2D Seismic Reflection Data Interpretation of Badin Area Integrated with Resservoir characterization Along with ID forward Modeling, Facies Analysis and Petrophysics Analysis

By

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CERTIFICATE

This dissertation submitted by **ABDUL WASIQ** son of MUHAMMAD ISHAQ is accepted in its present form by the Department of Earth Sciences, Quaid-i-Azam University Islamabad as satisfying the requirement for the award of BS. degree in Geophysics.

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First praise is to Allah, the most Beneficent, Merciful and Almighty, on whom ultimately we depend for sustenance and guidance. I bear witness that Holy Prophet Muhammad (PBUH) is the last messenger, whose life is perfect model for the whole mankind till the Day of Judgment. I thank Allah for giving me strength and ability to complete this study.

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ABDUL WASIQ

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Chapter#01

(1.) INTRODUCTION

(1.1) Introduction to the Study Area

Badin Block is not a geological entity nor is it different geologically from its adjacent parts. Due to oil and gas fields the area becomes distinctive amongst others but indeed has its extremely important petroleum geology and petroleum system to study and understand. The Badin Block is the part of the Lower Indus which is located to the southern eastern part of Pakistan. The Nagar parker Granite in the extreme Southeastern corner of Pakistan is the exposed part of the Indian craton. The area located to the west and northwest of Nagar Parker are the Tharparkar slope that dips westward and northwestward and where Indus basin most prolific hydrocarbon bearing territory is located. The main tectonic events which have controlled the structures and sedimentology of the Badin Block and also the Indus Basin are rifting of the Indian Plate from Gondwanaland (Jurassic or Early Cretaceous) which probably created NE-SW to N-S rift systems, isostatic uplift or ridge-push at the margins of the newly developed ocean probably caused uplift and eastwards tilting at the start of the Cretaceous. The disjointing of the Madagascar and Indian plates in the mid to Late Cretaceous which may have caused some sinistral strike-slip faulting in the region, hotspot activity and thermal doming at the Cretaceous-Tertiary boundary. This in turn caused uplift, erosion, extrusion of the Deccan flood basalts and probably the NNW-striking normal faults. Too far from Badin Block to the western edge of the Indian Plate at the time of Paleocene-Eocene the emplacement of the Bela Ophiolites may have caused gentle folding, Eocene passive margin conditions caused structural quiescence and carbonate deposition, Oligocene to present-day. The Himalayan collision caused sinistral transpression in the west of the Lower Indus Basin, with fold-thrust structures overprinted by sinistral flower structures but due to Badin Block distant location from the leading edge collision zone the impact is negligible in the structuration. The syn rift and post rift deposition of the Lower Goru and Upper Goru formations was continued during early to middle Cretaceous time which can be observed as relatively thin presence of Upper Goru on the top of the fault blocks (horst blocks) whereas thicker in the lows (graben). The fossils fauna found in the Goru Formation in Badin Block suggest that deposition took place in varied condition, i.e., from continental, transitional, deltaic, shallow marine to deeper marine conditions. The reported thickness of combined Goru Formation (Upper and Lower Goru) 2000ft to 7500ft. The oldest sediments have been reported in the well Marvi -1 (Total depth 17000 ft, drilled by Union Texas in 1997) inside Permian.

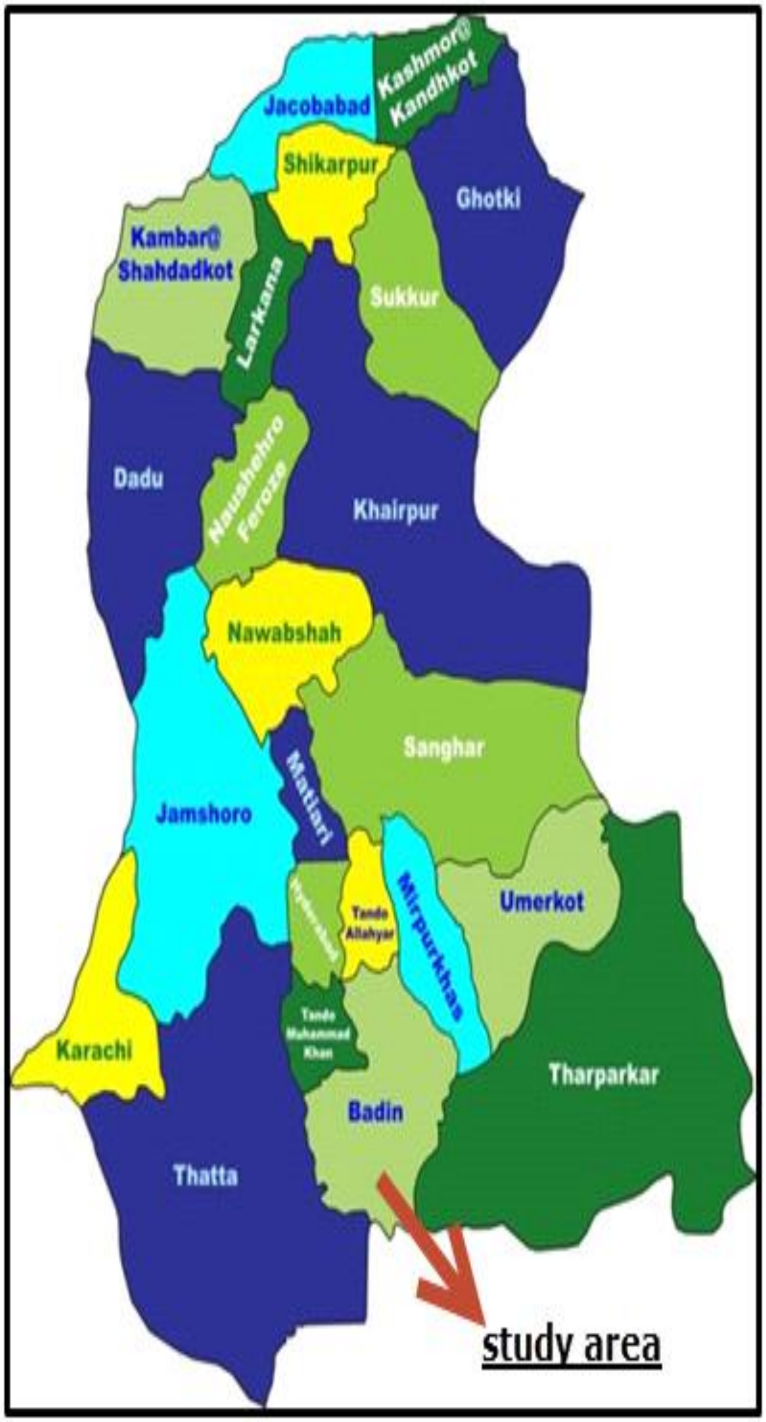


Figure 1.1 Location of the Badin Area

(1.2) Structural Setting and Tectonic History

During Cretaceous, there was a period of tectonic instability. The spreading rate was high,～20 - cm/ a in 80 - 53 Ma (Gnos*et al.,* 1997; Mahoney, 1988; Farah *et al.,* 1984). Badin Rift Basin is located in Thar platform area of Lower Indus Basin. It is the Sargodha High in fact which is considered to be a divide for Upper Indus Basin & Lower Indus Basin (Kadri, 1995). The Badin is characterized by a series of horst and graben structures present below the base Tertiary unconformity within Cretaceous and older strata. These horst and graben structures were formed as a result of rifting between India and Seychelles during the Late Cretaceous (Alam, 2002). The most significant styles seen are rifting, overprinted by shear modification and subsequently modified by doming. The major periods can be characterized as: Distal rift during the Late Jurassic & Early Cretaceous. Reactivation of Shear Modification during Middle Cretaceous. Inversion in Late Tertiary (Uplift and Doming). Badin area was distal to main deformation locations in all three cases, and exhibits a provisional degree of deformation across the Badin. As a result the degree of deformation is relatively low, and progressively increases from East to West. The extensional tectonics during Cretaceous time created tilted fault blocks over a wide area of eastern Lower Indus sub-basin. Seismic reflectors, representing Cretaceous and older layers, are broken by a system of faults with normal dip separation. The Cretaceous faults generally strike between N 30^{o} W and N 50^{o} W (Kemal*et al.,* 1991). Commonly, faults are arranged in enechelon sets, aligned in zones that trend almost north south. The tilted fault block traps were in existence at time of hydrocarbon generation. Fault associated structural closures are responsible for trapping oil and gas in Lower Goru sandstone in Badin block. The under filling of structures can be attributed to upward leakage across extensive structures and redistributed hydrocarbon (Kemal *et al.*, 1991).Numerous plays and prospects of hydrocarbon are associated with the Cretaceous system, consequently the Indus basin is attractive to petroleum exploration companies in Pakistan (Sheikh and Naseem,1999).

(1.3)Base Map

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

Sr.No	**Line Name**	**Line Direction**	Nature	**Wells**
1	PK 94 - 1803	NW-SE	STRIKE	
2	PK 92 - 1690	NE-SW	DIP	
3	PK 94 - 1802	NE-SW	DIP	
4	PK 94 - 1804	NE-SW	DIP	DOTI-01

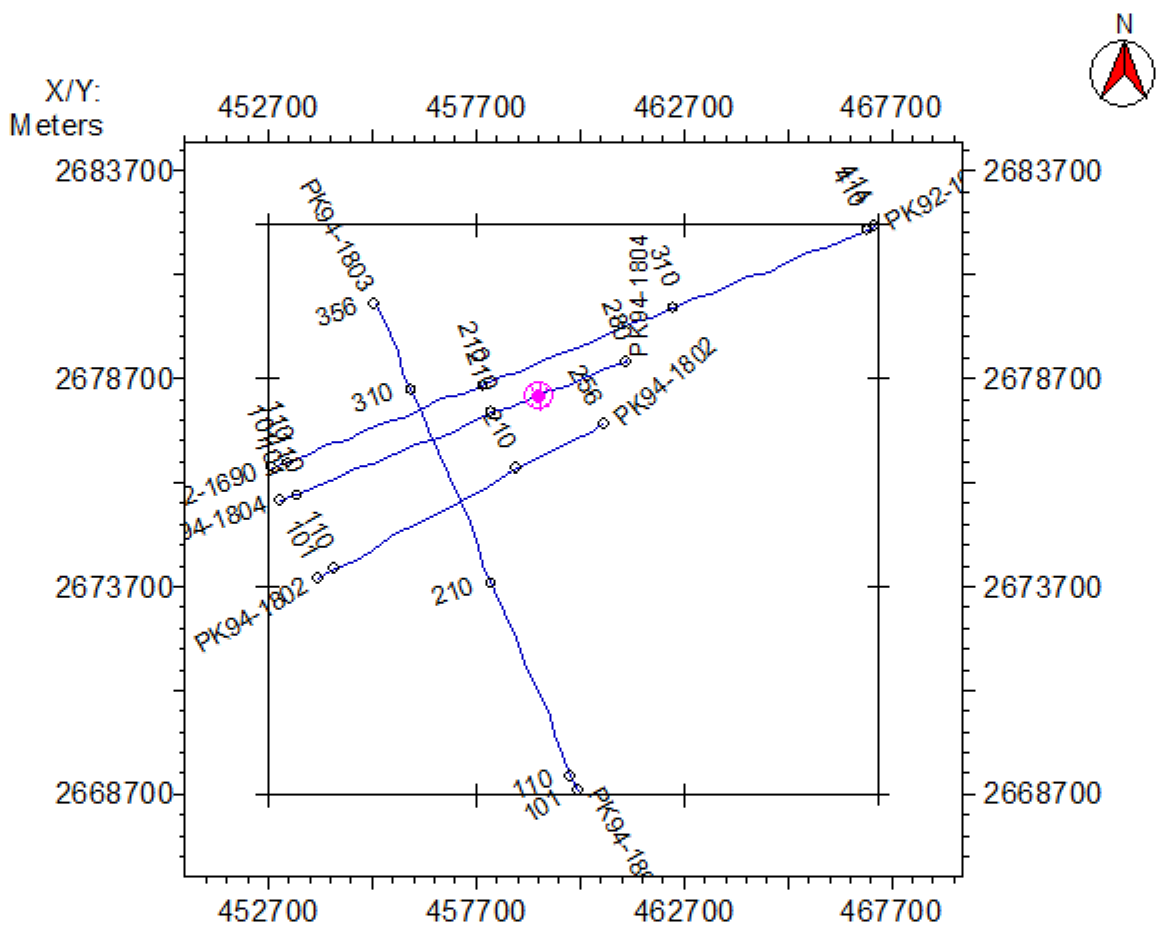


Figure 1.2 Seismic Line and Location of Well on Basemap of Badin Area

(1.4)Data Formats

Seismic reflection data which consist of following formats;

- SEG-Y
- LAS
- Navigation

All data sets used were provided by Directorate General of Petroleum concession (DGPC), Government of Pakistan upon the request of Chairman Department of Earth Sciences, Quaid-I-Azam University,Islamabad.

(1.5)Software Tools and Applications

SMT Kingdom 8.6

- Structural Interpretation
- Stratigraphic Interpretation
- Well correlation
- Seismic attribute analysis.
- Rockphysics and Petrophysics

(1.6)Analysis of Workflow

The Interpretation was carried forward using different techniques and steps with each step involve different processes which were performed using the software tools as mentioned above. Simplified workflow used in the dissertation is given in figure 1.3, which provides the complete picture depicting how the dissertation has been carried.

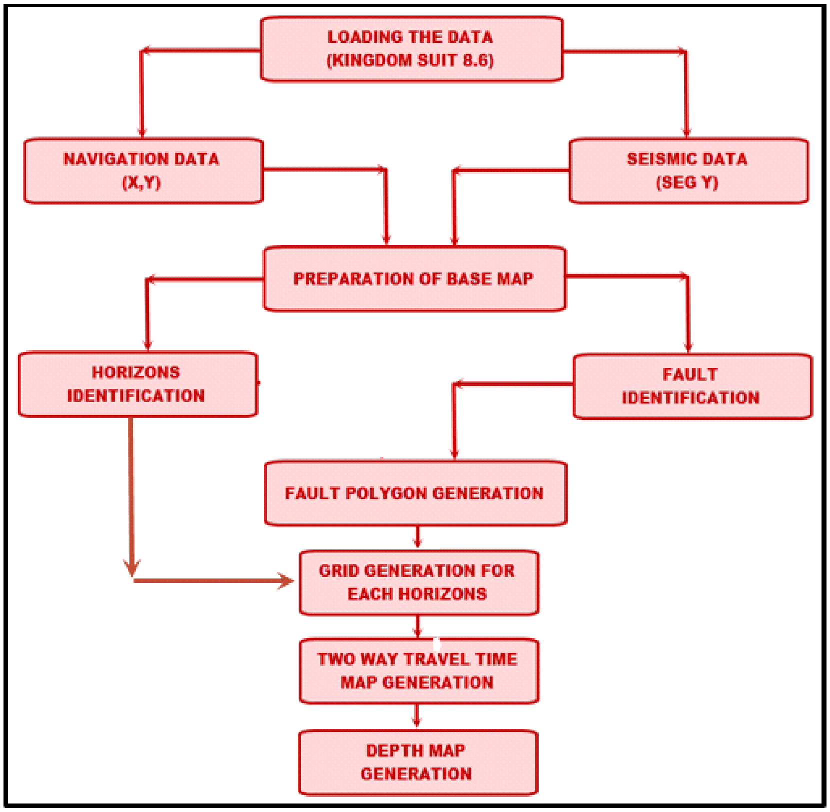


Figure 1.3 Work flow of seismic interpretation

(1.7)Objectives

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

- Structural and stratigraphic interpretation to find out the structural traps and horizons of interest.
- To generate time, depth contour map of the selected reflectors.
- Seismic attribute analysis to confirm the interpretation.
- 1 D forward modelling to confirm the marked horizons.
- Petro and rock physical analysis of reservoir formations to identify the net pay zone.

Chapter#02

(2)GENERAL GEOLOGY AND STRATIGRAPHY

(2.1)Indus Basin

The Indus Basin belongs to the class of basins. It is the largest sedimentary basin of Pakistan. The basin is oriented in NE-SW direction. Basement is exposed as outcrop at two places, one in NE as Sargodha High and second in SE as Nagger Parker High. It comprises of normal to moderate and some steeply dipping structures. The compressional regime of the tectonic plates resulted the basin into Upper, Middle and Lower Indus basin.

(2.2)Regional Geology

Pakistan has the northwest boundary of the Indian plate. The subduction of Indian plate under the Eurasian plate developed compressional thin-skinned tectonic features since Eocene time on the northern part of Indian plate. The continued compressional forces and subduction of Indian plate since Cretaceous produced the mountain ranges of the Himalaya and the chain of foreland fold and thrust belts as thick sheets of sediments thrusted over the Indian craton (Kemal, 1991).

In Northern Pakistan, the Himalayan trend can be divided into four major divisions. On the north of Main Karakoram Thrust (MKT) Karakoram and Hindukush Mountain ranges lies. Kohistan block is on the south of MKT and on the north of Main Mantle Thrust (MMT). Swat, Hazara and Kashmir lies between the MMT and Main Boundary Thrust (MBT). The outlying Potwar Plateau, bounded on the south by the Salt Range Thrust (SRT) is the foreland folds and thrust belts of Pakistan which is equivalent to the Sub-Himalaya (Pennock et al, 1989). Kazmi and Jan (1997) named the Northwest Himalaya as the Northwestern Himalayan Fold and Thrust belts, in their tectonic zones of Pakistan.Oligocene to present-day Himalayan collision caused sinistral transpression in the west of the Lower Indus Basin, with fold-thrust structures overprinted by sinistral flower structures. F.K Bender et al, 1995.

(2.3)Geology of the Area

Pakistan is divided into many basins in which Indus basin is a major basin divided into two parts. Northern and north-eastern part of the basin is known as upper Indus basin and the southernmost part of the Indus basin is known as Lower Indus basin, Badin Block is the part of this basin. The is situated between 24°-5'to 25°-25' north latitude and 68° 21' to 69° 20' east longitude It starts from south of Khairpur High and extends into the Arabian Sea. Petroleum exploration started in back in 1950's in the Lower Indus basin. The first gas discovery was Sari-Hundi in Kirthar Range; district Dadu whereas first major oil struck in early 1980's at Khaskheli, near Badin where several large and small oil and gas fields have been discovered since then. The Lower Indus basin can be divided into areas where Neogene to Cretaceous rocks are exposed along Kirthar Range, and into the areas where no surface geology exposed or minor at lesser extent geological units of Neogene to Pleistocene are cropping out. Badin Block are areas nearby all are without surface geological expression.

In Badin area, early Cretaceous Sembar Formation is considered as the principal source rock whereas clastics of the Early Cretaceous age Lower Goru Formation is the main reservoir. Traps in the Badin area is generally tilted fault blocks associated with normal faults developed during Late Cretaceous and Early Paleocene rift phase.

Badin area and northern part of Sindh province also fall in Indus Basin where Lower Goru Sands (Lower Cretaceous) are the main reservoir for oil and gas. In all these areas, Sembar shales are considered as the source rock. Habib Rahi limestone (Eocene) is the gas reservoir in the giant Mari Field. Ghazij shale is the cap rock for SML while Lower Goru shale provides cap rock for Pab. The intraformational shale within Lower Goru provides the seal.

The cap rock is invariably all the time is impermeable marl and shale sequence of Upper Goru Formation whereas the Early Paleocene volcanic flow, known as Deccan basalt, believed to be the reason for providing increasing temperature to the underlying sediments including source rock (Sembar and Goru) which help to generate hydrocarbon from the source and the process of the oil expulsion started to take place. A.H Kazmi et al, 1997.

(2.4)Boundaries of Lower Indus Basin

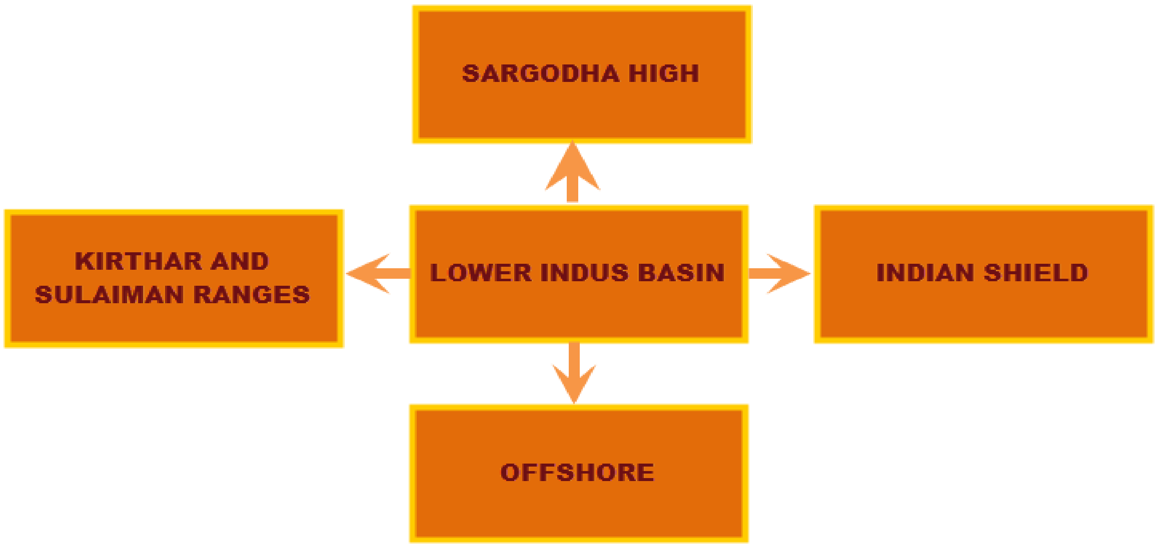


Figure 2.1 Boundaries of lower Indus basin

(2.5)Division of the Lower Indus Basin

Lower Indus Basin is further divided in to two classes

- Central Indus Basin
- Southern Indus Basin

My Study area belongs to Southern Indus Basin. So I will mainly focus on southern Indus Basin, its geology, tectonics and other aspects.

(2.5.1)Southern Indus Basin

The southern Indus basin (550 × 220 km) extends approximately between 24°N to 28°N Longitude and 66° to 71° E Latitude (V.N. Qadri and S.M. Shoaib, 1986). It is characterized by several structural Highs.

- Thar Platforms
- Karachi Trough
- KirtharForedeep
- Kirthar Fold Belt
- Offshore Indus

(2.5.2)Boundaries of Southern Indus Basin

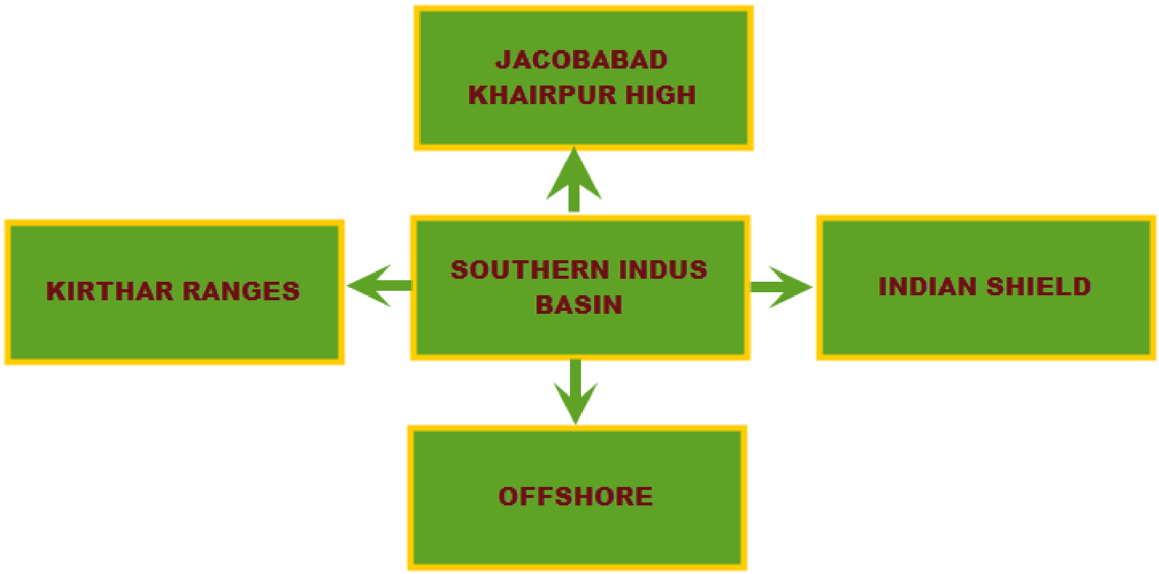


Figure 2.2 Boundaries of southern Indus basin

(2.6)Geological Description of Southern Indus Basin

In the present plate tectonic setting, Pakistan lies between northwestern corner of the Indian plate, the southern part of the Afghan craton, and the northern part of the Arabian Oceanic plate. The eastern part of the Pakistan was affected by Tertiary plate convergence, having intense collision between the Indo-Pakistan subcontinent and the Afghan craton in the North West (Chamman Transform Fault). The western part of the country affected by the Tertiary convergence between the Arabian Oceanic plate and the Afghan craton (Chagai Arc and the Makran Flysch Basin), and between a segment of Arabian Oceanic plate and the western rifted margin of the Indo-Pakistan subcontinent.

The western margin of the subcontinent (eastern part of Pakistan) is characterized by a broad NS trending sedimentary basin (southern Indus Basin) having thick. Tertiary sequences underlain by Quaternary sediments. It had been relatively tectonically stable during the Mesozoic, but the intensity of shallow Tertiary folding increasing westward and becomes more pronounced in the strongly folded and faulted area of axial fold and thrust belt (N.A Zaigham, 2000).

(2.7)History of Geological Evolution of Southern Indus Basin

Zaigham and Malik proposed a structural model for the evolution of southern Indus Basin. This corresponds to the initial rifting of the super continent Gondwanaland, probably during the Paleozoic (Smith & Hallam 1970; Powell, 1979). The divergent phenomena includes the formation of Basaltic magma in the upper part of the Asthenosphere, causing broad tectonic up warp and thinning of the overlying Lithosphere, probably resulting from plastic flow in the lower part and extensional faulting in the upper part. The thinning of Lithosphere continued and resulted in the collapse of the tectonic up warp over the magma blister and subsequently the process of sea floor spreading began with basaltic magma upwelling to the earth surface at oceanic Lithosphere.

Extensional forces broke the upper brittle crust into blocks separated by active faults during sea floor spreading. It appears that stretching of initial rifted stopped at some geological time during very late Paleozoic to very early Mesozoic (Ahmed & Zaigham, 1993). The stretched crust remained as Indus basin failed rift in sediments started to accumulate.

The third step represents subsidence of the stretched continental crust and simultaneous accumulation of the Mesozoic and Tertiary sediments in the Indus basin.

(2.8)Northward Drift of the Indian Plate and Opening of the Indian Ocean

The Indo-Pakistan subcontinent separated from the Gondwana motherland about 130 million years ago (Johnson et al. 1976). It has been estimated that between 130 M.A and 80 M.A. India moved northward at a rate of 3 to 5 cm/year (Johnson et al. 1976). From 80 M.A ago India moved at an average rate of about 16 cm/year relative to Australia and Antarctica (Powell 1979). According to Patriat and Achache (1984), before anomaly 22 (50 m.y.) this rate of movement varied between 15 and 25 cm/year (fig 2.2).

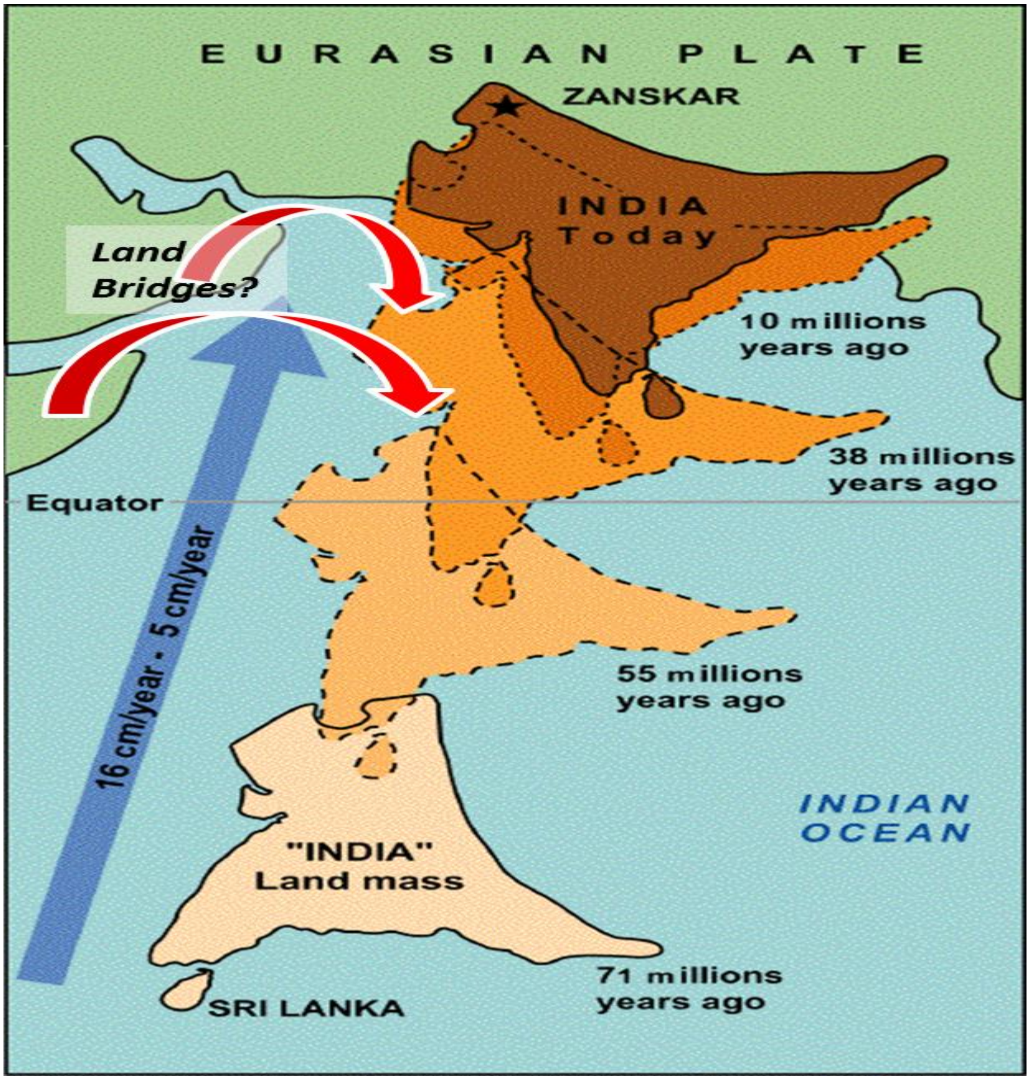


Figure 2.3 Northward drift of Indian plate

(2.9)Tectonic Zones

Two broad geological divisions of this region the Gondwanian and the Tethyan domains are discussed. In this scenario Pakistan is unique inasmuch as it is located at the junction of these two diverse domains. The southeastern part of the Pakistan belongs to Gondwanian domain and is sustained by the Indo-Pakistan crustal plate. The northern most and western regions Pakistan fall in tethyan domain and present a complicated geology and complex crustal structure.

On the basis of plate tectonic features, geological structure, orogenic history (age and nature of deformation, magmatism and metamorphism) and lithofacies, Pakistan may be divided into the following broad tectonic zones see (fig 2.3).

- Indus Platform and fore deep

- East Baluchistan fold-thrust belt
- Northwest Himalayan fold-thrust belt
- Kohistan-Ladakh magmatic arc
- Karakoram block
- KakarKhoarasan flysch basin and Makran accretionary zone
- Chagai magmatic arc
- Pakistan Offshore

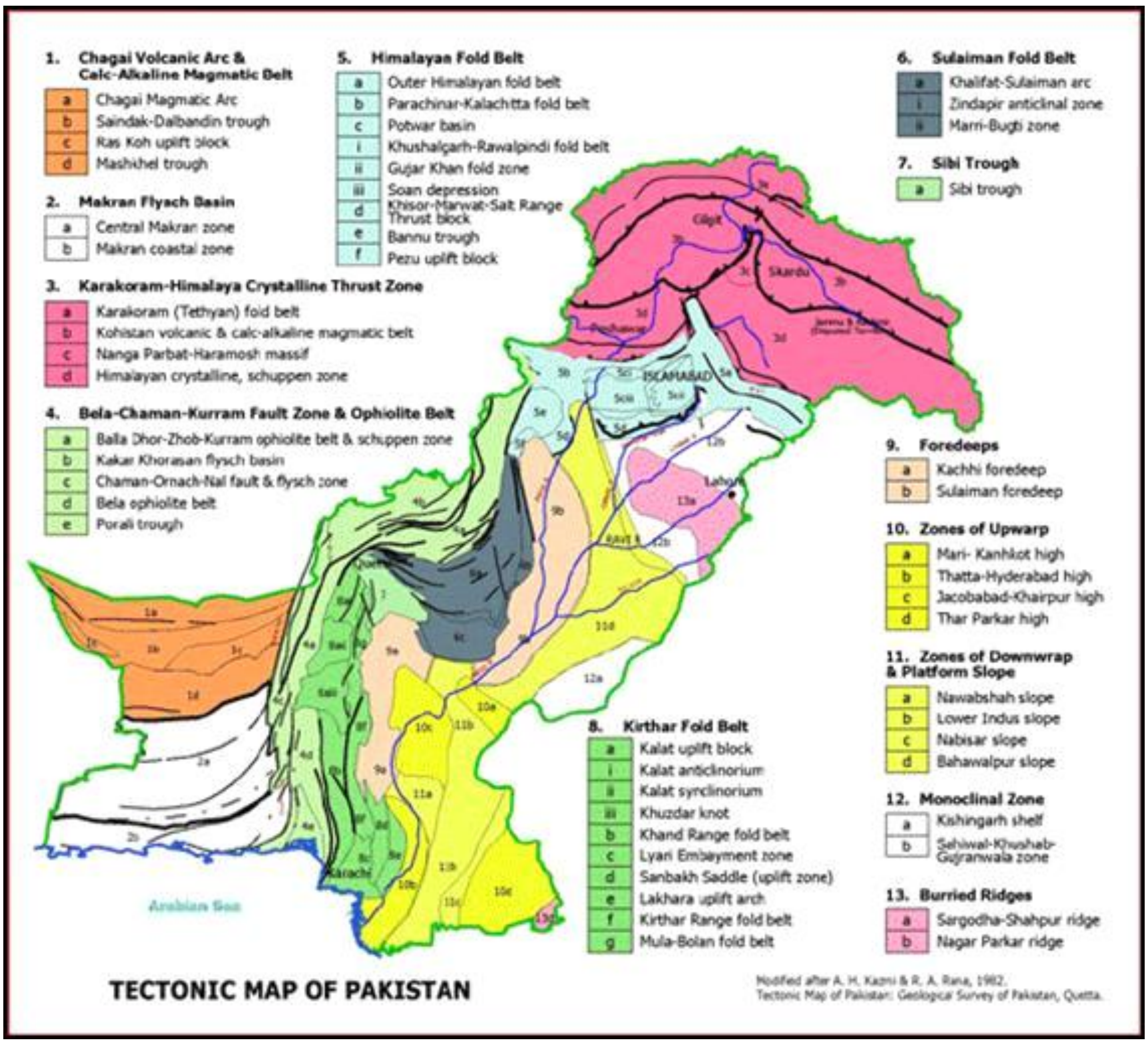


Figure 2.4 Tectonic map of pakistan

(2.10)Horsts and Grabens in Sindh Monocline

Sindh Monocline mainly contains one horst and two grabens named Hyderabad Horst, Sanghar Graben and Badin-Thatta Graben. The northwest movement of the Indian Plate generated compression, whereas accompanying anticlockwise rotation produced tension. As a result of tension, the platform was split into grabens and horst, which produced ideal setting for deposition of oil formations (Raza et al., 1990). The tectonic history shows sets of faults indicating two different episodes of rifting developed in the Monocline. The first set of the faults are associated with Early Cretaceous Kutch rift phases and second set is the consequence of Late Cretaceous Cambay rift. Sembar shales were buried to the depth where the temperatures were suitable for the transformation of OM into oil. Late Cretaceous Cambay rift further divided the area into a horst and two grabens.

The central block remained stable while the adjacent blocks were down faulted. The oil which was subjected to higher temperatures in the grabens due to deeper burial was cracked into the condensate and gas, while the oil in the central part (horst) remained unaffected. This is the deciding factor for the occurrence of the oil fields in the central part of the monocline and the concentration of condensate and gas fields in the north-eastern and south-western blocks. The horst is Hyderabad High where most of the oil fields from Pasahki to Laghari are situated. The northeastern block is Sanghar Graben where except Buzdar and Palli all the fields are condensates and gas fields. The south-western block is Badin-Thatta Graben where except Khaskheli only gas and condensate fields are present (Memon and Siddiqui, 2005)

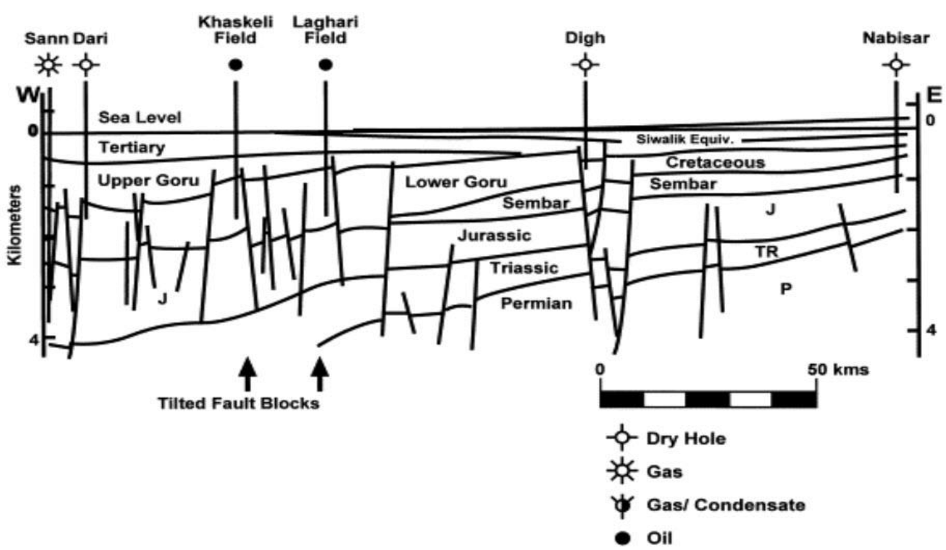


Figure 2.5 Geological Cross Section Of Sindh Monocline

(2.11) Structural Setting in the Badin Block

Badin Rift Basin is located in Thar platform area of Lower Indus Basin. It is the Sargodha High in fact which is considered to be a divide for Upper Indus Basin & Lower Indus Basin (Kadri, 1995). The Badin Rift is characterized by a series of horst and graben structures present below the base Tertiary unconformity within Cretaceous and older strata. These horst and graben structures were formed as a result of rifting between India and Seychelles during the Late Cretaceous (Alam, 2002). The most significant styles seen are rifting, overprinted by shear modification and subsequently modified by doming. The major periods can be characterized as: Distal rift during the Late Jurassic & Early Cretaceous. Reactivation of Shear Modification during Middle Cretaceous. Inversion in Late Tertiary (Uplift and Doming).

Badin area was distal to main deformation locations in all three cases, and exhibits a provisional degree of deformation across the Badin. As a result the degree of deformation is relatively low, and progressively increases from East to West. The extensional tectonics during Cretaceous time created tilted fault blocks over a wide area of eastern Lower Indus sub-basin. Seismic reflectors, representing Cretaceous and older layers, are broken by a system of faults with normal dip separation. The Cretaceous faults generally strike between N 30^{o} W and N 50^{o} W (Kemal *et al.*, 1991). Commonly, faults are arranged in enechelon sets, aligned in zones that trend almost north south. The tilted fault block traps were in existence at time of hydrocarbon generation. Fault associated structural closures are responsible for trapping oil and gas in Lower Goru sandstone in Badin block. The under filling of structures can be attributed to upward leakage across extensive structures and redistributed hydrocarbon (Kemal *et al.*, 1991).

(2.12)Major Formation of the Area (Badin)

Following are the major formations of Badin Area: -

(2.12.1)Sembar Formation

The Sembar formation consists of black silty shale with interbeds of black siltstone and nodularrusty weathering argillaceous limestone beds. In the basal part pyritic and phosphatic nodules and sandy shales are developed locally. Rock unit is glauconite.And it is proven a good source rock. This rock unit is widely distributed in Sulaiman and Kirther ranges. Its Lower contact with various Jurassic formations such as MazarDrik formation, Chilian limestone and Shirinab formation is disconfirmable while the upper contact is generally gradational with the Goru formation. The Sembar formation is correlated with Chichali Formation of the Kohat-Potwar

Province. This rock unit is richly fossiliferous and the most common fossils reported are the belemnites, Mullucs and others and the age given is Early Cretaceous (Shah, 1977).

(2.12.2)Goru Formation

The Goru formation consists of interbedded sandstone, shale and siltstone. The limestone is grained, thin bedded, light to medium grey in color (Shah, 1977).

On the basis of lithology Goru Formation is divided in two parts

- **Lower Goru**
- **Upper Goru**

1. Lower Goru

The lower Goru is main reservoir rock within the area. The lower Goru horizon as a general 5 divisions based on predominant lithologies (Gilbert Killing et al).

- The Basal Sand unit
- Lower Shale
- Middle sand unit (which has a good reservoir potential)
- Upper Shale
- Upper Sand

2. Upper Goru

The upper Goru sequence of middle to late cretaceous unconformable overlies the lower Goru formation which consists of mainly marl and calcareous claystone occasionally with inner beds of silt and limestone (Gilbert Killing et al). The Goru Formation is widely distributed in the Kirther and Sulaiman Province. The lower contact with the Sembar formation is conformable and is very locally reported unconformable by Williams (1959).The upper contact is transitional with the Goru formation may be correlated with the Lumshiwal Formation of the Kohat-Potwar Province. The formation contains foraminifers and bivalves and age given is Early Cretaceous (Shah, 1977)

(2.12.3)Parh Limestone

The Parh limestone is a lithologically very distinct unit. It is a hard, light grey, white, cream, olive green, thin-to-medium-bedded, lithographic and argillaceous limestone, with subordinate calcareous shale and marl intercalations.The formation is widely distributed in parts of the Axial Belt and Lower Indus Basin (Sulaiman and Kirther Province).

The lower contact with the Goru formation is transitional and conformable, while the upper contact with the Mughal Kot formation is unconformable through most of its extent. The formation is correlated with the Kawagarh Formation of the Upper Indus Basin. The formation is richly fossiliferous. Forms (Globotruncana, Gumbelina) are dominant. No macrofossils are known. Age given is Late Cretaceou.

(2.12.4)Ranikot Group

Blanford (1876) was the first to give the name Ranikotgroup.Vredenberg (1909a) subdivided the Ranikot group into Lower Ranikot (sandstone) an Upper Ranikot (limestone).One division of Ranikot group suggests that it comprise of three formations which are Khadro formation, consists of olive, yellowish brown sandstone and shale with interbeds of limestone. Keeping ascending stratigraphy order, Above Khadro formation is Bara formation (Lower Ranikot sandstone) consists of variegated sandstone and shale. and the upper one is the Lakhra formation (Upper Ranikot limestone) consists of grey limestone, grey to brown sandstone and shale. Various authers have given it different divisions. Below areexplained the three formations as part of the Ranikot group with details (Shah, 1977).

(2.12.5)Khadro Formation

The basal part of the formation is comprised of dark coloured limestone with shale, followed by olive, grey to green, soft, ferruginous, medium grained fossiliferoussandstone an olive, gery to brown gypsiferous shale with interbeds of fossiliferouslimestone. A number of basaltic lava flows are also present. The volcanics contain dark green and black basalt interbedded with mudstone, claystone and sandstone (Kazmi and Abbasi , 2008).The formation is widely distributed in Kirther fold belt and its thickness varies at different localities. Its lower contact is unconformable with Moro formation and Pab Sandstone, while its upper contact is conformable with Bara and Dungan formations in various parts of Kirther-Sulaiman fold belt. Khadro formation may be correlated with the lower part of the Rakhshani Formation of Chagai and RasKoharea.Fossils reported from the formation include Corbula Globigerina pseudobulloides and G. triloculinoides and so many others. And age given to the formation is Early Paleocene (Kazmi and Abbasi , 2008).

(2.12.6)Laki Formation

Nuttal (1925) subdivided the laki formation into the following units.

- Basal Laki Laterite
- Meting Limestone
- Meting Shale
- Laki Limestone

The HSC (1960) collectively placed them under their “laki Group”. Cheema et al. (1977) proposed division of this formation into two units., namely sohnari member(Basal Laki Laterite) at the base overlain by meting limestone and shale member, which include the three units of Nuttle, Meting Limestone, Meting Shale and Laki Limestone (Kazmi and Abbasi ,2008).

(2.12.7)NariGaj Siwalik and Alluvium Formation

The remaining formation of Cenozoic era is considered as remnants. The formations have not any importance in term of oil and gas (Gilbert Killing et al, 2002).

(12.13)Generalized Stratigraphy of the Study Area

Numerous plays and prospects of hydrocarbon are associated with the Cretaceous system, consequently the Indus basin is attractive to petroleum exploration companies in Pakistan (Sheikh and Naseem, 1999).

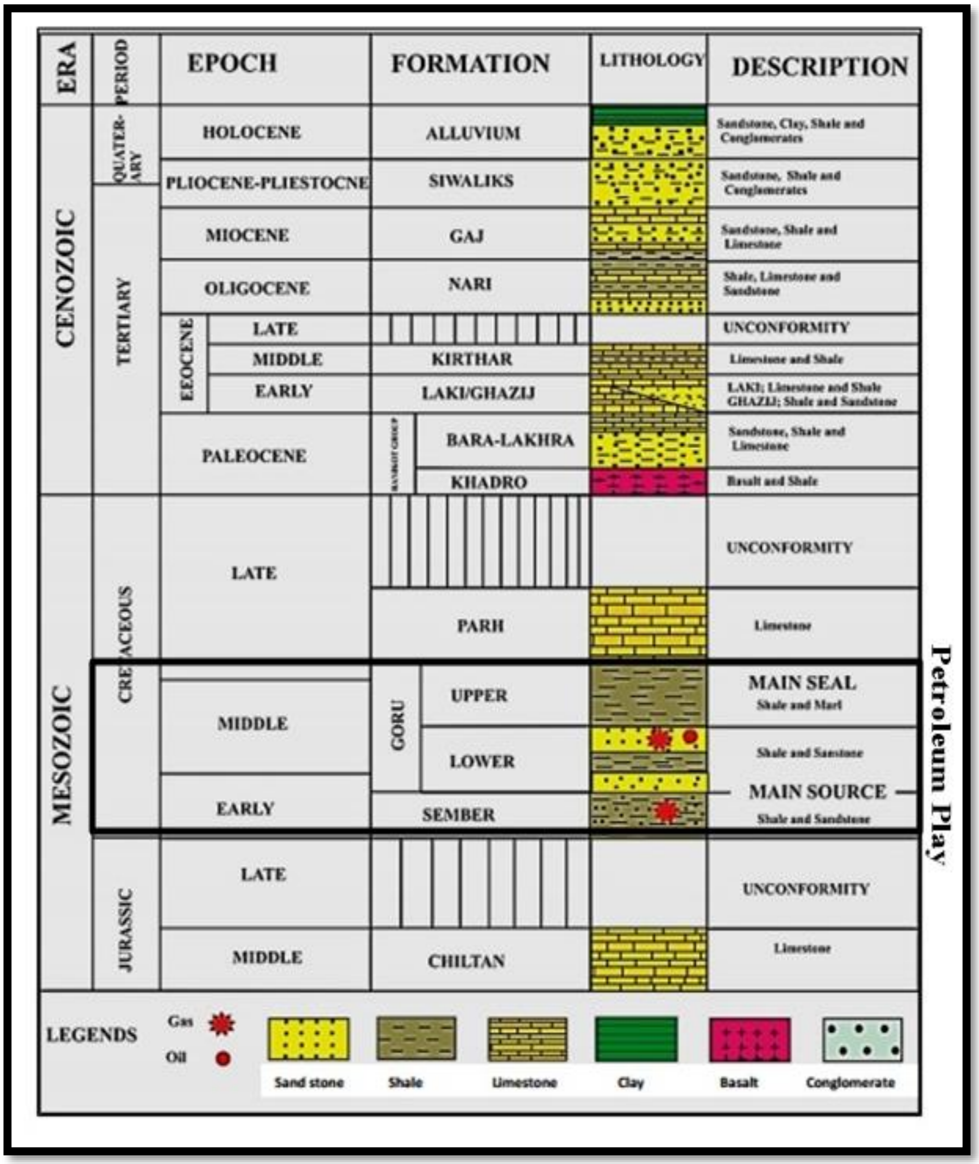


Figure 2.6 Statagraphic chart **(Modified after Zaigham et al., 2000).**

(2.14)Hydrocarbon Potential of Area

(2.14.1)Reservoir Rocks:

The Basal Sand of Lower Goru formation is target formation in the area. Massive Sand is another interesting producing reservoir from its various sand sheets of multiple thicknesses. The possibility of reservoir in Lower Goru overlain on Basal Sand could not be ignored although they have not proved as reservoirs still now (Kadri, 1995). Hydrocarbon targets may also exist in the Jurassic Chiltan Limestone, Paleocene and Eocene formations (Zaigham and Mallick, 2000).

(2.14.2)Seal Rocks:

Sember Formation, Bara-Lakhra, Laki-Ghazij and Kirthar Formations act as seal in Southern Indus basin (Zaigham & Mallick, 2000). Inter-bedded Shales (Upper, Lower and Talhar) of Lower Goru formation provides effective vertical and lateral seal and act as a primary seals. The Upper Goru forms the top and lateral seals for the Upper Sand units of Lower Goru formation. (Kadri, 1995).

(2.12.3)Source Rock:

Sembar is considered as source rock in the lower and middle Indus basins that has high vertical and lateral extension throughout the basins. Source rock in the study area is of early cretaceous. The lower Goru Sand provide the accumulation of hydrocarbon while the upper Goru shaly formation provide a trap. Normal fault provide as excellent seal to hydrocarbon.

(2.12.4)Traps:

All production in the study area is from structural traps. The tilted fault traps in the Lower Indus Basin are a product of extension related to rifting and the formation of horst and graben structures. The temporal relationships among trap formation and hydrocarbon generation, expulsion, migration, and entrapment are variable- throughout the Indus Basin. These provide the significant trapping system along tilted fault blocks and negative flower structures.

Chapter#03

(3)SEISMICACQUISITION AND PROCESSING

(3.1)Seismic Data Acquisition

Seismic investigation starts in the field with the acquisition of seismic data. Seismic data is of two types: seismic reflection data and seismic refraction data. However, seismic reflection data is used more frequently due to its wide application in the oil industry. Reflection refers to the seismic energy that returns from an interface of contrasting acoustic impedance, known as reflector. This energy is recorded at the surface by sensitive detectors which respond to the ground motion produced by the reflected energy in time from place to place, which is indicative of the shape of structural features and their locations in sub-surface. Therefore, reflection techniques are mainly used in oil industry to produce structural maps of such deep-seated configurations such as anticlines, faults and salt domes (Dobrin and Savit, 1988).

The primary objectives of good seismic acquisition should include the maximization of signal to noise ratios by taking advantage of means and opportunities that will not be available at the processing stage. Acquisition systems essentially comprise a source pattern, a detection spread, and a digital recording system. Seismic acquisition system consists of three basic subsystems:

- Seismic Energy Sources
- Seismic Detectors (Energy Receiving Units)
- Recording System

(3.2)Seismic Energy Sources for Reflection Shooting

A number of non-explosive and explosive energy sources have come into use for reflection prospecting. The various types used are as follows:

- Dynamite
- Vibroseis
- Land Air Gun
- Geograph (Dropping of weight)

- Dinoseis (by exploding gas mixture)
- Geoflex (Explosive cord buried in the ground at a shallow depth)

(3.3)Seismic Detectors

Seismic records obtained in prospecting show the motion of the earth's surface, as generated by explosives or other energy sources, at different, usually closely spaced observation positions. On land the motion is actually indicated in terms of particle velocity versus time. The proper translation of the signals thus obtained into geological information requires us to know as much as possible about the behavior of the seismic waves as they propagate through earth materials, but we must also understand the characteristics and performance of the instruments that record the waves when they return to the surface. Seismic detectors are shown in the fig 2.1 The primary elements of modern instrumental systems used to record seismic ground motion are geophones on land and hydrophones at sea. The recording element used for our dissertation is geophone of type 0Y0 and frequency of 10 Hz.

(3.3.1)Spread Geometry

Symmetric	2650-350–x–350–2650 M 1 – 24 –x– 25 – 48
Asymmetric	1450-350 – x – 350 – 3850 M 1 – 12 –x– 13 – 48
No. Of Groups	48
Group Length	159M
Group Interval	100M

Table Showing The Spread Geometry In The Acquisition Of Field Data

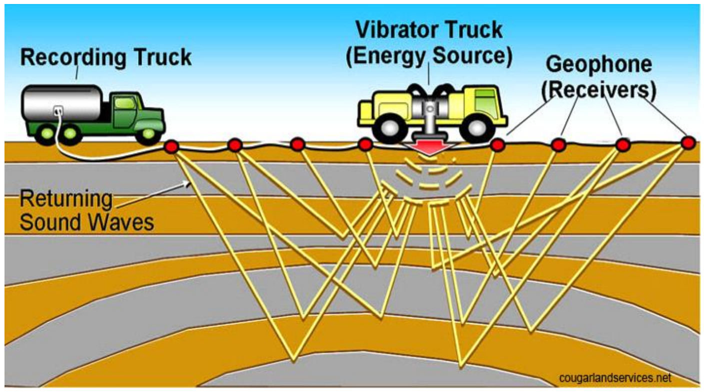


Figure 3.1 Showing The Source, Receivers, Geometric Spread And

Recording System For Seismic Data Acquisition

(3.3.2)Cable

The electric current, produced by geophone signals from ground vibrations is transmitted to recording system through seismic cable. Along the cable, at regular interval there are "Takeout" points where geophones can be connected to its pair of conductors. Each geophone requires two wire conductors.

(3.3.3)Common Depth Point (CDP) Profiling

Common reflection point is its synonym. The place where beds do not in multichannel seismic acquisition, on reflector we get the common reflecting point at depth is known as common depth point. Common midpoint is vertically above the common depth point, in case of flat layers.

While in case of dipping bed there is no common depth point. The fold of common depth is given by equation:

N= Number of phone arrays along a spread.

ΔX = Geophone interval

ΔS = Source interval

The seismic data of the study area is mostly ranging from 60 to 70 fold.

(3.4)Recording system

When ground vibrates, it is in continuous motion and geophones respond to this motion which produces electrical signals. These signals are recorded in two forms. i.e.

- Analog Recording System
- Digital Recording System

(3.4.1)Analog Recording System

A seismogram is a type of graph which shows how signal's amplitude varies with time. An analog seismogram is a continuous record of ground motion as a function of time.

(3.4.2)Digital Recording System

The technique of recording the geophone output at discrete moments is called digital recording because the recording consists of series of digits or numbers. Later these numbers can be plotted and the seismogram prepared by connecting the points (Robinson & Coruh, 1988). If the recording head magnetize this byte then it indicates "1" otherwise it is "0".

(3.4.3)Group Interval

Group interval should not be more than the double of geological feature and reflectors lateral extent. The group interval in the field was 100 meter.

(3.5)Seismic Data Processing

(3.5.1)Introduction

Data processing is sequence of operations which is carried out according to a pre-define program to extract useful information from a set of raw data. Data processing is to convert the information recorded in the field into a form that mostly facilitates geological interpretation (Al. Sadi, 1980). Seismic data processing strategies and results are strongly affected by field acquisition parameters. Additionally, surface conditions, environmental conditions and demographic restrictions have a significant impact on the quality of data collected in the field. Other factors that can influence the quality of data are weather condition and condition of recording equipment. In addition to field acquisition parameters, seismic data processing results also depend on the technique used in processing. (Dobrin, 1988).

(3.5.2)Objectives of Processing

The main objectives of seismic data processing are:

To improve the quality of data

To present the data in a form that is convenient for geological interpretation.

The end product of seismic data processing is a seismic section. Reflecting horizons are visible on the seismic sections and the interpreter can use the sections to map subsurface geological structure. The seismic data is presented in such a form that not only the structural section is obvious but also properties of the subsurface strata may be extracted from the data such as detailed seismic velocity analysis, amplitude and polarity of reflecting horizons and spectral content of data. The aim can be summarized as,

- Visibility of primary reflections
- Accuracy of reflection times
- Resolution
- Preservation of seismic signals

(3.5.3)Processing in General

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

(3.5.4)Processing Sequence

After the raw data has been collected from field, it passes through the whole processing sequence that includes different data processing techniques which are used to suppress the noise and enhance the quality of the data for better interpretation. The raw seismic data is processed to enhance the signal to noise ratio and get the final seismic sections. The generalized processing sequence flow chart (Khan, 2009) is given in Fig 3.2.

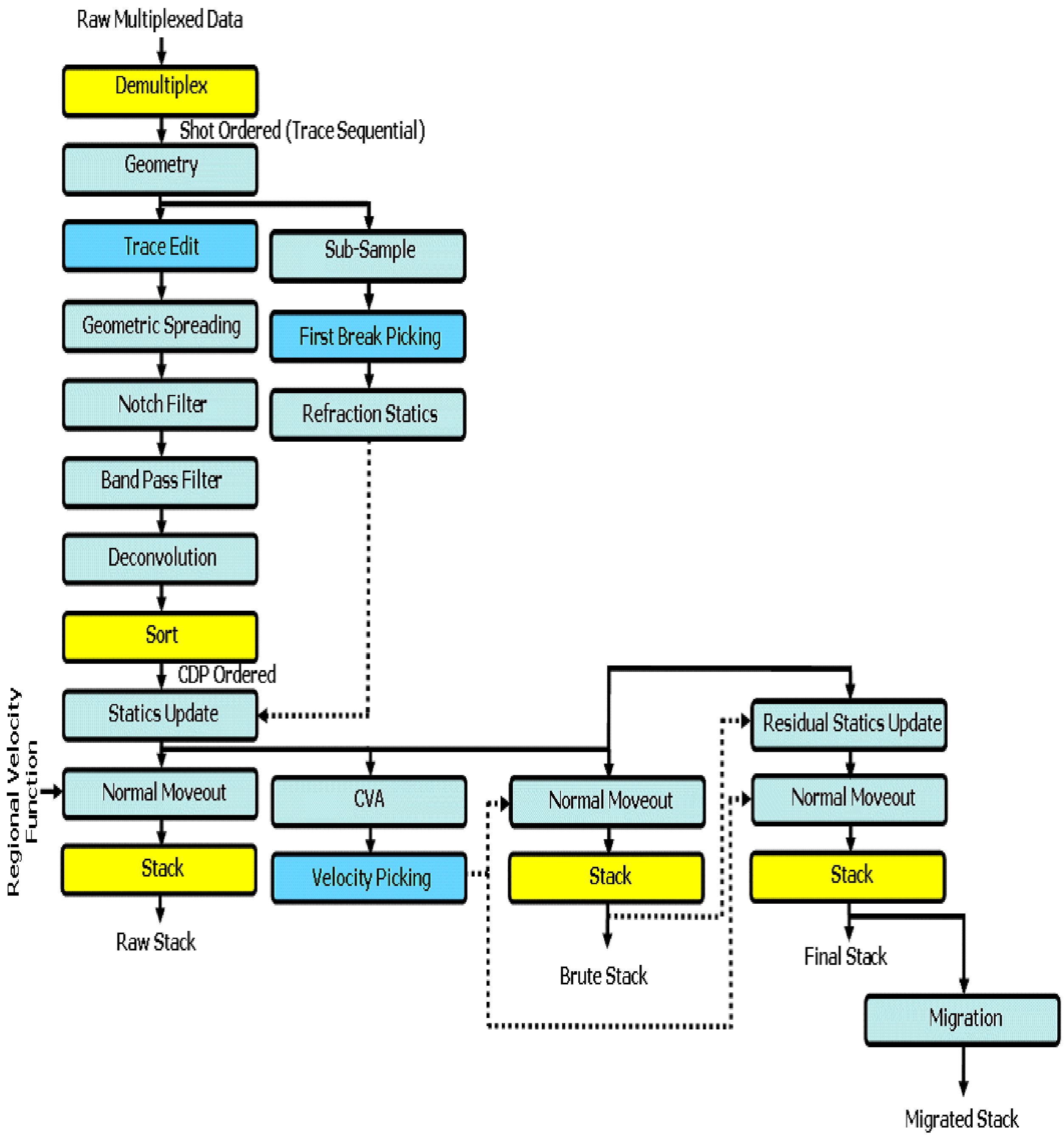


Figure 3.2 Seismic Data Processing Flow Chart. (Khan, 2009)

(3.6)Data Reduction

Data reduction is done by certain processing operations as discussed below.

- Demultiplexing
- Geometry definition
- Correlation
- Header generation
- Display
- Editing and muting
- Amplitude adjustment

(3.6.1)Demultiplexing

Data recorded on digital magnetic tape is not suitable for analysis therefore it is assembled from the digital tape by a sorting process. Thus "the process of sorting data from the magnetic tape into individual channel sequence is called demultiplexing. (Robinson &Coruh, 1988).

(3.6.2)Correlation

Correlation is simply the measurement of similarity or time alignment of two traces. Since correlation is a convolution without reversing the moving array, a similar frequency domain operation also applies to correlation (Yilmaz, 2001). There are two types of correlation.

- Cross Correlation
- Auto Correlation

A. Cross correlation

Measures how much two time series resemble each other. It is not commutative; output depends upon which array is fixed and which array is moved. As a measure of similarity, cross correlation is widely used at various stages of data processing (Yilmaz, 2001).

B. Auto Correlation

Correlation of a time series with itself is known as auto correlation. It is a symmetric function. Therefore only one side of the auto correlation needs to be computed. (Yilmaz, 2001)

(3.6.3)Editing and Muting

Raw seismic data contains unwanted noise and sometime dead traces due to instrumental reasons. Thus the quality of data recorded is first observed by visual examination of raw field traces. Data may be affected by following reasons;

- Polarity reversals in data.
- Poor traces as well as poor bits.

To remove polarity reversal, trace with reverse polarity is multiplied with it that becomes a trace with the polarity. Therefore editing is a process of removing or correcting traces, which in their original recorded taken, may cause stack deterioration.

After doing this all the contributing traces per each CDP are gathered together. Each trace in one CDP is identified by its shot point and receiver numbers .The CDP-gathers may be displayed as such for direct inspection and checking of edited data.

(3.6.4)Muting

Trace-muting is a special type of data editing. This term is applied for process of zeroing the undesired part of a trace. In order to avoid stacking nonreflection events (such as first arrivals and refraction arrivals) with reflection, the first part of the trace is normally muted before carrying out the stacking process.This is occasionally referred to as first break suppression (Al-Sadi,1980).

(3.6.5)Amplitude Adjustments

Amplitude adjustment is done to recover the true information present in the data. True information means data is irrespective of effect produced due to wave propagation through the subsurface. It is wellknown fact that a seismic wave is attenuated as it travels in a non-perfectly elastic medium. Along with this effect, signal is further modified by recording station. So reflection amplitude recorded in the field is the end-result of the interaction of the following main factors;

- Spherical divergence.
- Inelastic attenuation.

(3.6.6)Automatic Gain Control

A grain recovery function is applied on the data to correct for the amplitude effects of wave front (spherical) divergence. (Yilmaz, 2001). This amounts to applying a geometric spreading function, which depend upon travel time, and an average primary velocity function, which is associated with primary reflections in a particular survey area. Gain is applied to seismic data for spherical spreading correction.

Often AGC (automatic gain control) is applied to raise the level of the weak signals. AGC attempts to make amplitudes similar for all off sets, for all time and for all mid points. (Dobrin&Savit, 1988). A typical method of calculating the median or average amplitude with in sliding windows down the trace , then to calculate the multiples needed to equalize the median value in all the window.

(3.7)Geometric Corrections

In order to compensate for the geometric effects, we have to apply certain corrections on the recorded data .These corrections are called as geometric corrections (Dobrin & Savit, 1988). These corrections are applied on the traces gathered during trace editing and muting .The geometric corrections are

- Static correction.
- Dynamic correction.

(3.8)Migration

The process of shifting the reflection points to the positions that correctly image the reflector and remove diffraction images, so that we may get an accurate picture of underground layers.

If the reflector is flat, the reflection point will be located directly beneath the shot/receiver station, and the record section displays the event in its true position, plotted in time rather than depth (Robinson &Coruh, 1988).

However, if the reflector is not flat, the reflection point will not lie directly beneath the shot/receiver position, and the true position of the reflector will differ from its apparent position (Yilmaz, 2001). (Fig 3.3) shows the subsurface dipping reflector’s response.

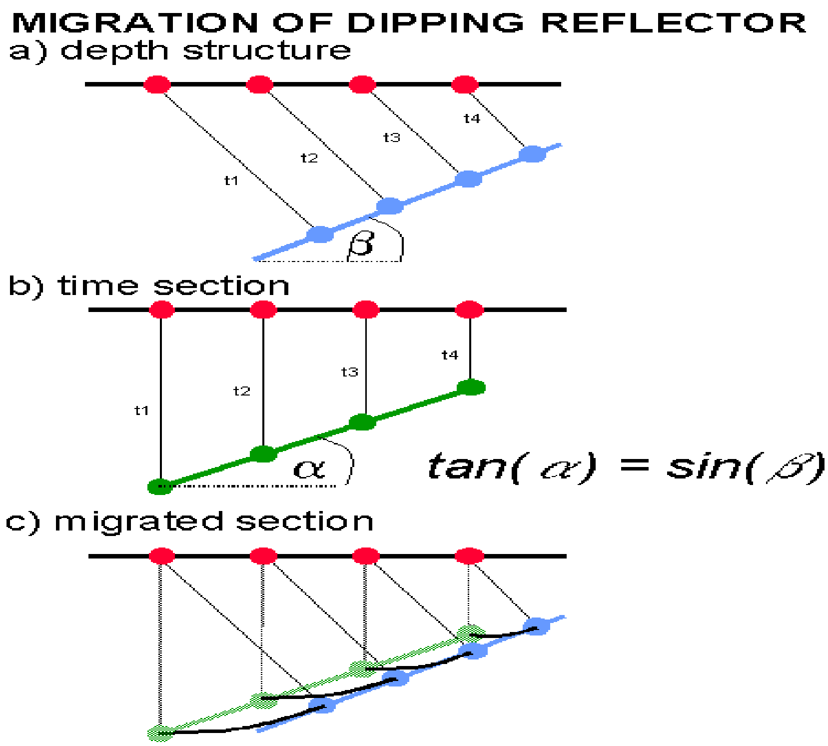


Figure 3.5 Migration of Dipping Reflector

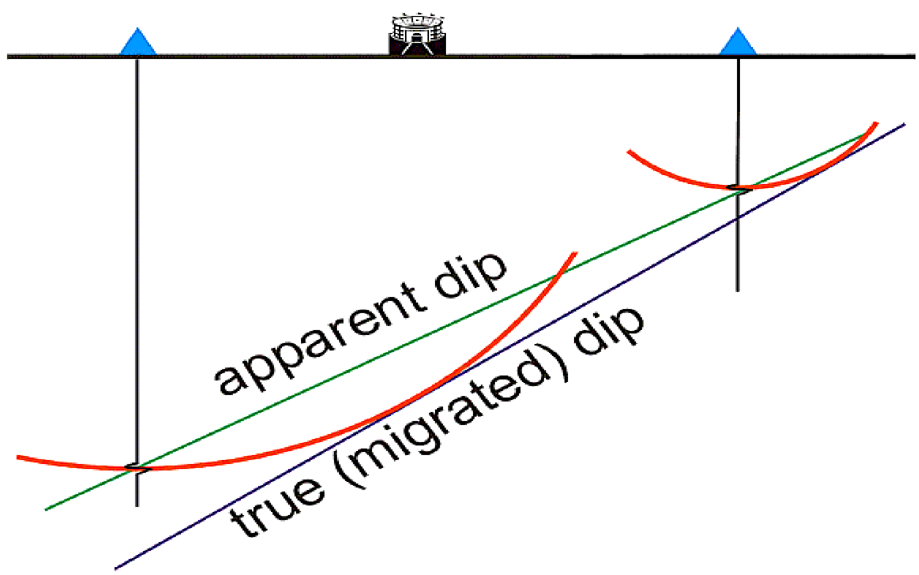


Figure 3.6 Apparent Dip vs True (Migrated) Dip

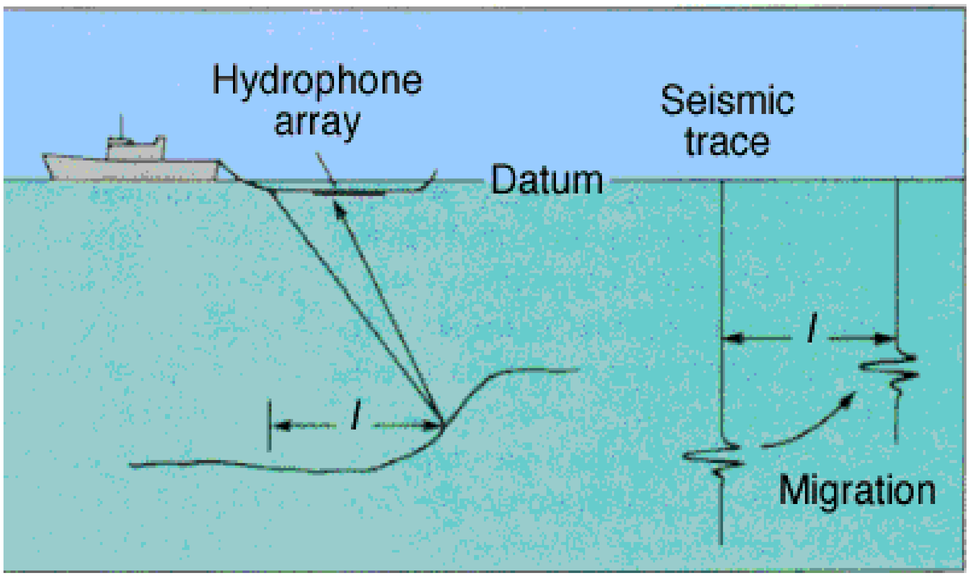


Figure 3.7 Diagram Of Datum And Hydrophone Array

Therefore, migration is a tool used in seismic processing to get an accurate picture of the subsurface layer. It involves geometric repositioning of recorded signals to show a boundary or other structure, where it is being hit by the seismic wave rather than where it is picked up now, not only the position but the dip angle can incorrectly image by vertically plotting.

(3.8.1)Important Features of Migration

Following are the important features of migration

- Migration steepens the reflectors, as the dip angle of the reflector in the geologic section is greater than in the time section.
- Migration shortens the reflectors, as the length of the reflector on the geologic section is shorter than in the time section; thus, migration moves reflectors in the up dip direction.
- When migration is applied in case of the undulating, reflector the crests become narrower and troughs become broad.

(3.8.2)Types of Migration

With respect to the stage when migration is applied on the seismic data during processing, there are two important types of migration.

- Pre-stack Migration.
- Post-stack Migration

Chapter#04

(4)INTERPRETATION

(4.1)Introduction

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

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

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

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

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

- Stratigraphical Analysis
- Structural Analysis

(4.2)Stratigraphical Analysis

Stratigraphy analysis involves the delineating the seismic sequences, which present the different depositional units, recognizing the seismic facies characteristic with suggest depositional environment and analysis the reflection characteristic variation to locate the both stratigraphy change and hydrocarbon depositional environment . The amplitude, velocity, frequency or the change in wave shape indicates hydrocarbon accumulation. Unconformities are marked by drainage pattern that help to develop the depositional environment. Reef, lenses, unconformity are example of stratigraphy traps (Sheriff, 1999).

(4.3)Structural Analysis

In structural analysis main emphases is on the structural traps in which tectonic play an important role. Tectonic setting usually governs which types of the structure are present and how the structural features are correlated with each other's, so tectonic of the area is helpful in determining the structural style of the area and to locate the traps. Structural traps include the faults, folds anticline, pop up, duplex, horst and grabins etc. (Sheriff, 1999).

Seismic section can predict the structure that scale up to few tens of kilometers. A fault with throw less than ¼ of the wavelength of seismic wave will difficult to pick in the seismic section (Badley, 1985).The study area lies in extensional regime, so general structure are normal related i-e horst and graben structure. A normal fault develops under extensional regime.

Over all four faults are marked on the seismic section which indicates the complexity of study area. These are marked on observing the sudden change in the position of the reflectors and distortion or disappearance of the reflection below the faults.

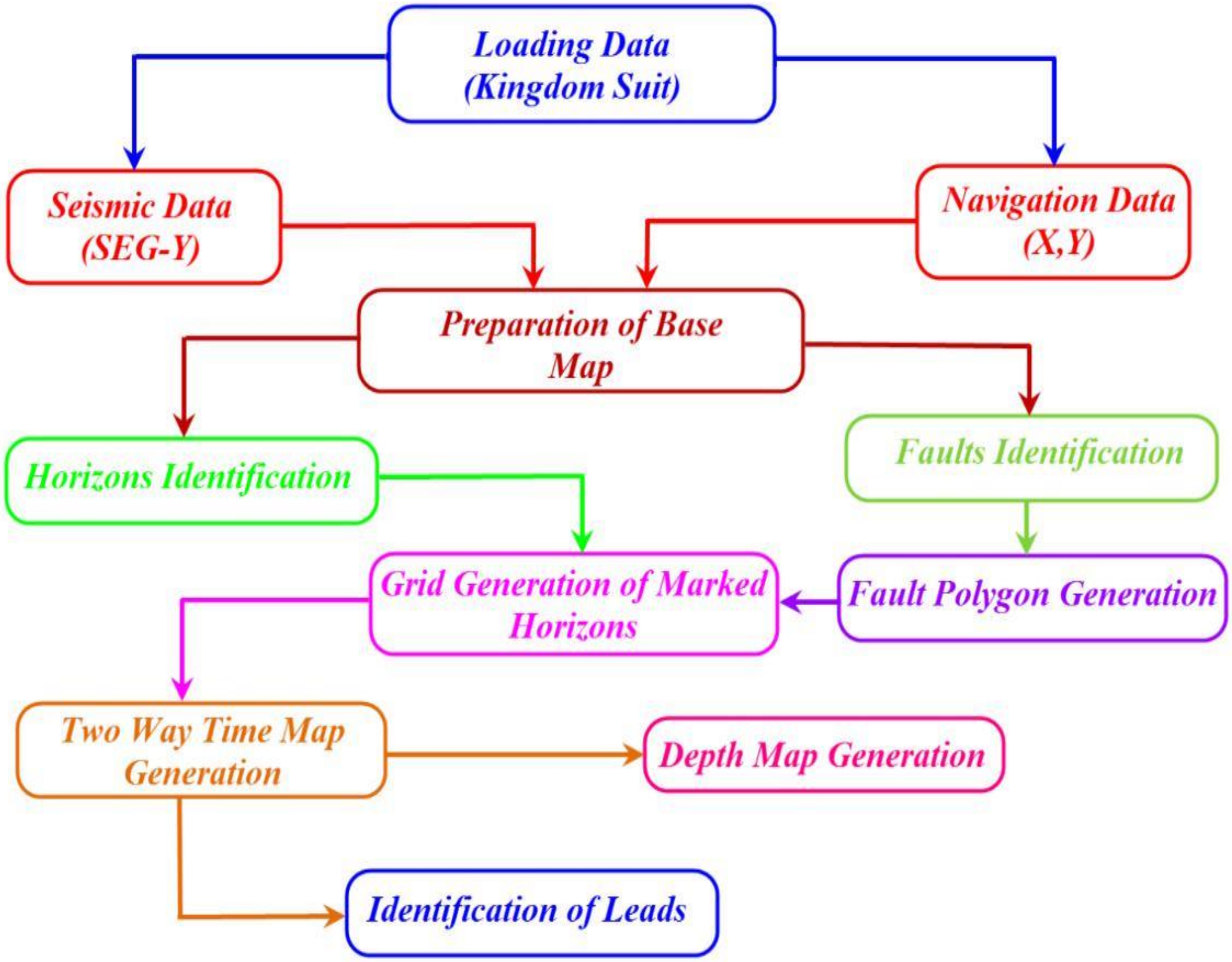


Figure 4.1 Work flow of kingdom

(4.4)Generation of Synthetic Seismogram:

Synthetic seismograms are artificial seismic traces use to establish correlations between local stratigraphy and seismic reflections. To produce a synthetic seismogram a sonic log is needed. Ideally, a density log should also be used, but these are not always available hence we can also used the constant density for that area. With the help of doti-01 the synthetic seismogram was constructed shown in the (Figure 4-1) in order to mark the horizons.

Synthetic seismograms provide a crucial link between lithological variations within a drill hole and reflectors on seismic profiles crossing the site. In essence, they provide a ground-truth for the interpretation of seismic data. Synthetic seismograms are useful tools for linking drill hole geology to seismic sections, because they can provide a direct link between observed lithologies and seismic reflection patterns (Handwerger et al., 2004). Reflection profiles are sensitive to changes in sediment impedance, the product of compression wave velocity and density. Changes in these two physical parameters do not always correspond to observed changes in lithologies. By creating a synthetic seismogram based on Sediment Petro-physics, it is possible to identify the origin of seismic reflectors and trace them laterally along the seismic line (Handwerger et al., 2004).

The following steps are adopted during the Generation of the synthetic seismogram using the IHS Kingdom.

1. Load the Las file of the well in the software.

2. Open 1D forward modeling Project and select the well logs.

3. Integrate the sonic log to rescale from depth in meters to two-way travel time in seconds.

4. Compute velocity from sonic log for P and S waves.

5. Create a TD chart for the well from the velocity logs.

6. Compute Acoustic impedance log using velocity and density log.

7. Compute the reflection coefficients from the time-scaled velocity log.

8. Compute a first-order Ricker wavelet as a digital filter with two millisecond increments of

9. Two-way travel time; using a frequency in Hertz (35 Hz frequency is used in this study)

10. Convolve the reflection coefficient log with the Ricker wavelet to generate the amplitudes of the synthetic seismogram.

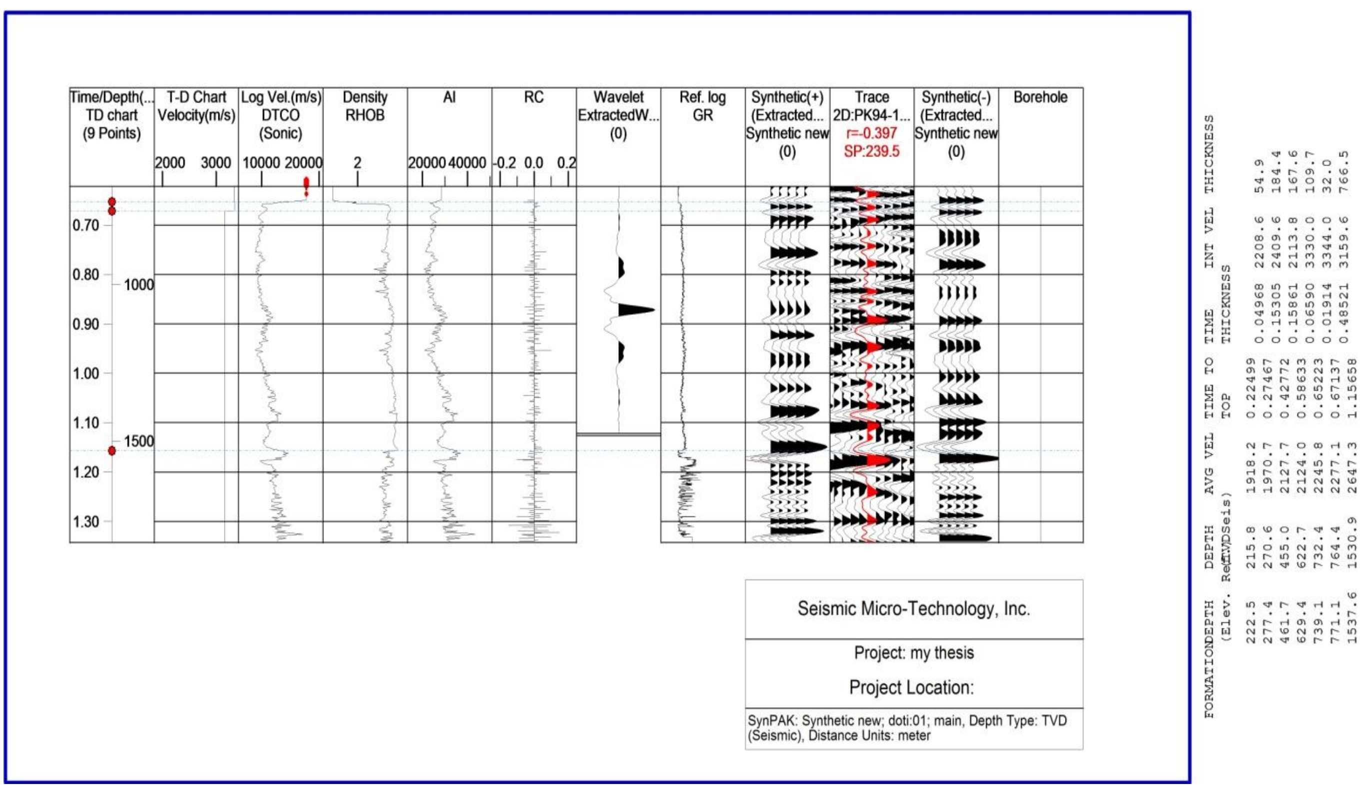


Figure: 4.2 Synthetic seismogram

(4.4)Marking of Seismic Horizons

The main (Prominent) reflections that are present on the seismic sections are marked, and then selected those reflectors that have good characteristics and continuity, and they can also be traced well over the whole seismic section.

There are difficulties in continuing the reflectors at the end of the seismic section and confusions are arrived where reflectors are mixed that may be due to sudden change in lithology, seismic noises, poor data quality or presence of salt in the subsurface at these locations. The seismic data was interpreted using kingdom which is used for interpretation.

The SEG -Y format data of seismic line **PK92-1804**, **PK92-1803** ,**PK92-1690 and PK94-1802** is loaded by kingdom software for interpretation. After loading data in kingdom software of lines using the interactive tools and applications of Kingdom Software prominent horizons are marked following the trend and continuity of the reflectors. The lines comprise normal faulting which shows a strike slip nature and horst and graben Geometry.

(4.5)Seismic Time Section

After marking seismic horizons and faults, the time of each reflector was noted at different vibrating points, and then the seismic time section is generated by plotting the two-way travel time of the reflectors and faults on y-axis against the shot points on x-axis. The seismic time section is simple; reproduction of an interpreted seismic section. The horst and graben structure present on the seismic sections may be a suitable place for the accumulation of hydrocarbons. Time section is the developed section of reflectors, which shows subsurface structure in time domain. Time section of the Lines PK92-1690 and PK94-1803 is shown reflectors are marked by tying with the line which is marked by using well top data of **Doti-01** well.

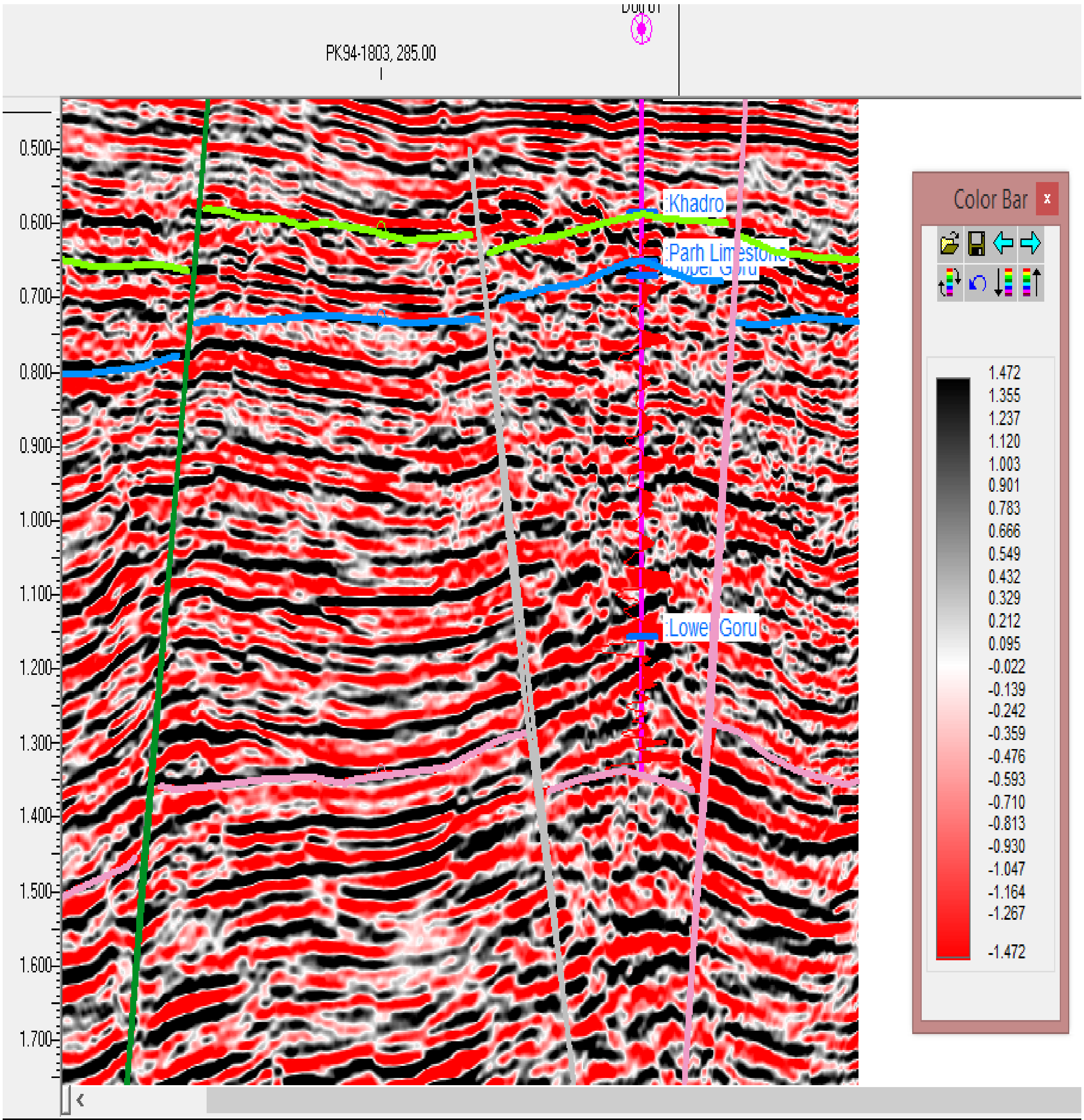


Figure 4.3 Sesmic section of Dip Line PK 92-1904

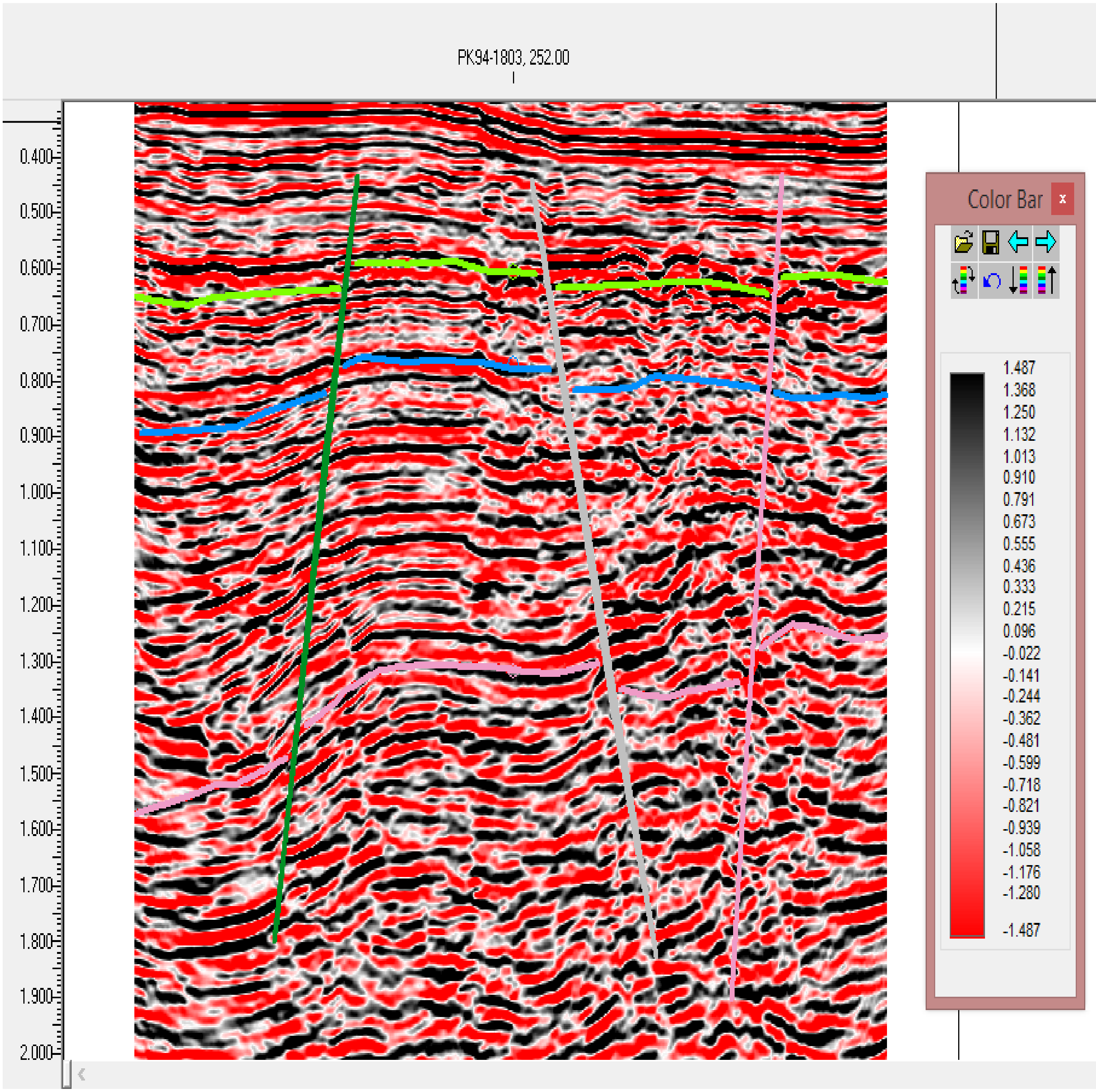


Figure 4.4: Sesmic section of Dip Line PK 92 1902

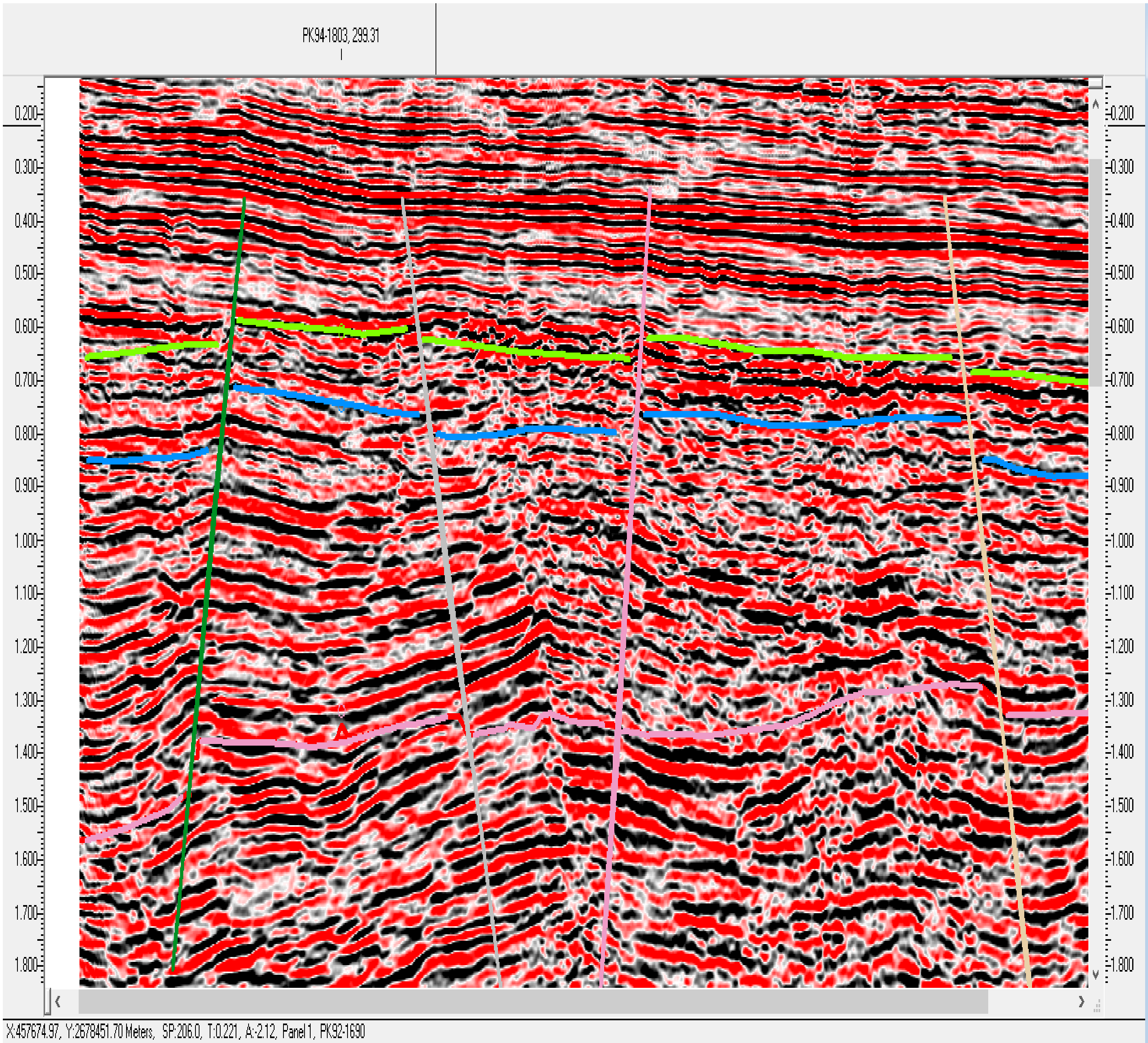


Figure4.5 : Sesmic section of Dip Line PK 1680

(4.6)Construction of Fault Polygon

We pick the fault on seismic section & find it at the other seismic lines. The fault in seismic section is called Fault Segment and the fault on map view is called Fault Polygon (Sroor, 2010). In any software for mapping an area all faults should be converted in to polygons prior to contouring. The reason is that if a fault is not converted into a polygon, the software doesn't recognize it as a barrier or discontinuities, thus making any possible closures against faults represent a false picture of the subsurface

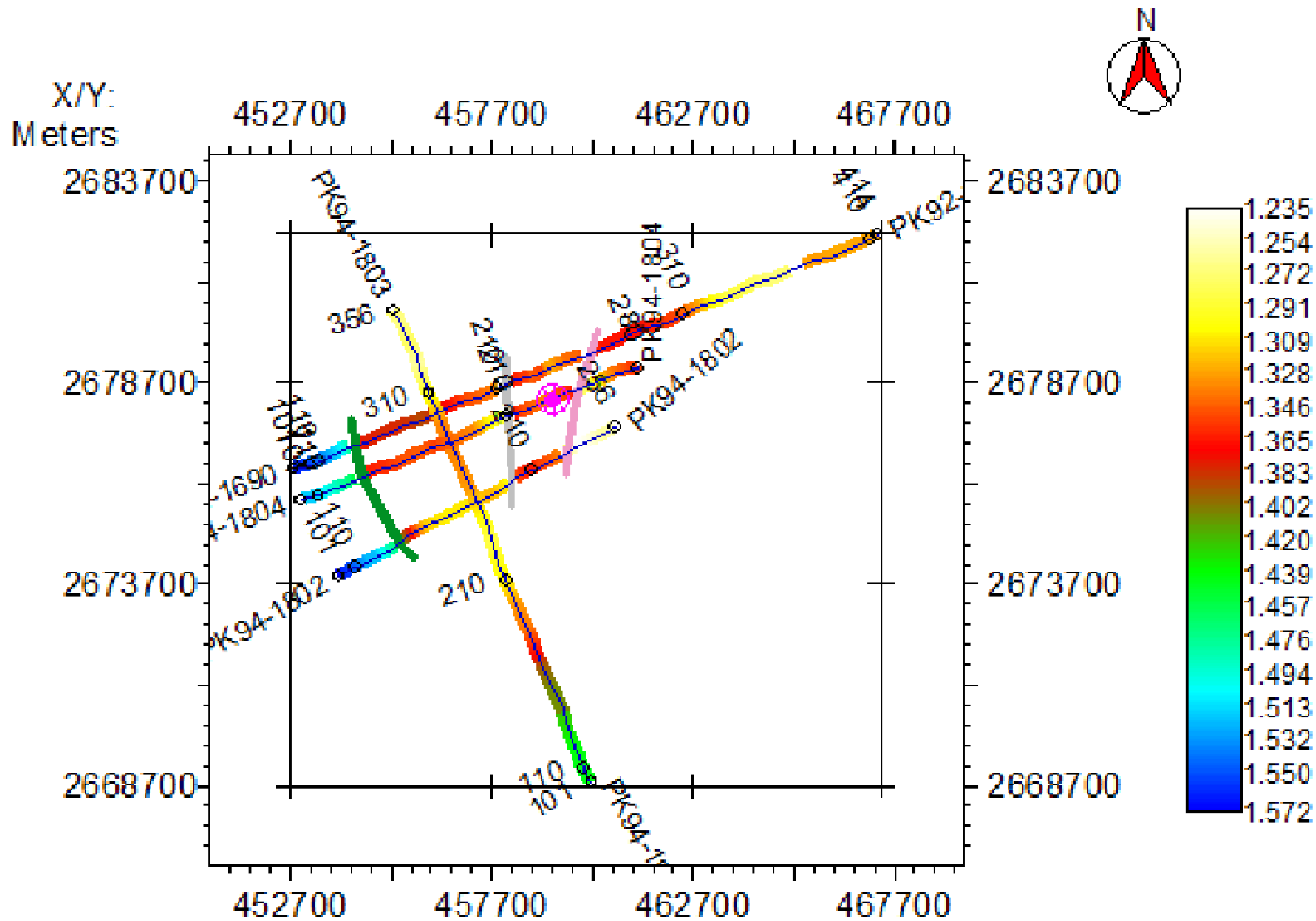


Figure 4.6 : Fault polygon of lower goru

(4.7)Contour Maps

Contouring is the main tool used in the seismic interpretation. After contouring it becomes obvious that what sort of structure is forming a particular horizon. The contour map of reflector is prepared. Seismic interpretation actually displays the most essential information extracted during interpretation in the form of time and depth contour maps. The contours are the lines of the same time or depth roving about the map as dictated by the data (Coffeen, 1986).

(4.7.1)Time Contours

After completing horizons and fault interpretation time contour maps are constructed. There are some reasons for making time maps. The times are read directly from the sections and are immediately available for mapping. The pattern of Time Contour map confirms the shape of the subsurface structure. Time contour maps of these formations show 2D-variations with respect to time and the hydrocarbons probably accumulate at those places where contour values are low.

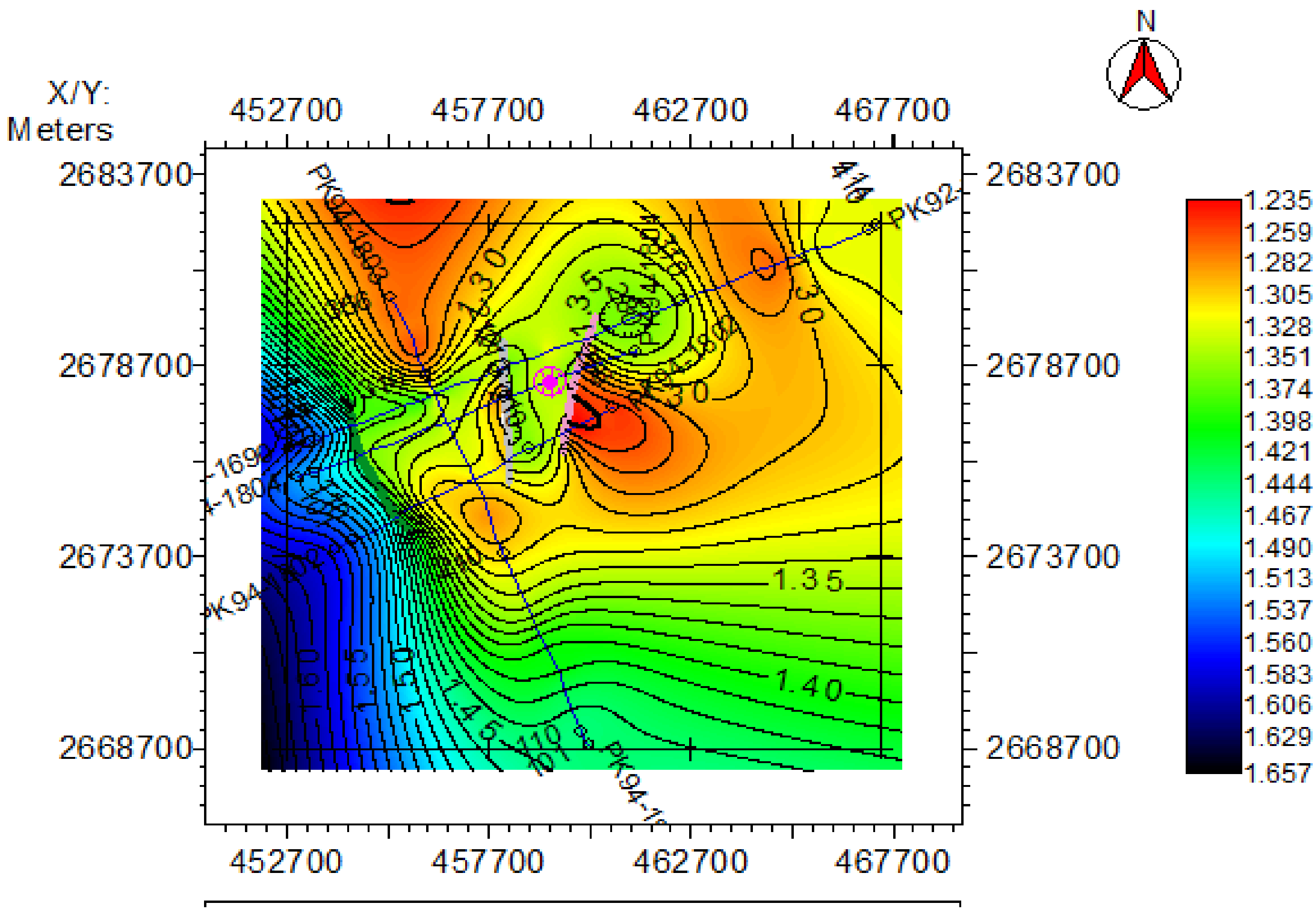


Figure 4.7: Time contours of the lower goru

(4.7.2)Depth Contours

When we read the time of a horizon from the section it tends to show the structure of the horizon in the subsurface, it does not show us the structure directly. Depth conversion and depth contour maps are constructed to see the horizons in the subsurface at their true positions. Depth must be calculated from time to make a map that is more truly related to the subsurface shapes, because structure is a matter of depth. The idea of converting the times into depths is very reasonable in case of showing the subsurface structures.

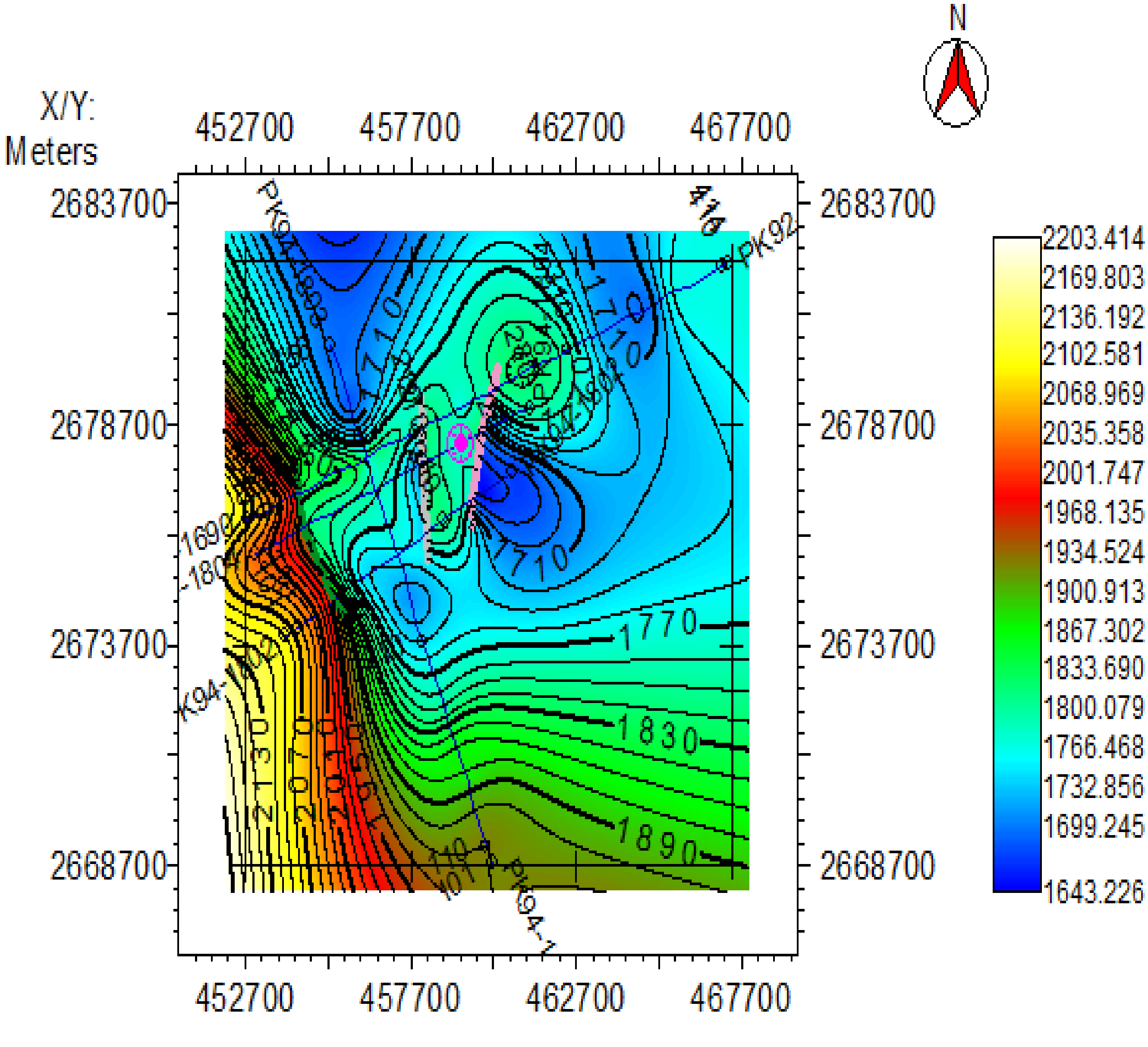


Figure 4.8:Depth contour of lower goru

As lower goru is recognize as a good reservoir rock of the Lower Indus Basin, depth contour map of this formation is constructed shown in Figure. Contour map confirms the horst and graben geometry in the area. The area with low value might be the good zone for the accumulation of hydrocarbons.

Chapter#05

(5)Petro physical Analysis

(5.1)Introduction

Petro physics is the study of the physical and chemical properties that describes the occurrence and behavior of the rocks, soils and fluids. To accurately characterize an oil or gas reservoirs, measurements such as resistivity and density are made, from which effective porosity, saturations and permeability can be quantified.

(5.2)Logs Used

The well logs analysis was carried out by using the following wire-line logs of Doti-01 issued by DGPC:

- Density log
- Neutron log
- Resistivity log
- Gamma Ray log
- Sonic log

(5.3)Petophysics

Petro physical analysis is the detailed analysis of a carefully chosen suite of wire-line services provide a method of inferring or deriving accurate values for the hydrocarbons and water saturations, the permeability, the porosity, and the lithology of the reservoir rock (Dewar, 2001).

- Petro physics uses all kinds of logs, core data and production data; and integrates all pertinent information
- Petro physics aims at obtaining the physical properties such as porosity, saturation and permeability, which are related to production parameters
- Petro physics is generally less concerned with seismic, and more concerned with using wellbore measurements to contribute to reservoir description

- Petrophysics can provide things like porosity, saturation, permeability, net pay, fluid contacts, shale volume, and reservoir zonation
- Petrophysics is the interest of Petroleum Engineers, Well Log Analysts, Core Analysts, Geologists and Geophysicists (Dewar, 2001)

(5.4)Petro physical Analysis

Electrical well logging was introduced to the oil and gas industry over half a century ago and since then, many improved and additional logging tools and devices have been developed and have been put in general use. The art of interpretation of the data advanced along with the advancements in well logging science. Today, the detailed analysis of a carefully chosen suite of wire-line services provides a method of inferring or deriving accurate values for the following:

- Hydrocarbons and water saturations
- Permeability indexdcs
- Porosity
- Lithology of the reservoir rock.

(5.5)Interest Zones

The zones of interest are defined on the basis of source, reservoir and seal rock formations given in well tops of Doti-01 well. The zones of interest which are marked are listed in the Table 4.1

Table: Interest zones

Zones	Starting Depth (m)	Ending Depth(m)	Thickness(m)
Upper Goru	770	1530	760
Lower Goru	1530	1830	300

(5.6)Strata Characterization

The lithologies are marked by Gamma Ray log deflections; it is a good indicator of shale. The shale and sand formations are identified by this log, but sometimes calliper and SP log information is also very important for strata characterization. Sand and shale lines are marked at the minimum and maximum values of Gamma Ray in the selected zone of interest, A cut off line is marked in the middle of the two lines which is used to demarcate sand and shale formations.

(5.7)Calculating Shale Volume

The source formations are commonly shally with higher radioactive content and are therefore indicated by a higher Gamma Ray value. On the other hand, it is also assumed that the radioactive material is not present in other formations which are termed as clean formations. This creates a contrast between shale and other formations.

The Gamma Ray log along with sand and shale lines as well as linearly computed volume of Shale curves for a depth range of 1530 meters to 1830 meters. It can be observed that both curves are similar to each other when linear computations are used.

Volume of shale plot gives the clear picture of reservoir which is not as better because of more shally content in the reservoir. Demonstrates the range of reservoir is not so much. This is one of the probable reasons of the dryness of well Doti-01. It cannot produce economical amount of hydrocarbon.

(5.8)Porosity Calculation

The pore spaces which are not occupied by the rock fragments are named as porosity. Porosity is created due to inter granular spaces, voids formed by dissolution of grains as well as fracturing of rocks. The symbol used for porosity is "ϕ" and expressed either by percentage or in decimals. The primary porosity is developed between the grains at the time of deposition, but due to fracturing and dissolution the pore spaces become void creating secondary porosity. Secondary porosity is mainly observed in limestone. In this work density is calculated using the following methods:

❖ Density Porosity

It is derived from density log using the following equation

Density Porosity = (Density Matrix - Density Log) / (Density Matrix- Density Fluid)

❖ Neutron Porosity

It is directly obtained from Neutron log values.

The Average Porosity is obtained by taking the mean of the above two;

Average Porosity = (Density Porosity + Neutron Porosity)/2

Finally Effective Porosity is given by;

Effective Porosity = Average Porosity * Vmatrix

Where Vmatrix is Volume of Matrix given by 1- Vshale

These porosities are calculated to confirm the interpretation of porosity logs.

(5.9)Calculation of Resistivity of Water (Rw)

Water saturation is the percentage of pore volume in rock that is occupied by water of Formation. If it is not confirmed that pores in the Formation are filled by hydrocarbons, it is assumed that these are filled with water. To determine the water and hydrocarbon saturation is one of the basic goals of well logging. To calculate saturation of water in the Formation, a mathematical equation was developed by Archie. All the parameters of Archie equation can be calculated from resistivity and spontaneous potential logs.

(5.10)Result of Petrophysical Evaluation

The zone of sand by petrophysical evaluation along with depth of lower goru and description of intrest zone is given below for Doti-01 as shown in the table

Table:result of petrophysics

Vol of shale	**25-30%**
Effective porosity	**10-15%**
Water saturation	**75-80%**
HCs saturation	**20-25%**

(5.11)Petrophysical analysis

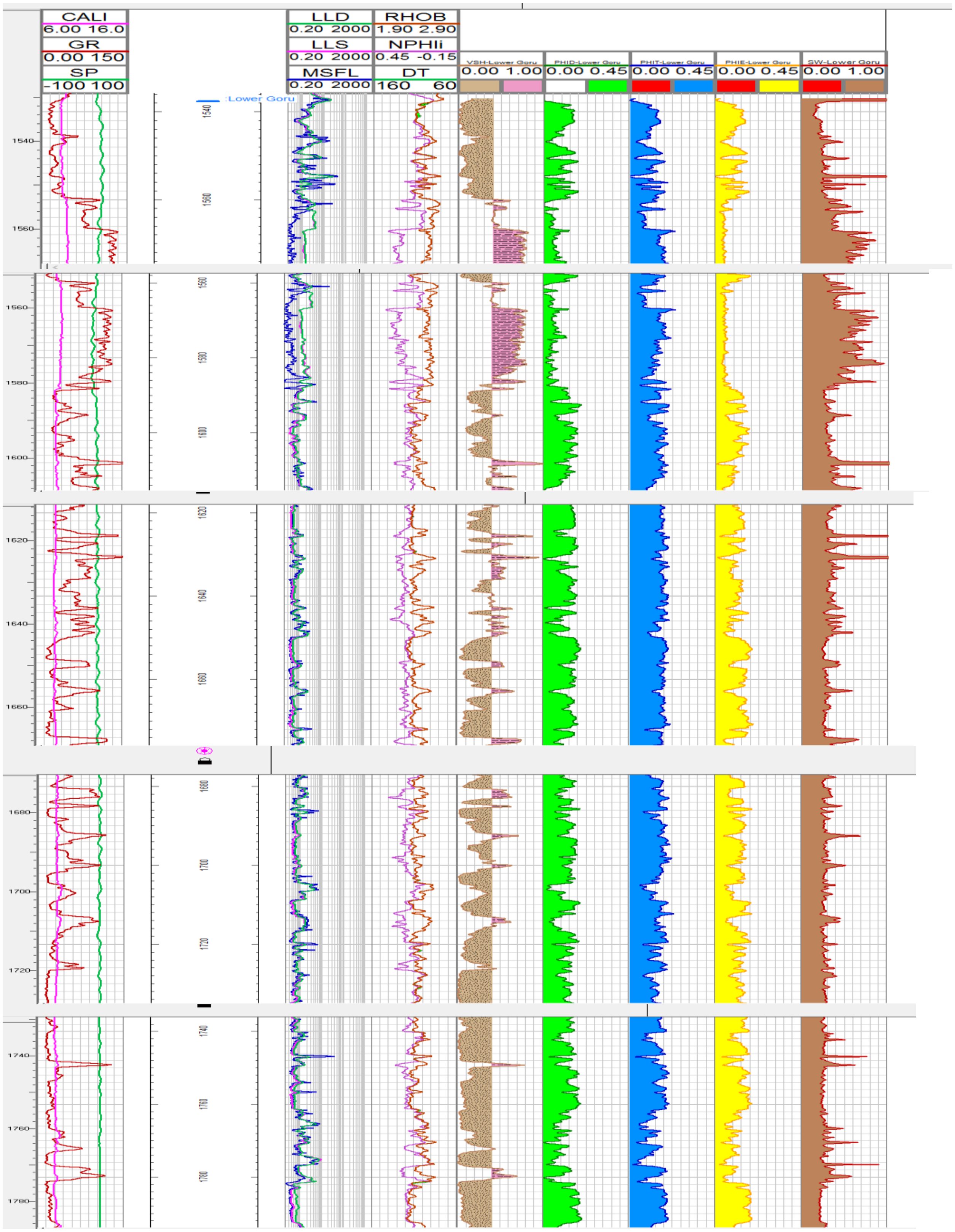


Figure : 5.1 Well logging of Lower Goru Reservior

Chapter#06

(6)Facies Analysis

(6.1)Introduction

The identification of a bed's lithology is fundamental to all reservoir characterization because the physical and chemical properties of the rock that holds hydrocarbon affect the response of every tool used to measure formation properties. Understanding reservoir lithology is the foundation from which all other Petrophysical calculations are made. To make accurate Petrophysical calculations of porosity, water saturation (Sw), and permeability, the various lithologies of the reservoir interval must be identified and their implications understood. Lithology means "the composition or type of rock such as sandstone or limestone. There is a material correlation between the behaviour of well logs and the lithologic and depositional facies of penetrated formations, since modern logs are sensitive to factors that vary with the makeup of those formations, (Saggaf and Nebrija, 2000). In geology, facies the observable attributes of a sedimentary rock body that reflect the depositional processes or environments that formed it. These depositional environments are classified as terrestrial, continental slope.

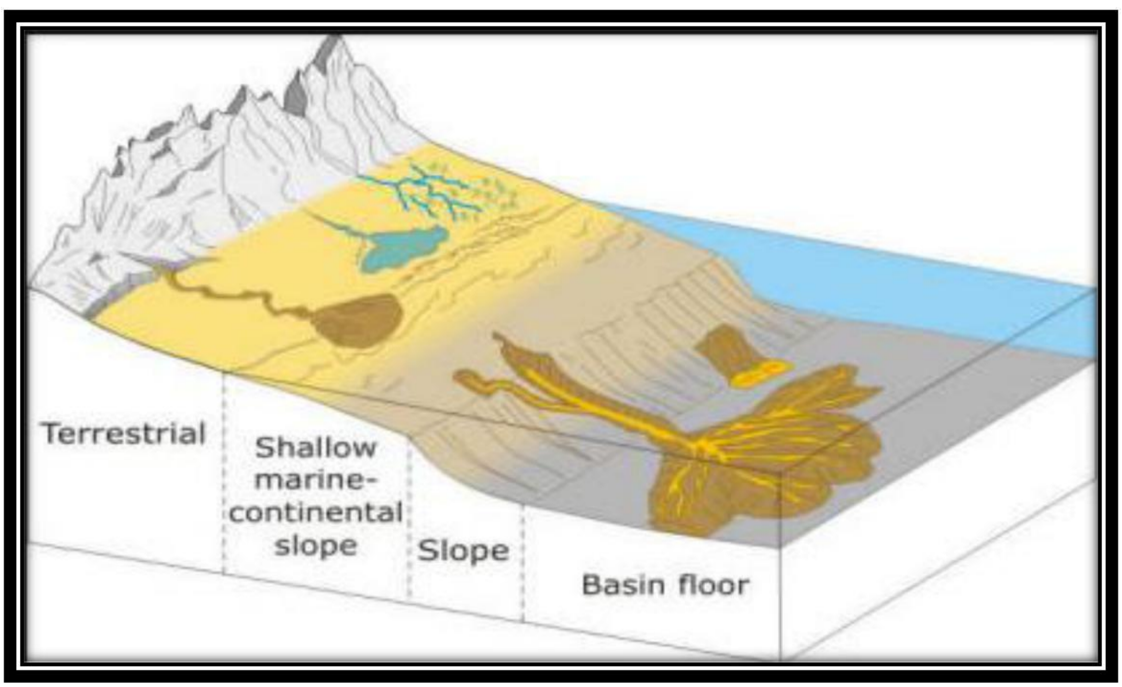
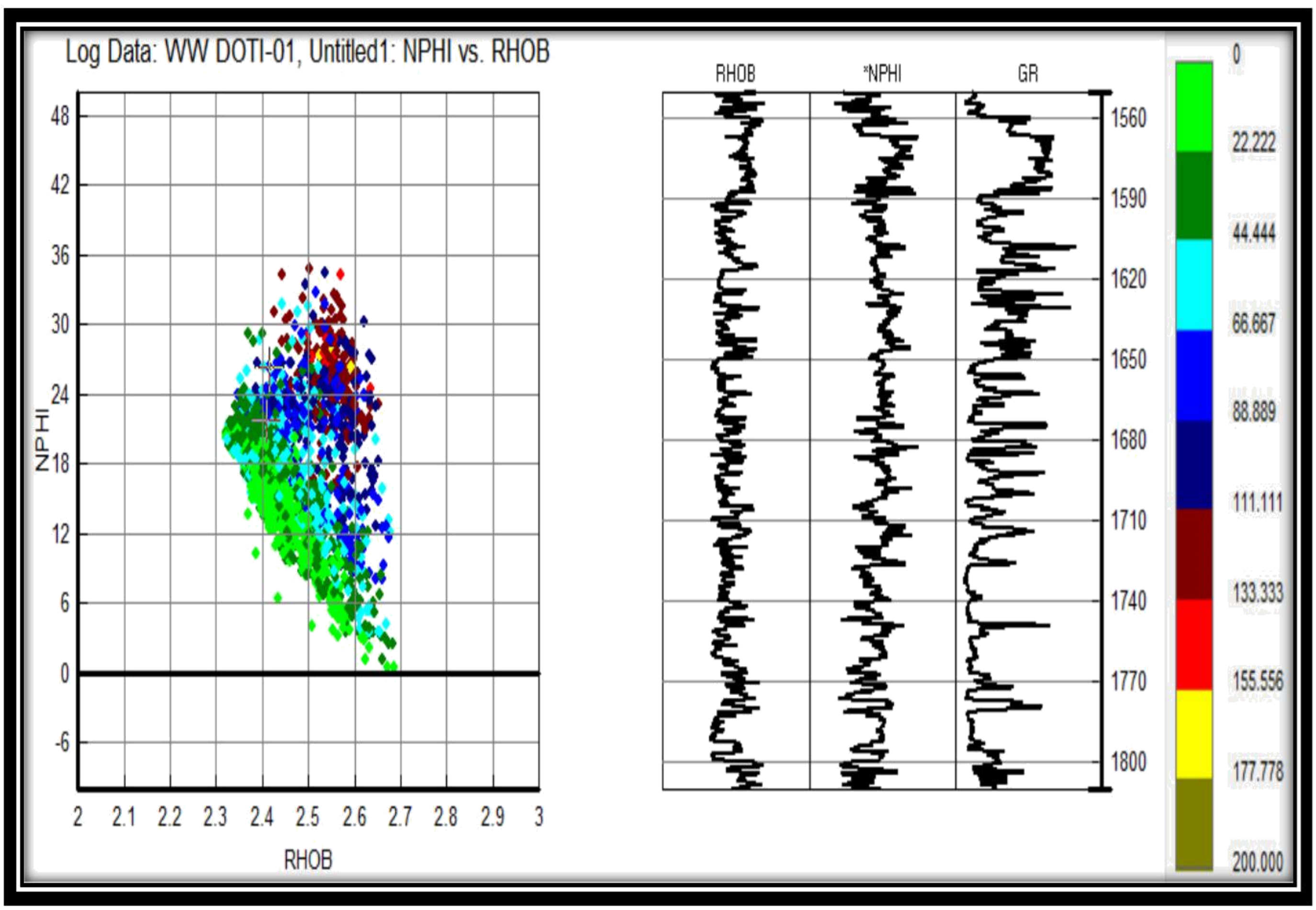


Figure 6.1 Depositional environments, (Rais etal, 2012).

(6.2)Cross Plot of NPHI and Gamma Ray

Using unsupervised approach the cross plot between density and neutron porosity is obtained. Figure shows the standard cross plot between NPHI and RHOB. Gamma ray used as reference log. The neutron log is measuring the hydrogen population of the formation. Therefore, it records a nearly constant response through sands and increases in shales. Since the population of hydrogen is nearly the same in water, oil, and wet clay, the neutron log cannot distinguish between them. Hydrogen population is therefore no longer controlled by the pore distribution. The neutron log then measures increased hydrogen as the clay volume increases.

High gamma ray log and neutron porosity log indicate the shale while the low response of both logs shows the existence of clean sand. Moderate gamma ray log indicates the shaly sand around the shale sand boundary. Figure below shows the lithology model for Doti-o1 well



Figuure:6.2 Facies model showing clustered points of different lithologies

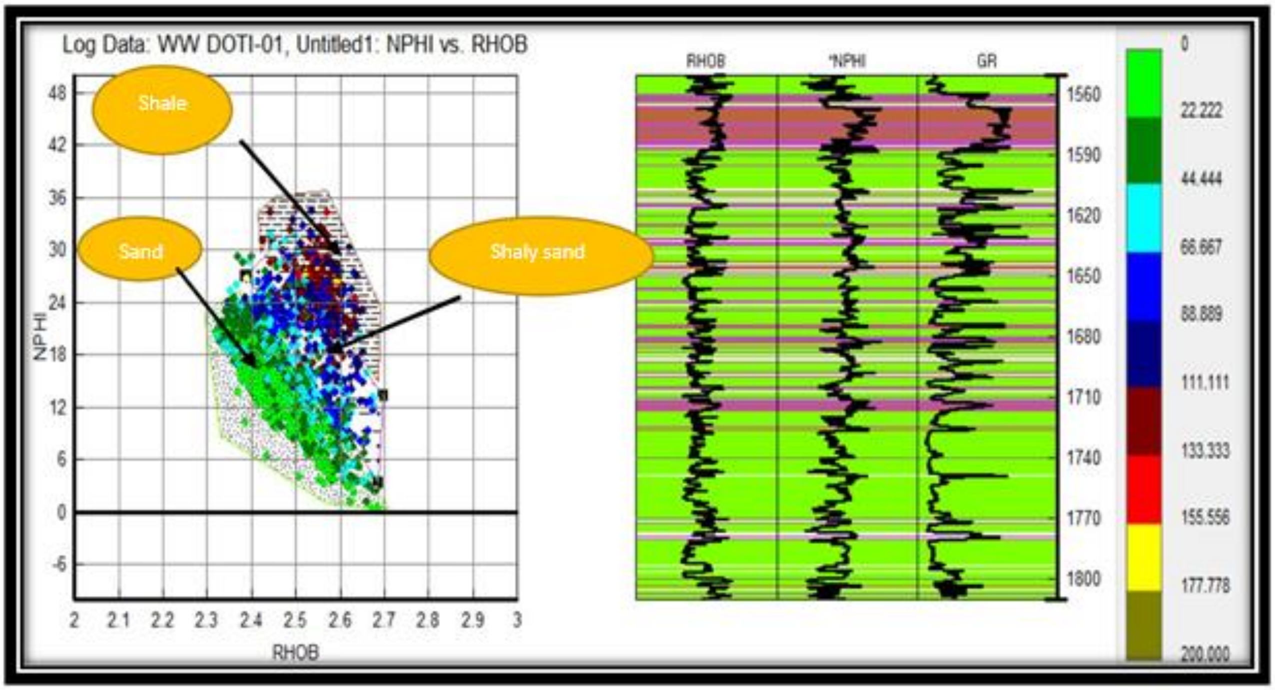


Figure 6.3: Model showing shale sand shaly sand in NPHI vs RHOB log

7 Conclusion

The thesis work ends with following conclusions:

- The seismic interpretation indicates horst and grabben structure in the area.
- Petrophysical analysis shows Lower Goru formations are good reservoirs.
- Results of seismic interpretation, well log interpretation and seismic attributes justified the dryness of well Doti-01
- Petrophysical modeling and Facies modelling indicates that interval Lower Goru Member are the hydrocarbon bearing zone and contains about 24% saturation of hydrocarbons in well Doti-01..
- Time and Depth contour maps of Lower Goru help us to confirm the presence of horst and grabben structure in the given area.This structure acts as a trap in the area, which is best for hydrocarbon
- Synthetic seismogram help to marked reflectors which confirm the presence of stratigraphic interpretation.
- The structure is confirmed and lateral variations are studied with the help of 2D forward modeling.

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