2D SEISMIC INTERPRETATION OF LINE

NP-84-44
&
DISCRIMINATING THE RESERVOIR BY USING CROSS PLOTS

QUAID-I-AZAM UNIVERSITY
ISLAMABAD

By

Muhammad Asif
M.Sc Geophysics
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Department of Earth Sciences
Quaid-e-Azam University
Islamabad

Approval Certificate

The dissertation submitted by **Muhammad Asif** is accepted in its present form by the Department of Earth Sciences, Quaid-i-Azam University Islamabad as satisfying the requirements for the Degree of MASTER OF SCIENCES in ***GEOPHYSICS***.

RECOMMENDED BY

Supervisor: ____________________
(Mr. Matloob Hussain)

External Examiner: ____________________

Chairman: Zulfiqar Ahmad
(Earth Science Department) **(Dr. Zulfiqar Ahmad)**
Date: 2010

DEPARTMENT OF EARTH SCIENCES
QUAID-E-AZAM UNIVERSITY ISLAMABAD

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CHAPTER# 4

SEISMIC INTERPRETATION

DADICATION

My whole thesis work is dedicated to my

Parents, my Brother and Sister, Teachers,

Friends

Who build me so high

And all

Those who love me and whom I love.

ACKNOLEDGEMENTS

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

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M.Sc. Geophysics

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ABSTRACT

This dissertation is based on the interpretation of 2D Seismic reflection data. Seismograph service limited acquired the data in the Ratana Area in April 1985 by using suitable recording parameters. The data passed through a desirable processing sequence and finally a time section was prepared. A time section is produced from the seismic section using the VP points and the two-way-times (TWT) of the reflectors and faults. These average velocities are then used to find the depths of the formations for the Geoseismic Section or Depth Section. The seismic section is recorded for 4.6sec.

The line NP84-44 is strike line. The direction of the strike lines is NNW-SSE. The section comprised of a total of Vibroseis points from VP-200 to VP-444. Three prominent reflectors are marked on the seismic sections on the basis of observed reflection events. The marked horizons show deformation in the area caused by compressional tectonics. Pop up structures are present in the section.

Chapter # 01

Introduction to the Line

1.1 Introduction To The Area:

The given dissertation is to interpret the seismic section along seismic line NP-84-44 of Ratana block in the North Potwar consisting of vibroseis points 200-444 and oriented in SE-NW direction. 90

The length of line is 11.9km

Ratana area of NP is the upper Indus basin which is characterized by compression regime and bounded between latitude and longitude. Ratana block is important for its oil and gas.

1.2 Objectives and Methodology:

The main objectives and procedure of the dissertation are:

- To determine the times for each CDP at some constant interval on the basis of variation of these velocities in each velocity panel and then to determine the average velocities at certain constant interval of time from each CDP data.
- Identification and Marking of Reflectors
- To prepare the Mean Velocity Graph of mean average velocity vs. selected constant time.
- To prepare and analyze the structure using the Time Section and the Dix Iso-Velocity contour map.
- To calculate the depth of each interface using the provided average velocity information and then prepare a depth section.
- To prepare two way Time contour map and Depth contour map of Chorgali Formation using the lines NP-84-41, NP-84-42, NP-84-43, NP-84-44, NP-86-08 to develop an understanding of tectonic and structural framework of the area.

1.3 Line NP-84-44:

A migrated seismic line NP-84-44 of North potwar area oriented in SE-NW direction with vibroseis points from 200 to 444 were provided by the department of Earth Sciences, Quaid-e-Azam University.

This section was prepared by oxy in May 1987. The root mean velocities at different time were given; using these velocities the mean average velocities can be calculated. Then time and depth section were prepared to investigate subsurface.

Three reflectors named as R1, R2, R3, and basement were marked and then their time and depth sections prepared. Thrust faults were marked; thrusting is due to compressional regime in the area.

1.4 Base map:

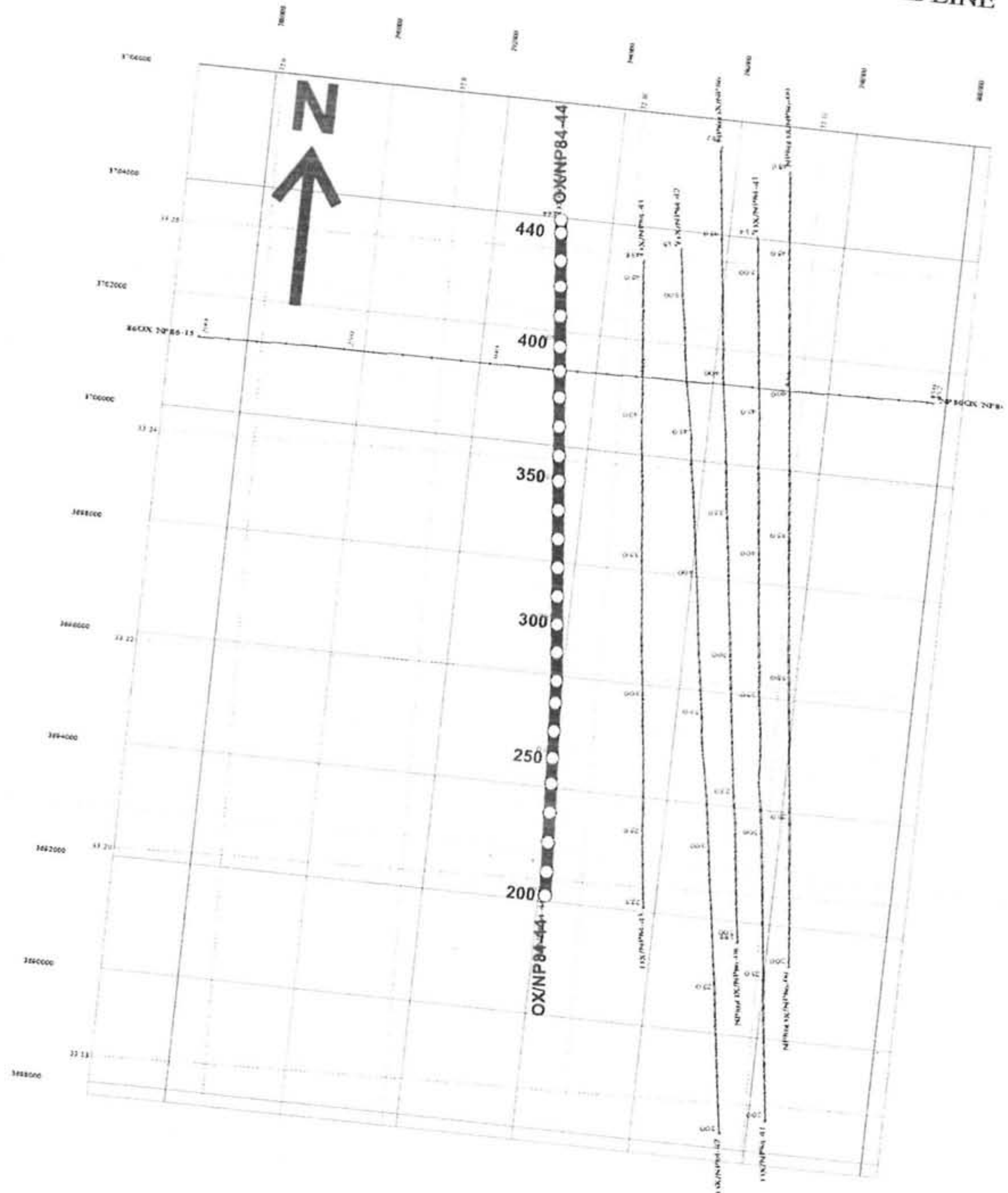
A base map typically includes locations of concession boundaries, wells, seismic survey points and other cultural data such as buildings and roads, with a geographic reference such as latitude and longitude or Universal Transverse Marketer (UTM) grid information. (www.glossary.oilfield.slb.com/)

The project area is located in upper Indus Basin which contains many oil and gas field. The different field and processing parameters are given on seismic time section along the seismic velocities. The Latitude and Longitude of the base map are given below

Latitude: 33°, 18', 00" N to 33°, 27', 00" N

Longitude: 72°, 05', 00" E to 72°, 14', 00" E

INTRODUCTION TO THE LINE



Chapter # 02

Geology and Tectonics

2.1 Introduction:

This chapter deals with the geology and tectonics of the study area. Information about the geology of study area is of vital important; because geology of an area greatly affects response of a seismic survey performed there. Himalayas is the youngest mountain system of the world. In northern Pakistan there are three mountains ranges Hindukush, Karakorm and Himalaya. Geographically two rivers Hunza and Indus separate them. It is approximately 2400 km long and 200 km to 300 km wide. The Himalayas cover an area of approximately 600,000 sq. km in south Asia. (Kazmi and Jan, 1997)

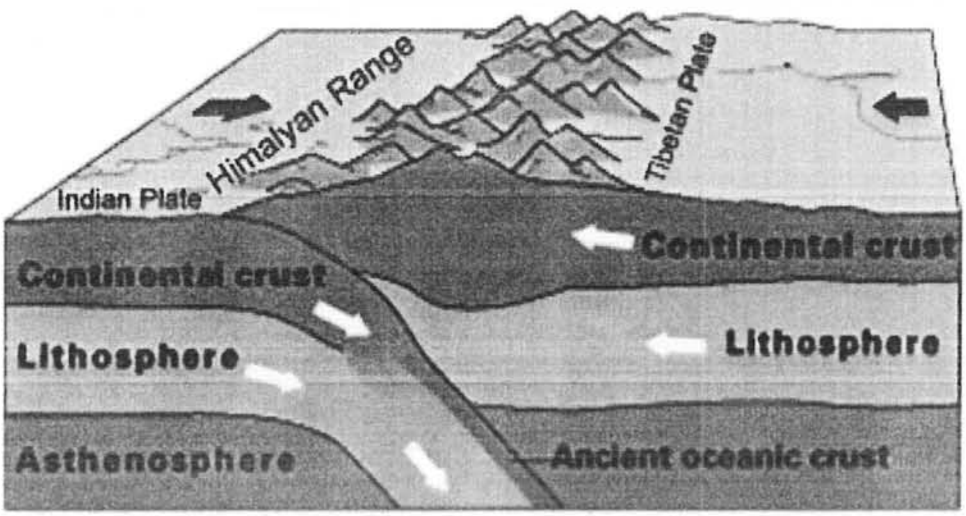


Fig 2.1 subduction of Indian plate beneath Eurasian plate and formation of Himalaya. (www.ranjan.net.np/geologyofnepal.htm)

2.2 Regional Geological Settings:

The Indian Ocean and the Himalayas, two of the most pronounced global features surrounded the Indo-Pakistan subcontinent, have a common origin. Both are the product of the geodynamic processes of sea-floor spreading, continental drift and collision tectonics. A plate of the earth's crust carrying the Indo-Pakistan landmass rifted away from the super continent Gondwanaland followed by the extensive sea-floor spreading and the opening up of the Indian Ocean. Propelled by the geodynamic forces the Indian plate traveled 5000 Km northward and eventually collided with Eurasia. The subduction of the northern margin of the Indian plate finally closed the

Neotythes and the Indian Ocean assumed its present widespread expanse. This collision formed the Himalayas and the adjacent mountain ranges.

Pakistan has been divided into two broad geological zones, which are the:

- Gondwanaland Domain
- Tethyan Domain

Pakistan is unique in as much as it is located at the junction of these two diverse domains. The southern part of Pakistan belongs to Gondwanian Domain and is sustained by the Indo-Pakistan Crustal Plate. The northern most and western region of Pakistan fall in Tethyan Domain and present a complicated geology.

2.2.1 Northward Drift Of The India And Opening Of The Indian Ocean:

The Indo-Pakistan subcontinent separated from the Gondwana motherland about 130 million years ago.

It has been estimated that between 130 m.y. and 80 m.y. India moved northward at a rate of 3 to 5 cm/year. From 80 m.y. 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.

2.2.2 Formation Of Kohistan-Ladakh Island Arc And Its Collision With Eurasia:

The Neotethys had begun to shrink by the time Indian began its northward drift around 130 m.y. ago. Intra-oceanic subduction generated a series of volcanic arcs (Kohistan-Ladakh, Nuristan, Kandhar) during the Cretaceous (Searle 1991, Treloar and Izatt 1993).

2.2.3 India-Eurasia Collision And Himalayan Upheaval:

The abrupt slowing down of Indian's northward movement between 55 and 50 m.y. ago is attributed to this collision (Powell 1979). The abrupt slowing down of Indian from 18-19.5 cm/year to 4.5 cm/year occurred at 55+Ma. A combined India-Australia plate started moving away from Antarctica. Motion ceased along the former plate boundary (the Ninety East

Ridge), and the Proto-Owen fracture no longer remained at transform fault, though it was reactivated later, about 20 Ma ago.

Since 55 Ma ago India has steadily rotated counterclockwise. Coupled with Arabian's separation from Africa about 20 Ma ago, this rotation caused convergence in Balauchistan, closure of some the some smaller basins (Scistan, Katawaz), collision various crustal blocks in Iran-Afghanistan region and formation of the Balauchistan fold-and-thrust belt.

The India Eurasia collision produced the spectacular along uplifted and deformed 2,500 Km long Indo-Pakistan plate margin.

2.3 Regional Tectonic Settings :

Pakistan has been divided into two main geologic zones:

Gondwanian Domain (a part of Indian plate)

Tethyian Domain (a part of Eurasian plate)

The southern part of Pakistan is included in the Gondwanian Domain. Upper and Lower Indus Basins are present in this Gondwanian Domain.

The northern and western regions of Pakistan fall in Tethyian Domain. 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, This zone presents a complicated geology.

Pakistan possesses the north western boundary of the Indian Plate. The underthrusting of the Indo-Pak plate beneath the Eurasian Plate is producing thin-skined tectonic features since Eocene time on the North Western fringe of the Indo-Pak Plate. The continued underthrusting of the Indo-Pak since Cretaceous produced the spectacular mountain ranges of the Himalayas and a chain of foreland fold and thrust belts as thick sheets of sediments thrusted over the Indian craton. (Kazmi & Jan, 1997)

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 Pakistan may be divided into the following broad tectonic zones.

Figure.2.2.

- Indus Platform and fore deep
- East Balochistan fold-and-thrust belt
- Northwest Himalayan fold-and-thrust belt
- Kohistan-Ladakh magmatic arc
- Karakoram bloack
- Kakar Khoarasan flysch basin and Makran accretionary zone
- Chagai magmatic arc
- Pakistan offshore

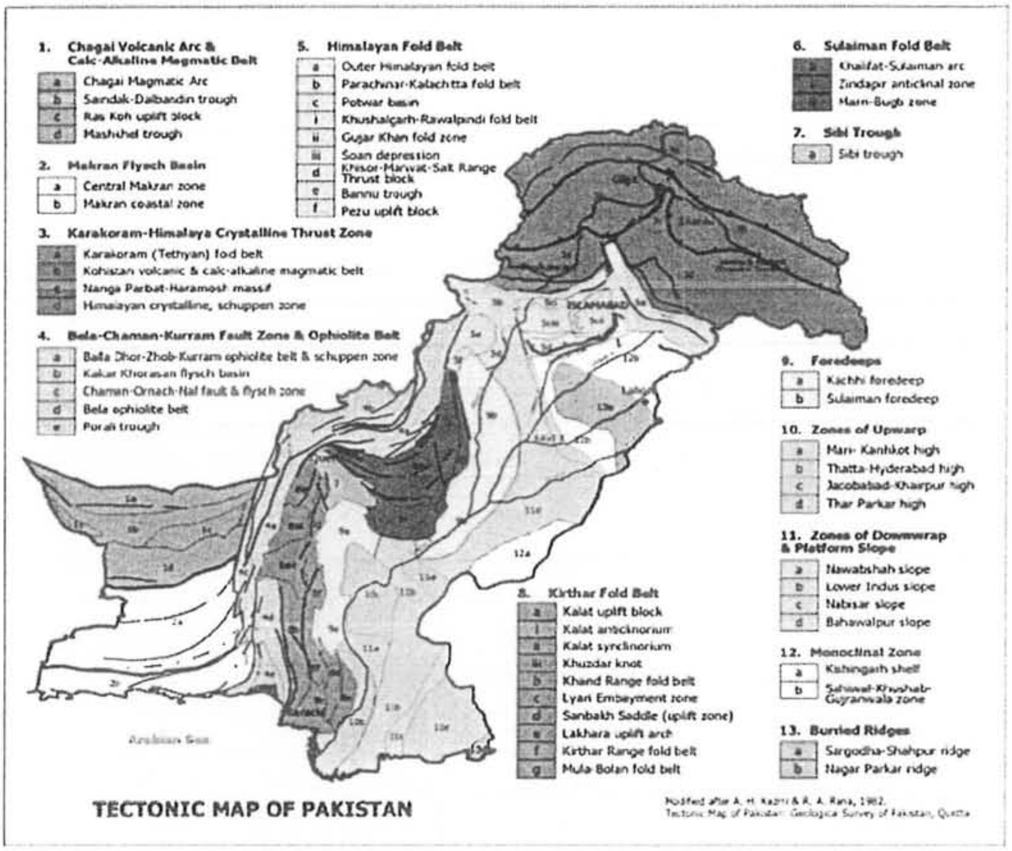


Fig 2.2 (Tectonic Zones of Pakistan) (www.gsp.com.pk)

2.4 The Sedimentary Basins of Pakistan

In term of genesis and different geological histories, Pakistan comprises three main sedimentary basins:

- Indus Basin
- Pishin Basin
- Baluchistan Basin

Sediments get developed at certain place, they may be deposited at the place of their origin or may get transported to other place by transporting agents, and the sediments deposited at the place of origin are called Molasses, what happens with the transported sediments? They are often deposited at a place which is characterized by regional subsidence and where they could get preserved for longer periods of time, such a place is called a Basin, substratum of the basin is called Basement, the accumulated sediments in a basin are called Sedimentary Cover, the gradual settling of sediments in a basin is called Subsidence, the point of maximum sedimentary accumulation in basin is called Depocenter.

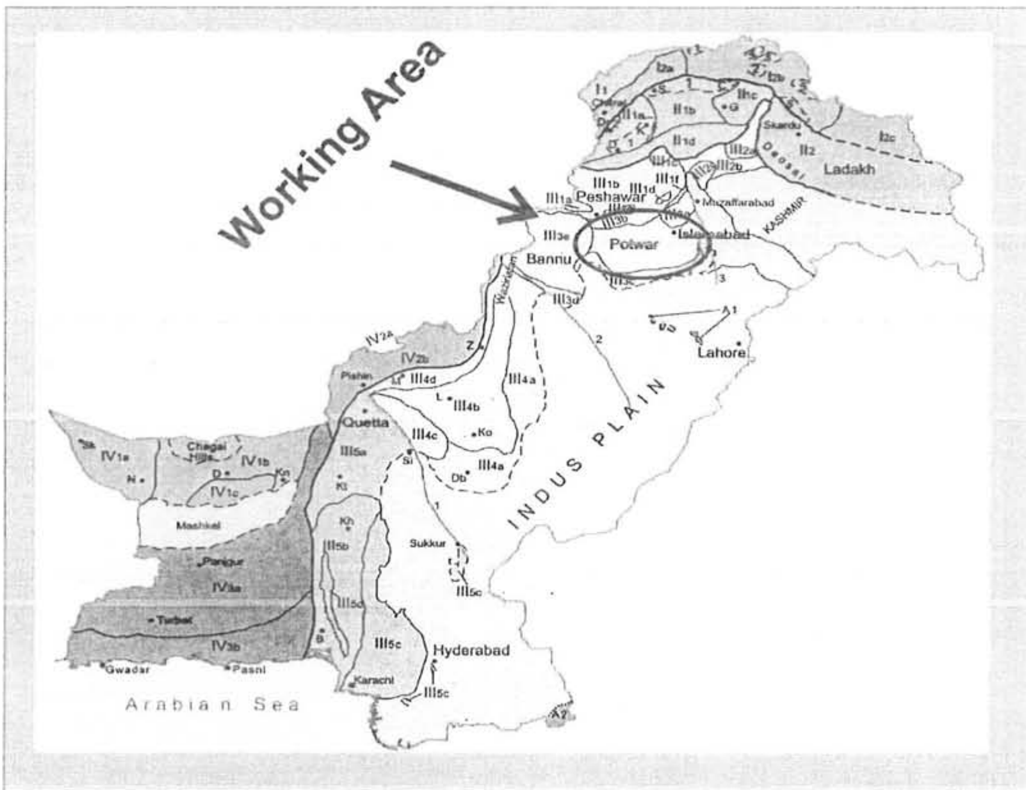


Fig. 2.3 Tectonic basin in Pakistan (www.gsp.pk.com)

a). Indus Basin:

Indus Basin includes the 25000 square Km of South-East of Pakistan. It includes the Thar-Cholistan desert and Indus Plain. It has 80% of Pakistan population. Tectonically it is much stable area as compare to other tectonic zone of Pakistan. It comprises of buried ridges, platform slop, zone of up warp and dawn warp. (Kazmi & Jan, 1997)

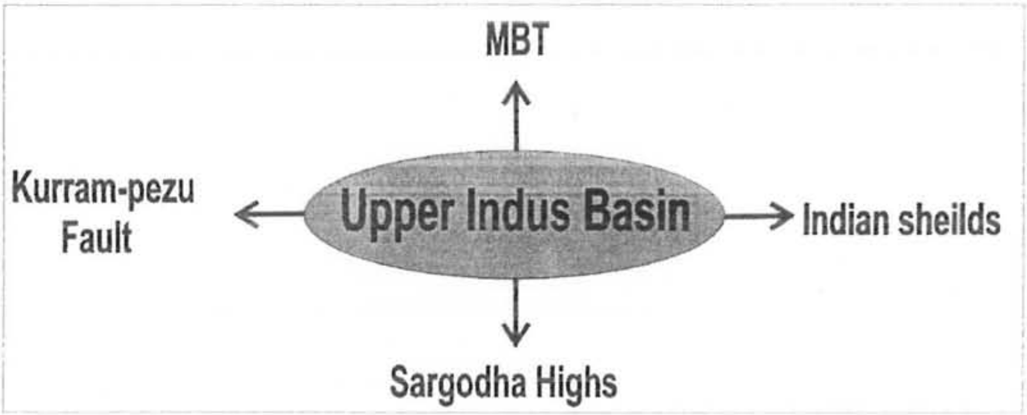
It is the largest basin oriented in NE-SW direction. Basement is exposed at two places, one in NE (Sargodha High) and second in SE corner (Nagar Parker High). (Riaz Ahmad, 1998)

Structurally Indus Basin divided into two main parts:

- Upper Indus Basin (in north)
- Lower Indus Basin (in south)
  - ✓ Along the Sargodha High
  - ✓ Lower Indus Basin is further divided into:
- Central Indus Basin (in north)
- Southern Indus Basin (in south)
- Along Jacobabad – Khair- pur High (Sukhur Rift)

We are interested in upper Indus basin as our concerned area is located in this basin.

Boundaries of Upper Indus Basin:



1 Upper Indus Basin:

It is located in the northern Pakistan and separated from the lower Indus Basin by the Sargodha High. In its north MBT, while in east and west strike slip faults Jhelum and Kalabaugh is located, Upper Indus basin is subdivided into Potwar and Kohat Basins along the Indus River.(Kazmi & Jan, 1997)

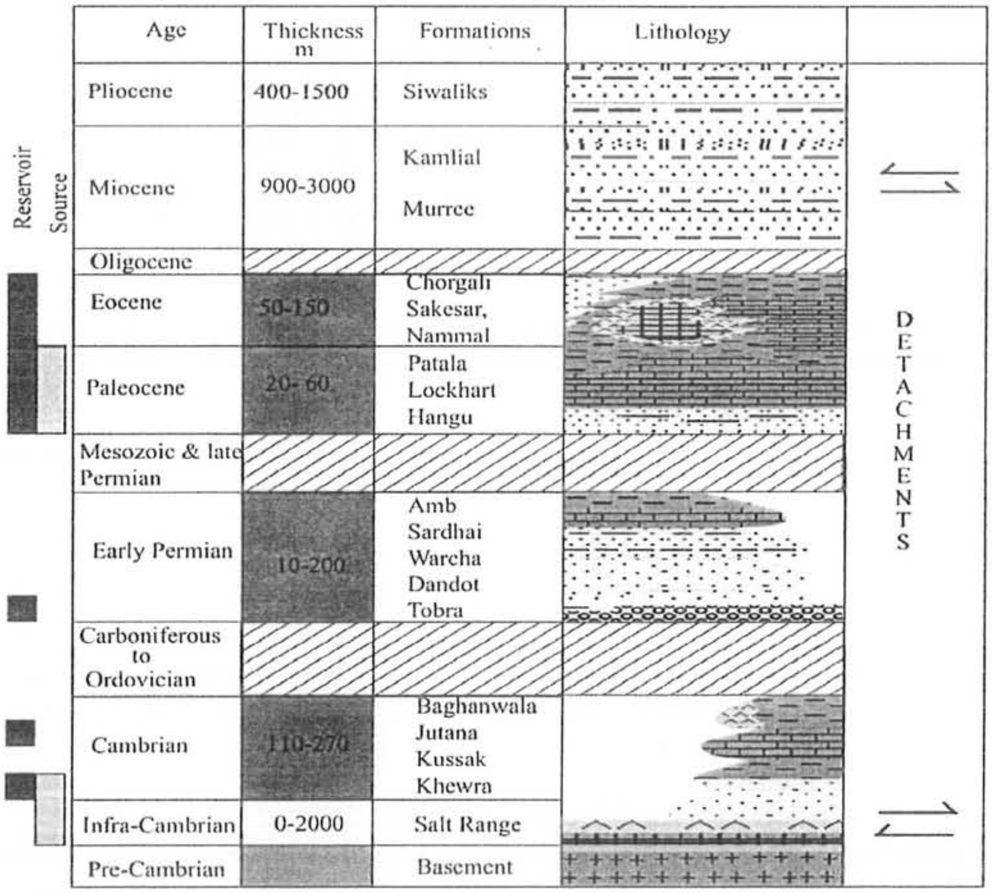


Fig 2.4 Stratigraphic Column of Upper Indus Basin.(www.gsp.com.pk)

2.5 Potwar Basin :(General)

Geological Boundaries & Structure Styles:

Structurally Potwar Basin is divided into North Potwar Deform Zone (NPDZ) in the north, Soan Syncline and Southern Potwar Deformed Zone (SPDZ) in the south. Potwar basin is covered by the molasse sediments ranging in age from Miocene to Pleistocene. Precambrian to Tertiary sequence is exposed along the ranges in south. (Shami & Baig, 2003)

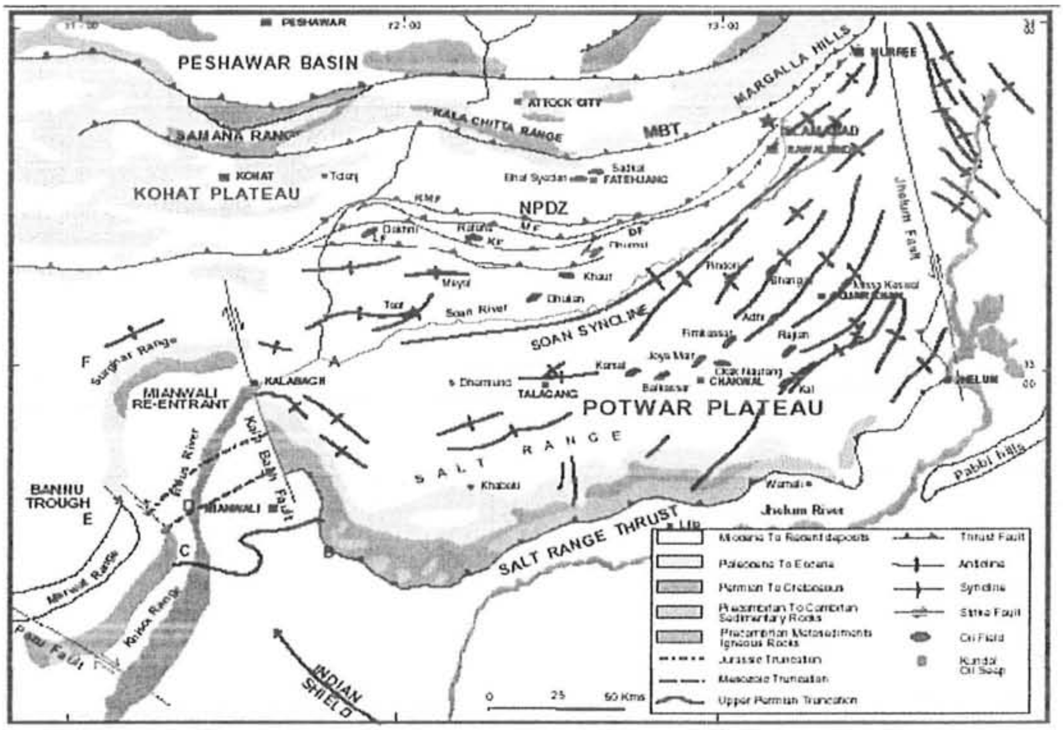


Fig. 2.3 Tectonic division of Potwar Basin

2.6 Potwar Plateau:

The Potwar Plateau and Salt Range are located in the south-western foothills of the Himalayas, in northern Pakistan. The region extends over 120 km from the Main Boundary Thrust (MBT) in the north to the Jhelum River in the south . (Jaswal et al., 1997)

The South Potwar sub-basin frequently referred to as the Potwar Plateau due to its relatively constant elevation (averaging 500 m above sea level). Neogene molasse is widely exposed in surface outcrops, whereas a long living petroleum exploration has resulted in a huge subsurface data base (including both seismic and wells). Pakistan is considered to be seismically active; however, the Potwar Plateau appears to be relatively more active as compared to the adjacent areas of the Kohat Plateau and the Salt Range. The seismicity appears to be scattered in most of the area. Only distinct patterns are seen along the Jhelum Fault i.e. in the northeastern part and along the MBT i.e. in the northern portion. The epicentral distribution appears to be concentrated in nearly NE-SW and NW-SE directions along the MBT. (pakistan journal of hydrocarbon research)

2.7 Division of Potwar Plateau:

The Potwar Plateau can be divided into following zones on the basis of intensity, type, trend and timing of the deformation.

1. Northern Potwar deformed zone (NPDZ)
2. Soan syncline
3. Eastern Potwar Plateau
4. Central Potwar Plateau
5. Western Potwar Plateau

Potwar plateau Shield is nearly undeformed south of Soan syncline, but is deformed on its northern and eastern margins.

1. Northern Potwar Deformed Zone (NPDZ):

The northern part of Potwar Plateau, also referred to as the Northern Potwar Deformed Zone (NPDZ) lies between the Main Boundary Thrust and the Soan Syncline. The North Potwar sub-basin, which is bordered by the Khari Murat Ridge and coeval back thrusts in the south, by the northern flank of the Soan syncline in the southeast, and by the MBT in the north. In addition to Neogene outcrops, it also comprises a number of surface anticlines and thrust fronts along which the Eocene platform carbonates are exposed. Westward these thrust are continued in Shakardara area of Kohat Plateau. It represents severest and oldest phase of deformation within Potwar Plateau as it is marked by imbricate stack of thrust faults, tight isoclinal to overturned folds, vertical dips and thrust bounded ridges. Pariwali, Khaur, Dhulian, Ballkassar, Karsal structures are the prominent tectonic features of this area.

Dhulian and Khaur anticlines are oil and gas producing structures. The youngest oil producing formations (at Khaur) is Murree formation. However the presence of oil and gas suggest migration of oil from older formations to Murree formation through deep seated buried faults. The tectonic style of NPDZ resembles more to the north of MBT Himalayan zone. Almost all the fold axis and thrusts are aligned in E-W direction. Shallow-marine carbonate strata of the Eocene Chorgali Formation form an important hydrocarbon producing horizon in the northern part of the Potwar Basin (N-Pakistan).

2. Soan Syncline:

It is an asymmetric with steeper northern flank and shallower southern flank. Axis of syncline is roughly parallel to the Soan River. The Soan syncline is not a true syncline. Its present configuration has resulted from deformation and rotation (more severe in eastern Potwar Plateau) of an initially broad syncline that develops in the south of NPDZ. The uplift along its northern (MBT) and southern (SRT) boarders not only caused deformation with in the syncline but also change the slope of Potwar Plateau from NW-SE to NE-SW.

3. Eastern Potwar Plateau:

There are some north facing basement normal faults noted to exist beneath the Chak Beli Khan, Chak Naurang, Qazian and south of Bhaun structures. Apart from EW and NE ward trending normal offsets, a few north south trending basement faults with reverse offsets have also been recognized in the east Potwar Plateau. So the deformation of the east Potwar Plateau has largely been controlled by these basement faults. All major salt accumulations are along basement normal faults.

In eastern Potwar Plateau, major structures are parallel to sub parallel with each other and show a wavy trend (two of the thrusts i.e. Dilljabba and Riwat have resemblance in their wavy pattern). These structures are aligned in NE direction, changing to EW direction westward, and turning northwards near Jhelum fault in the east.

Bhangali, Adhi and Misa Kaswal oil field are the well known structural traps created by tectonic forces in the eastern Potwar plateau.

4. Central Potwar Plateau:

The most important feature of the central Potwar plateau is a large normal fault (throw = 1Km) in the basement beneath the northern flank of the salt range that causes the ramping of the entire section. This basement normal fault has been intercepted as being due to flexure of the Indian plate. Another important difference between eastern and central Potwar plateau is the lack of major deformation in the southern portion of central and western Potwar. The surface of the central Potwar plateau between the north flank of the salt range and the Margala hills is essentially flat, while there is change in the basement slope being 1.3° in the front and underneath the Salt Range to 3.6° under the central and northern Potwar Plateau.

5. Southern Potwar Plateau:

Southern Potwar plateau, although has been pushed at least 20 km southward (), yet it has undergone almost no internal deformation, except broad, gently folded anticlines (Khan et al., 1986, Baker, Leather, 1987). This phenomena is due to the week evaporate layer and to the increase in the basement slop(1.9°-3.6°) in the Central Potwar as opposed to 0.6 °in the eastern Potwar Plateau.

6. Western Potwar Plateau:

Structurally it is much less deformed than rest of the Potwar Plateau; it is characterized by a series of gentle folds, incipient in nature having a general NE to EW trend with the exception of Dhadambar anticline, which is aligned in a NW direction parallel to the Kalabagh fault. Faulting predominates over folding in extension, distribution and intensity. Folding in southwest Potwar Plateau follows two trends, NW and NE which are the directions of the basement faulting. In this part, the Potwar Plateau is not only over-spilling southwards but also westwards onto the Kalabagh thrust due to uplift and room available. Important structures of western Potwar plateau are Ghabir, Khabakki, Dhadambar, Jhatla.

2.8 Boundaries of Potwar Plateau:

1. Main Boundary Thrust (MBT)
2. Jhelum Fault
3. Kalabagh Fault
4. Salt Range Thrust

1. Main Boundary Thrust (MBT):

A hairpin-shaped system of faults truncates the Murree Formation on the east, north and west. It has the Mesozoic and an earlier rock against the Murree Formation. This fault continues northwestward, turns westward near the syntaxis and then bends southward towards Balakot. (Kazmi & Jan1997)

2. Jhelum Fault:

It is left lateral strike slip fault along the western margin of the axial zone of the syntaxis. The Jhelum Fault apparently dislocates the MBT and terminates the eastward continuation of some of the structures of NW Himalayan fold and thrust belt. A number of east-west trending faults join the Jhelum fault at an acute angle pointed northward, indicating a relative left-lateral strike slip movement. (Kazmi &Jan, 1997)

3. Kalabagh Fault:

This fault forms the western margin of the salt range and extends NNW from near Mianwali town for a distance of 120 km. In Southward the Kalabagh Fault apparently displaces the Salt Range Thrust. (Kazmi &Jan, 1997)

4. Salt Range Thrust:

This Thrust Fault runs along the southern margin of the Salt Range, between Jhelum and Indus River, and it has pushed the older rocks of the Salt Range upon the less deformed Tertiary sequence of the south lying Jhelum plain. The thrust is exposed near Jalalpur and Kalabagh.

(Kazmi &Jan, 1997)

2.9 Stratigraphy:

The stratigraphy of the Potwar is established from the outcrops mainly from the well sections. The rocks exposed at the surface in this area range from Recent to Pliocene in age. In the limits of the Jhatla structure only Pliocene strata are exposed i.e. Nagri Formation in the core of the Jhatla structure and Dhok Pathan Formation.Potwar Sub-Basin preserves the sediments from Pre-Cambrian to Quaternary age and all of these formations are exposed in the Salt Range, unconformity separates the Cambrian strata from the Permian and Eocene strata from the Miocene.

2.9.1 Stratigraphic Equivalence and Variations:

The stratigraphic equivalence across different sub basins is the most interesting aspect of this period (Eocene).In Kohat basin the Eocene is represented by Panoba Shekhan, Koldana and Kohat formations. The shekhan limestone is equivalent to the upper part of sakesar limestone in Potwar basin. In contrast to the east Potwar plateau central and western Potwar plateau have been known for lack of significant evaporate sequence. Both the basins (kohat and Potwar) have gone through a similar evolutionary history.The existence of Early Eocene evaporites more in the Kohat area than in the Potwar Plateau indicates the limits of basins in the local region. In contrast to the east Potwar plateau central and western Potwar plateau have been known for lack of significant evaporate sequence.

2.9.2 Drilling Characteristics:

The Eocene rocks are very heterogeneous (Shales limestone, evaporate, coal, and minor sand stones). In the carbonates, the main drilling problems are severe loss of drilling fluids in fractured gas bearing reservoirs (e.g. Habib Rahi Lime Stone).

2.10 Hydrocarbon Potiental in the Area:

Geology of the Potwar Plateau makes it a favorable site for the hydrocarbon accumulations located on the continental margin. The Potwar sub-basin is one of the major hydrocarbon-producing provinces of the country. Multiple reservoirs of carbonate and clastic sediments of Cambrian through Miocene age occur. In total 11 reservoirs are known to be productive. Out of these fractured carbonates of Sakesar and Chorgali units are the major producing reservoirs. (Iqbal and Ali, 2001)

The Indus basin, including the Kohat-Potwar depression, belongs to the category of extra-continental downward basins which account for 48% of the world's known petro l e u m resources. (Riva, 1983)

A seepage of oil occurs in shekhan limestone as films on the outcrps.In numerous localities of salt range seepages of oil have been reported which are generally believed the result of migration along the uncofermity. (Iqbal.B.Kadri)

The plateau has numerous traps both structural and stratigraphic formed as a result of the Himalayan Orogeny. The platform zone of the Potwar Plateau is a proven oil bearing area and contains all the known oil fields of the plateau.A This zone has produced about 112 million bbl of oil (and associated gas) against the original proved recoverable reserves of over 200 million bbl. The producing zones are Cambrian, Permian, Jurassic, Paleocene and Eocene. The porosity in the tested wells is recorded up to 24% and permeability's up 300 md. The gray shale of the Mianwali Formation (Triassic), Datta (Jurassic), Patala Formation (Paleocene), Salt Range Formation (Pre-Cambrian), Dandot Formation (Permian) are the potential source rocks in area with an average geothermal gradient of 2 cenigrade/100 m is producing oil from the depth of 2750-5200m.

(a) Reservoir Rocks:

The Cambrian, Permian, Jurassic, Paleocene and Eocene reservoirs are producing oil in SRPFB. The fractured carbonates of the Sakesar and Chorgali Formations are the major producing reservoirs in Upper Indus Basin. (Shami & Baig, et.al. 2003)

Reservoir Characteristics

Rocks of this period have the maximum quantity of hydrocarbon discovered so for in Indus basin. In middle Indus basin the Eocene lime stones have excellent reservoir qualities e.g. Sui main limestone, is gas bearing has good porosity may be affected by bioturbation and storm reworking. In such case rocks have no preserved primary porosity and can have effective secondary porosity as result of fracturing.

In upper Indus Potwar basin oil bearing reservoirs belong to early Eocene limestones with low matrix porosity and high fractured providing most of voidage. In this basin saksar and chorgalli formations form the fractured reservoirs for various oil fields e.g. Adhi(PPL),Dakhni(OGDC), Dhurnal(OXY).

(b) Source Rocks:

The grey colored shale of the Mianwali. Datta and Patala Formations are potential source rocks in SRPFB. The oil shales of the Eocambrian Salt Range Formation include 27% to 36% TOC in isolated pockets of shales, and are considered as the source rock in SRPFB. (Khan & Raza, 1986)

(c) Cap Rocks:

The Kuldana Formations acts as a cap for the reservoirs of Chorgali and Sakesar limestones in SRPFB. The clays and shales of the Murree Formation also provide efficient vertical and lateral seal to Eocene reservoirs in SRPFB. (Shami & Baig, et.al. 2003)

Oil & Gas Field in Upper Indus Basin:

Age	Formations	Lithology	Oil&Gas Field	Production
Eocene/Paleocene	Lockhart/ Sakesar/ Chorgali	Limestone	Dhurnal, Dakhni Balkassar & Chalk-Naurang	Oil
Jurassic	Data & Samana Suk	Sandstone & Limestone	Dhulian, Toot & Meyal	Oil
Permian	Tobra Nilawahan & Zaulch Group	Conglomerate& Limestone	Adhi & Dhurnal	Oil
Cambrian	Khewra Sandstone	Sandstone	Adhi & Missa Keswal	Gas

Chapter # 03

Seismic Data Acquisition and Processing

3.1 Seismic Data Acquisition:

Seismic acquisition system consists of:
Energy Sources
Energy Receiving
Unit Recording Systems

Acquisition starts from shot and ends at recording the seismic events through various steps. The basic setup consists of seismic source, a long string of seismic detectors, called geophones, a vehicle carrying the computer. The results for all of the shots; explosion generates seismic waves, radiating though the ground encounter a boundary between two different strata, a portion of the waves are reflected back upwards detected by the geophones, and recorded by the computer. The entire apparatus then moves forward for the next shot.

As the apparatus moves along the path, each point along each boundary is sampled by reflections arriving at different geophones.

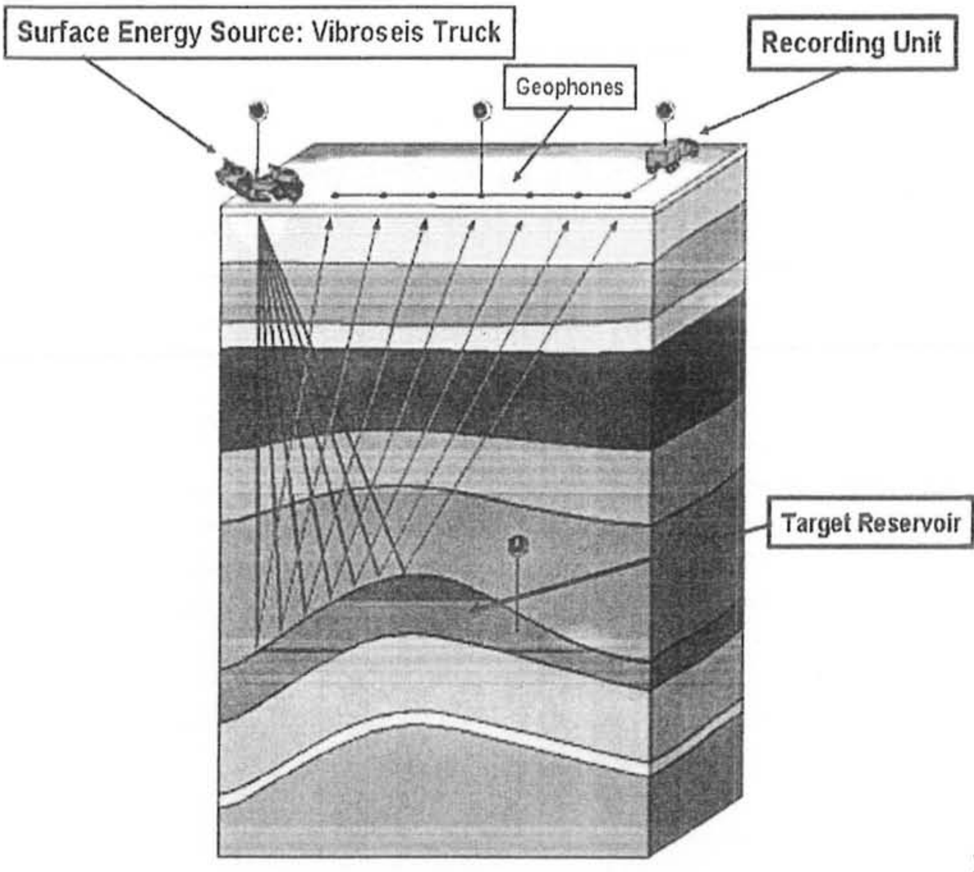


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Fig 3.1 systematic picture of seismic data acquisition

Fig 3.3 Vibroseis truck

3.1 Acquisition Setup:

The seismic acquisition setup involves the following;

- The spread configuration.
- Shooting types
- Shooting parameters

- Recording parameters

1) The Spread Configuration:

The lay out on the surface of the detectors which give recorded output for each source. There are some basic spreads.
End on spread
Inline offset spread

Split Spread/Centre shooting
Fan shooting

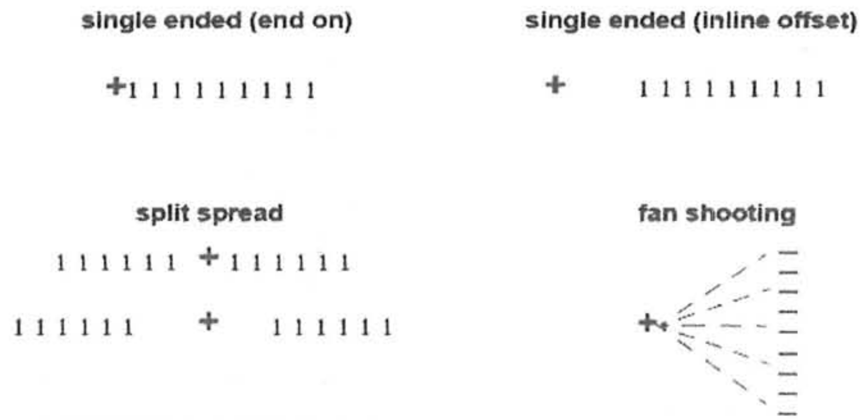


Fig 3.4 Systematic scheme of different spread configuration

1) Shooting Types:

The common shooting types are
Symmetric shooting (In this type the number of channels on sides of source is same)
Asymmetric shooting (In this the number of channels on sides of source is not same)
End shooting (The source is at one end of the spread)
Roll along/Roll out shooting

2) Shooting Parameters:

Shooting parameters include:

- Source size
- Number of holes
- Hole depth
- Shot at or between the pickets

3) Recording Parameters:

The recording parameters include:

- Group Interval
- Group Base
- Number of Channels
- Number of Geophones in a Group
- Geophone Array(Linear or Weighted)
- Sample Rate
- Record Length
- Coverage (Folds)
- Zero Offset and Common Offsets
- Seismic Cable

Seismic cable is used to transmit geophone signal to recording system. Each geophone requires two wire conductors. (Robinson & Coruh, 1988)

3.3 Recording Systems:

Two Types of recording system which are given below:

3.3.1 Analog Recording Systems:

Analog systems are systems for which the input and output are analog signals i.e. continuous amplitude signal .For an analog seismogram is a continuous record of ground motions as a function of time.

3.3.2 Digital Recording Systems:

Digital recording represents the signal by a series of numbers which denote values of the output of the geophone measured at regular interval, usually 2 or 4 milliseconds. The digital recorder makes use of binary numbers to store the measurement of geophone signal strength and has a significant advantage for the purpose of computer processing. The digital data recorded on a tape is in the form of binary numbers.

3.4 Seismic Methods:

Seismic Methods deal with the use of artificially generated elastic waves to locate hydrocarbon deposits, geothermal reservoirs, groundwater, archaeological sites, and to obtain geological information for engineering.

3.4.1 Seismic Reflection Method:

A seismic reflection survey measures how long it takes seismic waves generated by some seismic source into the ground, and reflect off of the boundaries to a series of geophones on the surface usually disposed along a straight line. It requires relatively little equipment, very accurate, resolving the subsurface to a resolution of under a meter. It has the disadvantage of being manpower-intensive and using high explosives.

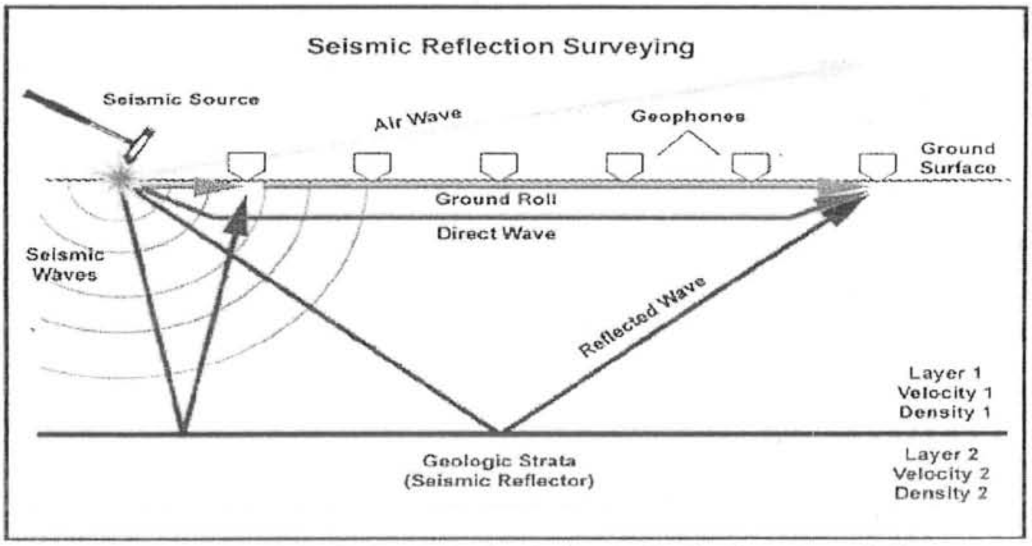


Fig 3.5 shows the Basic layouts for Seismic Reflection Acquisition

Structural information is derived principally from paths that fall into two main categories: refracted and reflected paths .If we know the speed of sound in the earth and the geometry of the wave path, we can convert that seismic travel time into depth.

Fundamental Law of Reflection:

This law states that "the angle of incident (between the ray and the normal to the interface) is equal to the angle of reflection (between the reflected ray and the interface)". Mathematically: $\theta_i = \theta_r$.

3.4.2 Seismic Refraction Method

When waves travel from one medium into another, the light waves may undergo a phenomenon known as refraction, only when there is a difference in the index of refraction, which is manifested by a bending or change in direction of the light. Same apparatus as a seismic reflection survey, but uses a different property of seismic waves to image the subsurface. Rather than detecting reflection of seismic waves, it measures the time taken for seismic waves to travel along the boundaries between strata, both having different acoustic impedance, then wave changes its path.

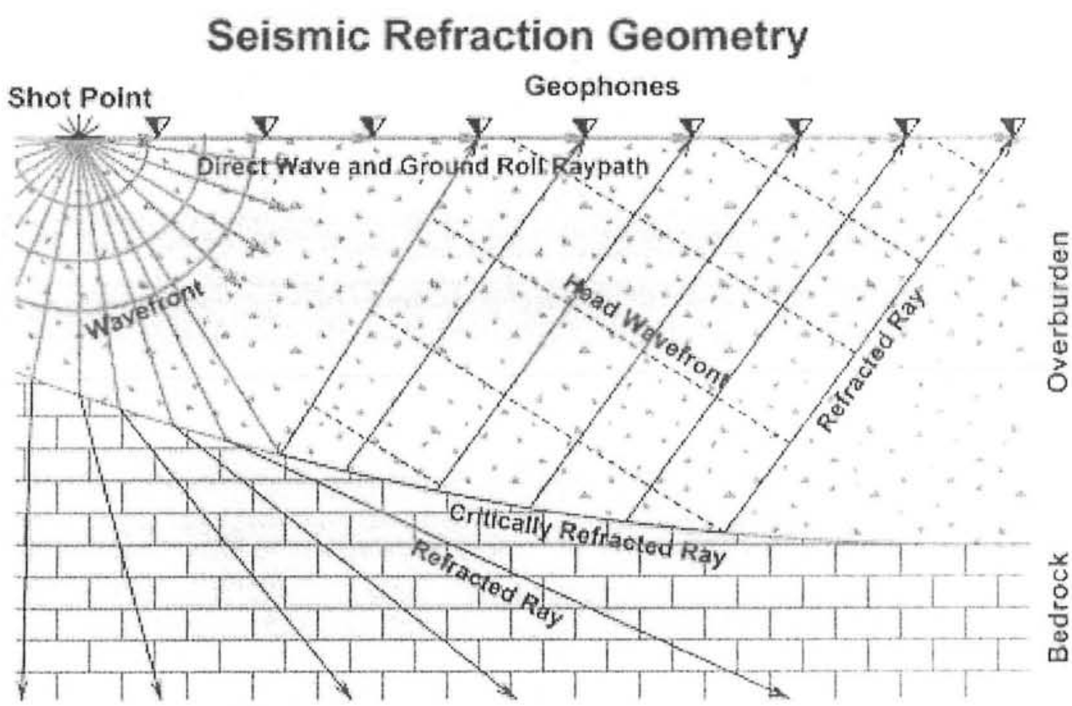


Fig 3.6 Seismic Refraction Geometry

Seismic refraction is generally applicable only where the seismic velocities of layers increase with depth. In addition, since seismic refraction requires geophone arrays with lengths of approximately 4 to 5 times the depth to the density contrast of interest, seismic refraction is commonly limited to depths less than100

3.5 Types of Seismic Waves:

There are mainly two types of Seismic Waves:
Body waves
Surface waves

1 Body Waves:

These are those waves, which can travel though the earth interior and provide vital information about the structure of the earth. The body waves can be further divided into the following;

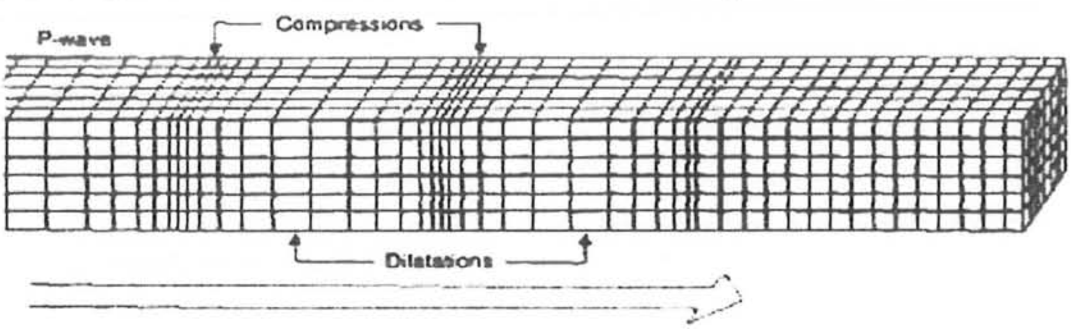
- P- waves (Primary waves)
- S- waves (Secondary waves)

1) P-Waves/Compressional Waves/Longitudinal Waves:

Here particles of media move in the direction of wave, it can pass through any kind of material.

$$Vp = \sqrt{\frac{(4/3)\mu + k}{\rho}},$$

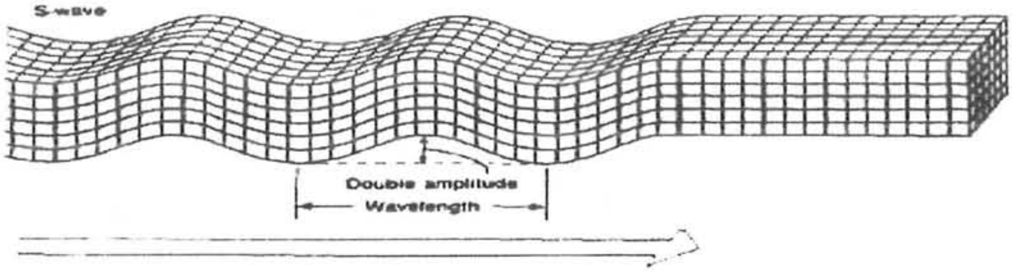
μ is the shear modulus is the bulk modulus is the density of the medium.



2) S-Waves/Shear Waves/Transverse Waves:

Media particles move in the vertical direction to the direction of propagation of wave, it can pass only through solids.

$$Vs = \sqrt{\frac{\mu}{\rho}}.$$



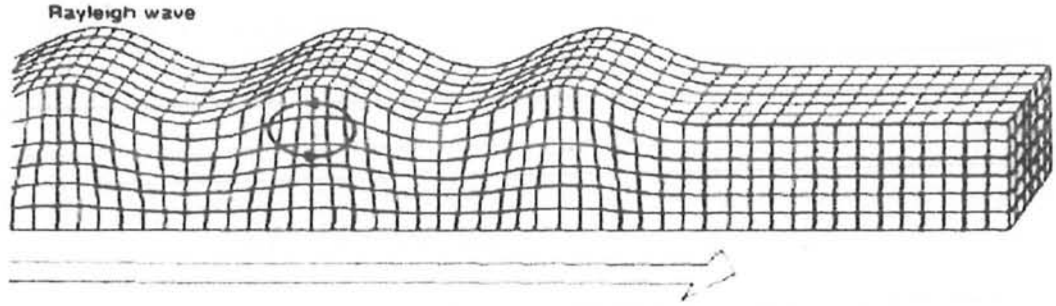
2 Surface Waves:

These waves travel along the surface of a medium or closer to the border between two different mediums. There are two types of surface waves.

1) Raleigh Waves
2) Love Waves

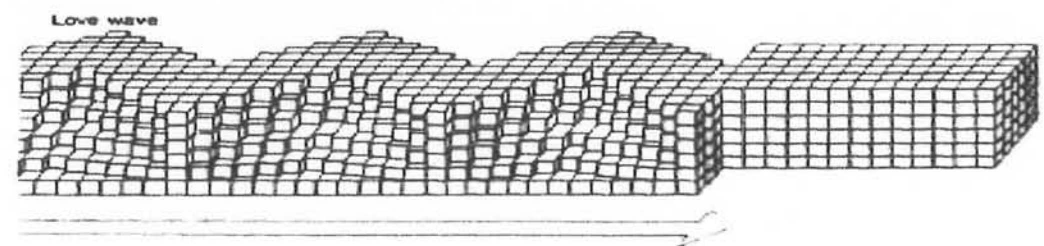
1) Raleigh Waves:

These waves travel along the free surface of a solid material. These are also called as "ground roll". (Dobrin, 1976)



2) Love Waves:

These are surface waves which are observed only when there is a low-speed layer overlying a higher speed substratum. The wave motion of these waves is horizontal and transverse. Speed of love waves is equal to shear wave speed for following cases.



3.6 Effect of Physical Properties of Rocks on Seismic Velocities:

Whenever there is a change in grain size and mineralogical composition of rock, velocity behavior changes. Increase in grain size will result increase in velocity. The seismic velocities in rocks are affected by several factors:

- Effect due to Porosity
- Effect due to Density
- Effect due to Age of Rock
- Effect due to Overburden Pressure or Depth of Burial
- Effect due to Fluid Content in the Pores
- Effect due to Litho logical and Mineralogical Composition of Rock
- Effect due to Temperature

3.7 Types of Seismic Velocities:

A medium is made up of a sequence of layers of different velocities, so it is necessary to specify the kind of velocity that is used in processing and interpretation. (Al-Sadi, 1980)

Instantaneous Velocity

Average Velocity V_{avg}

Interval Velocity V_{int}

Root Mean Square Velocity V_{rms}

Normal-Move out OR Stacking Velocity Vnmo

Migration Velocity

Importance of Seismic Velocities

The Seismic Velocities may be used to establish the following:

- True depth
- Stacking of seismic data
- Migration of seismic data
- Possible lithology determination
- Possible porosity estimate

3.8 Processing in General:

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

Observational Data ⇒ Processing System ⇒ Useful Information

3.9 Processing in Sequence:

The seismic data processing sequence can be broadly defined in five categories:

- Data Reduction
- Geometric Corrections
- Data Analysis and Parameter Optimization
- Data Refinement

A detailed Processing Sequence Flow Chart is given as:

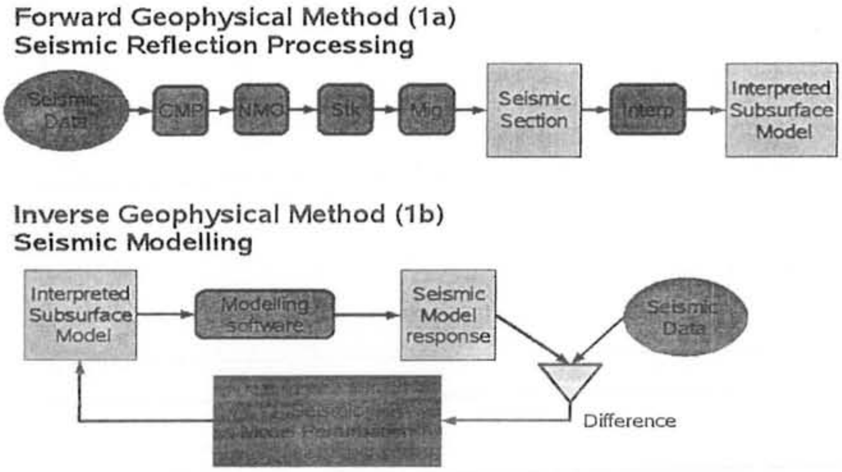


Fig: 3.7 Detailed Processing Sequence Flow Chart

3.9.1 Data Reduction:

Data reduction is done by certain processing operations as below.

- Demultiplexing
- Correlation
- Header Generation
- Display
- Editing and Muting
- Amplitude Adjustment

1 Demultiplexing:

Data from the field arrive at the processing center in tapes written in multiplexed format because that is the way the sampling is usually done in the field successive samples on the tape represent the succession of channels at the same instant in time. Multiplexed data thus use time, not channel, as the primary index is the first step in any data processing sequence .So the process of sorting data from the magnetic tape into individual channel sequence is called Demultiplexing.).

This scrambled sequence is called Multiplexed data, and the unscrambling multiplexed array into Trace Sequential Array is called Demultiplexing. The digital seismic data is recorded on magnetic tape by the recorder in the following way:

A11, A12, A13,..........,A1m
A21, A22, A23,..........,A2m
....
....
....
....
An1, An2, An3,..........,Anm

(Robinson & Crouch, 1988)

After that data has been Demultiplexed, it is stored on tape in a convenient format in the above way, which is used in further processing.

1 Correlation:

Correlation is simply the measurement of similarity or time alignment of two traces. There are two types of correlation:
Cross Correlation
Auto Correlation

1. Cross Correlation:

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

2. Auto Correlation:

Cross 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.

3. Vibroseis Correlation:

The sweep is transmitted through earth and reflected signal. Each reflection is a near duplicate of a sweep itself, so the reflections in vibroseis record overlap act are indistinguishable. To make it useable reflections are compressed into wavelets through cross-correlation of data with original input sweep. After correlation each reflection on record looks similar to impulsive

source data. This involves cross correlation of a sweep signal (input) with the recorded vibroseis trace. The sweep is a frequency-modulated vibroseis source signal input to the ground .There is two types of sweep:
Up Sweep (When frequency of the vibroseis source signal increases with time)
Down Sweep (When frequency of the vibroseis source signal decreases with time)

1 Header Generation:

After All of the sample from a given field trace are assembled into an array, a large amount of archival information is placed in a reserved block called a trace header, which is located on the just ahead of the data samples. Trace header information may include location and elevation of source and receiver, field record number, trace number etc.

2 Display:

The data so processed is generally displayed in various modes to summarize the information gathered. At any point of processing sequence the seismic analyst can display the data in wiggle trace or other modes. The choice of display is a matter of the client taste, but is not affected by company dictum.

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
Editing

This term is applied for process of zeroing the undesired part of a trace. In order to avoid stacking non-reflection 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.

4 Amplitude Adjustment:

Amplitudes of the seismic wavelet are adjusted because it dies out as the input wave travels down to the earth and losses it energy due to the spatial spreading of the wave or absorption. Besides, spherical spreading and energy dissipation in earth, there are other reasons for the observable decay in seismic amplitude with time. Under the knowledge of such reasons amplitude of the seismic wavelet is adjusted:

3.9.2 Geometric Corrections:

A seismic trace on a field monitor shows reflected energy bursts from subsurface rock layer interfaces. However, when reflected energy bursts, then several corrections are applied to compensate the geometric effects. Removing near surface effects requires two corrections we use
Static correction
Dynamic correction

1 Static Correction:

Static correction compensates the effect of weathered layer and elevation effect due to unleveled surface .So static correction is of two types:

1) Elevation correction:

The effects of topography on a trace's reflection times are removed by applying this correction which, in effect, moves both source and receiver vertically to a pre-selected datum surface. This surface is usually (but not always) a flat datum plane the elevation corrections for source and receiver are:

$$EC_S = (E_D - E_S)/V_S,$$
$$EC_R = (E_D - E_R)/V_C$$

The elevation datum surface is chosen before the first data from a new area are processed. In areas of gentle relief it is usually a flat plane about 100ft. below the average surface elevation in the area.

2) Weathering correction:

A weathering correction replaces the actual travel time through the weathered layer by a computed travel time. The computed travel time would result if the weathered layer (the low velocity layer) were replaced by and equal thickness of the underlying higher velocity rock. Although the weathered layer does vary in thickness, its approximate thickness is usually known from previous experiences in the prospect area.

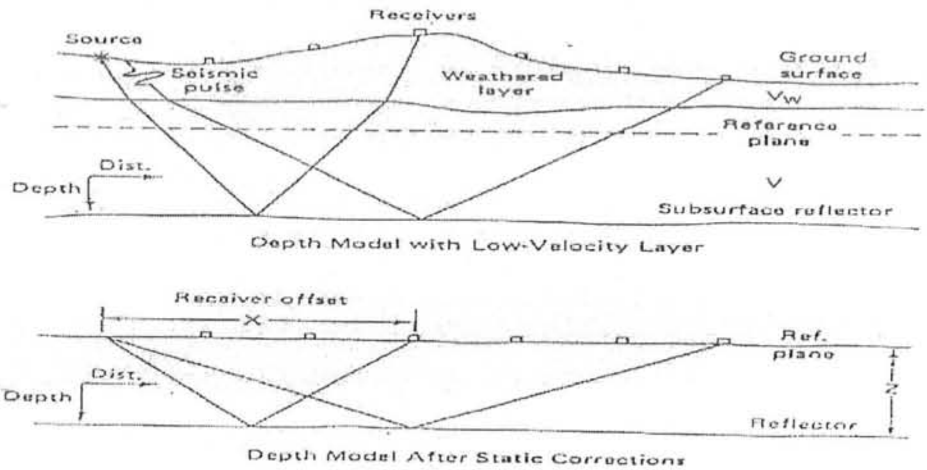


Fig 3.8 shows different depth model before and after correction

2 Dynamic Correction:

Dynamic correction compensates the effect of offset of receiver from the source .It is also related to the shape of the subsurface interfaces .It is also of two types:
Normal move out correction (NMO).
Dip move out correction

1) Normal move out correction (NMO):

Normal move out correction is related more to the non-dipping interfaces, applied to pre-stack data. Here the effect is shown on a single trace with NMO adjusts the original time to that which would have been observed at the midpoint, which must be less than the other path time ,operates on one trace at a time. It is the process to cancel the travel time delay caused by the geometry of reflection with the estimated velocity. After the NMO correction the every traces of the CMP gather may simply be summed and result a noise reduced trace (CMP stack).

NMO equation is

$$Tx^2=To^2+x^2/v^2$$

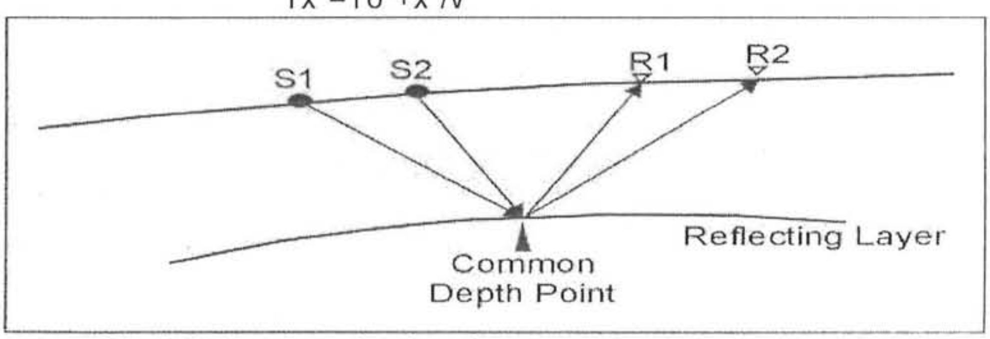


Fig 3.9 Common depth point

2) Dip MoveOut (DMO):

Dip MoveOut (DMO) is a process that is applied after NMO. Since NMO assumes the reflection comes from a horizontal bed, it is picking up only one of many possibilities. For one trace with one reflection event, all possible travel paths have the same length that is, the distance from source to reflection point to receiver is a constant. The geometrical shape with this property is an ellipse (upper). Some of the original path possibilities are shown in red. NMO reduces travel time based on a horizontal reflector (blue path), while DMO does all the other. Since DMO operates on several traces, so expensive than NMO. Equation for the dipped reflector is

$$Tx^2 = To^2 + x^2/v^2 \cos^2\alpha$$

Trace Gathering

Traces are routinely gathered into groups having some common elements.

Common Source Point Gather
Common Depth Point Gather
Common Receiver Point Gather
Common Offset Gather
Common mid Point Gather

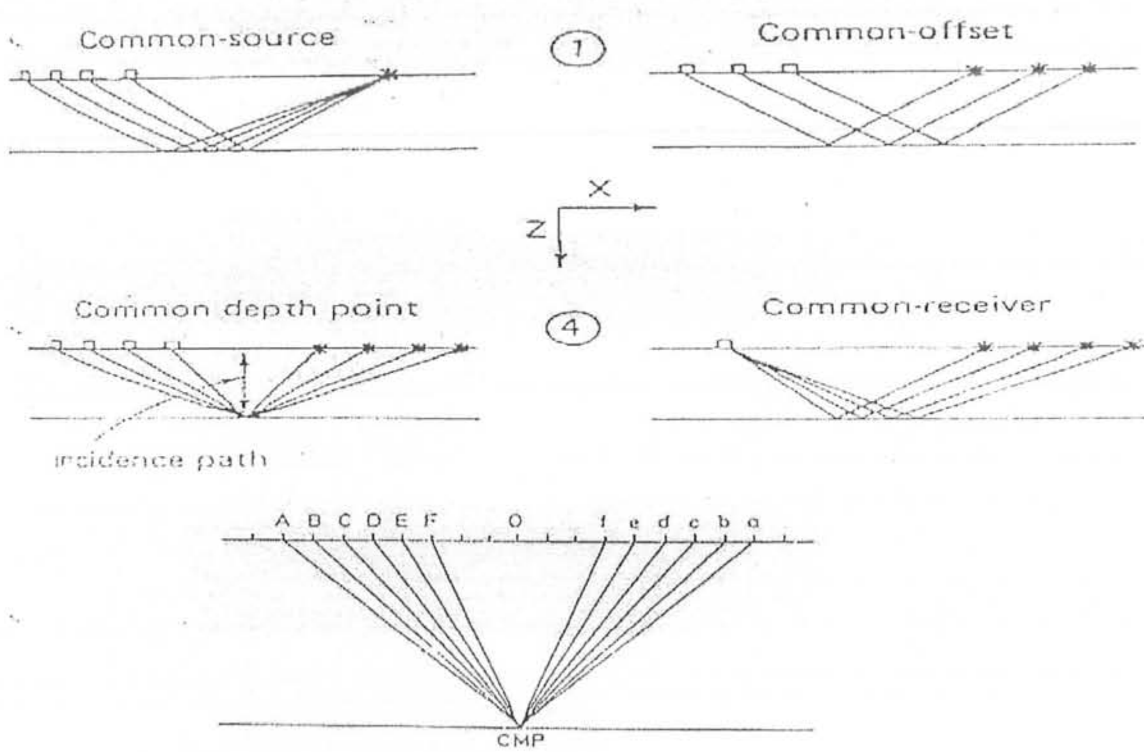


Fig 3.10 shows different CDP model

3.9.3 Data Analysis and Parameter Optimization

The following three steps are involved in this procedure;

- Filtering
- Deconvolution
- Velocity Analysis

1) Filtering:

Filtering is a process of spectrum modification which involves suppression of certain frequencies. (Robinson & Coruh, 1988)
A filter is a system, which discriminates against some of its input. Seismic data always contain some signal information, which we want to preserve. Everything else is called noise, and we want to remove it. These systems, which are generally called filters work either by convolution in the time domain or by spectral shaping in the frequency domain.
The common types of filters are the following:

- Low pass frequency filter
- High pass frequency filter
- Band Pass frequency filter
- Notch filter
- Inverse filter

Velocity filter

PROCESS	PURPOSE	WHEN APPLIED
Band Pass Filter	Attenuate noise-having frequency outside of signal band.	Best before stack and before NMO.
Notch Filter	Attenuate narrow frequency band noise with signal band.	Best before stack.
2-D Filter	Spatial band pass filter, attenuate random noise or events separable by dip.	Any time after data reduction, depending on type of events to be removes.

2) Deconvolution:

It assumes the input is minimum phase and all frequencies are to be leveled in the spectrum. The effect of this type of filter is to concentrate the energy of the pulse as near as possible to the front of the wavelet, i.e. to turn the wavelet into as near a spike as possible.

3) Velocity Analysis:

After the NMO correction the every traces of the CMP gather may simply be summed and result a noise reduced trace (CMP stack). A series of normal move out corrected traces are stacked to produce a single output trace. This calculation is repeated for each constant velocity until the range of velocities applied extends from the minimum to maximum to be encountered in the area. A plot of velocities against record time for each analysis location represents the velocity function for that location. Velocity analysis is performed on selected CMP or CDP gathers. The out put from one type of velocity analysis is a table of numbers as a function of velocity vs. Two-way zero off set time also called as velocity spectrum. Numbers present in the table represent some measure of signal coherency along the hyperbolic trajectories governed by velocity, off set, and travel time.

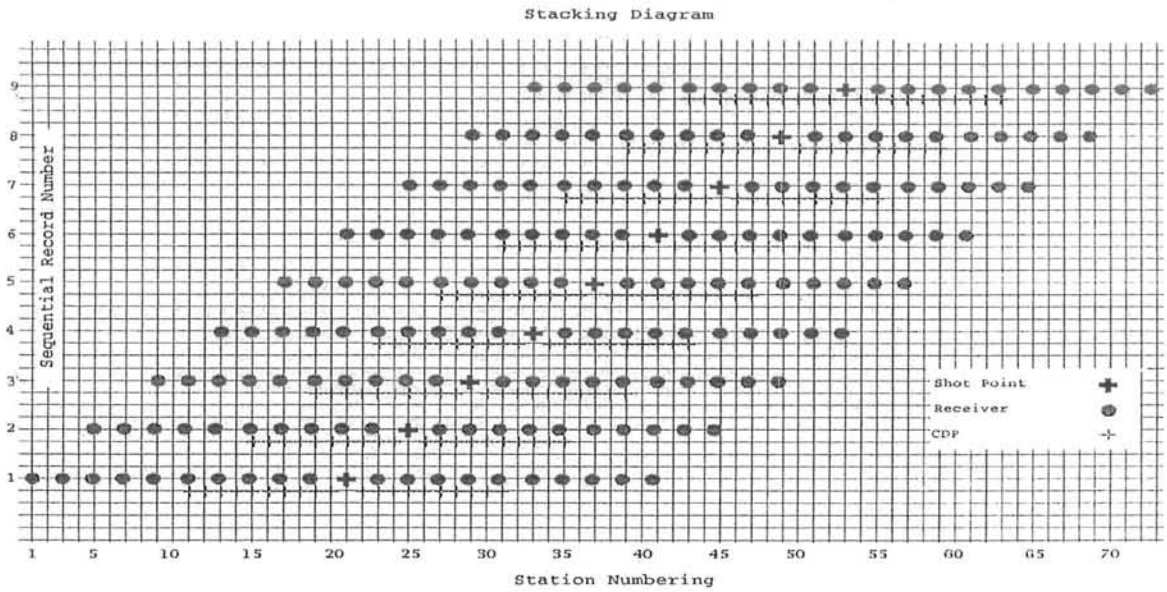
3.9.4 Data Refinement:

Data refinement consists of the following two main stages;

- Stacking
- Migration

1. Stacking:

It consists of the summation of the traces of each CMP gather after correcting them to compensate for the Offset between source and receiver. This is known as the Normal move out (NMO) correction.



2. Migration

The term migration refers to the movement of the observed events to their true spatial positions. The concept of migration can be summarized as; the seismic signal recorded by a receiver (geophone) is a superposition of seismic waves originating from all possible directions in the sub terrain. Thus the recorded events most often are not from reflectors directly below the receiver but from geological formations far away from the point of recording.
Migrated seismic section can be directly translated into geological depth sections using appropriate velocity information. Migration removes the diffracted arrivals resulting from point source. (Kearey & Brooks, 1988)

3.10 Survey Parameters:

The recording parameters of seismic line NP-84-44 are:

3.10.1 Display Parameters:

TRACES/INCHES	14.0
INCHES/SEC	3.75
POLARITY	NORMAL
BIAS	0.0
DISPLAY DATE	MAY 1987
SUPERVISOR	LARRY SHANABROOK

3.10.2 Source Information:

ENERGY SOURCE	VIBROSEIS
VP INTERVAL	50M
SWEEP LENTH	12SEC
SWEEP INTERVAL	8-47HZ
SWEEPS/STATION	3-4

3.10.3 Receiver Information

NUMBER OF GROUPS	96
GROUP INTERVAL	50 METERS
GEOPHONES PER GROUP	36
GEOPHONE FREQUENCY	10
GEOPHONE SPACING	2.85

CHANNEL:	1	48	49	96
OFFSET:	2500M	150M	150M	2500M

3.10.4 Processing Parameters:

1) Demultiplex input Data Processing.(Resample data to 4 MSec)
2) Vibroseis correlation [zero phase]
3) Traces edit
4) Spherical Divergence and Inelastic attenuation Compensation
5) Spherical whiting (Frequency range 6-55 Hz)
6) CMP Sort.
7) Band Pass Filter

Time (MSEC)	Frequency (HZ)
400	10-48
1500	8-48
2500	8-30
5000	6-24

8) Normal Fold	48
9) Time Varient Scalling	Square Root Balance
10) Gate Length	500 msec

Chapter # 04

Seismic Data Interpretation

Introduction:

In seismic, interpretation is defined as: "The translation of seismic information into geologic terms". If it is carried out successfully this process calls for the greatest possible coordination between geology and geophysics. Interpretation is the transformation of the seismic reflection data into a structural picture by the application of correction, migration and time depth conversion. (Dobrin,1976)

4.1 Meaning of Interpretation:

The word interpretation has been given many different meanings to geophysicist who handle seismic reflection records and by geologists who put the information from them to use.

- Planning and programming
- Choice of field parameters
- Selection of processing procedure

After seismic map is constructed, an important part of it its interpretation is integrating the seismic data on it with geologic information from surface and subsurface sources e.g. fault traces or geologic contacts. This involves identifying reflectors and making tie to wells or surface features. All this depends upon the amount of information available.Under favorable circumstances, interval velocities can be determined from reflection records with enough precision to permit them to serve as a basis for identifying lithology. Geophysicist deals with the seismic section. In seismic method physical measurements are made at the surface, which are then interpretation in terms of what might be in the subsurface the position and behavior of interfaces, which gives rise to each reflection event is then calculated from arrival times. Resulting information is then combined into cross section, which represent the structure of geological interface responsible for the reflection event.The seismic reflection interpretation usually consists of calculating the position of, an identifying geologically, concealed interfaces or sharp transition zones form seismic pulses return to the ground surface by reflection. The influence of varying geological condition is eliminated along the profiles to transform the irregular recorded travel times into acceptable subsurface models. This is very important for confident estimation of the depth and geometry of the bedrock or target horizons. (Dobrin, 1988)

According to Badly (1985), reflection seismic uses sound waves to investigate the subsurface. The acoustic impedance governs reflections, which is one of the rock properties.

Acoustic impedance = interval velocity *density

Reflections arise at boundaries across which acoustic impedance changes. No reflection occurs impedance does not change even if lithology

changes. The greater the difference in the acoustic impedance is, the stronger the reflection. The size of change is defined by reflection coefficient (RC).
The major aim of seismic reflection surveying is to reveal as clearly as possible the structure of the subsurface. The geological meaning of seismic reflection is simply an indication of an acoustic impedance boundary where we want to know that whether this boundary marks a fault or a stratigraphic contact with any other boundary. We want to distinguish the feature that is not marked by the sharp boundaries.
A sequence of sedimentary rocks is grouped into unit called formations. These formations can be described in terms of age, thickness and lithology of the consistent layers.To distinguish different formation by means of seismic reflection is an important question in interpretation of data, which may be structural, lithology, or stratigraphic.

4.1.1 Seismic Section:

The seismic section of line no NP84-44 is given below:

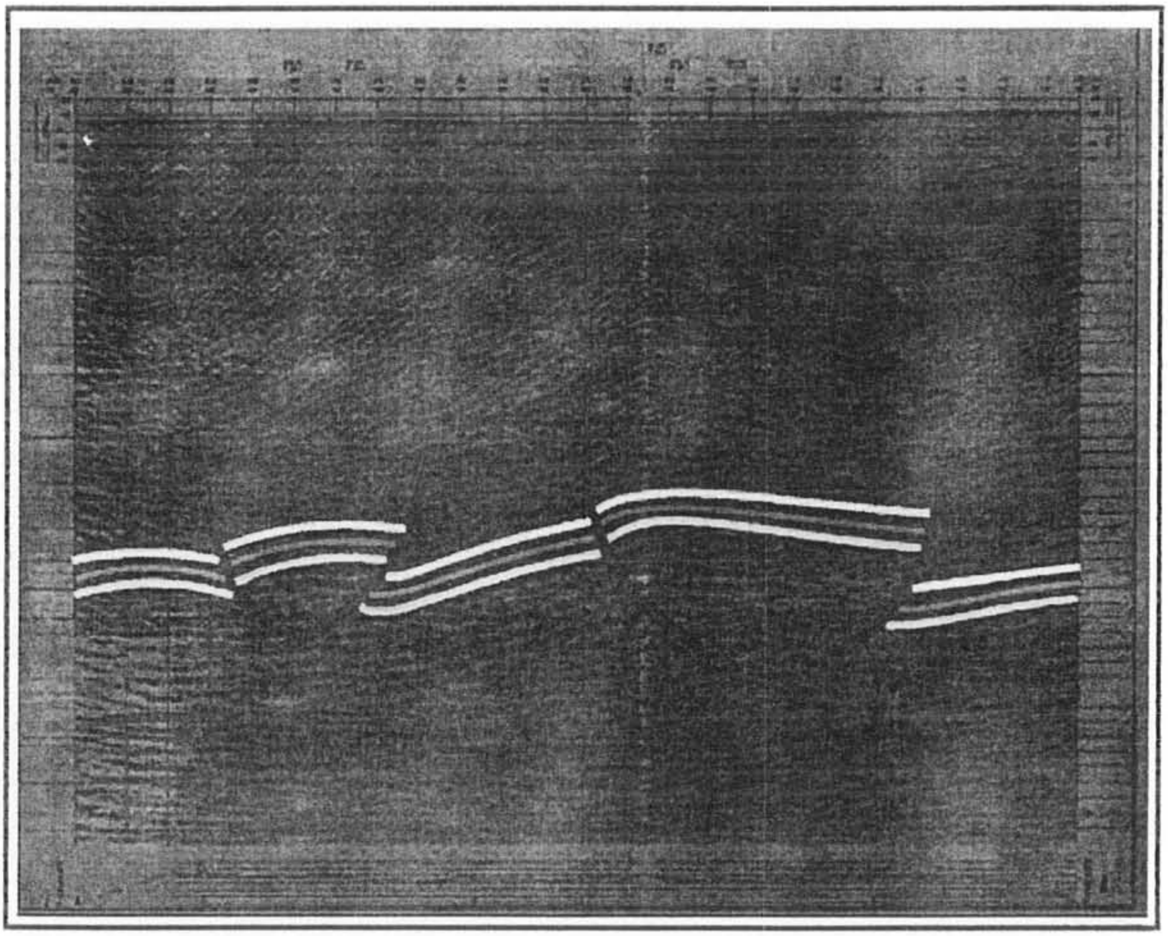


Fig 4.1 interpreted seismic section

4.2 Seismic Data Analysis:

There are two main approaches in the analysis of seismic data:

- Structural Analysis
- Stratigraphic Analysis

4.2.1 Structural Analysis:

In structural interpretation main emphasis is on the structural traps in which tectonic play an important role. Tectonic setting usually governs which types of structures are present and how the structural features are correlated with each others, 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, anticlines, duplex etc. (Sheriff, 1999)

Seismic sections can predict the structure that scale up to few tens of kilometers. For large scale interpretation we have to use the grids of seismic lines. Unmigrated section is not suitable for structure interpretation, because it creates many problems like synclines becomes narrows and vice versa. Even a migrated section not fully fit for complex area like the area of study, Ratana in this dissertation; because of the velocity distortion create the difficulty like the planar fault plane appears as curved in seismic section. A fault with throw less than ¼ the wavelength of seismic wave will difficult to pick in the seismic section. (Badly, 1985)

In the study area of Ratana, due to compression regime thrusting is common. A thrust fault develops under high pressure system and to develop it requires high pressure under the thrust plane, complex array of structures are associated with these faults that are difficult to resolve on the seismic section especially in case of low angle thrust. In the seismic section of given line NP84-44 a thrust fault is marked that make a pop up structure that may generate hydrocarbons, these are marked by observing the sudden change in the position of reflectors and distortions of disappearance of the reflection below the fault. The thrust fault is not basement rooted that gives some indication of thin skin tectonic involvement in the study area. Thrust fault has dislocated all the prominent reflectors except the basement. In the study area the basement has normal faulting that indicates the rifting in this region and involvement of extensional features before the Indo-Eurasian collision.

4.2.2 Stratigraphic Analysis:

Stratigraphy analysis involves the delineating the seismic sequences, which present the different depositional units, recognizing the seismic faces characteristic with suggest depositional environment and analysis the reflection characteristic variation to locate the both stratigraphy change and hydrocarbon depositional environment .

Hydrocarbon accumulation is indicated by the amplitude, velocity, frequency or the change in wave shape. Variation of the amplitude with the offset is also an important hydrocarbon indicator. 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 Seismic Horizons:

First I marked the main reflections that are present on the seismic section, and then selected those that showed good characteristics and continuity and can be trace well over the whole seismic line. I picked three reflectors on the seismic section (NP84-44). Chogali Formation has its specific reflection pattern so it is easily recognized due to that.

Reflections in the upper part of the section are not clear so reflectors are not marked there. After marking the entire prominent all the reflectors were given names with the help of well tops on the line number NP86-09 on which well is located. After ting this line to my line reflectors were given names and noted their time across different vibrating points then by using the following relationship I converted these times into depth.

$$D = (Vav * T)/2$$

Where

D= depth of Reflector in meters,

Vav= mean average velocity in m/s

T = Two way travel time in seconds

4.4 Interval velocity And Interval Velocity Graph:

Interval velocity is the average velocity over some interval of travel path of the wave. It can be calculated by Dix equation, that is,

$$V_{n,int} = \frac{V_{n,rms}^{2} * T_n - V_{n-1,rms}^{2} * T_{n-1}}{T_n - T_{n-1}}$$

Where Vint = interval velocity in m/s, Vrms = root mean square velocity in m/s and T is the two way travel time of the seismic wave in millisecond.

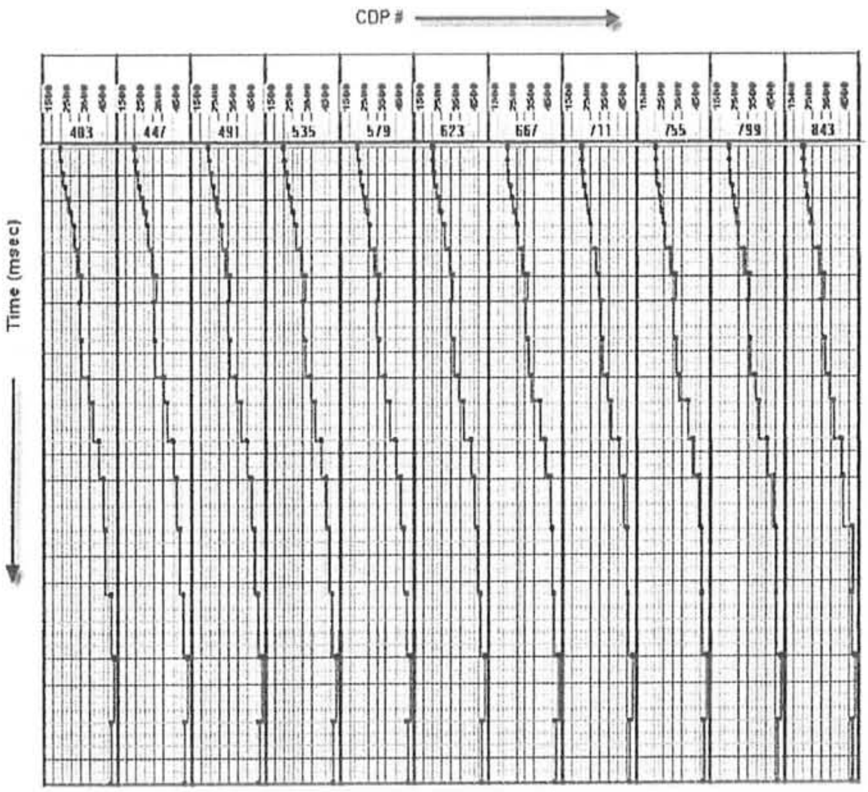


Fig. 4.2 Interval Velocity Graph

4.5 Average velocity And Average Velocity Graph:

This is simply the depth 'z' of a reflecting surface below a datum divided by the observed one way reflection one way time 't' from the datum to the surface.So that

$$V_{avg} = z / t$$

If 'z' represents the sum of the thicknesses of the layers z1, z2, z3... z**N**, then average velocity defined as

$$V_{avg} = (Z1+Z2+ Z3+......+ Z_n) / (T1+ T2+ T3+......+ T_n)$$

Average velocity can be calculated by using the interval velocities provided on the seismic section using the DIX formula which is:

$$V_{n,avg} =(V_{n,int}(T_n - T_{n-1}) + V_{n,ave}*T_{n-1}) / T_n$$

From this, average velocities at constant interval of time can also be calculated and then use it for the "Average Velocity Graph". The purpose of preparation of this graph is to observe the vertical variation of average velocity from bottom to top. Where these lines intersect there some sort of disturbance is present. It is also seen that to find depth average velocity is used.

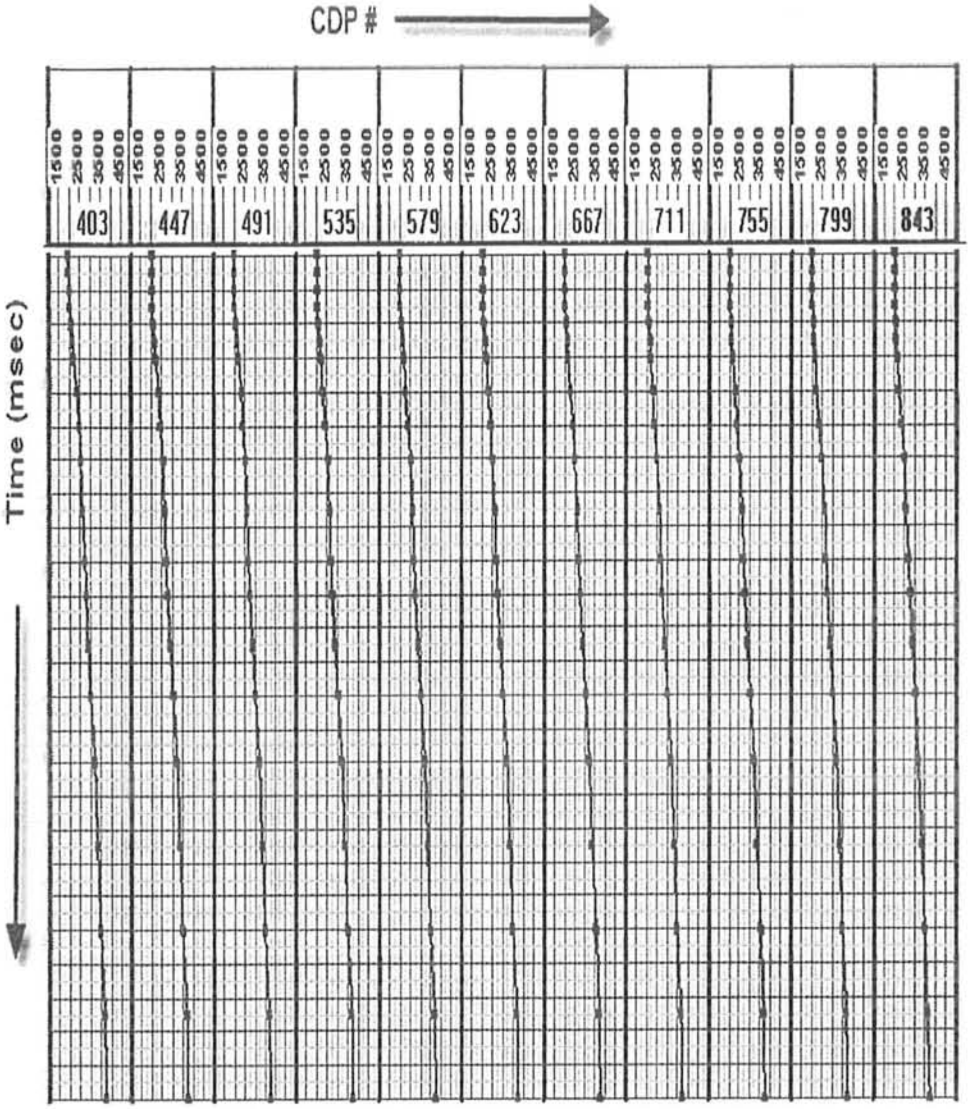


Fig. 4.3 Average Velocity Graph

4.6 Mean Velocity And Mean Velocity Graph:

This is simply calculated by dividing the sum of average velocities at constant intervals of time with the total number of observations so that

Vmean = (Vavg 1+Vavg 2+Vavg 3+.........+Vavg n) / N

From these mean velocities the "Mean Velocity Graph" can be made by plotting mean velocities against the time. From the graph it is seen that the velocity is increasing with the depth with time for the whole a

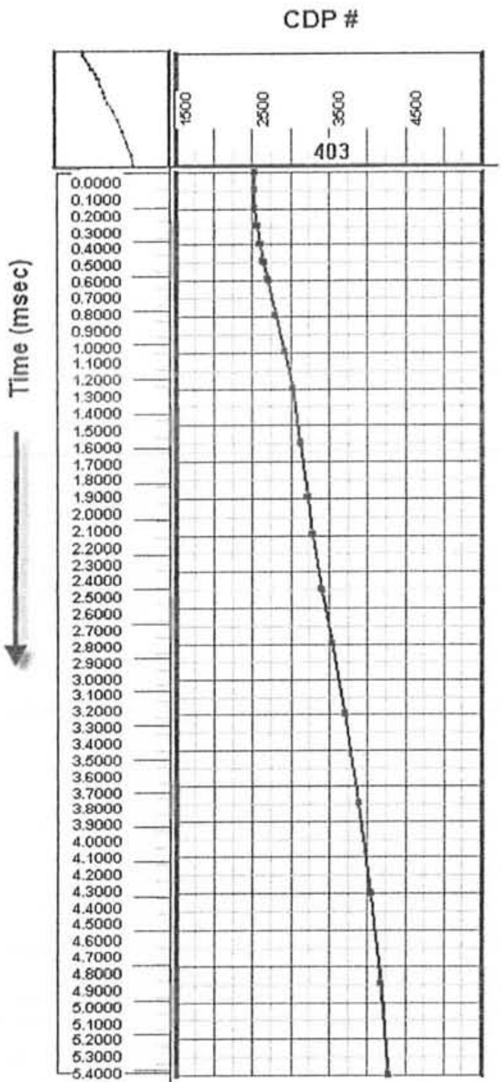


Fig. 4.4 Mean Average Velocity Graph

4.7 Iso-Velocity Map:

Whenever the CDP's plotted against the average velocities, a section formed which shows the lateral and vertical variations of the same velocity layers at different CDP's. The map so formed is termed as the Iso velocity map.

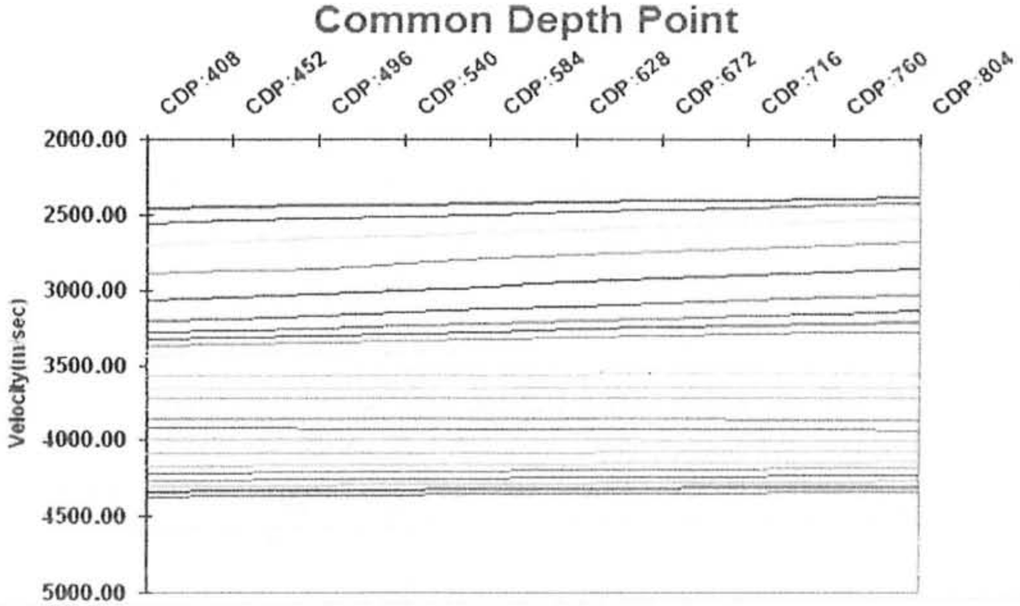


Fig 4.5 Iso- velocity map

4.8 Seismic Time Section:

Seismic time section is simple reproduction of an interpretated seismic section. After marking seismic horizons and faults, I note the time of each reflector at different vibrating points, and then the seismic time section is generated by plotting the two-way travel time of the reflectors and fault on y-axis against the vibrating points on x-axis. There are pop up structures between F1 & F2 and F3 &F4 which is suitable for hydrocarbon accumulation.

Time Section (OX/NP84-44)

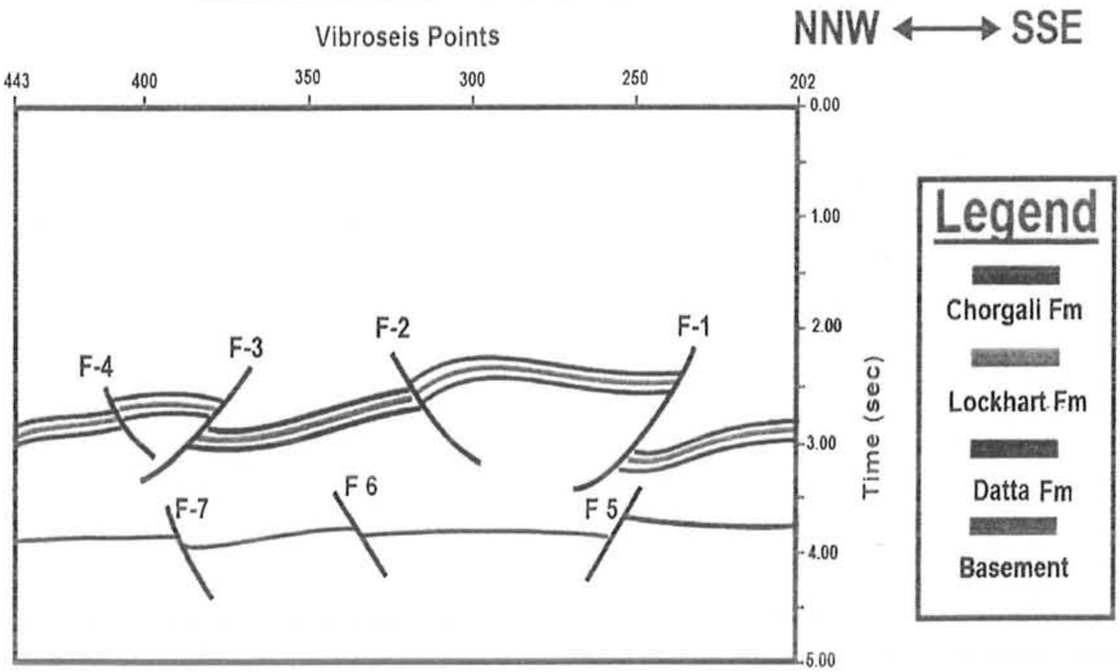


Fig 4.6 Time section of line NP84-44

4.9 Seismic Depth Section:

When we make a map of seismic time it is intended to show the structure of a horizon in the subsurface. Obviously it does not show the structure directly. Structure is matter of depth and the map is travel time of sound waves. To make a map that is more truly related to the subsurface, depths must be calculated from the times. Here we need truly velocities. So with the help of formula below, we can convert the time into depth.

S (m) = [Vave (m/msec)* T (msec)] / 2000

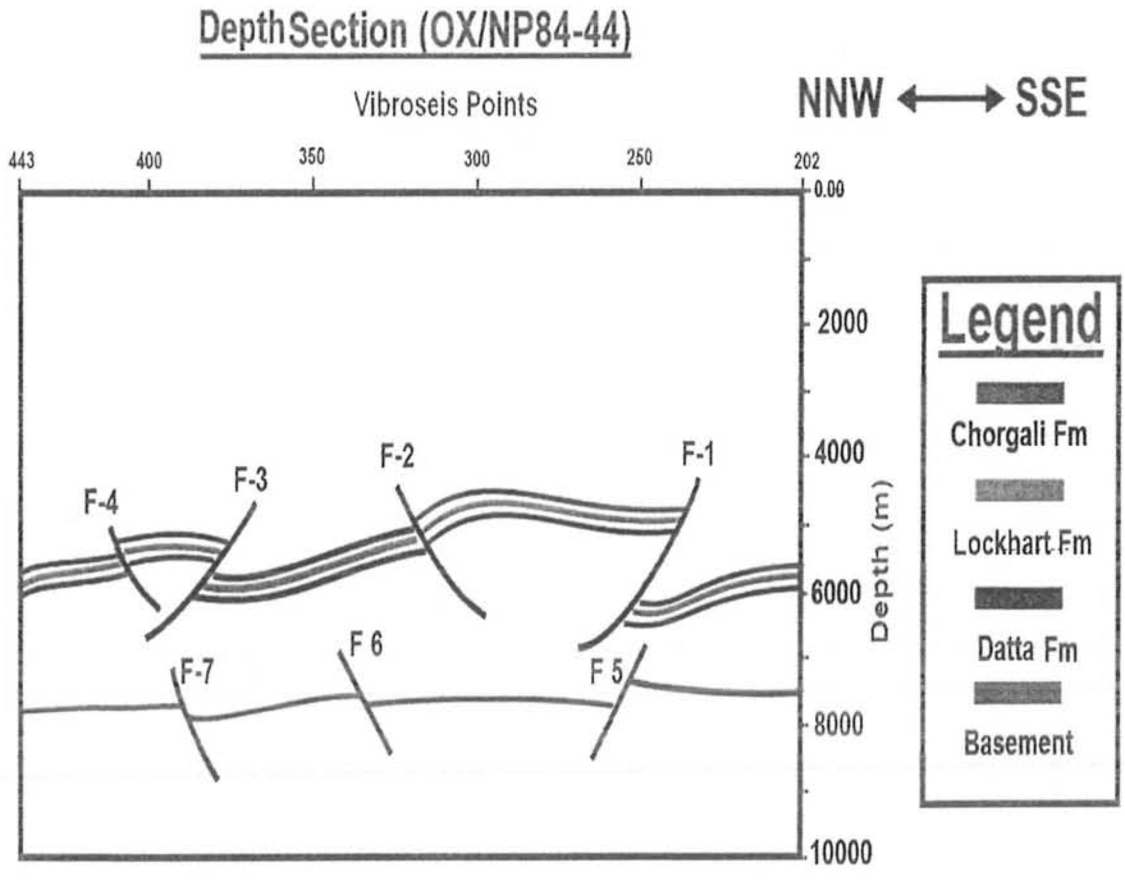


Fig 4.7 Depth section of line NP84-

4.10 Well correlation

By correlating the well tops of Ratana -01, Ratana -02, Ratana-03 and Mianwala 01 I have identified that thickness of different formations varies in the area. some formations are absent in some part of the area like Nagri formation is not present in the Ratana-02 well, while it is present in the Ratana 03 with a considerable large thickness, this shows the litho logical variation in the area, while Chinji formation thickness decreases from Ratana-02 to Ratana-03

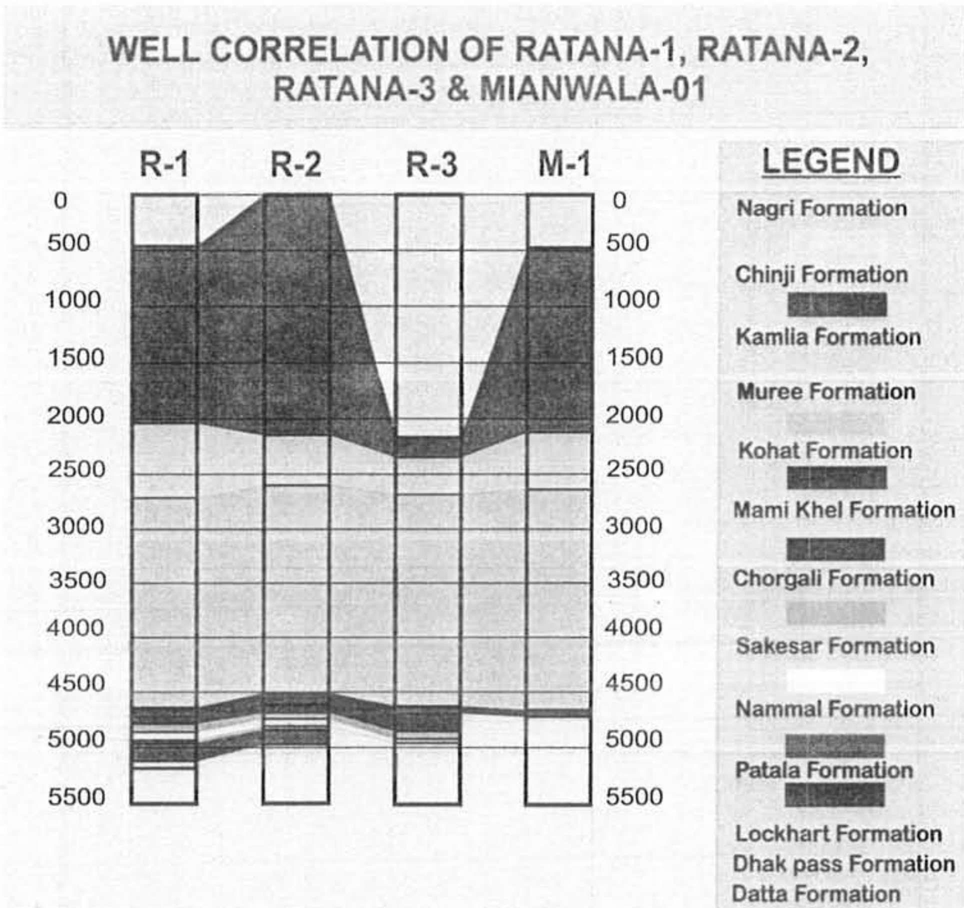


Fig4.8 Well Correlation of Ratana-01,Ratana-02,Ratana-03 and Mianwala-01

4.11 Contouring:

Contour lines show the same events. Proficiency in contouring- the quest for a two dimensional representation of a three-dimensional surface is a basic skill that should be in the armory of every interpreter.

The art of contouring is to use the data values honestly, while at the same time keeping in mind the desired geological shape. (Badley, 1985)

4.11.1Contour and Surface Contour Maps of Chorgali Formation:

For preparation of these maps time of Chorgali Formation was picked from lines NP84-44, NP86-08, NP86-09, NP84-41 and NP84-42. Also depth is calculated with the help of average velocity. Then using surfer software these maps are prepared in these maps the close contours show the anticlinal structure in the subsurface that is the ideal condition for hydrocarbons accumulation. Thus that is the prospective place.

Time Contour Map Of Chorgali Formation

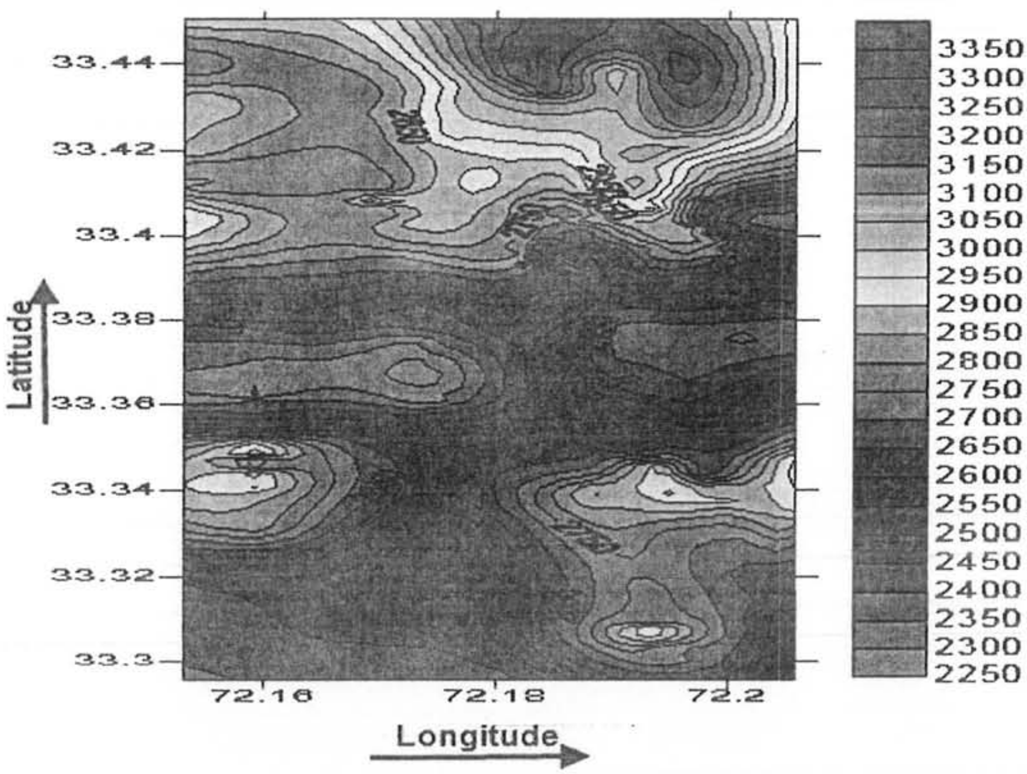


Fig 4.9 Time contour map of Chorgali Formation

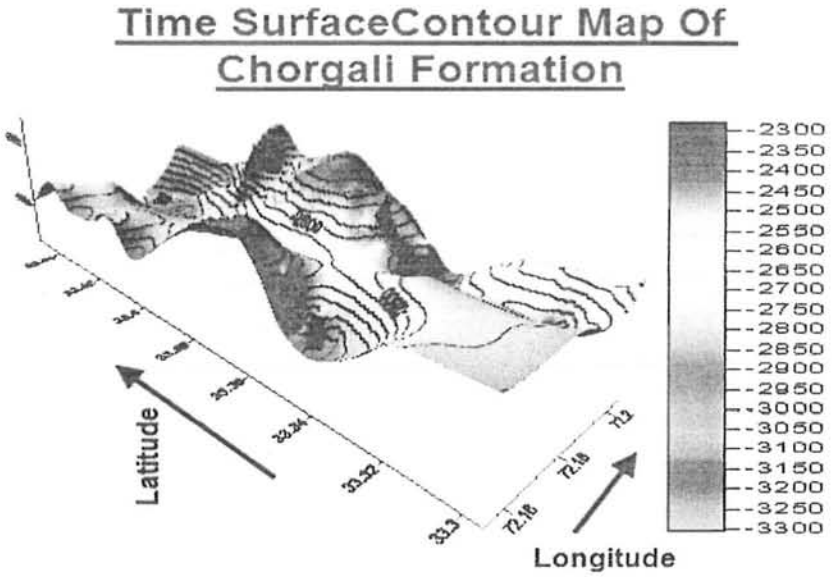


Fig 4.10 Time surface contour map of Chorgali Formation

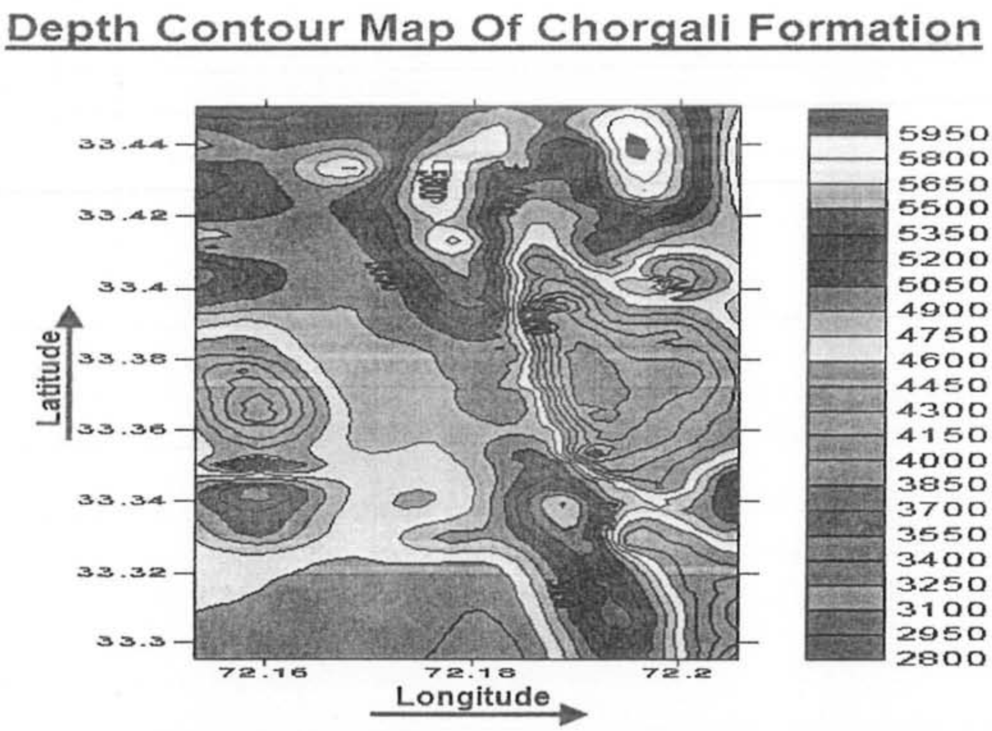


Fig 4.11 Depth contour map of Chorgali Formation

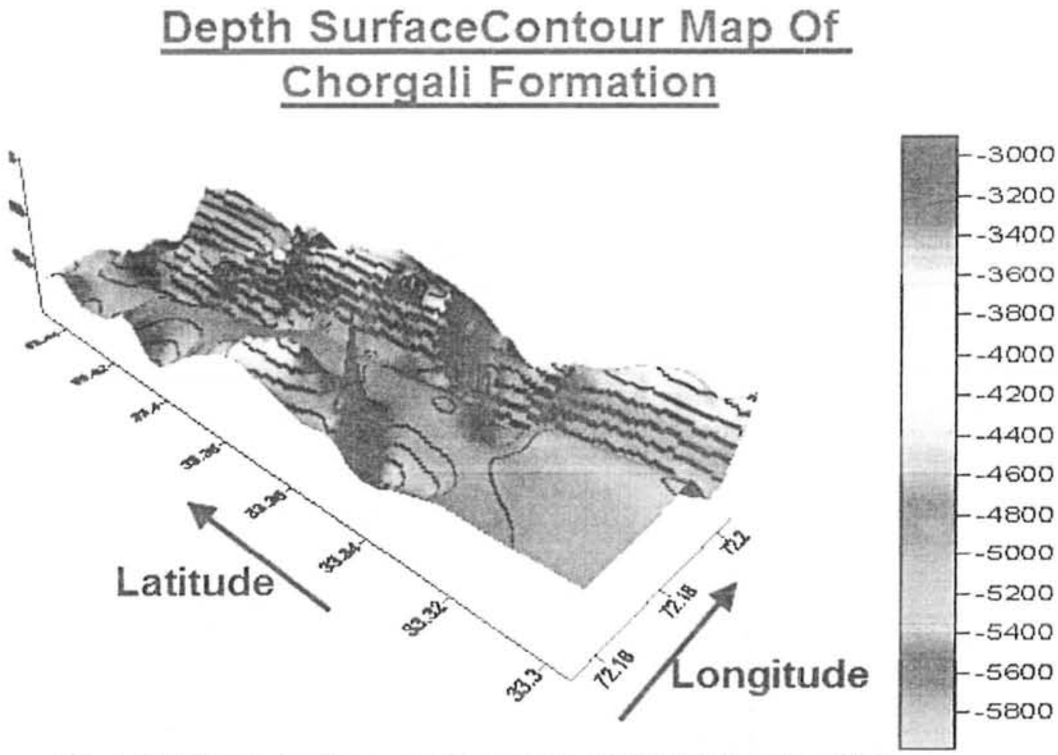


Fig 4.12 Depth surface contour map of Chorgali Formation

4.12 An Introduction to Rock Physics:

Rock physics describes a reservoir by rock physical properties such as porosity, rigidity, compressibility, properties that will effect how seismic waves physically travel through the rock. The rock physicist seeks to establish relation between the material properties and the observed seismic response, and to develop a predictive theory so that properties may be detected seismically. Establishing relationship between seismic expression and the physical properties therefore requires.

1. Knowledge about the elastic properties of the pore and rock frame.
2. Models for rock-fluid interaction. This is the domain of rock physics.

Typically rock physics studies will answer question such as:

Rock physics uses sonic logs, density logs and also dipole(shear velocity)logs if available.

Rock physics aims to establish P-wave(Vp), density, S-wave velocity(Vs)and their relationship to elastic modulli k and u(rigidity modulus), porosity pore fluid, temperature, pressure etc. for a given lithologies and fluid type. Rock physics talks about velocities and elastic parameters because these are what link physical properties to seismic expression. Rock physics may use information provided by the petrophysicist, such as shale volume, saturation levels, and porosity in establishing relation between rock properties or in performing fluid substitution analysis.

4.12.1 Calculation of S-wave velocity:

S-wave velocity
$Vs = (Vp-1.36)/1.16$
Bulk Modulus (k)
$K= \rho (Vp^2- 4/3Vs^2)$
Shear Modulus (μ)
$\mu= \rho Vs^2$
Poisson's Ratio(s)
$S=1/2(Vp^2-2Vs^2)/(Vp^2-Vs^2)$
The Lames's Parameter (λ)
$\lambda =Vp^2 \rho -2\mu$
Density
$\rho =0.31*(Vp)^{1/4}$
Acoustic Impedance
P-wave Impedance= ρ *Vp
S-wave Impediance= ρ *Vs

4.12.2 Rock Physics Parameters with Graphs vs depth (x-axis):

After calculating the rock physics parameters including, poisson's ratio, elastic modulies etc. their graphs are drawn with depth at x axis.

a. Density Calculation:

The density of subsurface rock is calculated by the following relation as p-wave velocity is known.

$$\rho = 0.31*(Vp)^{0.25}$$

Where
ρ = density of rock unit.
Vp = velocity of P-wave.

In seismic methods, the density and velocity are most important parameters. The geologists determine the rock types or composition, age, digenesis and burial history while the engineers determine the porosity, permeability, saturation, temperature and pressure gradient. As the density of hydrocarbons is much low, so the zones of low density may indicate hydrocarbons or other less dense material. The values of density are calculated on each CDPs.

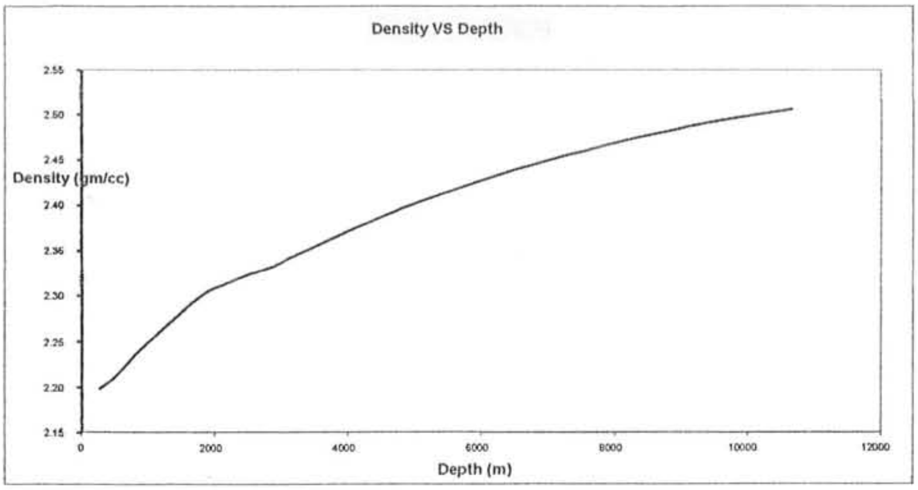


Fig 4.13 showing variation of density with depth

b. Bulk Modulus (k)

Bulk modulus is the measure of the ability of a rock body to resist the change in volume. Let us consider a sphere of original volume V under certain pressure P. When pressure is increased by ΔP, its volume reduces to V' by decrease in volume by amount ΔV. Then K is mathematically defined as the ratio of change in pressure to original pressure.

If the value of K is infinity (∞), then material is said to be incompressible. On the other hand, if the value of K is zero (0), then the material can be easily compressed. (Robert J. Lillie. et al. 1999)

The value of K is calculated by the following relation.

$$K= \rho (Vp2 \; - 4/3Vs^2)$$

Where

K = bulk modulus

ρ = density of rock

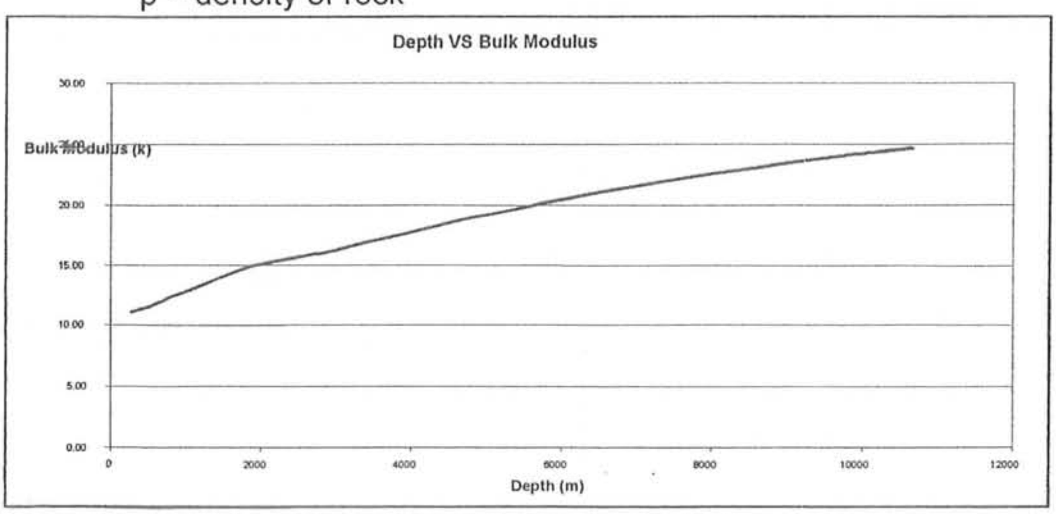


Fig.4.14 Variation of Bulk Modulus with depth

c. Shear modulus (μ):

Shear modulus is the measure of the ability of a rock body to resist the change in shape when forces are applied. It is calculated by the following relation.

$$\mu = \rho * Vs^2$$

Where

μ = shear modulus

Vs = shear wave velocity.

The value of shear modulus is determined on each CDP and given in Appendix. If the value of shear modulus is more then the rock unit is more fractured and more sheared.

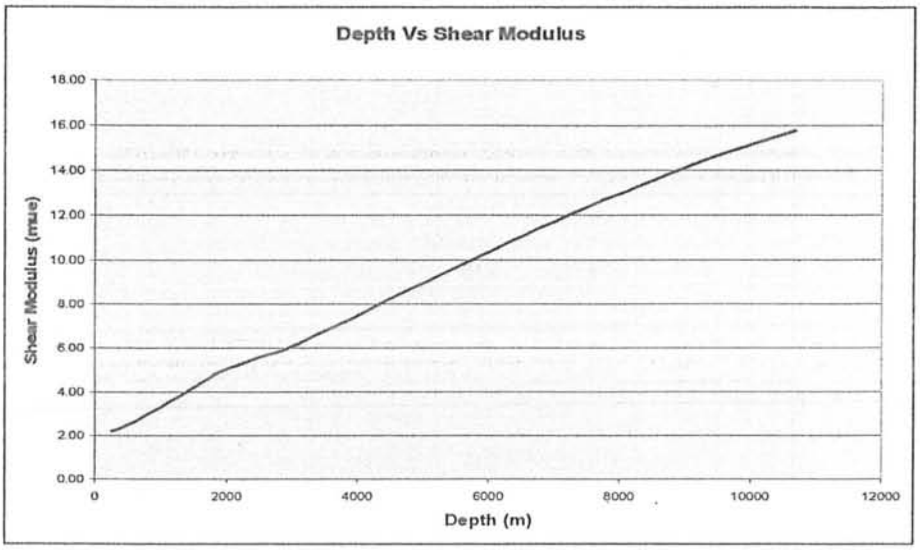


Fig 4.15 Relation b/w shear modulus and depth

d. Poisson's Ratio (σ):

It is the ratio of the transverse strains (EW) to the longitudinal strain (EL). It is the measure of the amount of transverse distortion compared to the longitudinal distortion.

σ= Transverse Strain/ Longitudinal Strain

Poisson's ratio can also be expressed as

$$\sigma = 1/2\ (Vp^2 - 2Vs^2) / (Vp^2 - Vs^2)$$

As this formula is function of shear velocity and primary velocity so it approximates the trend of seismic velocities. For hard rocks, the Poisson's ratio has high values while soft rocks have lower values of Poisson's ratio. This is because of contrast in shear and primary velocities. Also the velocities of seismic waves depend upon the compaction of the subsurface material or hardness and softness of rocks and may be because of lithology. The value of Poisson's ratio is determined on each CDPs.

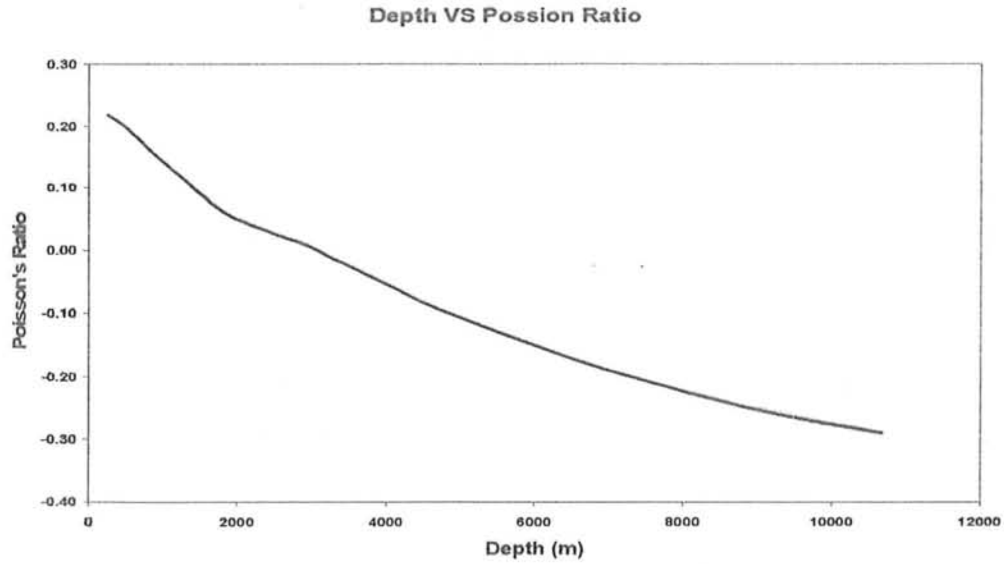


Fig 4.16 Variation of poisson's ratio with depth.

e. Lame's Parameter (λ):

It is calculated using the relation

$$\lambda = Vp2*\rho-2\mu$$

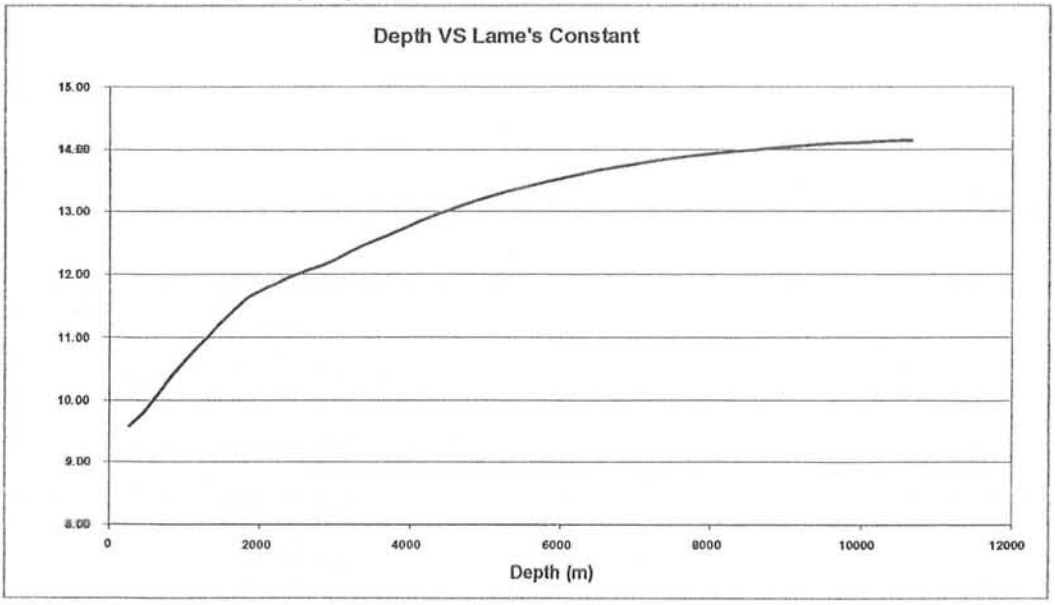


Fig 4.17 variation of Lame's constant with depth

f. CROSS PLOT OF POISSON'S RATIO AND VP/VS RATIO:

The value of Poisson's ratio is cross plotted against Vp/Vs ratio for each CDP of the seismic line.

Hard rocks have the small values of Poisson's ratio. This is indicated on the curve where is linear and flat, having the small values of Vp/Vs ratio. For most elastic solids, it is about 1/2 and for hard and rigid rocks, it ranges from 0.05 to 45. (Telford,1976) Soft rocks have the higher values of Poisson's ratio and greater the contrast between the shear wave velocity and primary wave velocity. For fluids having no rigidity (μ=0), the Poisson's ratio have maximum value .

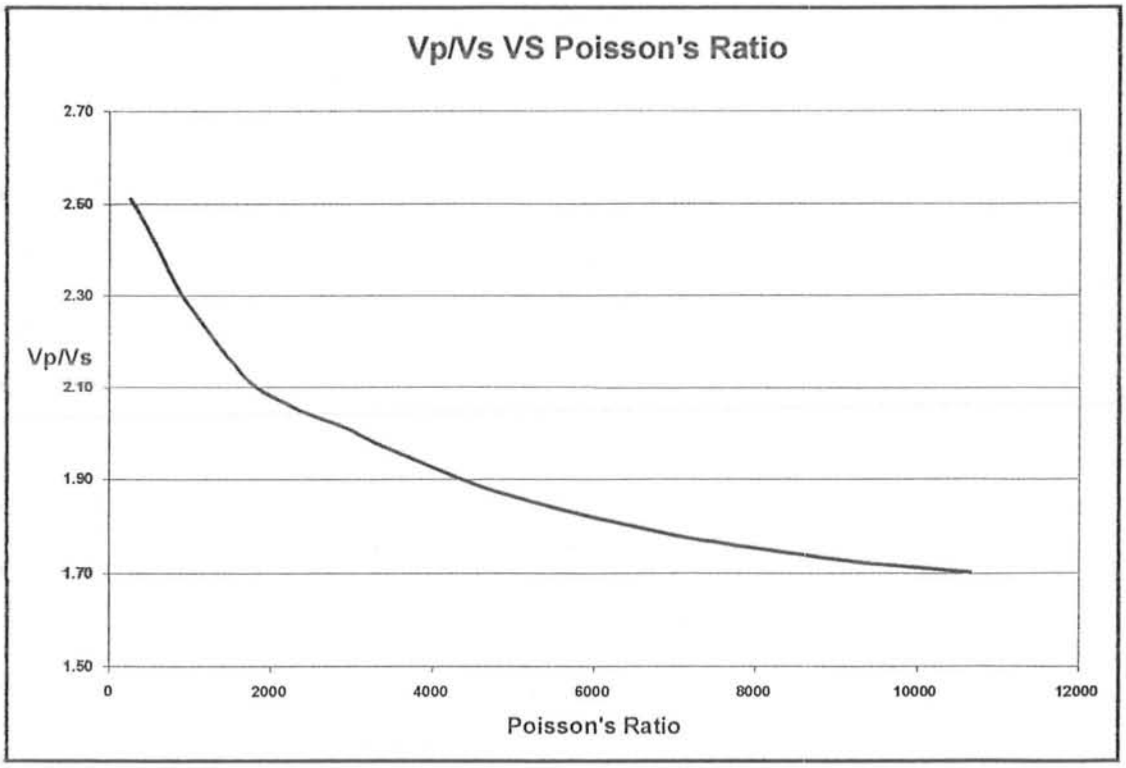


Fig 4.18 Cross Plot of Poisson's ratio and Vp/Vs ratio.

CONCLUSIONS:

- As the study area lies in compressional regime, four reverse faults are observed. Faults are indicated by the disturbance or discontinuity in reflectors.
- Reflectors are given name just upon occurrence of succession.
- Other physical properties like Density, Bulk Modulus (k), Shear modulus (μ), Poisson's Ratio (σ), and Lame's Parameter (λ) are calculated and their relation with depth is observed by plotting graph between them.
- The contour data shows the in this area anticlinal structure is present due to compressional regime and it is a best location for oil accumulation.

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