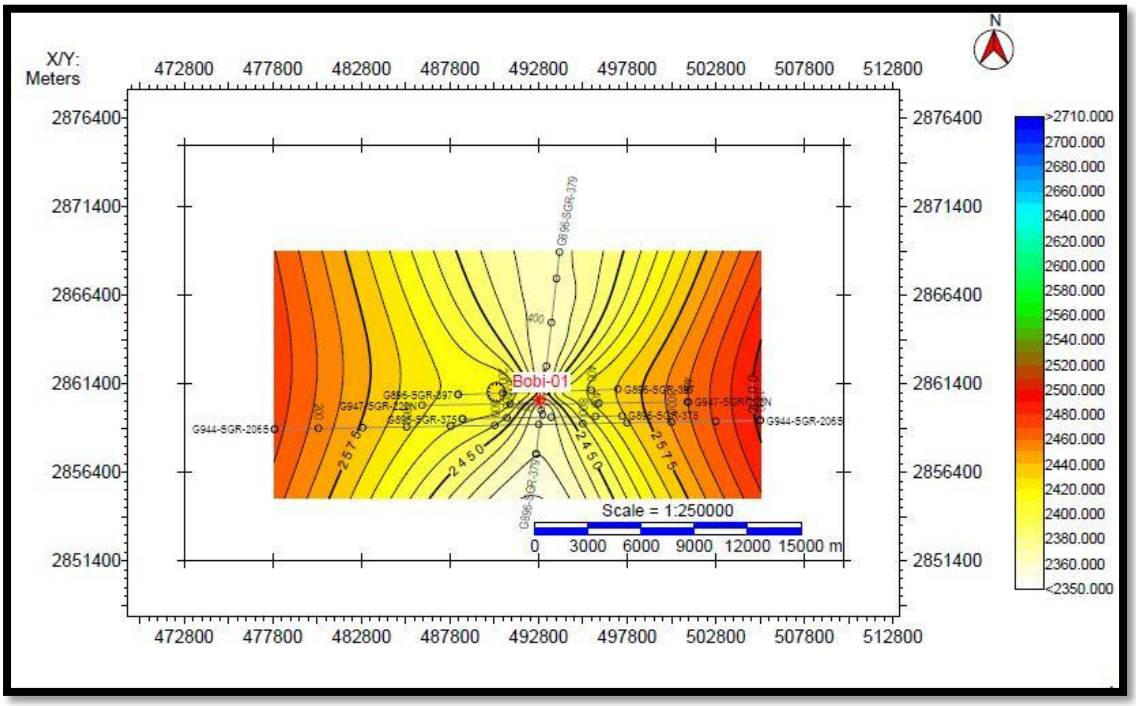


Figure 7.10 Velocity contour map of Mughal Kot Formation.

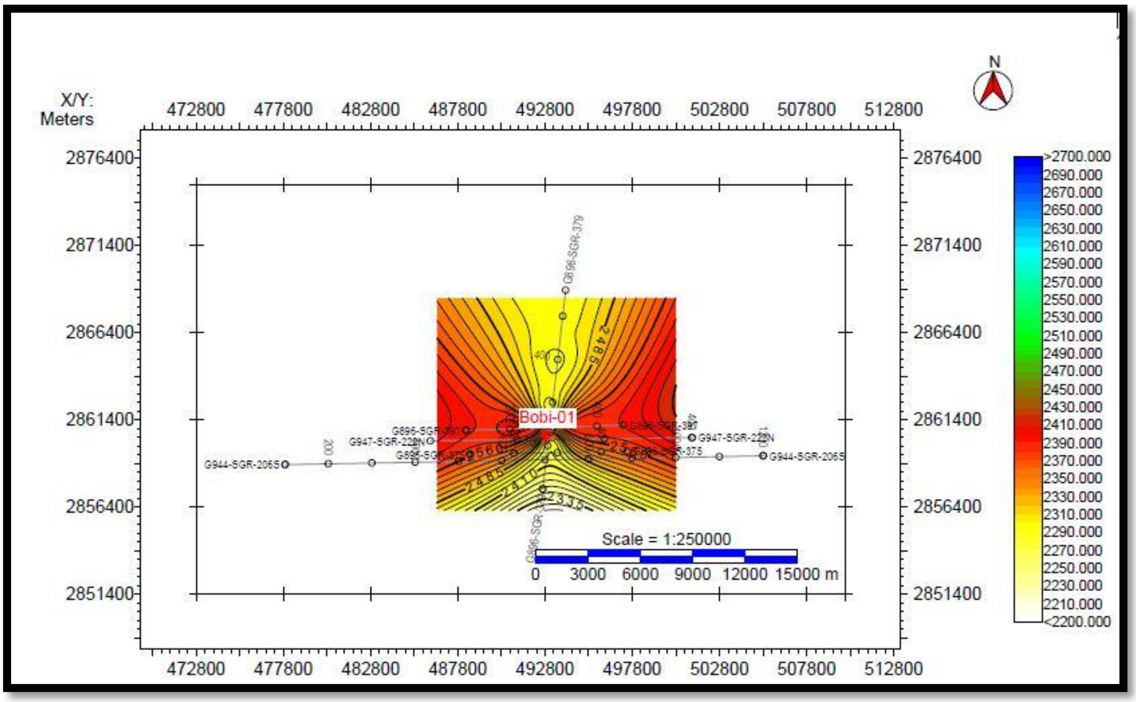


Figure 7.11 Velocity contour map of Lower Goru Formation.

7.2.9 Depth contour maps

Depth contour map represent the horizons in units of depth i.e., meters. This gives more accurate position of the horizons in the subsurface. The interpretation of depth contour map is similar to that has been done for time contour map except that in case of depth contour map, the units is in meters instead of sec. In following figures, the depth contour map are given which are generated with the help of the reflection time values and the velocity values of 944-SGR-206, 947-SGR-222, 896-SGR-379 and 896-SGR-397 lines in Sanghararea. There are five reflectors on the seismic section of the seismic lines mentioned above that were the topic of study, These reflectors of interest are the Mughal Kot Formation, Pab Formation and Lower Goru Formation.

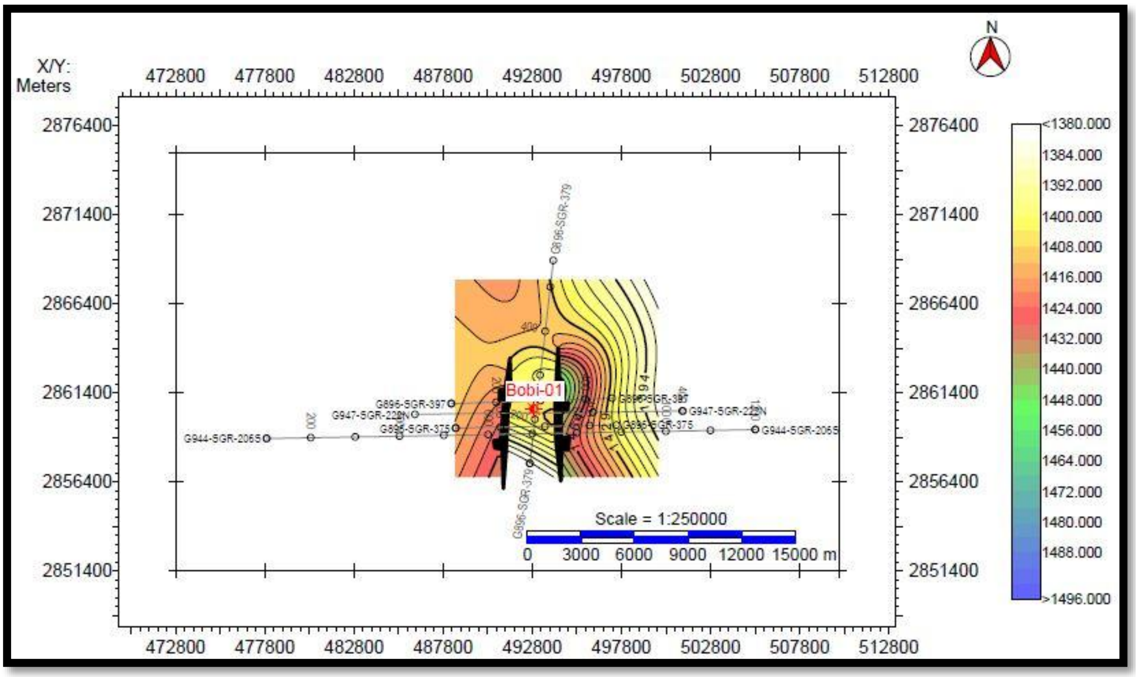


Figure 7.12 Depth contour map of Pab Formation.

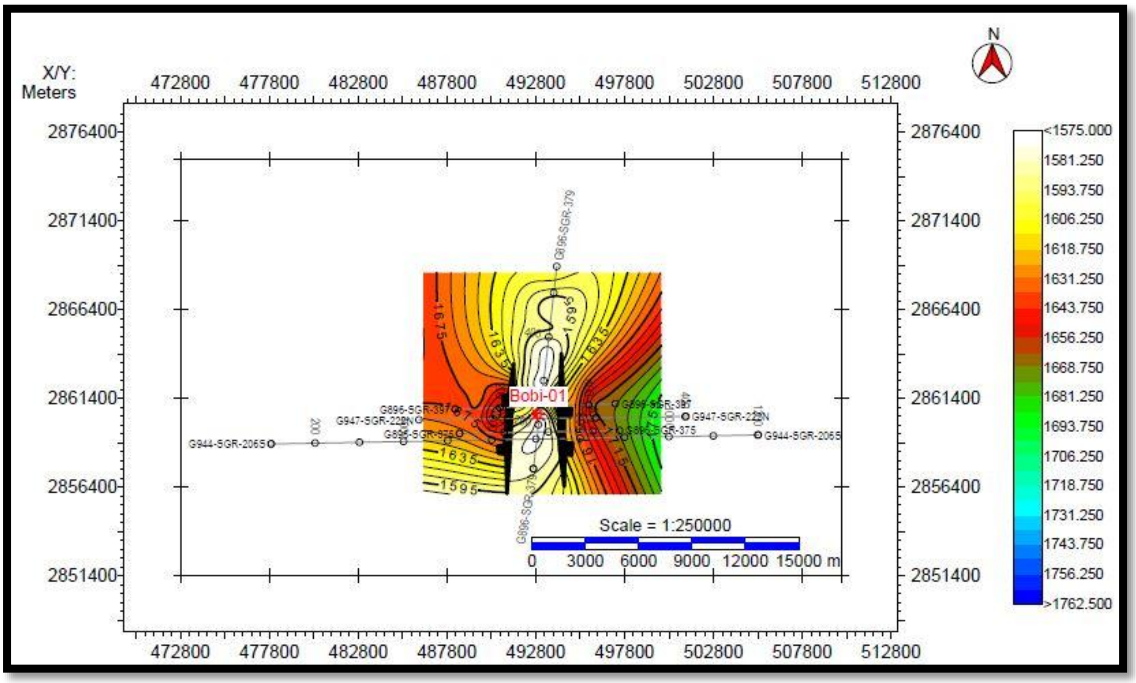


Figure 7.13 Depth contour map of Mughal Kot Formation.

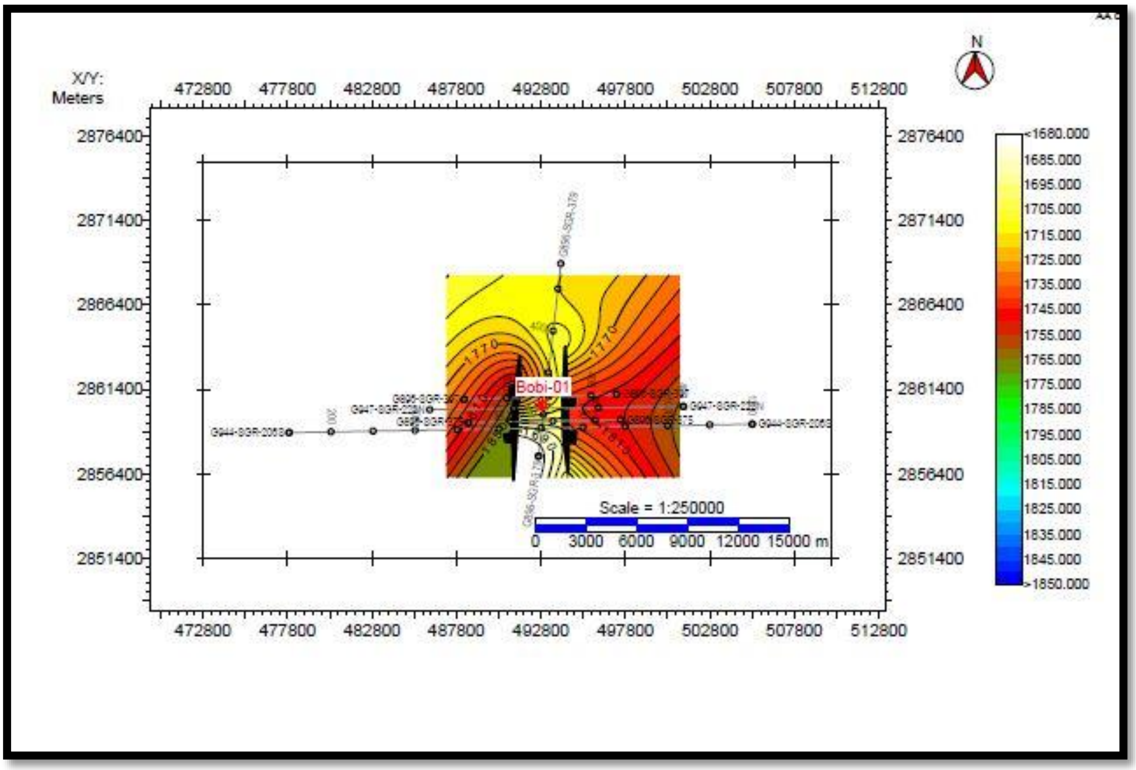


Figure 7.14 Depth contour map of Lower Goru Formation.

CONCLUSIONS

2D seismic interpretation of Sanghar area leads to the conclusion that three Reflectors were marked that are prominent on all seismic lines and Ranikot Formation is dipping from West to East direction. The general direction of fault strike is NNW-SSE. Extensional rifting is the major contributing phenomenon in this region with some lateral movement (strike-slip). This led to a Horst-Graben pattern. Time and depth contour maps generated showing leads, the main lead on which Bobi-01 was drilled are fault bounded from the three sides, whereas from the north it is dip bounded.

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