2-D SEISMIC DATA INTERPRETATION AND SPECIAL WORK ON ROCK PHYSICS OF THE GIVEN LINE 845-KBR-28 IN KABIR WALA AREA

BY

ASIF RAZA
M.Sc GEOPHYSICS
2006-2008

DEPARTMENT OF EARTH SCIENCES
QUAID-I-AZAM UNIVERSITY
ISLAMABAD.

CERTIFICATE

This dissertation submitted by **Asif Raza S/O Khadim Hussain** 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 M.Sc. degree in **Geophysics.**

Recommended By

Madam Shazia Asim
(Supervisor)

Shazia

Dr. Zulfiqar Ahmad
(Chairman Department of Earth Sciences)

Zulfiqar Ahmad 7/8/8

External Examiner

Department of Earth Sciences
Quaid-i-Azam University
Islamabad

ACKNOWLEDGEMENT

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 (P.B.U.H)** 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.

I am especially indebted to my dissertation supervisor **Madam Shazia Asim** for giving me an initiative to this study. Her inspiring guidance, dynamic supervision and constructive criticism, helped me to complete this work in time. Special thanks to **SIR. MATLOOB** for this help in preparation and understanding of geology of the area. I also pay my humble regards to

Dr. Zulfiqar Ahmed, Chairman, Department of Earth Sciences, Quaid e-Azam University, for his cooperation and guidance throughout the period of masters.

The selfless, devoted and sincere cooperation of my senior **Mr. M Muyassar** have been fortune to have a very nice company of my elder brothers and seniors **Mr.Zaheem** and **Mr.M.Pervaiz.**

.I also acknowledge the help, the encouragement, endless love, support and prayers of my family, which have always been a source of inspiration and guidance for me all the way.

Asif Raza

M.Sc Geophysics

2006-2008

DEDICATION

MY BELOVED AMMY WHOES LOVE AND CARE ENABLES ME TO ACHIEVE THIS GOAL OF MY LIFE.

MY BELOVED ABBU WHOES HARD WORK MAKES ME SUCCESSFUL TO CONQUER THE SUCCESS OF LIFE.

MY RESPECTABLE UNCLE TALIB HUSSAIN WHO GAVE ME COURAGE TO FACE THE LIFE COURAGEFULLY.

MY BUDY IRFAN HAIDER RABBANI WHOES SUPPORT ALWAYS MAKES ME STANDS STILL IN THE STORMS OF JIGGLING LIFE.

MY TWINKLE LITTLE STAR SHAN-E-FATIMA WHOSE PRAYERS ARRISES ME TO TE HEIGHTS OF PEAK.

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Abstract

A seismic reflection line 845-KBR-28 KABEER WALA(PUNJAB)area was provided by the department of Earth Sciences, Quaid-e-Azam University for interpretation. The given line is oriented in **N-S direction**. The section comprised of a total of short points from 420 to 690 were used in the interpretation. The section is a final stacked migrated section. The interval velocities at different time were given, using these velocities the average velocities can be calculated..

Total ten reflectors named as R1, R2, R3, R4, R5 ,R6, R7, R8, R9and R10 were marked and then interpreted. The reflectors were horizontal .Two different methods were employed for the estimation of depths of the reflectors. The resulting depth sections showed similarly patterns with the seismic section.

Time and depth section are prepared to examine the general trend of reflectors. Lithology characterization was also done using the values of reflection coefficient to determine the changes in the lithology with respect to depth.

INTRODUCTION

1.1 Introduction to the Area

The given Project is to interpret the Seismic Section along the seismic Line 845-KBR-28 of Kabir wala area,of central Indus basin. The Seismic Section was provided by the department of earth science (Q.A.U). This section was prepared by OGDCL in JUN 13-18,1984. The project area lies in central Indus basin, which has a number of oil and gas discoveries. Fig 1.1 shows the area under observation.

Location of the area

Latitude 30°34' 00" N
Longitude 72°00'00" E

Location of the area of interest

The project area is located in Kabir Wala area of central Indus basin as shown in Fig.1.1.

1.2 Objectives:

- To know the procedures /techniques involves in acquisition and under standing the processing phenomenon in order to assess the quality of data.
- Identification and Marking of Reflectors
- Velocity Analysis as a parameter.
- Preparation of time section.
- Preparation of depth section.
- Structural interpretation of the subsurface using seismic data.
- Stratigraphic setting of the area

Fig.1.1 Map showing the location of area of interest

1.3 Seismic section

The seismic section of line845-KBR-28 of Kabir Wala begins with first shot point 100 and lost shot point 950.the length of the line is about the direction of the line is North to South. The different and suitable field and processing parameters are given on seismic time section along the seismic velocities.

1.4 Survey parameters:

The seismic line line845-KBR-28 was recorded with the following parameters.

1.4.1 Field parameters

AREA	Kabir Wala
RECORDING AUTHORITY	OGDC
CREW	SP-5
DIRECTION OF SHOT	N-S
COVERAGE	3000%
DATE OF SHOT	Jun 13,1984

1.4.2 Source parameters

ENERGY SOURCE	DYNAMITE
S.P. INTERVAL	100 M
DEPTH	2 M
CHARGE	0.5 KG
PATTERN	7 HOLES IN LINE

1.4.3 Receiver parameters

SPREAD	3100-150-0-150-3100
GEOPHONE TYPE	SM-4;10 HZ
GEOPHONE INTERVAL	4.89 M
GROUP WIDTH	20 M
GROUP BASE	103 M

1.4.4 Instruments

SYSTEM	SN 348/34
FORMAT	SEG-B
NOTCH FILTER	IN
FIELD SAMPLING INTERVAL	2 MILLI SECOND
RECORDING LENGTH	6 SECONDS
ALIAS FILTER	125 HZ

1.4.5 Filtring parameters

PERCENT GAIN	141
HORIZONTAL SCALE	16 TRACES/INCH.
VERTICAL SCALE	2.5 INCH/SEC
POLARITY	BLACK= POSITIVE

GEOLOGY AND TECTONICS

2.1 Regional Geological Settings

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

- 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 Tectonic Zones:

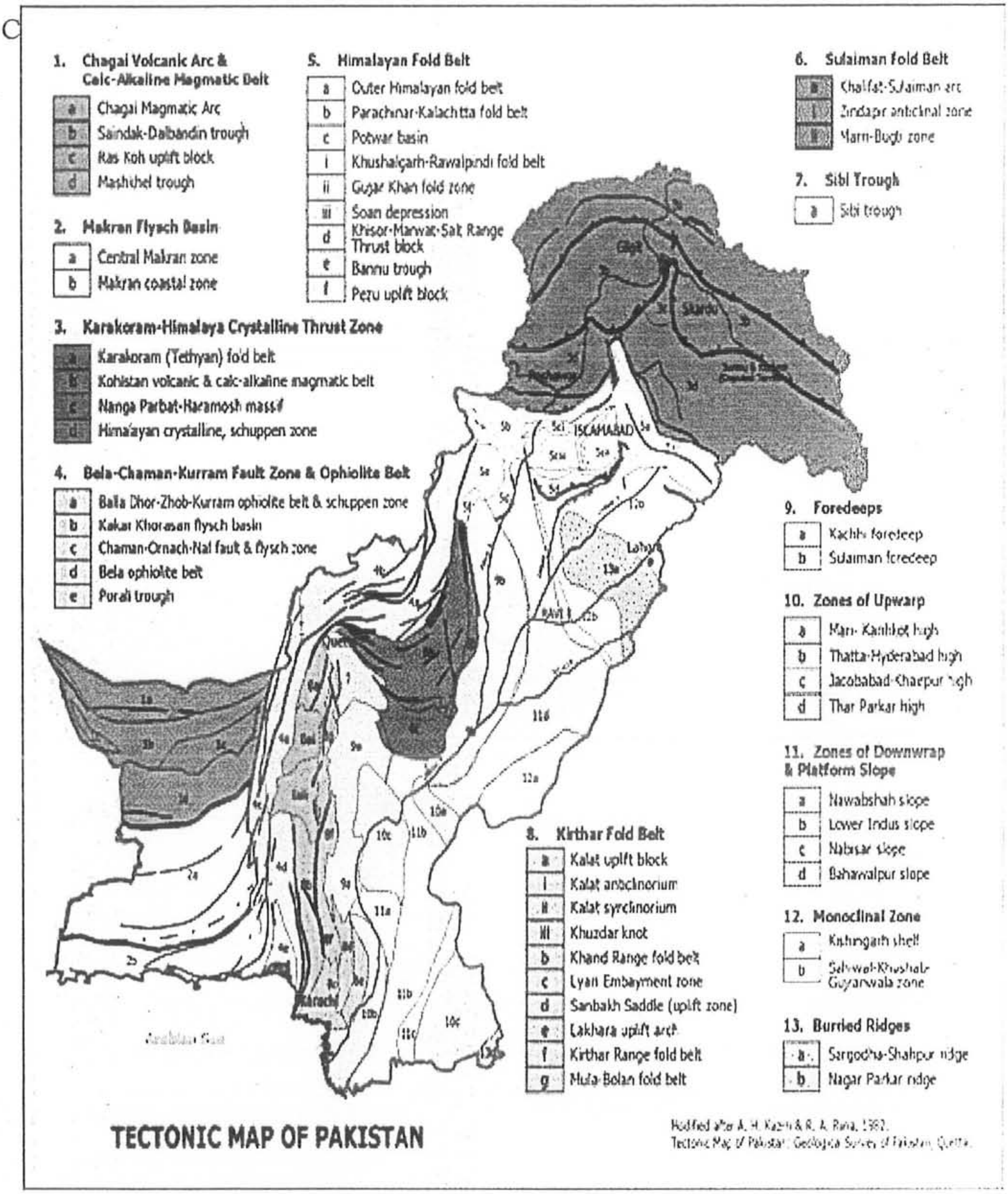
On the basis of plate tectonic features, geological structure, orogenic history (age and nature of deformation, magmatism and metamorphism) and lithofacies, Pakistan may be divided into the following broad tectonic zones (see Map 2.1).

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

With in these broad tectonic zones there are subtle differences in tectonic and changes in structure style to merit further subdivision into smaller subdivision. Here we are not concern about those we are going to discuss the relevant that is the Indus Plateform and Foredeep which is our area of interest as from all above mentioned tectonic zones our seismic line belongs to this area. (Kazmi A.H, et al. 1977)

➢ Indus Plateform and Foredeep

This zone extends over an area exceeding 250,000 square km, in southern Pakistan and includes the Indus plain and Thar-Cholistan Deserts. It hosts 80% of Pakistan population, extensive coal deposits, valuable oil and gas fields, potential for geothermal energy and vast groundwater reservoir.



Modified after A. H. Kazmi & R. A. Rana, 1982.
Tectonic Map of Pakistan: Geological Survey of Pakistan, Quetta.

Figure: 2.1 Tectonic Map of Pakistan

2.3 Sedimentary Basins:

Basin is an area characterized by regional subsidence and in which sediments are preserved for the longer periods of time. In a basin a receptacle or container, which is basin's substratum is called the **Basement.** The container fill or content, which is the accumulation of sediments resting on the basement, is called a **Sedimentary cover.** The gradual settling of the basin is called **Subsidence.** The point of maximum sedimentary accumulation is called the **Depocenter.** The depocenter may not correspond to the zone of maximum subsidence (Duval, 1999).

Sediments originate at a certain place. These sediments may be deposited at the same place or may be transported to some other place by transporting agents. The sediments deposited at the same place are called molasses deposits. The transported sediments rest on the basement of a basin and form the sedimentary cover.

2.4 Basins of Pakistan:

Pakistan is comprised of following major Basins these includes

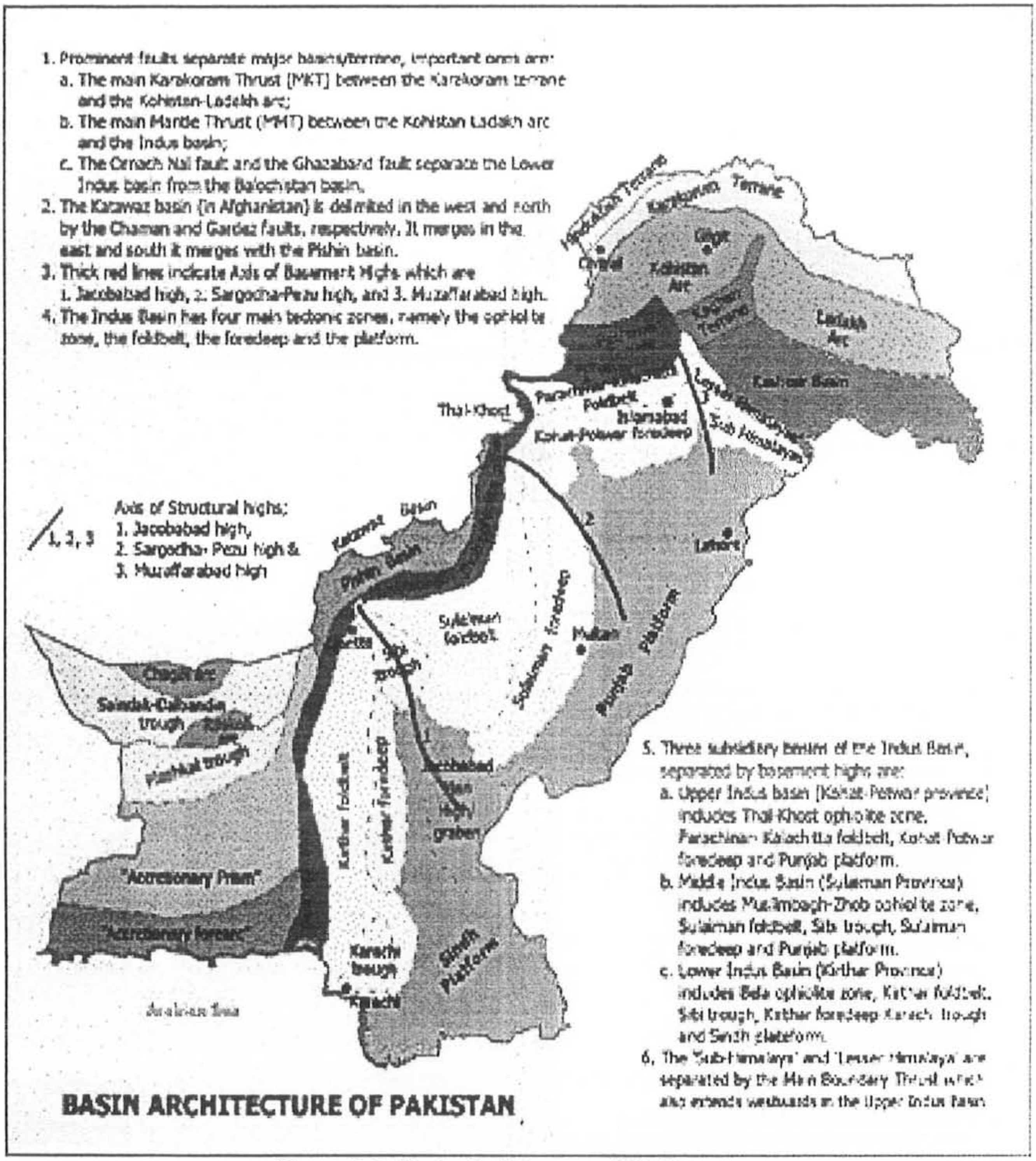
1. Indus Basin.
2. Balochistan Basin.
3. Kakar Khorasan Basin

Indus basin is further subdivided into three parts which are given below

2.4.1 Indus Basin:

The geological history of the Indus Basin goes back to Pre-Cambrian age. The depositional features mark the limit of the basin and it's divisions. Following is the classification of Indus Basin.

A. Upper Indus Basin
B. Middle Indus Basin
C. Lower Indus Basin (Kadri, 1995).


1. Prominent faults separate major basins/terrane, important ones are:
   a. The main Karakoram Thrust [MKT] between the Karakoram terrane and the Kohistan-Ladakh arc;
   b. The main Mantle Thrust (MMT) between the Kohistan Ladakh arc and the Indus basin;
   c. The Ornach Nal fault and the Ghazaband fault separate the Lower Indus basin from the Balochistan basin.
2. The Katawaz basin (in Afghanistan) is delimited in the west and north by the Chaman and Gardez faults, respectively. It merges in the east and south it merges with the Pishin basin.
3. Thick red lines indicate Axis of Basement Highs which are 1. Jacobabad high, 2. Sargodha-Pezu high, and 3. Muzaffarabad high.
4. The Indus Basin has four main tectonic zones, namely the ophiolite zone, the foldbelt, the foredeep and the platform.

Axis of Structural highs:
1. Jacobabad high,
2. Sargodha- Pezu high &
3. Muzaffarabad high

5. Three subsidiary basins of the Indus Basin, separated by basement highs are:
   a. Upper Indus basin (Kohat-Potwar province) includes Thal-Khost ophiolite zone, Parachinar Kalachitta foldbelt, Kohat Potwar foredeep and Punjab platform.
   b. Middle Indus Basin (Sulaiman Province) includes Muslimbagh-Zhob ophiolite zone, Sulaiman foldbelt, Sibi trough, Sulaiman foredeep and Punjab platform.
   c. Lower Indus Basin (Kirthar Province) includes Bela ophiolite zone, Kirthar foldbelt, Sibi trough, Kirthar foredeep Karachi trough and Sindh platform.
6. The 'Sub-Himalaya' and 'Lesser Himalaya' are separated by the Main Boundary Thrust which also extends westwards in the Upper Indus Basin

BASIN ARCHITECTURE OF PAKISTAN

Figure 2.2: Basin Architecture of Pakistan

The project lies in central Indus basin therefore description of central Indus basin is given below.

➢ Central Indus Basin:

BOUNDARIES OF CENTRAL INDUS BASIN:

Directions	Boundaries
East	Indian Shield
West	Marginal Zone Of Indian Plate
North	Sargodha High
South	Sukkur Rift

This basin is located just south of the Sukkur Rift. The oldest rocks encountered in the area are of Triassic age. Khairpur-Jacobabad High became a prominent feature, this is indicated by homogeneous lithologies of Chiltan Limestone which is of Jurassic age and Sembar Formation which is of lower cretaceous age and lie across the high. This part of the Indus Basin comprises the following main units are

(a) Punjab Platform
(b) Suliman Depression
(c) Suliman Fold Belt

2.5 General Geology Of The Area:

The central Indus basin is a major gas province containing some 70% of Pakistan known gas reserves. The area (Kabir wala) is generally configurated in simple terms of geology and geomorphology. Main features of significance are water bodies of the Indus river, sand dunes of Thal and several creeks passing through the area of the district longitudinally in extreme west. Sand dunes are quite rampant in thal portion of the district which vary in size, height, texture, composition and nature of movements.

Generally speaking the area is plain devoid of any conspicuous features such as hills, montains and big depressions.

Stratigraphy of the Area

Source Rocks:

Potential source rocks are Sembar Shles, Shles of Mughalkot Formation, Ranikot Formation and Sirki are also considered for their source potential.

Reservoir Rocks:

Sui Main Limestone and Sui Upper Limestone are the main producer where as limestone of Habib Rahi is considered as secondary reservoir.

Cap Rock:

The Ghazij Shales act as cap for Sui Main Limestone and Sui Upper Limestone and also Sirki Shales over Habib Rahi Limestone act as a cap rock.

Detailed stratigraphy of the area is given as below:

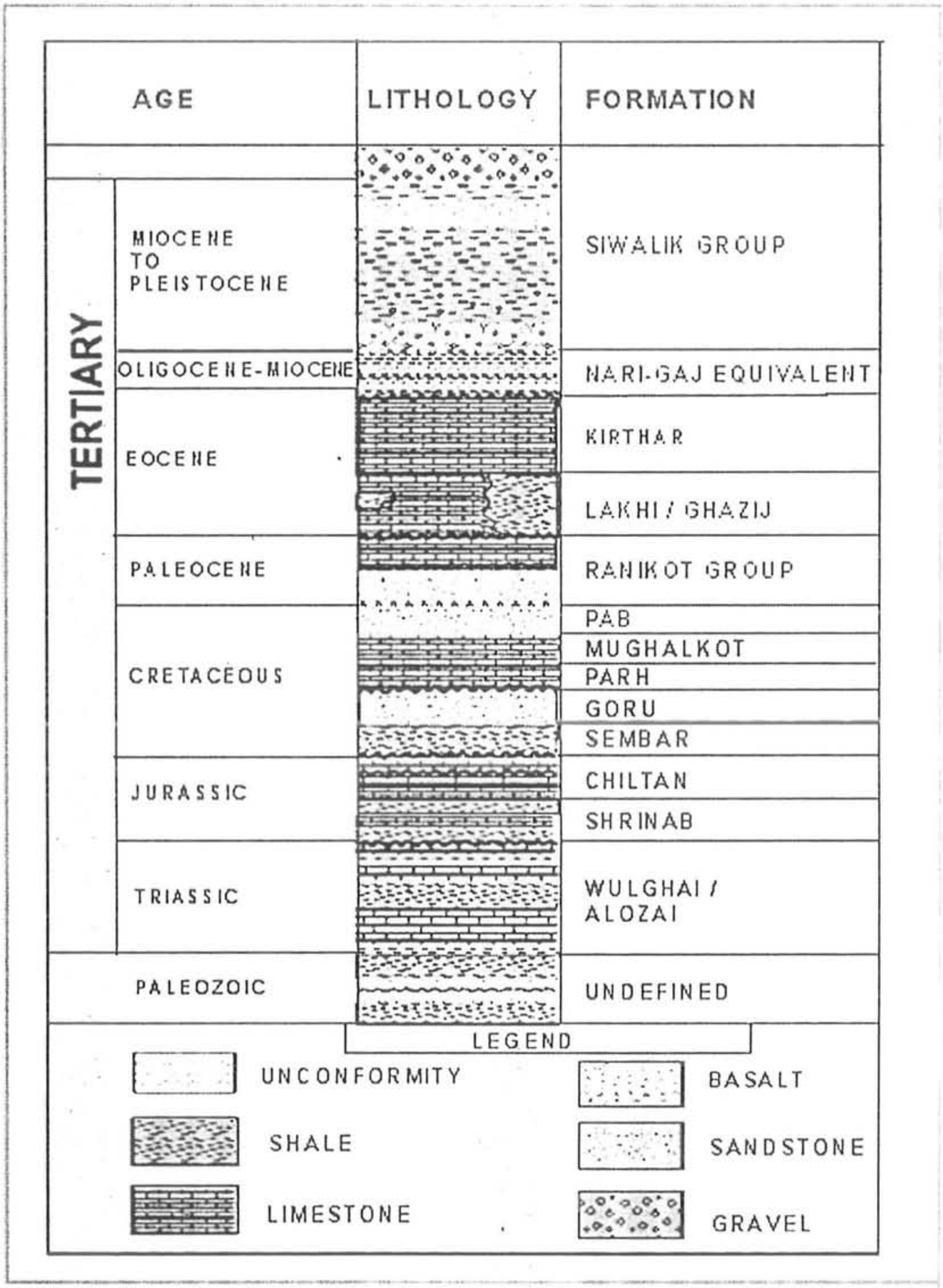


Figure 3: Stratigraphic Column of Central Indus Basin

Petroleum Prospects of Central Indus Basin

Central Indus Basin:

This basin is comprised of duplex structures characterized by large anticlines and domes in the passive roof sequence of the Sulaiman Fold belt followed eastward by genteelly dipping strata of Punjab monocline which has few tectonic folds and faults. The basin contains a sedimentary sequence ranging from Pre Cambrian to Recent. It is essentially a natural gas bearing zone and contains 9 gas fields including one giant field Sui with 8.6 TCF recoverable reserves and one large field Pirkoh with 2.6 TCF recoverable reserves. The main producing strata range in age from Cretaceous to Eocene. This basin is characterized by wide variation in geothermal gradient. Low geo thermal gradient occur in the eastern part. It has been observed that there is zone of very low thermal gradient around the Sargodha Shahpur buried ridges which may be due to the high thermal conductivity of the shield, however in the central part of this basin, in the sulaiman depression there is a zone with high geothermal gradient. The main gas field of Mari, Khandkot, Sui, uch, Loti, Zin, Pirkoh and Jandran are concentrated in this region and it is likely that the heat flow from this hot spot has contributed to development of these fields. It is view that in this region Oil window may be below the gas producing horizon with the possibility of oil occurrence in Cretaceous sediments below the gas horizon

(Khan and Raza)

Source Rocks of Central Indus Basin:

Kirthar lime stone, laki/ghazij lime stone or shale of Eocene age.
Dunghan or ranikot shale of Paleocene age.
Mughalkot limestone or marl chichale or sembar shale of cretaceous age.

Reservoir Rocks Central Indus Basin:

Kirthar lime stone, laki/ghazij lime stone and sui main limestone of Eocene age.

Dunghan or ranikot sandstone of Paleocene age.

Pab sandstone, chichale, Goru sandstone, sembar sandstone or limestone of cretaceous age.

Khewra sandstone of Cambrian age.

Cap Rocks of Central Indus Basin:

Kirthar laki/ghazij shale of Eocene age.
Dunghan or ranikot shale of Paleocene age.
Mughalkot chichale sembar shales of cretaceous age.
Kussak shale of Cambrian age.

2.6 General Geology of area:

1)Alluvium:

Age: Recent
Lithology: Sandstone, Siltstone and Clay deposit by the River Indus.

Sandstone: offwhite, light gray, fine to medium grain, subangular to subrounded friable.

Siltstone: Earthy light grey, medium hard.

Clay: Khaki, earthy, soft and stickly.

Contact: Contact with underlying Siwaliks is unconfirmable.

1) **Siwaliks:**

Age: Pliocene

Lithology: Sandstone with interclation of clay.

Sandstone: Offwhite, Yellowishwhite, friable to medium hard, fine to medium grained, subangular to subrounded, moderately sorted, slightly calcareous.

Clay: khaki,soft.

Contact: Contact with underlyingNari Formation is unconformable.

2) **Nari Formation:**

Age: Oligocene

Lithology: Sandstone with streaks of clay.

Sandstone: Off white ,transparent, quartoze, medium to coarse grain, subangular to subrounded, loose, moderately sorted, non-calcarious.

Clay: Brown, soft.

Contacts: contract with underlying Kirther Fornmation is unconfirmable.

3) **Kirther Formation:**

Kirther Formation is divided into four members:

a) Drazinda Member:
b) Pirkoh Limestone Member
c) Sirki Member
d) Habib Rahi Limestone Member

a) **Drazinda Member:**

Age: Middle Eocene

Lithology: Shale with interclation of marl

Shale: Greenish grey,soft,laminated,moderately indurated.

Marl: greenish grey, off white,soft.

Contact: Upper contact is unconformable with Nari formation and lower contact with Pirkoh Limestone is conformable.

b) **Pirkoh Limestone Member:**

Age: Middle Eocene

Lithology: Limestone with thin marl

Limestone: Dirty white, white, creamy,mediamgrained,hard and fossiliferrous.

Marl: Grey, soft to mediam hard,grading to limestone.

Contact: Upper contact with Darzinda Member and lower contact with Sirki Shale Member is conformable.

c) **Sirki Member:**

Age: Middle Eocene

Lithology: Shale with thin bands of limestone.

Shale: Bluesh green, soft, slightly calcarious.
Limestone: Offwhite, hard, fosilliferous.

Contacts: Upper contact with Pirkoh Limstone and lower contact with Habib Rahi Limestone is confirmable.

d) **Habib Rahi Limestone Member:**

Age: Middle Eocene

Lithology: Limestone with thin bands of Marl.
Limestone: Offwhite, white, creamy, fossilliferous.
Marl: Greenish grey, soft, sticky.

4) **Ghazij Formation:**

Age: Lower Eocene.

Lithology: Shale with thin beds of limestone.
Shale: Greenish grey, pyretic, calcareous with occasional fossils.
Limestone: White, medium hard having thickness 8 to 10m.

Contact: Upper contact with Habib Rahi Limestone and lower contact with Sui Upper Limestone is conformable.

5) **Sui Main Limestone:**

Age: Lower Eocene.

It has following three units.

a. Sui Upper Limestone.
b. Sui Shale.
c. Sui Main Limestone.

a. **Sui Upper Limestone:**

Age: Lower Eocene.

Lithology: Limestone 100%.

Limestone: White, off-white, medium hard, fossileferous.

Contact: Upper contact with Ghazij Shale and lower with Sui Shale member is conformable.

b. **Sui Shale:**

Age: Lower Eocene.

Lithology: Shale with thin bands of limestone.
Shale: Greenish grey, pyretic, calcareous with occasional fossils.
Limestone: White, medium hard having thickness 8 to 10m.

Contact: Upper contact with Sui Upper Limestone and lower with Sui Main Limestone is conformable.

c. **Sui Main Limestone:**

Age: Lower Eocene.

Lithology: Limestone with traces of shale.
Limestone: Off-white, creamy, Medium to hard, calcitic veins, marly and highly fossilferous.
Shale: Light greenish grey, light grey, laminated fossileferous.

Contact: Upper with Sui Shale and lower with Dunghan Formation is conformable.

6) **Dunghan Formation:**

Age: Upper Paleocene.
Lithology: Off-white, creamy grey, medium to coarse grained limestone.
Contact: Upper contact with Sui Main Limestone and lower contact with Ranikot Formation is conformable.

7) Ranikot Formation:

Age: Upper to Middle Paleocene.
Lithology: **Nodular** limestone with sandstone and argarrigileous shale.
Contact: Upper contact with Dunghan Formation and lower contact with Pab Sandstone is disconformable.

8) Pab Sandstone:

Age: Lower Cretaceous.
Lithology: White to brown colour sandstone with subordinate shale.
Contact: Upper contact with Ranikot Formation is disconformable and lower contact with Fort Munro Formation is conformable.

9) Fort Munro Formation:

Age: Lower Cretaceous.
Lithology: Limestone, marl and shale.
Contact: Upper contact with Pab Sandstone is conformable and lower contact with Parh Limestone is conformable.

10) Parh Limestone:

Age: Lower Cretaceous.
Lithology: Light grey micritic limestone and marl.
Contact: Upper contact with Fort Munro Formation is conformable and lower contact with Goru Formation is conformable.

11) Goru Formation:

Age: Middle to Upper Cretaceous.
Lithology: Sand, light grey shale and some gluconitic beds of sandstone.

It has following two units.

a. Upper Goru
b. Lower Goru
    - Upper shale
    - Middle sand
    - Lower shale
    - Basal sand
    - Talhar shale
    - Massive sand

Contact: Upper contact with Parh Limestone and lower Sembar Formation is conformable.

12) Sembar Formation:

Age: Upper,cretaceous.
Lithology: Green to greenish grey shale + thin bands of sandstone and siltstone. Shale is highly fossileferous.
Contact: Upper contact with Goru Formation is conformable and lower contact with Chiltan Limestone is disconformable.

13) Chiltan Limestone:

Age:	Middle to Late Jurassic.
Lithology:	Dark grey to black, oolitic to pisolitic limestone.
Contact:	Upper contact with Sembar Formation is disconformable and lower contact with Shrinab Formation is conformable.

Chapter 3 seismic mthods

3.1 Introduction

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. It provides data that, when used in conjunction with other geophysical, borehole and geological data, and with concepts of physics and geology, can provide information about the structure and distribution of rock types.

Exploration seismic methods involve measuring seismic waves traveling through the Earth. Explosives and other energy sources are used to generate the seismic waves, and arrays of seismometers or geophones are used to detect the resulting motion of the Earth. The data are usually recorded in digital form on magnetic tape so that computer processing can be used to enhance the signals with respect to the noise, extract the significant information, and display the data in such a form that a geological interpretation can be carried out readily.

(Kearey et al, 2002)

3.2 Seismic Reflection Method

The basic technique of seismic exploration consists of generating seismic waves and measuring the time required for the waves to travel from the source to a series of geophones, usually disposed along a straight line directed toward the source. From a knowledge of travel times to the various geophones, and the velocity of the waves, one attempts to reconstruct the paths of the **seismic waves.**

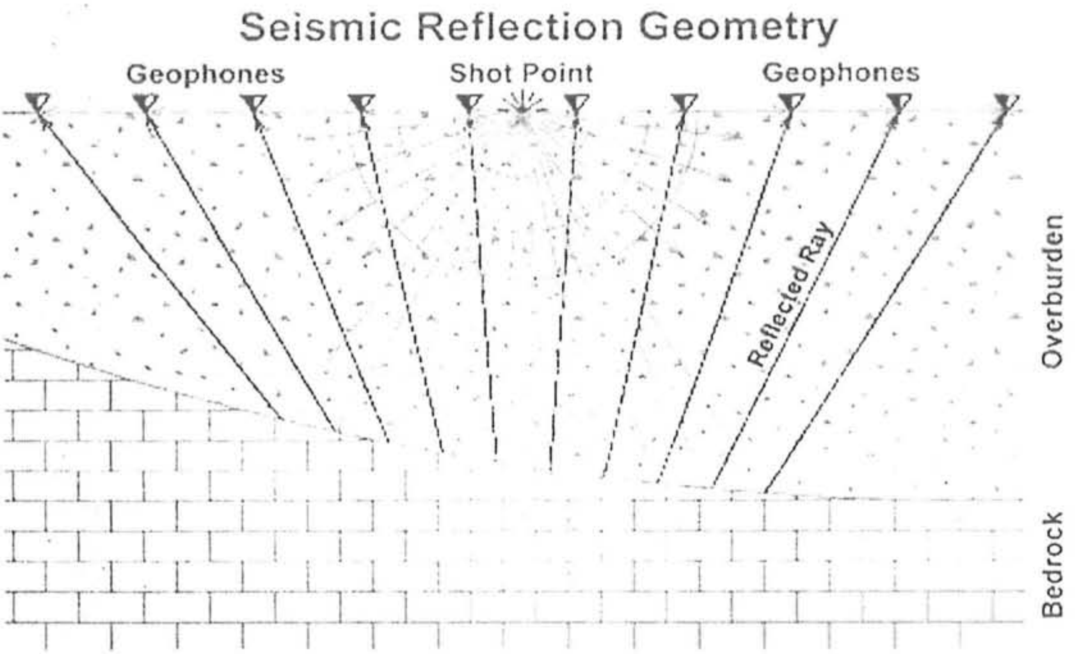


Figure 3.1 (Seismic Reflection Geometry)

Structural information is derived principally from paths that fall into two main categories: refracted paths in which the principal portion of the path is along the interface between two rock layers and hence is approximately horizontal; and reflected paths in which the wave travels downward initially and at some point is reflected back to the surface, the overall path being essentially vertical. For both types of path, the travel times depend on the physical properties of the rocks and the attitudes of the beds.

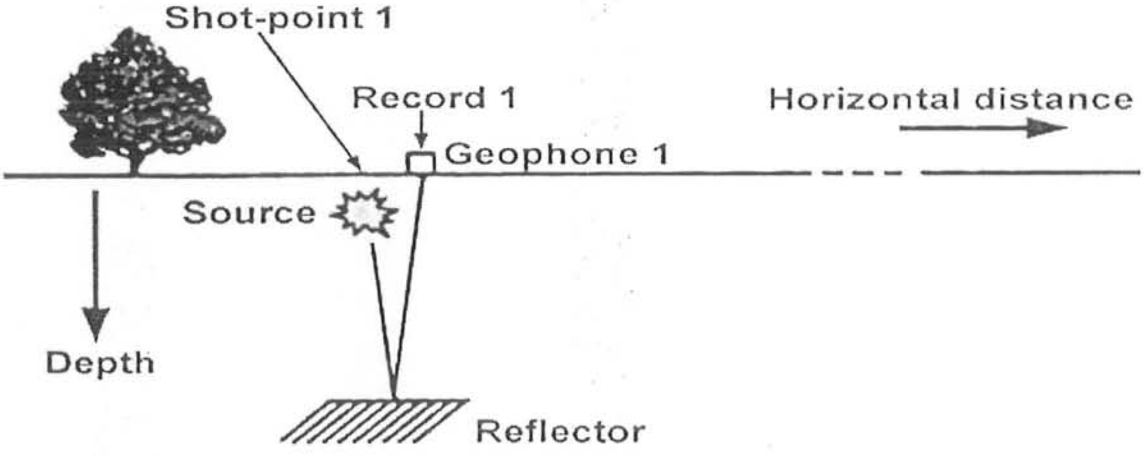


Figure 3.2 (Basic layout for Seismic Reflection Acquisition)

Reflections of acoustic waves from the subsurface arrive at the geophones some measurable time after the source pulse. If we know the speed of sound in the earth and the geometry of the wave path, we can convert that seismic **travel time** to depth. By measuring the arrival time at successive surface locations we can produce a **profile**, or cross-section, of seismic travel times.

The objective of seismic exploration method is to deduce information about the rocks from the observed arrival times together with variations in amplitude, frequency and waveform. (Telford, et al. 1990)

3.3 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:

$$\theta_i = \theta_r.$$

Where θ_i is angle of incidence.
θ_r is angle of reflection.

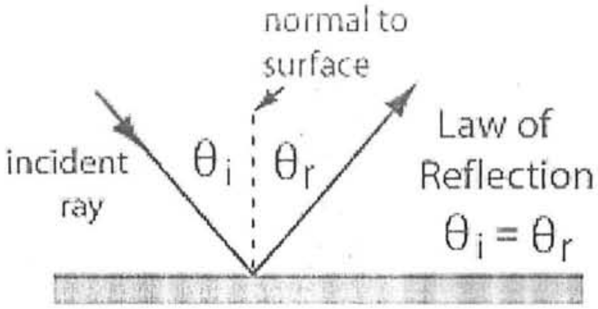


Figure 3.3 (Fundamental Law of reflection)

3.4 Seismic Refraction Method

Refraction method is based on the study of elastic waves refracted along geological layer. This method is generally used for determining low velocity zone (weathered layer). There is one type of refraction, which gives rise to a phase that can travel back to the surface. This corresponds to the case of critical incidence. Seismic refraction method is helpful in the interpretation of seismic data.

(Al-Sadi, 1980)

The waves which return from the top of interface are refracted waves, and for geophones at a distance from the shot point, always represent the first arrival of seismic energy. (Telford, 2004)

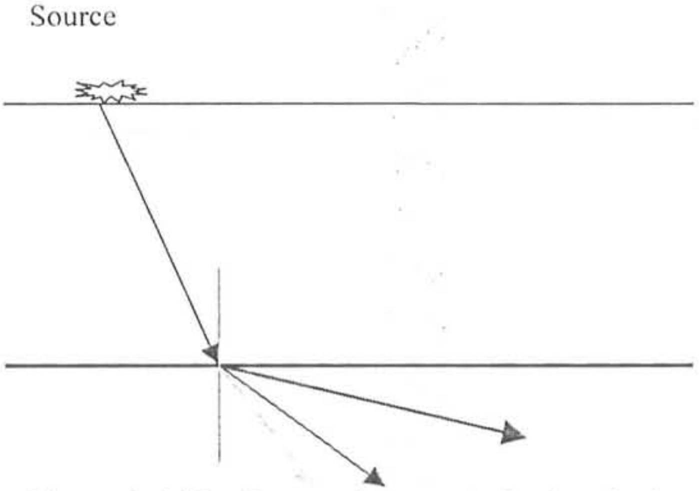


Figure 3.4 (Fundamental concept of refraction)

When an incidence wave crosses an interface between layers of two different velocities, the wave is ***refracted***. That is, the angle of the wave leaving the interface will be altered from the incident angle, depending on the relative velocities. Going from a low-velocity layer to a high-velocity layer, a wave at a particular incident angle (the "**critical angle**") will be refracted along the upper surface of the lower layer. As it travels, the refracted wave spawns up going waves in the upper layer, which impinge on the surface geophones.

Sound moves faster in the lower layer than the upper, so at some point, the wave refracted along that surface will overtake the direct wave. This refracted wave is then the first arrival at all subsequent geophones, at least until it is in turn overtaken by a deeper, faster refraction. The difference in travel time of this wave arrival between geophones depends on the velocity of the lower layer. If that layer is plane and level, the refraction arrivals form a straight line whose slope corresponds directly to that velocity. The point at which the refraction overtakes the direct arrival is known as the "**crossover distance**", and can be used to estimate the depth to the refracting surface.

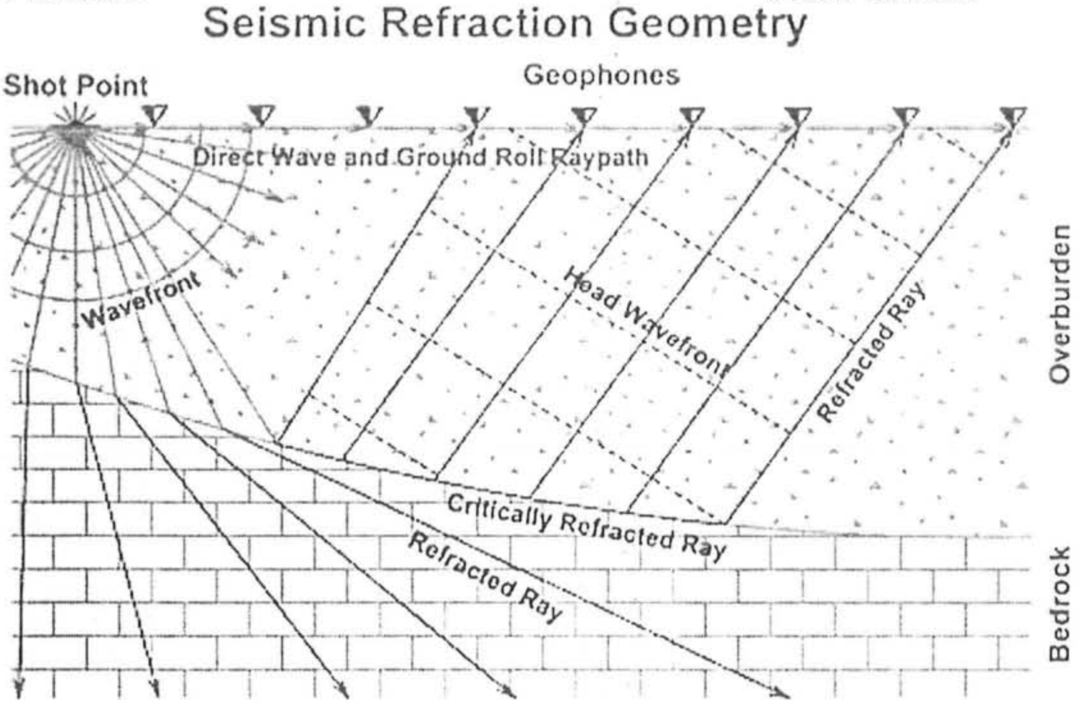


Figure 3.5 (Seismic Refraction Geometry)

Seismic refraction is generally applicable only where the seismic velocities of layers increase with depth. Therefore, where higher velocity (e.g. clay) layers may overlie lower velocity (e.g. sand or gravel) layers, seismic refraction may yield incorrect results. 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 mapping layers only where they occur at depths less than 100 feet.

(Dobrin, 1988)

3.5 Fundamental Law of Refraction

A wave traversing a boundary between two media of velocity V1 and V2 is such that

$$\sin i/V1 = \sin r/V2$$

Where:

i = incident angle.
r = refraction angle.

- **Critical Refraction**

Every wave from a source in the upper layer when reaches the boundary at different angles of incidence then it continues in the lower layer according to Snell's Law. Now a certain angle of incidence for which angle of refraction is 90° is called as critical angle and refraction at this stage is called as critical refraction as shown in fig.3.6

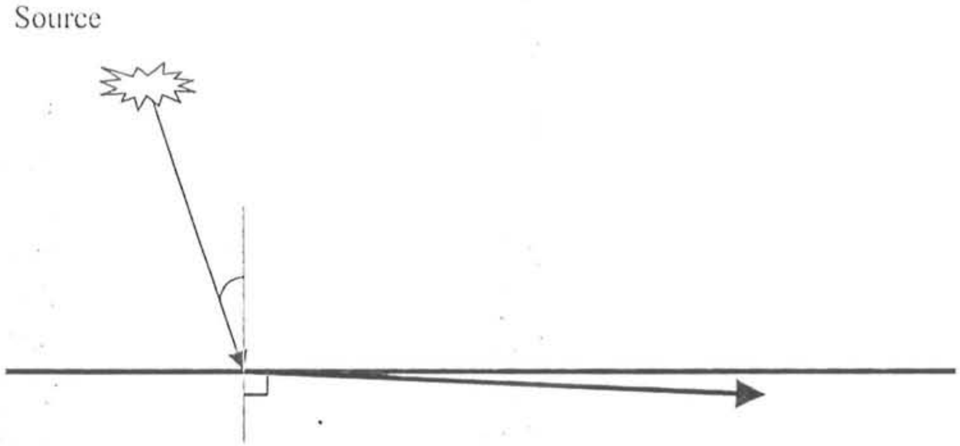


Figure 3.6 (Critical refraction between two Mediums)

For critical refraction, Snell's Law attains the form as follow:

$$\sin i_c = V_1/V_2$$

Where

ic= Critical angle.

- **Diffraction**

Laws of reflection and refraction apply till that the interface is continuous and approximately planar. At abrupt discontinuities in interfaces, or structures whose radius of curvature is shorter than the wavelength of incident wave, the laws of reflection and refraction no longer apply. These discontinuities give rise to a radial scattering of incident seismic energy. This radial scattering is called as diffraction.

"Diffraction is the bending of a wave around objects or the spreading after passing through a gap. It is due to any wave's ability to spread in circles or spheres in 2D or 3D space ".

OR

"A type of event produced by the radial scattering of a wave into new wave fronts after the wave meets a discontinuity such as a fault surface, an unconformity or an abrupt change in rock type".

Diffracted phases are commonly observed in seismic recording and sometime are difficult to discriminate from reflected and refracted phases.

(Kearey et al, 2002)

3.6 Seismic Wave Theory

➢ Elastic Properties of Solids

The seismic method utilizes the propagation of waves through the earth, since this propagation depends upon the elastic properties of the rock so it is necessary to know the elastic properties of the subsurface material.

The size of a solid body can be changed by applying forces to the external surface of the body. These external forces are opposed by internal forces, which resist the changes in size and shape. As a result, the body tends to return to its original condition when the external forces are removed. Similarly, a fluid resist changes in size (volume) but not changes in shape. This property of resisting changes in size or shape and of returning to the undeformed condition when the external forces are removed is called elasticity.
(Dobrin, 1988)

Stress: "Stress is the force (F) (applied) per unit area (A) of the body".

Its unit in SI system is Pascal and one Pascal is equal to one Newton per square meter.
Mathematically;
Stress = F/A

Mainly there are two types of stress:

1. **Normal Stress**
2. **Tangential Stress**

(Heiland,1968)

Strain: "Change in size and shape of the body when external forces are applied on that body".

Strains can be divided into four types.

- ➢ Longitudinal Strain
- ➢ Transverse Strain
- ➢ Shear Strain
- ➢ Dilation

➢ Hooke's Law:

According to this law,
"Stress is the directly proportional to strain provided the elastic limit of the body is not exceeded. This limiting value depends upon the nature of rock body".

Mathematically: **Stress α Strain**

➢ Elastic Modules[1]

The linear relationship between stress and strain in the elastic filed is specified for any material by its various elastic modules, each of which expresses the ratio of a particular type of stress to the strain and provides a measure of rigidity. There are certain types of elastic modules as given below;

- Bulk modulus
- Shear modulus
- Young's modulus
- Poisson's ratio

➢ Bulk Modulus (K)

"It is the ratio of stress to the volumetric strain"
Given by the relation as:

$$\text{Bulk modulus } K = \frac{\text{Volume Stress } P}{\text{Volume Strain } \Delta V/V}$$

Mathematically it can be represented as,

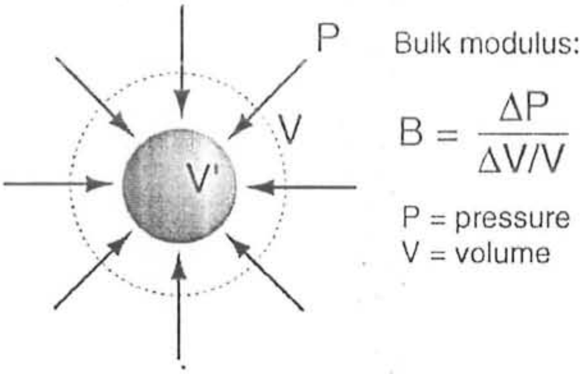


Figure 3.7 (Bulk Modulus)

Where 'k' is the compressibility coefficient.

➢ Shear Modulus (μ)

The shear modulus is defined as "the ratio of shearing stress " τ " to the resulted shear strain "tan θ ". It is denoted by "μ".
Mathematically:

$$\text{Shear Modulus } \mu = \frac{\text{Shearing Stress } (\tau)}{\text{Shearing Strain } (\tan\theta)}$$

(Kearey et al, 2002)

It is also called as rigidity modulus.
For liquids and gases, shear modulus (μ) =0
(Robinson &Coruh, 1988)

---

[1] Kearey, 2002

- **Young's Modulus (E)**

It is defined as the" ratio between longitudinal stress and longitudinal strain". It is also called stretch modulus. It is denoted by "E".

Mathematically:

$$\text{Young's Modulus } E = \frac{\text{Longitudinal Stress } F/A}{\text{Longitudinal Strain } \Delta L/L}$$

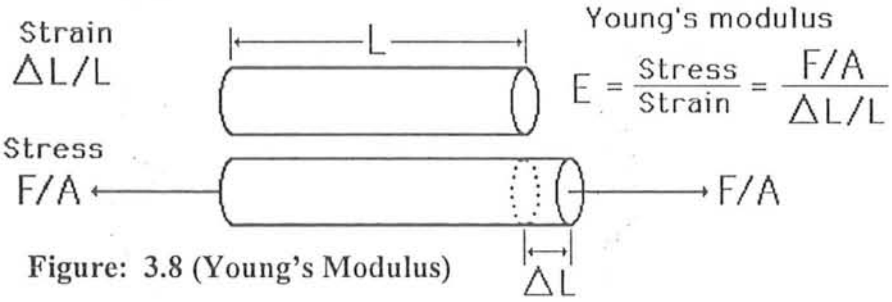


Figure: 3.8 (Young's Modulus)

- **Poisson's Ratio (σ)**

"The ratio of Transverse strain to longitudinal strain" is known as Poisson's Ratio. It is denoted by "σ".

Mathematically:

$$\text{Poisson's Ratio } \sigma = \frac{\text{Transverse Strain}}{\text{Longitudinal Strain}}$$

- **Relationship between Elastic Module**

The all four module can be interrelated in the following way

$$K = E / 3(1-2\sigma)$$

$$\mu = E / 2(1+\sigma)$$ **(Dobrin, 1988)**

3.7 Seismic Waves

Wave is a progressive disturbance propagated from point to point in a medium or space without progress or advance by the points themselves. Seismic waves are generally referred to as elastic waves because they propagated like that in an elastic band when it is stretched.

The theory of elasticity reveals that the energy propagated through the earth in the different form of seismic waves. Seismic waves are parcels of elastic strain energy that propagate outwards from a seismic source such as an earthquake or an explosion. (Kearey, 2002)

Laws Governing Seismic Waves[1]

There are three fundamental laws that govern the seismic wave propagation.

- Huygen's principle
- Fermat's principle
- Snell's law

Huygens's Principle

According to this principal,

"Every point on a wave front is a source of new wave that travels away from it in all directions" Figure 3.9 shows the generation of wave fronts by succeeding waves

"A wave front is the li Figure 3.9 (Huygens's Principle)ne or curve of crest and troughs."

"Each individual point is the centre of its own circular wave front. The combined circles create the new wave fronts."

Fermat's Principle

It states that

"Elastic waves travel between two points along the paths requiring the least time." See fig.3.10.

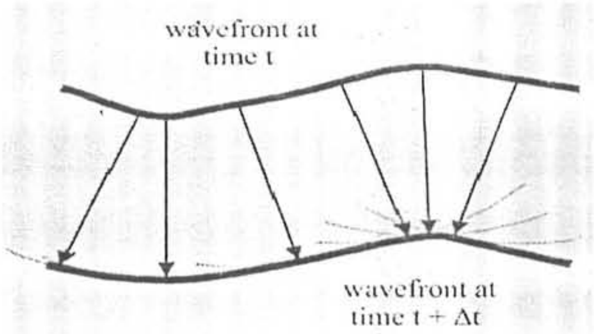


Figure 3.9 (Huygens's Principle)

(Robinson & Crouch)

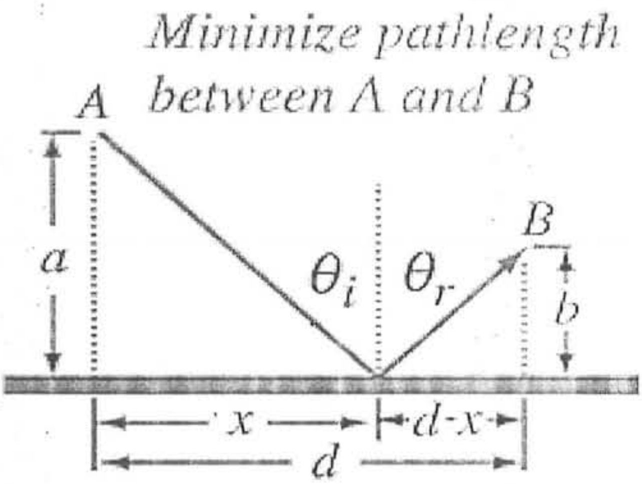


Figure 3.10 (Fermat's Principle)

This reduces to $\frac{x}{\sqrt{a^2+x^2}} = \frac{(d-x)}{\sqrt{b^2+(d-x)^2}}$ which is $\sin\theta_i = \sin\theta_r$

This shows that: $\boxed{\theta_i = \theta_r}$ Law of Reflection

The path length L from A to B is

$$L = \sqrt{a^2+x^2} + \sqrt{b^2+(d-x)^2}$$

Since the speed is constant, the minimum time path is simply the minimum distance path. This may be found by setting the derivative of L with respect to x equal to zero.

$$\frac{dL}{dx} = \frac{1}{2}\frac{2x}{\sqrt{a^2+x^2}} + \frac{1}{2}\frac{2(d-x)(-1)}{\sqrt{b^2+(d-x)^2}} = 0$$

Robinson & Coruh, 1988)

- **Snell's law**

According to this law

> *"Direction of refracted of reflected waves traveling away from a boundary depends upon the direction of the incident waves and the speed of the waves"*

Mathematically, $$\frac{\sin(\alpha_1)}{V_1} = \frac{\sin(\alpha_2)}{V_2},$$

Where V_1 and V_2 are velocities in the upper and lower layers, α_1 is the angle of the incident ray-path with respect to the vertical, and α_2 is the angle of transmission of the refracted ray-path with respect to the vertical. Figure 3.11 shows the reflection of incident waves form a surface.

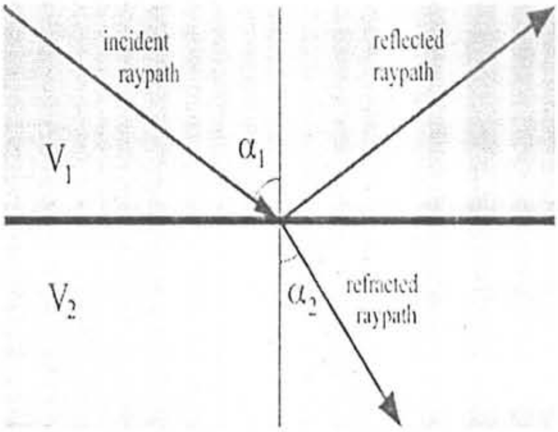


Figure 3.11(Refraction and reflection of an incident wave)
(Robinson & Coruh, 1988)

- **Reflection- and transmission-coefficients**

To derive the reflection and transmission coefficients for elastic waves, the boundary conditions at the interface are needed and are described by the Zoeppritz-Equations. These reflections coefficients depend on

- Difference in density
- Difference in velocity
- Angle of incident of the wave

The Reflection- and Transmission coefficient give the ratio between the incident amplitude (A_0) and the reflected (A_R) and transmitted (A_T) amplitude, respectively. In the special case of an incident wave perpendicular at an interface for a P-wave, a simple expressions for the reflection and transmission coefficient is obtained.

- **Reflection coefficient**

These coefficients compare the amplitude of incident wave and reflected wave. Value of reflection coefficient varies from -1 to +1. For R=0, there will be no reflection, wave will be transmitted. It can be mathematically represented as;

$$R = \frac{A_R}{A_0} = \frac{v_2\rho_2 - v_1\rho_1}{v_2\rho_2 + v_1\rho_1} = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

- **Transmission coefficient**

Transmission coefficients are those which compare the amplitude of incident wave and refracted wave. Value of transmission coefficient varies from 0 to2. If Ai is the amplitude of incident wave and At is the amplitude of transmitted wave, then transmission coefficient T is given as follow;

$$T = \frac{A_T}{A_0} = \frac{2v_1\rho_1}{v_2\rho_2 + v_1\rho_1} = \frac{2Z_1}{Z_2 + Z_1}$$

The product $Z = v\,\rho$ is known as the acoustic impedance.

(Khan, 1988)

- **Types of Seismic Waves**

Seismic waves are messengers that convey information about the earth's interior. Basically these waves test the extent to which earth materials can be stretched or squeezed some what as we can squeeze a sponge. They cause the particles of materials to vibrate, which means that passing seismic waves temporarily deforms these particles can be described by its properties of elasticity. These physical properties can be used to distinguish different materials. They influence the speeds of seismic waves through those materials. **(Robinson & Coruh, 1988)**

There are mainly two types of Seismic Waves:

- Body waves
- Surface waves

- **Body Waves**

Theses 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)

P- Waves (Primary Waves)

The particular kinds of waves of most interest to seismologists are the compressional or P-waves also called as compressional waves, longitudinal waves, primary waves, pressure waves, and dilatation waves (**see Fig. 3.12**). In this case the vibrating particles move back and forth in the same direction as the direction of propagation of waves. P-waves can pass through any kind of material - solid liquid or gas. The P-waves velocity depends upon density and elastic constants. (Dobrin, 1976)

The seismic velocity of a medium is a function of its elasticity and can be expressed in terms of its elastic constants. For a homogeneous, isotropic medium, the seismic P-wave velocity Vp is given by;

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

Where:

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

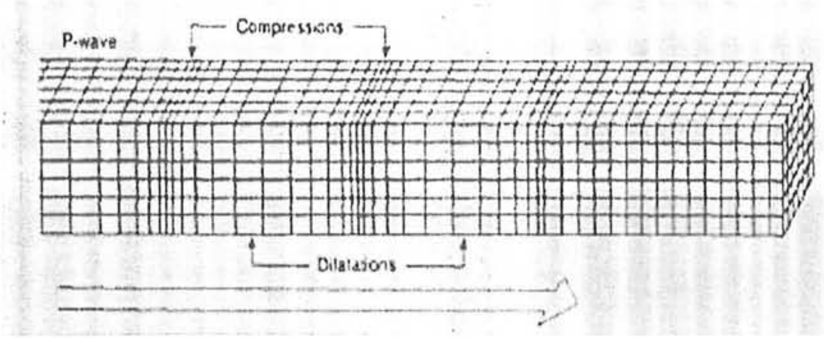


Figure 3.12 (The propagation of P-waves in an Elastic Medium)

S- Waves (Secondary waves)

In shear waves, the particles vibrate in a direction perpendicular to the direction of propagation of waves (see Figure 3.13).

Figure 3.13 (The propagation of S-waves in an Elastic Medium)

They are also called as Shear waves, transverse waves, and converted waves. For ideal gases and liquid $\mu=0$.

S-waves cannot pass through fluids. The velocity of S-waves is given by (using the same notation as of V_p); (Dobrin, 1976)

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

Characteristics of Body Waves

- These waves travel with low speed through layers close to the earth's surface, as well in weathered layers. (Robinson & Coruh,)
- Frequency of body waves in exploration vary from 15Hz to 100 Hz. (Parasnis, 1997)

Surface Waves

A part from body waves more complicated patterns of vibration are observed as well. These kinds of vibrations can be measured only at locations close to the surface. Such vibrations must result from waves that follow paths close to the earth's surface, hence known as surface waves.

In a bounded elastic solid, surface waves can propagate along the boundary of the solid. Frequency of surface waves is less than 15Hz.

(Parasnis, 1997)

Surface waves are also of two types;

- Raleigh waves
- Love waves

Raleigh Waves

Type of surface waves having a retrograde, elliptical motion at the free surface of a solid and it is always vertical plane. Raleigh waves are principal component of ground roll. The Figure 3.14 shows the propagation of Raleigh waves in an elastic medium.

(Kearey, 2002)

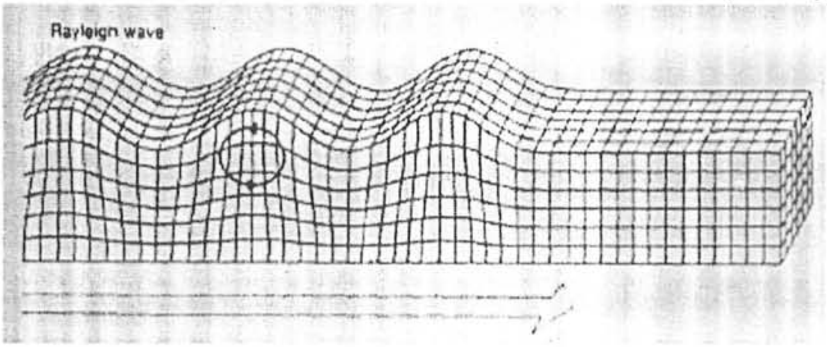


Figure 3.14 (Propagation of Raleigh waves in an Elastic Medium)

➢ Love Waves

A type of surface waves having a horizontal motion i.e. transverse to the direction of propagation. The velocity of these waves depends on the density and modulus of rigidity and not depends upon the bulk modulus (k). The Figure 3.15 shows the propagation of Love-waves in an elastic medium.

(Kearey, 2002)

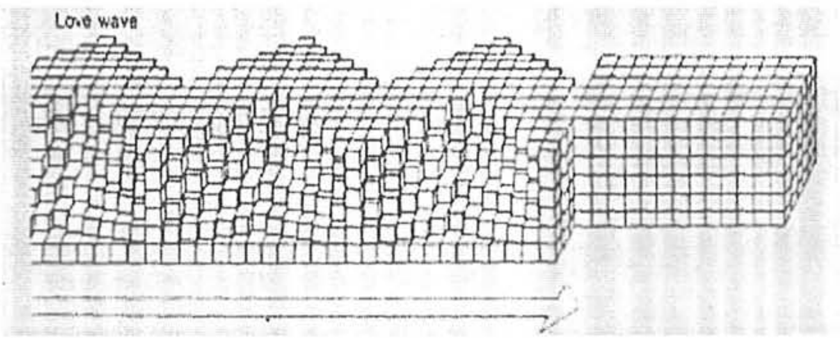


Figure 3.15 (Propagation of Love waves in an Elastic Medium)

➢ Attenuation of Seismic Waves

Attenuation is simply the fall of energy of a wave with increase in distance from source. The energy of a wave in a given medium is directly proportional to the square of its amplitude. (Dobrin, 1976)

Fall of energy can be due to

1. **Spherical Divergence**
2. **Absorption**

1. Spherical Divergence

Spherical divergence is spread out of a wave from its source. As the source wavelet travels farther and farther from the source, its amplitude of vibration grows smaller. It is because of the fact that the continuously expanding spherical wave as expands, the same amount of energy, once received from source at time of onset of wave, has to be distributed over the larger area.

Change in amplitude of a wave with distance due to spherical divergence is given as:

$$H = \frac{H_0}{X}$$

Where:

H: amplitude at distance x.

H_0: initial amplitude of the wave as it left the source.

X: distance from source.

2. Absorption

Absorption is simply the capture of energy of the wave by particles of the medium through which it propagates. It happens when particles of the medium start to vibrate, due to wave propagation, particles start to collide and so to rub each other. Due to this friction, some of the wave energy is converted into the heat energy. In this way, energy of wave propagating through the medium is decreased and amplitude decreases. Change in amplitude due to this absorption is given as:

$$H = H_0 e^{-\alpha x}$$

Where:

α: absorption coefficient.
x: distance from source.

(Robinson &Coruh, 1988)

➢ Wave Conversion

When a wave reaches the boundary between two substances having velocities, it divides up into waves that reflect from the boundary or refract across the boundary. So an incident wave is converted into reflected and refracted waves. An incident wave can be P-wave, S_V- wave or S_H-wave.

(Robinson & Coruh, 1988)

- When incident wave is P-wave then it is reflected and refracted as P-wave and S-wave (see Figure 3.16 a)
- When incident wave is S_V-wave then it is reflected and refracted as P-wave and S_V-wave (see Figure 3.16 b)
- When incident wave is S_H-wave then it is reflected and refracted as S_H-wave (Figure 3.16 c)

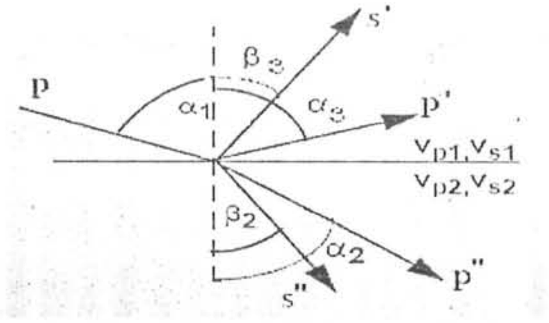


Figure 3.16 a (Wave conversion of P-wave into various waves

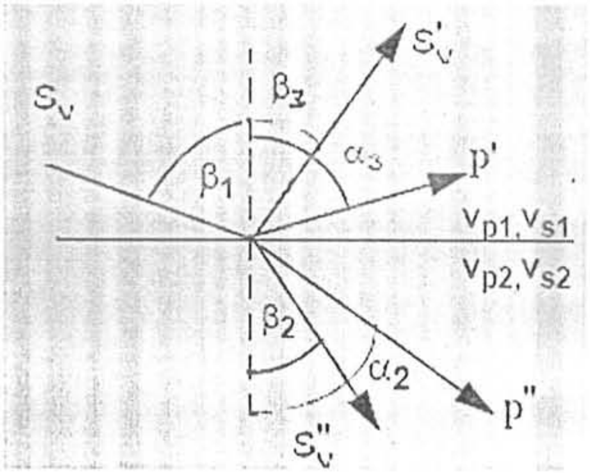


Figure 3.16 b (Wave conversion of S_V-wave into various waves)

Where

- P is the incident wave
- P' is the reflected wave
- P" is the refracted wave
- S is the incident wave
- S 'is the reflected wave
- S " is the refracted wave
- S is the incident wave
- S ' is the reflected wave
- S "is the refracted wave
- α1 incident angle of P-wave
- α2 reflected angle of P-wave
- α3 refracted angle of P-wave
- β1 incident angle of S-wave
- β2 reflected angle of S-wave
- β3 refracted angle of S-wave

Seismic Velocities

4.1 Introduction

Velocity is the bridge between time and depth, between milliseconds and feet, between timing lines and drill stem. Routinely velocities are used to stack seismic data, to migrate seismic data, and to convert time-recorded seismic sections to depth sections and time maps to depth maps. Velocities are also used more sophisticated ways, such as in attempts to predict porosity, geologic age, lithology, fracturing, fluid content, geopressure, and even drill-bit wear. Velocity data contain an enormous amount of information.

(Dobrin, 1988)

❖ The Nature of Velocity Data

Seismic velocities vary largely in sedimentary rocks as compared to igneous and metamorphic rocks. Metamorphic and igneous rocks have little or no porosity and, the seismic wave velocity depend upon the elastic properties of the material making up the rock material itself. In terms of lithology, whenever there is a change in grain size and mineralogical composition of the rock, velocity behavior changes. An increase in grain size will result in the increase in velocity. In many areas, seismic velocity data can be used to identify lithology in discrete formations within the geologic section.

(Dobrin, 1988)

❖ Effects of Physical properties of Rocks on Seismic Velocities

The Seismic velocities in rocks are affected by following physical properties of rock. These properties vary greatly in sedimentary rocks than in metamorphic rocks.

1. Porosity of rock
2. Consolidation of rock
3. Lithology of rock
4. Pore fluid type
5. The geologic age and depth of burial

1. Porosity:

Porosity decreases the velocity of propagating waves. The relation between porosity (Φ) and velocity (V) has been defined by the following relation

$$1/V = \Phi/V_f + (1-\Phi)/V_m$$

Where

Vf = Velocity of fluids in pore spaces.
Vm = Velocity of solid material making up the rock matrix.
V =Velocity in saturated rock.
Φ =Fractional porosity.

Now porosity is dependent upon consolidation of rock body. Also porosity decrease with depth as the result velocity increases.

1. Consolidation of Rock

Wave velocity increases with the consolidation of rocks.

2. Lithology of Rocks

Lithology also has control over the velocity of waves. It is because of the fact that every material has its own density. Also it is well known that velocity decreases with density increase. Lesser is the density, more is the velocity. However effect of density on velocity is also encountered by the elastic module. Shale content in rock tends to have lower seismic velocity and more in sand content.

3. Pore Fluid Type

Velocity is also dependent on fluid type because it is dependent on k(Bulk modulus),which is measure of incompressibility and it is dependent upon porosity, compressibility of fluid, dry rock and grains. Higher the incompressibility, higher the wave velocity e.g. sand containing water in pore space has higher seismic velocity then containing the oil and if containing gas has lower velocity.

4. Geologic Age and Depth of Burrial

The relationship between velocity and depth and geologic age of rock is given as follows

$Vp = K^* (Z^*T)^{1/6}$

Where

Vp = velocity of fluids in porous medium (feet or meter /sec.)
Z = Depth of burial (meters/feet)
T = Geologic age of formation (years)
K= Constant.It is equal to 125.3 when Z is in feet and is equal to 46.5 when Z is in meters.

(Dobrin,1976) ,(Al-Sadi, 1980)

- Average Velocity

For a given age, velocity increases as depth increases, and for a given depth, velocity increases as age increases.

4.2 Velocity Estimation

Velocity as a seismic parameter plays an important role in almost the whole range of activities involved in seismic prospecting. The accuracy of data reduction, processing and interpretation of seismic data depends mainly on the correction of velocity measurements.

Since, in seismic prospecting, we require velocity values as a function of depth, all velocity determination methods aim at computing velocity depth- or time- function. Velocity estimation can be done by;

(Robinson & Coruh, 1988)

- By use of an exploration-well
- Velocity can be obtained by using well shooting
- The can be obtain from continuous velocity survey
- By the use of reflection travel times
- By the use of refraction travel times

4.2.1 Variations in Seismic Velocities

There are two types of variations in seismic velocities;

1. Lateral variation in seismic velocity
2. Vertical variation in seismic velocity

4.2.2 Lateral variations in Seismic Velocities

These variations are supposed because of slow changes in density and elastic properties due to changes in lithology or physical properties. Lateral variations make events appear to move up or down on time sections.

(Robinson & Coruh, 1988)

4.2.3 Vertical variations in Seismic Velocities

These variations are due to lithological changes of layering and increasing pressure due to increasing depth. Normally seismic velocities increase with the increase in depth. Vertical variation in velocity cause differences in the two way travel times of layers of equal thickness.

(Robinson & Coruh, 1988)

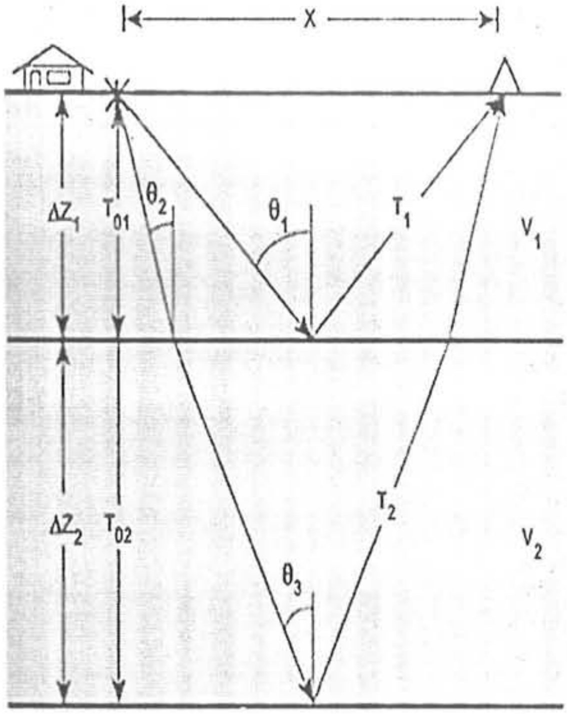
4.3 Types of Velocities used in Seismic Exploration

The different types of velocities used in seismic exploration are;

- Interval Velocity
- Root-Mean-Square Velocity
- Normal-Move out Velocity
- Instantaneous Velocity
- Stacking Velocity

4.3.1 Average Velocity

Average velocity is simply the total distance traveled divided by the total time traveled. The average seismic velocity is the distance traveled by a seismic wave from the source location to some point on or within the earth divided by the recorded travel time (Al. Sadi, 1980). The Figure 6.1 shows a two-layer case by which the average velocity is calculated.



$$V_{a01} = 2\,\Delta Z_1/T_{01}$$

$$V_{a02} = (2\,\Delta Z_1 + 2\Delta Z_2)/(T_{01}+T_{02})$$

$$V_{a1} = (2\,\Delta Z_1/\cos \Theta 1_2)T_1$$

$$V_{a2} = \{(2\,\Delta Z_1/\cos \Theta_2) + (2\,\Delta Z_2/\cos \Theta_3)\}/(T_{01}+T_{02})$$

Figure 4.1: (A two-layer case by which the average velocity is calculated
If concerned with the distance and time from the surface of the earth to a point at depth, then the one-way distance and time is used (Dobrin, 1988). The average velocity in this

$$\sum^{n} z_i \qquad \sum^{n} v_i t_i$$

$$V_a = \frac{z}{t} = \frac{2z}{2t} = \frac{2z}{T}$$

Nevertheless, if considering with the distance from the surface of the earth to a point at depth and back to the surface, then two-way distance and travel time is used, and average velocity equals 2Z/T. So, average velocity can be expressed as

Where,
t is : One-way travel time.
T is: Two-way travel time.

4.3.2Interval Velocity

Interval velocity, V, is defined as the thickness of a particular layer divided by the time it takes to travel from the top of the layer to its base. The interval velocity is ΔZ (the thickness of a stratigraphic layer) divided by Δt (the time it takes to travel from the top of the layer to its base). The equation for interval velocity is:

$$V_i = \frac{Z_m - Z_n}{t_m - t_n} = \frac{Z_m - Z_n}{T}$$

(Dobrin, 1988)

The thickness $\Delta Z = Z_m - Z_n$ is also equal to the isopach value of the interval. A typical interval-velocity-versus-time curve compared to the average velocity is shown in Figure 6.2. The discrete boundaries in the interval-velocity curve indicate stratigraphic and velocity differences between two contiguous layers. The average velocity can be determined by averaging the weighted summation of the interval velocities. If we sum the interval velocities for a series of rock layers, and weight them according to the two-way travel time within each layer, ΔT, the average value would be equal to the average velocity. The equation for average velocity, V_A, in terms of interval velocity is: (Yilmaz, 2001)

Where

ΔZ is the interval thickness or isopach thickness.

4.3.3 Root-Mean-Square (RMS) Velocity

$$V_a = \frac{\sum V_i \Delta T}{\sum \Delta T} = \frac{2\sum \Delta Z}{\sum \Delta T}$$

The root-mean-square (RMS) velocity is a weighted average. It is used as weighting process where the amount of weighting is determined by the value of the interval velocities. The weighting is accomplished by squaring the interval velocity values. So, in this approach, greater weight is given to the greater interval velocities. The equation for RMS velocity is given below:

$$\sum^{n} v_i^2 t_i$$

[illegible]

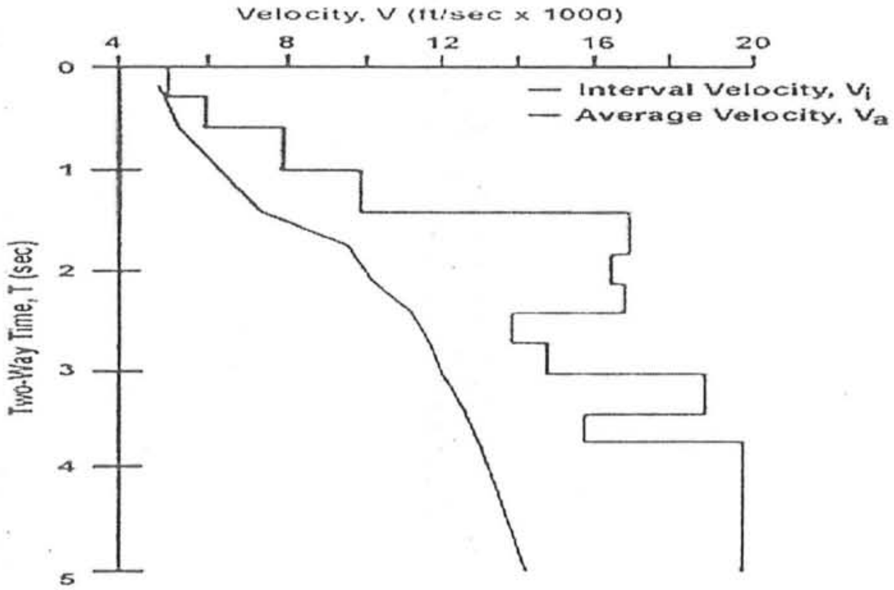


Figure 4.2: (Interval-Velocity vs. Time Curve compared to the Average Velocity)

By comparing the equations it is clear that the RMS velocity is always greater than the average velocity. RMS velocity is strictly a mathematical weighted average and has no intrinsic meaning (Robinson & Coruh, 1988). Figure 6.3 shows a graphical comparison between the root mean square velocity and the average velocity.

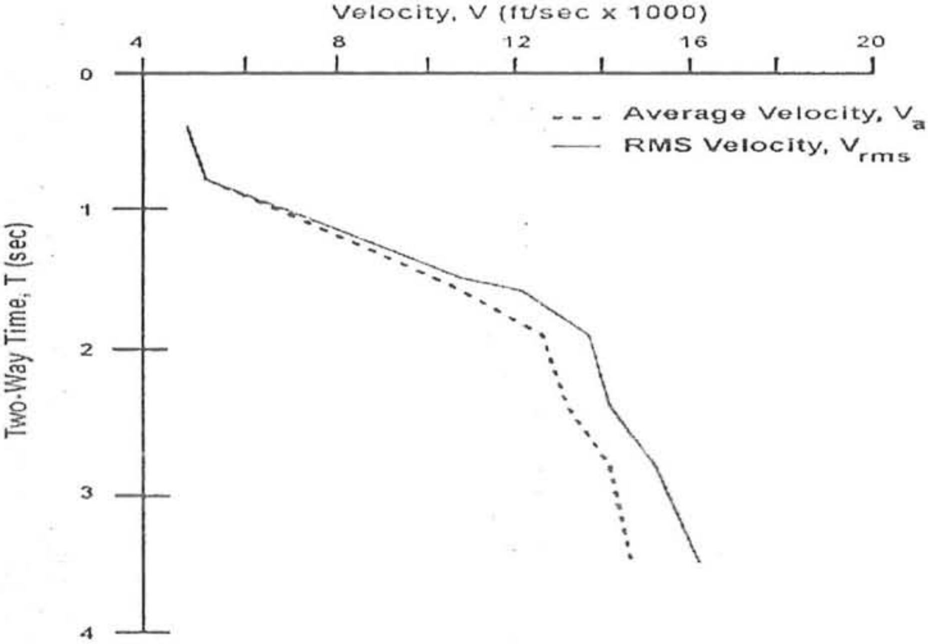


Figure 4.3: (Comparison b/w Root Mean Square Velocity and Average Velocity)

4.3.4 Normal-Move out Velocity

The normal-move out (NMO) velocity, or stacking velocity, V_{nmo}, has a horizontal component (X). Therefore, it is dependent on the offset, depth, and spread length. Seismic

Records with source-to-receiver distances will yield different NMO velocity values. The NMO velocity increases as the value of X increases (Rehman, 1989). The equation for NMO velocity is:

$$V_{nmo} = \frac{X}{\sqrt{T_x^2 - T_x^2}} = \frac{X}{\sqrt{2T_0 \Delta T_{nmo}}}$$

Where, X = the offset distance from source to receiver, T_x = the two-way travel time of a seismic wave reflected off a particular interface and recorded at the receiver location, and

T_0 = the two-way travel time of the seismic wave reflected off the particular interface at the zero-offset location.
We can calculate the NMO correction, ΔT_{nmo}, from the average velocity (by Figure 22). From the Pythagorean Theorem, we know that

$$d^2 = \Delta Z^2 + \left(\frac{X}{2}\right)^2$$

If we know the normal-movement velocity, it can be related to the average velocity using the equation $T = T_0 + \Delta T_{nmo}$ (Telford, 2004). Then approximate the NMO correction as a function of average velocity:

$$T_0 + \Delta T_{nmo} \approx \sqrt{T_0^2 + \frac{X^2}{V_a^2}}$$

$$\Delta T_{nmo} \approx \sqrt{T_0^2 + \frac{X^2}{V_a^2}} - T_0$$

The NMO correction can also be approximated from the RMS velocity. In this case,

$$\Delta T_{nmo} \approx \sqrt{T_0^2 + \frac{X^2}{V_{rms}^2}} - T_0$$

$$\Delta T_{nmo} \approx \frac{X^2}{2 T_0 V_{rms}^2}$$

4.3.5 Instantaneous Velocity

If the velocity varies continuously with depth, its value at a particular depth 'Z' is obtained from interval velocity by contracting the interval ZI-Z2 to an infinitesimally thin layer having a thickness dZ (Telford, 2004).The interval velocity then becomes the derivative of Z with respect to "t", which is the instantaneous velocity, defined as follows:

$$V_{inst} = \frac{dz}{dt}$$

4.3.6 Stacking Velocity

It is the velocity obtained from normal move out (NMO) measurements, used to maximize events in stacking process. It is approximately but not exactly same the RMS velocity. Stacking velocity is almost always greater than the average velocity. (Dobrin, 1976)

Stacking velocity 'Vst' is based on the relation

$$T^2 = 0T2+X^2/V^2$$

Where,

X = Source-receiver offset for a CMP sequence of shots.

T = Travel time of the reflection at X.

Tn = Travel time at the zero offset/vertical travel time.

CONCLUSION:

Vav ≤ Vrms ≤ Vst

(Dobrin1976)

4.4 Correlation between Velocity Types

In seismic prospecting we are dealing with a medium which is made up of a sequence of layers of different velocities. In dealing with this kind of situation, it is necessary to specify the kind of velocity we are using. When velocity is measured for a defined depth interval, it is called as interval velocity and when it is determined for several layers it is called as average velocity.

Relationship between interval velocity, root mean square velocity and average velocity is given by "Dix Formula". If root mean square velocities (V_{rms}) is given then interval velocities (V_{int}) can be determine by using the following form of Dix formula

Al-Sadi, 1980)

If, on the other hand ,if given the Average Velocity (V_a), Interval Velocity (V_{int}) can be determined by another form of Dix- formula.

(Al-Sadi,1980)

$$V_{\text{int}} = \frac{V_{a,n} * t_n - V_{a,n-1} * t_{n-1}}{t_n - t_{n-1}}$$

Now, if we are given with interval velocities (V_{int}) and we have to determine average velocities (V_a), (Al-Sadi, 1980), then Dix formula attains the form as given below. So if we are given with any of the interval, root mean square velocity or average velocity, the remaining two by using the corresponding form of Dix-formula.

$$V_{a,n} = \frac{(V_{\mathrm{int},n} * T_n — T_{n-1}) + (V_{a,n-1} * T_{n-1})}{T_n}$$

4.5 Factors Affecting Velocity

Different factors affect the seismic velocities, by which we infer the rock type or rock condition from an observed seismic velocity. The porosity, mineral composition, inter-granular elastic behavior and fluid properties are the primary factors which affect seismic velocities and these factors are dependent upon overburden pressure, fluid pressure, micro cracks, age and depth of burial. The overburden pressure is usually defined as the vertical stress caused by all the material, both solid and fluid above the formation when a rock is buried, it is influenced by the overburden, which increases with time.

The increase of overburden causes the squeezing out of water from the rocks. But an impermeable layer is overlain by the compacting layer, in such case it will shut off the path for water to squeeze out. Therefore water is locked in the pores. Its stiffness then resists the deformation of rock grains into voids; therefore, it tends to maintain the porosity at great depth. Such rocks are said to be over pressure. The usual increase of velocity with depth can be reduced dramatically both by the maintenance of porosity and by the reduction of cementation by circulating water. (Dobrin, 1988)

Processing

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. It can be said "as an approach by which the raw data recorded in the field is enhanced to the extent that it can be used for the geological interpretation" (see figure 5.1). 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 have a significant impact on the quality of data collected in the field. Lack of seismic reflected events on seismic section is not the result of a subsurface void of reflectors. Rather it is caused by low signal-to-noise ratio (S/N) resulting from energy scattering and absorption in the medium of propagation.

Surface conditions have an influence on how much energy from a source can penetrate into the subsurface. Besides surface conditions, environmental conditions and demographic restrictions can have significant impact on field data quality. 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. Processing algorithms are designed for and applied to either single channel time series, individually, or multi-channel time series.

(Dobrin,1988)

5.2 Processing in General

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

Observational Data ⇒ Processing System ⇒ Useful Information

5.3 Processing Sequence

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

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

5.3.1Data Reduction

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

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

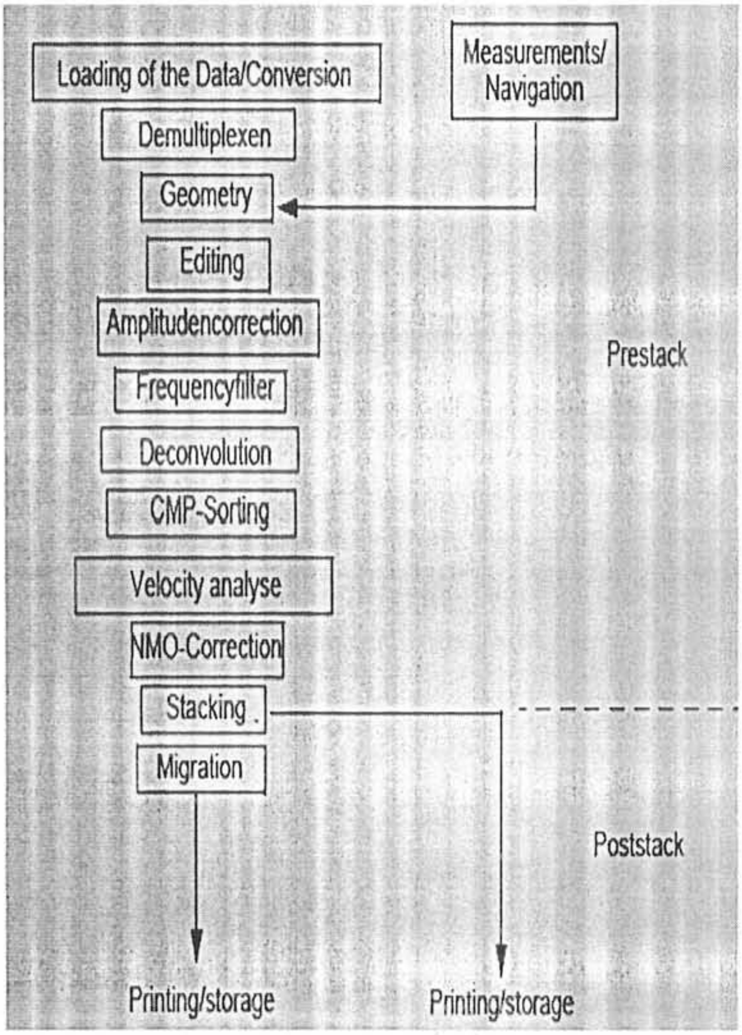
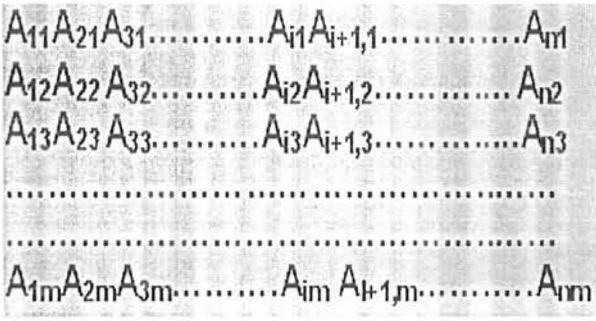


Figure 5.1 (Detailed Processing Sequence Flow Chart)

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*. Suppose there are four geophone arrays. Instantaneous voltage recorded by each geophone yields an array of samples. If each sample is identified by its geophone group source (A, B, C, D) and by its chronological sequence in that group (1, 2, 3, and 4). Then the output



$A_{11}A_{21}A_{31}$……….$A_{i1}A_{i+1,1}$…………..A_{n1}

$A_{12}A_{22}A_{32}$……….$A_{i2}A_{i+1,2}$…………..A_{n2}

$A_{13}A_{23}A_{33}$……….$A_{i3}A_{i+1,3}$…………..A_{n3}

……………………………………………………

……………………………………………………

$A_{1m}A_{2m}A_{3m}$……….$A_{im}\ A_{i+1,m}$…………..A_{nm}

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 (Robinson & Coruh, 1988).

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

Definition

The layout of receivers for each shot record the location of all shots along the line, and all such field information must be described in detail to the computer for the geometry-specification step. Most geometry programs can access the digitized base-map file.

Computer access is particularly necessary for processing crooked lines in which sources and receivers are not uniformly distributed along a straight traverse. The geometry program must calculate a source-receiver mid-point based on the two ground locations. All relevant geometric information is retained in the trace headers on the tape so that each trace is uniquely and accurately located. Later programs will time shift or filter as a function of ground location, offset, and/or other spatial coordinate(s) and time.

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;

1. Cross Correlation
2. 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. As a measure of similarity, cross correlation is widely used at various stages of data processing (Yilmaz, 2001). For instance traces in a CMP gather are cross correlated with a pilot trace to compute residual static's shift. It is the fundamental basis for computing velocity spectra.

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. (Yilmaz, 2001)

Vibroseis Correlation

The signal generated by a vibroseis is not a short pulse but rather a sweep lasting some seven to ten seconds. 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 (Yilmaz, 2001). There are two types of sweep;

1. Up Sweep (When frequency of the vibroseis source signal increases with time)
2. Down Sweep (When frequency of the vibroseis source signal decreases with time)
3.

Importance of Vibroseis Correlation

For Vibroseis source, we have a sweep (a train of waves) rather than a short pulse/source wavelet whereas most seismic impulsive sources generate a very short pulse which can be used directly to examine subsurface structure Vibroseis sweep lasts for several seconds depending upon the sweep time. So in case of vibroseis source all reflected and refracted signals on a vibroseis seismogram overlap one another extensively. Even after demultiplexing of the vibroseis seismogram it is impossible to recognize the reflections. So vibroseis correlation procedure is applied.

(Robinson. & Coruh, 1988)

Vibroseis correlation enables us to extract from each of the long overlapping sweep signals on vibroseis seismogram, a short wavelet much like those obtained with seismic impulsive source

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 (Rehman, 1989).After doing this all the contributing traces per each CDP are gathered together.

Each trace in one CDP is identified by it s shot point and receiver numbers .The CDP-gathers may be displayed as such for direct inspection and checking of edited data.

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 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.

(Al-Sadi,1980)

Muting is useful to remove useless information from the processing stream in a way that first identifies the information to be removed and then blanked. Muting is categorized as *Initial Muting,* to remove first arrivals; usually done later in processing, and *Surgical Muting,* to remove air waves or ground roll energies.

Amplitude Adjustment

Amplitudes of the seismic wavelet is 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:

a. Trace Normalization

b. Trace Balancing

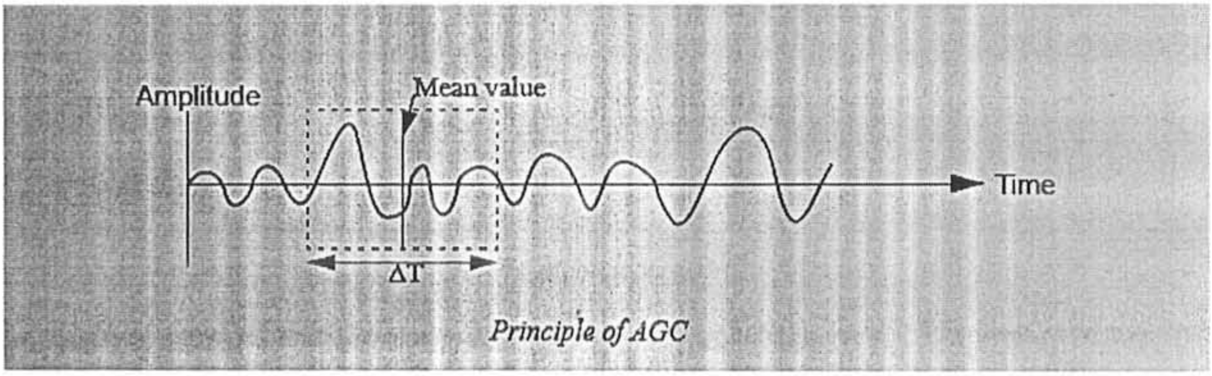
a. Trace Normalization

Trace Normalization is an amplitude adjustment applied to the entire trace. It is directly applicable to the case of a weak shot or a poor geophone plant. All absolute values of a trace are summed and compared with a reference value. A scaling factor is determined from the difference between the summation and the reference value, which is used to multiply all data with. Other possibilities of trace normalization could be *Average value* (Arithmetic or RMS), *Median*, *Maximum Value* to compensate the difference in amplitude which occurs due to the increasing distance between the source and receiver and the lateral differences in amplitudes. But the loss of amplitude with increasing depth is not taken into account.

b. Trace Balancing-AGC

The AGC function does not employ a gain to the whole trace, but employs a gain to a certain time sample within a time gate. First, the mean absolute value of trace amplitudes is computed within a specified time gate. Second, the ratio of the desired 'RMS' level to this mean value is assigned as the value of the gain function. This gain function is then applied to any desired time sample within the time gate; say the n^{th} sample of the trace. The next step is to move the time gate one sample down the trace and compute the value of the gain function for the $(n+1)^{th}$ time sample and so on (fig. 5.2). The time gate is very important. Very small time gates can cause a significant loss of signal character by boosting zones that contain small amplitudes. In the other extreme, if a large time gate is selected, then the effectiveness of the AGC process is lessened. 256- to 1024-ms AGC time gates are commonly chosen.

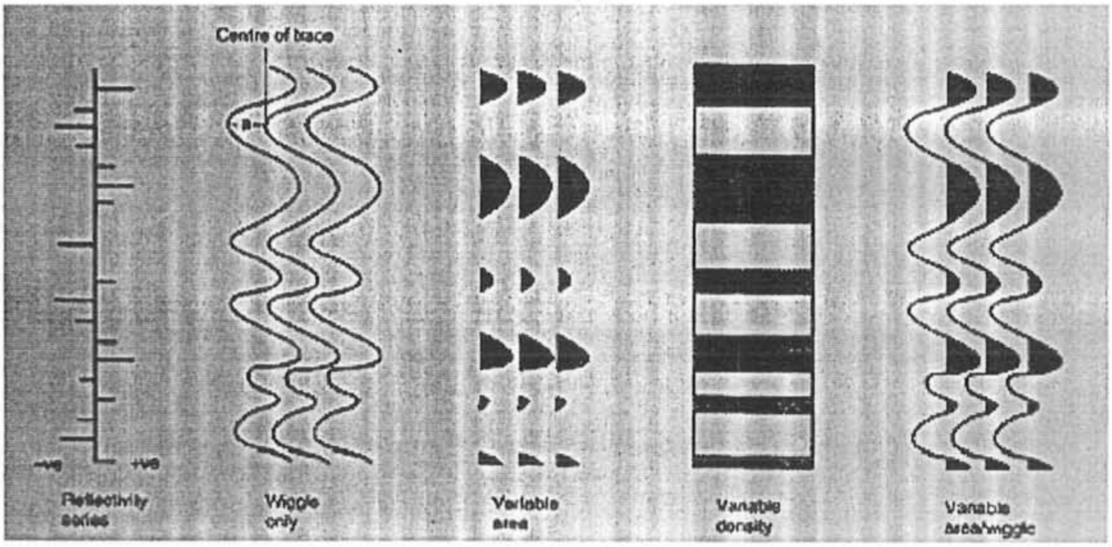
A disadvantage is that when the AGC gain is applied, it is not possible to reconstruct the original signal again. Therefore, the AGC is only used for display and printing purposes.



Principle of AGC

Display

The data so processed is generally displayed in various modes (fig. 5.3) 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. Currently, the data provided by OGDCL is the variable area with wiggles plot.



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, 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.

In interpretation of seismic section, variations in amplitudes of reflections can be the important factors .Lateral amplitude variations, from trace to trace, within a reflection event (bright spots) may be the direct indications of the presence of hydrocarbons. Vertical amplitude variations, from event to event, may be helpful in identifying and correlating reflecting horizons.

5.3.2 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, 1988). These corrections are applied on the traces gathered during trace editing and muting .The geometric corrections are

1. Static correction
2. 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

- Elevation correction
- Weathering correction

For land data, elevation corrections are applied at the stage of development of field geometry to reduce the travel times to a common datum level (Yilmaz, 2001).This level may be flat or floating along the line.

3. 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.

Normal move out correction is related more to the non-dipping interfaces. On the other hand dip move out correction is related to the dipping reflectors. It accounts for the effect of dip of the subsurface interface along with the effect of offset distance of receivers (Robinson & Coruh, 1988).

Dip-move out correction is applied to data following the normal-move out correction using flat-event velocities (Yilmaz, 2001). Figure 5.4 is the diagrammatical representation of the concept of static and dynamic corrections .

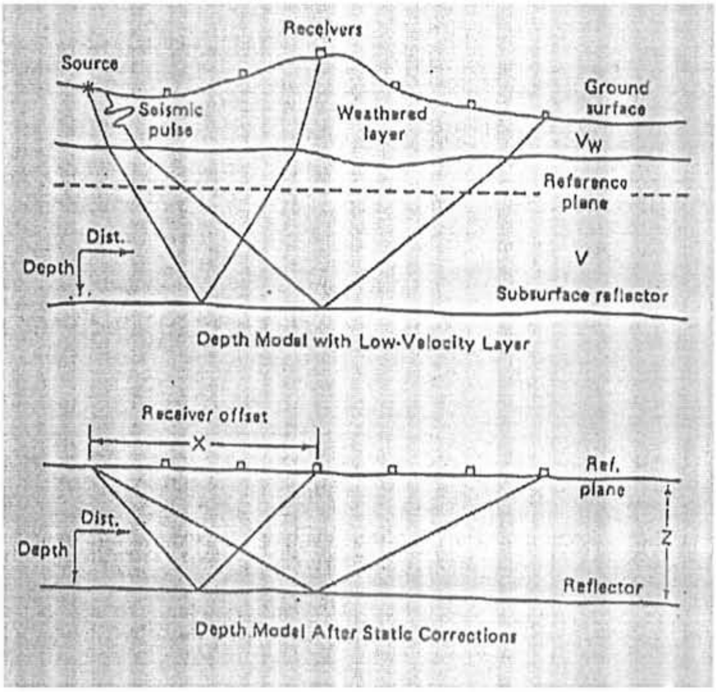


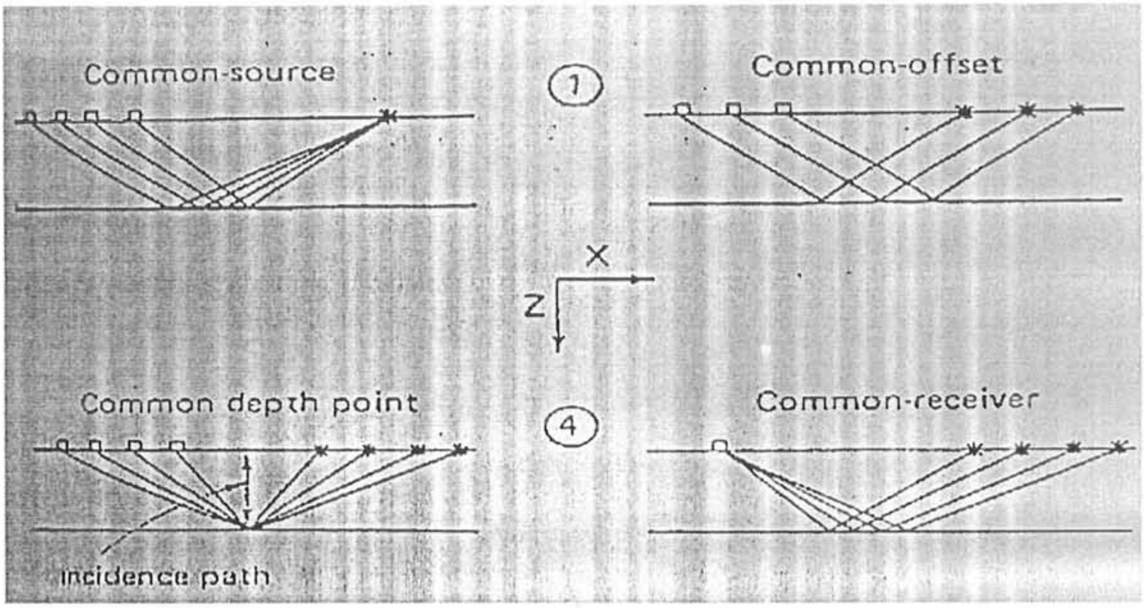
Fig. 5.4: Diagrammatic representation of static and dynamic corrections.

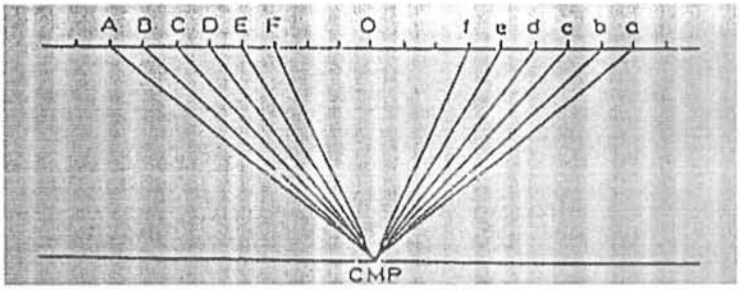
Trace Gathering

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.
-

The concept of various types of Trace Gathers is shown in the Figure 5.5 as fallow





CMP Gathers

Fig5.5: Diagrammatic representation of different trace gathers

The classical shooting pattern involves the procedure of a fixed shape spread, which moves along a linear profile at a regular move up rate. Such a spread is made up of equal inter-trace distances and a defined offset (Yilmaz, 2001). This technique ensures CDP coverage of a fold, which increases as the move up rate decreases. Multifold coverage can be calculated in terms of number of recording channels N, the geophone interval (X) and (S), and source interval as;

Fold number = $N X/2 S$

The ability to combine seismogram traces to obtain multifold reflection vastly improve signal to noise ratio. CDP technique is most common for data acquisition now days.

5.3.3 Data Analysis and Parameter Optimization

Three steps involved in this procedure. These three are:

1. Filtering
2. Deconvolution
3. Velocity Analysis

1. Filtering

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. Different trace configuration and increase in number of geophones at a point may decrease the noise but all the noise is not cut, so filters are used for further enhancement of signal. Thus filtering

> *"Is a process of spectrum modification which involves suppression of certain frequencies" (Robinson & Coruh, 1988)*

Digital Filters

It is numeric operator, which is convolved with a given digital function to filter out certain frequency components. It is also called time domain filter. Frequency filtering is avoided because weak reflection in the same frequency range that may be filtered out (Al-Sadi, 1980).The systems, which are generally called filters work either by convolution in the time domain or by spectral shaping in the frequency domain to remove the undesired information (Yilmaz,2001). The most common types of filters used are as follows

1. Low pass frequency filter
2. High pass frequency filter
3. Band Pass frequency filter
4. Notch filter
5. Velocity filter
6. F-K filter
7.

F-K Filters

Events that dip in the (t,x) plane can be separated in the (f, k) plane by their dips. This allows the elimination of certain types of unwanted energy from the data. In particular, coherent linear noise (in the form of ground roll), guided waves, and side-scattered energy commonly obscure the genuine reflections that may be present in recorded data. These types of noise usually are isolated from the reflection energy in the (f, k) space.

Deconvolution

It is the process by which the wavelet associated with the significant reflections is compressed and reverberatory energy that trails behind each reflection is largely attenuated .It is a filtering process designed to improve resolution and suppress multiple reflections. Deconvolution can be considered either in the time domain or in the frequency domain. In the time domain the object is to convert each wavelet with its reverberations and multiples, into a single spike. If we know the shape of the wavelet, we can design an operator which, when convolved with the seismic trace, with convert each wavelet into a single spike (Dobrin, 1988)

It is a class of operations developed as a mean of partially reversing the effect of earth filter. When dynamite is blasted, spike is produced that is visible in the seismogram. Spike has very high frequency and short wavelength. When it travels through earth its amplitude decreases and it becomes a waveform, with lower frequency and greater wavelength. Thus earth is absorbing higher frequencies with time and depth. This behavior of earth is termed as hi-cut filter.

Thus Deconvolution with a reverse process by which these higher frequencies are reproduced, called reverse filtering. Sometime- there are fake reflectors produced due to multiples which can cut by Deconvolution and deeper reflections become identifiable.

(Yilmaz, 2001)

Velocity Analysis

Velocity in seismic processing is an important parameter, which controls the stacking quality. Thus the proper velocity value gives the optimum dynamic correction which leads to efficient stacking process. The seismic traces of a common depth point gather are basis for each velocity analysis. Before velocity Analysis suitable static correction and data enhancement procedures are applied to the data (Yilmaz, 2001).

A series of normal moveout corrections, each based on arbitrary constant velocity are then applied to each trace of data set. Then NMO 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. The velocity increments may not be uniform but may be rather small for application of slower velocities, which yield large normal moveout and large for higher velocities. 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.

The curve in each spectrum represents the velocity function based on picked maximum coherency values associated with the primary reflections. The pairs of numbers along each curve denote the time_ velocity values for each pick. These velocity time pairs are picked from these spectra based on maximum coherency peaks to form velocity functions at analysis locations.

n areas with complex structures, velocity spectra (defined above) often fail to provide sufficient accuracy in velocity picks. In that case, the data on staked with a range of constant velocities (called as constant velocity analysis), and the constant velocity stacks themselves are used in picking velocities. (Yilmaz, 2001)

5.3.4 Data Refinement

The processes described till now are used to make data free of the factors that decreases its quality. Also these processes are used to reformat the data and to diagnose its characteristics (Rehman, 1989). Data refinement consists of the following two main stages.

1. Stacking
2. Migration

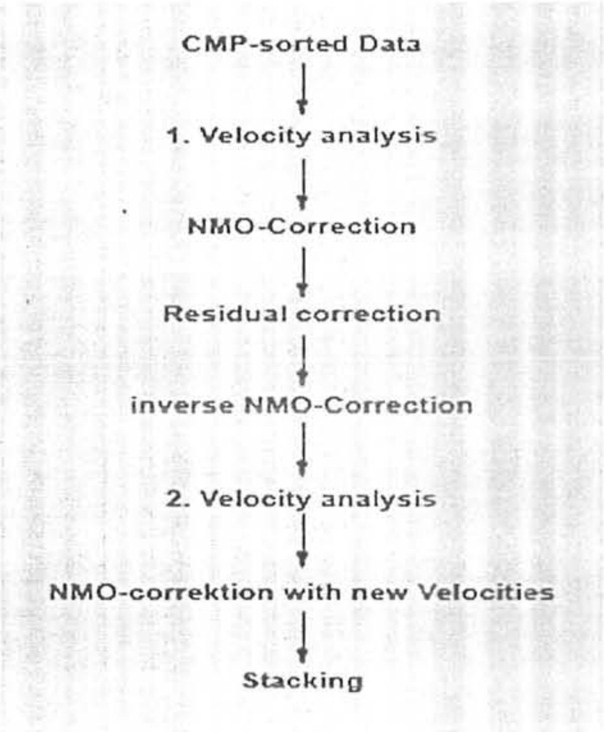
Along with these two processes, there is another procedure occasionally used in data refinement and is called as Residual Statics.

1. Stacking

Stacking is simply the process of adding up together the traces present in certain gathers, obtained during the seismic data acquisition .It is applied only when the all necessary corrections have been applied. The result of stacking is the corrected gather. In the "corrected gather" the traces have been gathered into the depth order. Both the static and dynamics corrections have been applied to it and the traces have been muted (Dobrin, 1988). All that remains is to stack the data. Stacking result in a single stacked trace as an out put for each depth point present in gathers.

One or other of two considerations is the basis for selecting the seismogram traces that will be stacked. Common offset stacking is done with traces that have the same source-receiver offsets, all of which are centered on the same point. (Dobrin, 1988)

Scheme of Residual Static Corrections



Stacking is a data compression of one to two orders of magnitude. The signal-to-random noise ratio is increased through an N fold stack by N. After stacking, the data are displayed at the surface location of the midpoint between source and receiver. When all adjustments to the data have transformed the offset data into time and phase coincidence with the zero offset traces, the common midpoint CMP and CDP are both widely often interchangeably. With dipping reflectors, the CMP after conventional processing is not the CDP. The correct positioning of reflection point will be by migration.

(Dobrin, 1988)

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). Figure 5.6 shows the subsurface dipping reflector's response.

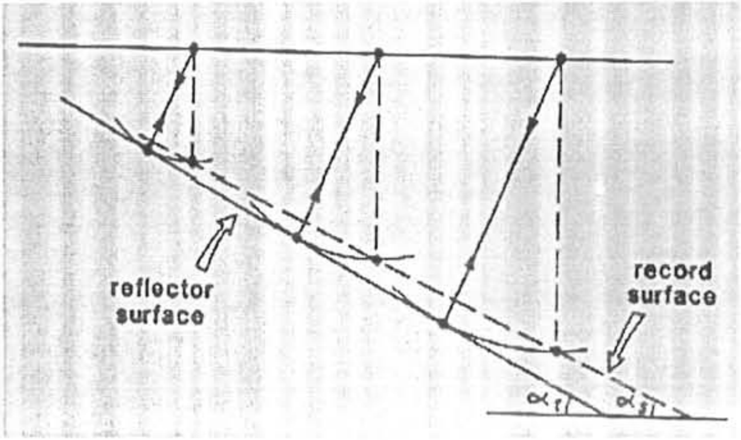


Figure 5.6: (Seismic response form a dipping reflector, the recorded surface gives the apparent dip of the reflector surface)

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 imaged by vertically plotting (Rehman, 1989).

Important features of Migration

Following are the important features of migration (Rehman, 1989);

1. Migration steepens the reflectors, as the dip angle of the reflector in the geologic section is greater than in the time section.
2. 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
3. When migration is applied in case of the undulating, reflector the crests become narrower and troughs become broad.

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.

1) Pre-Stack Migration.
2) Post-Stack Migration

INTERPRETATION

6.1 Introduction

To create a subsurface model on an area and estimate about its hydrocarbon potential, it is necessary that a number of seismic lines should be provided besides having a good grip our the geology of the area it is very difficult to construct a useful subsurface geological model with the help of single line. However, the interpretation that was possible with the available data has been done in this dissertation.
The interpretation of reflection data involves its expression in geologic terms. It is quite different from both seismic data acquisition and data processing. There is experience required to be effective in both these areas. However, standard interpretation techniques are almost more of an art than a science. When carefully carried out, it requires the fitting together of all pertinent geological and geophysical information into an integrated picture that is more complete and more reliable than either source is likely to give alone. Ideally, this integration would be accomplished most efficiently if a single person highly competent both in geophysics and in geology did it. In actual practice, individuals with adequate training and experienced in both fields are very few and it is usually necessary for a geophysicist and a geologist to collaborate at this stage of the interpretation.

Geophysicist deals with the seismic section. In seismic methods physical measurements are made at the surface, which are then interpreted in terms of what might be in the subsurface. The position and behavior of the interfaces, which gives rise to each reflection event is then calculated from arrival times. Resulting information is then combined into cross section, which represents the structure of geologic interfaces responsible for the reflection events.

Coordination of geological information with the reflection data is two-way process. Using geological data, the geophysicist can generally decrease the number of unknowns with which he must work and thus should have a better chance of arriving at a unique solution of those that remain.

According to Dobrin and Savit, interpretation is the transformation of the seismic reflection data into a structural picture by the application of corrections, migration and time depth conversion.

The seismic reflection interpretation usually consists of calculating the positions of, and identifying geologically, concealed interfaces or sharp transition zones from seismic pulses returned to the ground surface by reflection. The influence of varying geological conditions is eliminated along the profiles to transform the irregular recorded travel times into acceptable subsurface models.

According to badley 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.

Reflection arises at boundaries across which acoustic impedance changes. No reflection occurs if the acoustic impedance does not change, even if the lithology changes. The greater the difference in the acoustic impedance is, the stringer the reflection. The size of change is defined by the reflection coefficient.

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 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 features that are not marked by the sharp boundaries

A sequence of sedimentary rocks is grouped into units called formations. These formations can be described in terms of age, thickness and lithology of the consistent layers. To distinguish different formations by means of seismic reflection is an important question in interpretation of data, which may be structural, lithological, or stratigraphic.

There are two main approaches to the interpretation of the seismic sections:

- Structural Analysis
- Stratigraphic Analysis

6.1.1 Structural Analysis

It is the study of reflector geometry on the basis of reflection time. The main application of the structural analysis of seismic section is in the search for structural traps containing hydrocarbons. Most structural interpretation use two-way reflection times rather depth and time structural maps are constructed to display the geometry of selected reflection events. Some seismic sections contain images that can be interpreted without difficulty. Discontinuous reflections clearly indicate faults and undulating reflections reveal folded beds.
According to badley the cross section is representative of the structure being studied. Much structural information is based on the interpatation of seismic section .Usually it is difficult to make a certain structural interpatation on the basis of only one seismic section. Grids of seismic data are required to determine the 3-D geometry
In structural analysis the main objective is to search out structural traps containing hydrocarbons .In such analysis interpretation usually take place against background

of continuing exploration activity and associated increase in amount of information referred to subsurface geology. The most common structural features associated with the Oil are anticlines and faults.

Faults are mainly of three types
Normal faults
Reverse faults
Thrust faults
Normal faults are the faults in which hanging wall has gone down with respect to the footwall, or these may be defined as the faults in which die area is gained while movement of the hanging wall and footwall. So it is believed that mainly the tensile forces are responsible for the normal faults.
A reverse faults is a dip-slip fault, either high or low angle, on which the hanging wall has moved up relatives to the footwall. Low angle reverse faults are commonly termed thrust and the term reverse fault is used only for high angle faults (Badly, 1990).
Thrust develop only under a compression stress system and to develop to require high pore pressure beneath the thrust plane ,.the complex array or structure commonly associated with a thrust ,although observe in out crop are difficult to see in the seismic section (Badley,1990).

6.1.2 Stratigraphic Analysis

Seismic stratigraphy is used to find out depositional processes and environmental settings, because genetically related sedimentary sequences normally consist of concordant strata that show discordance with sequence above and below it. It also helps to identify formations, stratigraphic traps and unconformity.
The success of the seismic reflection method in finding Stratagraphic type varies with the type of trap involved most such entrapment features are reef, unconformity, disconformity's, pinch-outs.

6.2 Interpretation Of Given Data

Given seismic section is compiled from CDP stacked traces that have been migrated and deconvolved to remove false images that are artifacts of processing. This seismic section displays reflection arrival times. A variation along a profile is called Time Scanning.

6.2.1 Reflector Selection

It is better to select the reflection, which is real and shows good character and continuity and can be followed throughout the area, (Badley, 1985) and on this basis the reflectors are marked as **R1, R2, R3, R4, R5, R6, R7, R8,R9** and **R10** in the given seismic section.

6.2.2 Velocity Variations

Velocity variation is basically concerned with the information of the velocities given in the upper part of the seismic section. In the velocity windows of the given seismic section, the RMS velocities with respect to time are given. With the help of RMS velocities we are able to calculate the Interval velocities.

VEL WINDOW KBR-28-8 AT SP 430

time	vrms	vint	vave
0	1500	1500	1500
600	1800	1800	1800
860	2050	2534.493	2022.056
1260	2200	2492.113	2171.28
1380	2400	3926.831	2323.937
1500	2500	3447.463	2413.819
1700	2600	3253.46	2512.6
1830	2675	3511.294	2583.546
2380	2900	3547.344	2806.272
2770	3100	4114.982	2990.531
3375	3350	4313.392	3227.666
4600	3800	4827.478	3653.703
6000	4400	5960.345	4191.919

VEL WINDOW KBR-28-9 AT SP 480

time	vrms	vint	vave
0	1500	1500	1500
730	1900	1900	1900
930	2000	2328.841	1992.224
1275	2200	2665.398	2174.377
1460	2400	3478.583	2339.636
1565	2500	3614.323	2425.158
1840	2650	3379.161	2567.74
2150	2900	4079.888	2785.771
2400	3050	4120.437	2924.798
2990	3300	4165.048	3169.53
3875	3500	4104.242	3383.006
6000	4400	5685.534	4198.485

VEL WINDOW KBR-28-10 AT SP 520

time	vrms	vint	vave
0	1500	1500	1500
800	1900	1900	1900
1280	2100	2396.525	2086.197
1400	2375	4332.123	2278.705
1720	2500	2985.97	2410.289
1975	2750	4051.597	2622.205
2300	2950	3953.504	2810.323
2600	3200	4693.346	3027.595
4300	3600	4137.632	3466.447
6000	4400	5962.234	4173.587

VEL WINDOW KBR-28-11 AT SP 565

time	vrms	vint	vave
0	1500	1500	1500
870	2000	2000	2000
1130	2200	2766.002	2176.248
1240	2300	3148.448	2262.492
1420	2400	2999.63	2355.932
1730	2500	2914.535	2456.028
1975	2700	3825.398	2625.9
2430	2900	3643.012	2816.347
2840	3100	4089.278	3000.115
6000	4400	5303.08	4213.01

VEL WINDOW KBR-28-12 AT SP 610

time	vrms	vint	vave
0	1500	1500	1500
760	1900	1900	1900

VEL WINDOW KBR-28-13 AT SP 655

time	vrms	vint	vave
0	1500	1500	1500
800	2000	2000	2000

1085	2100	2506.146	2081.565	1240	2200	2523.346	2185.703
1240	2200	2801.785	2171.592	1440	2500	3871.95	2419.904
1750	2600	3380.567	2523.922	1630	2700	3895.139	2591.864
1990	2800	3964.215	2697.626	2375	3000	3569.502	2898.534
2440	3100	4175.803	2970.24	3730	3500	4236.33	3384.516
2850	3250	4028.776	3122.521	6000	4400	5571.62	4211.97
4120	3600	4282.548	3480.102				
6000	4400	5778.021	4200.117				

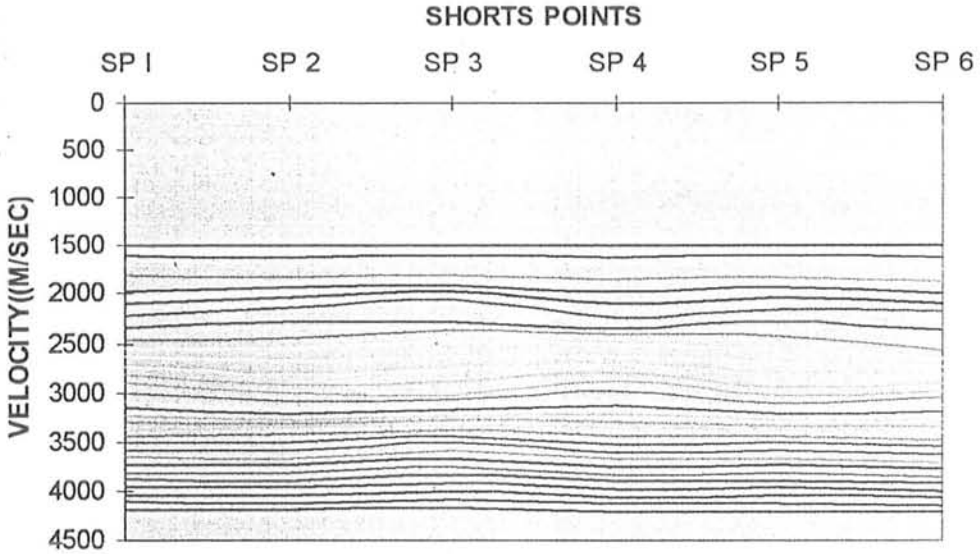
Iso velocity graph

With the help of velocity information, the velocity contours are drawn which show both the vertical and lateral variations in the velocities. The vertical variation is mainly due to the formational changes, overburden pressure and age factor etc, however lateral variations in velocities may be due to folding and dipping of stratThe graph, which shows the velocity contours, is called the "Isovelocity Map".

DATA FOR ISO VELOCITY GRAPH

SP I	*SP 2*	*SP 3*	*SP 4*	*SP 5*	*SP 6*
1500	1500	1500	1500	1500	1500
1600	1609.589	1600	1614.943	1605.263	1625
1700	1719.178	1700	1729.885	1710.526	1750
1800	1828.767	1800	1844.828	1815.789	1875
1970.812	1932.278	1900	1959.77	1922.346	2000
2103.332	2029.182	1977.582	2088.124	2034.078	2084.411
2219.44	2134.778	2055.164	2231.131	2148.359	2168.821
2338.917	2286.038	2278.705	2345.55	2282.127	2373.064
2463.21	2443.305	2360.945	2414.052	2420.296	2564.713
2555.787	2547.001	2476.772	2504.563	2560.11	2661.936
2642.161	2680.272	2636.675	2636.364	2703.684	2744.374
2728.535	2813.576	2752.441	2720.077	2824.846	2826.812
2815.721	2924.798	2882.747	2803.79	2946.008	2907.852
2910.213	3007.758	3027.595	2892.543	3029.667	2979.531
3002.29	3090.718	3079.225	2982.186	3103.95	3051.209
3080.681	3171.942	3130.854	3061.527	3164.755	3122.888
3159.073	3220.185	3182.484	3138.293	3221.067	3194.567
3236.361	3268.429	3234.114	3215.058	3277.379	3236.246
3305.918	3316.672	3285.743	3291.824	3333.691	3337.925
3375.475	3364.915	3337.373	3368.589	3390.003	3410.032
3445.032	3430.975	3389.003	3445.355	3446.315	3482.936
3514.589	3507.726	3440.632	3522.12	3510.741	3555.839
3584.146	3584.477	3508.043	3598.886	3587.338	3628.743
3653.703	3661.228	3591.236	3675.651	3663.936	3701.646
3730.591	3737.979	3674.429	3752.417	3740.533	3774.55
3807.479	3814.73	3757.622	3829.182	3817.13	3847.453
3884.367	3891.481	3840.815	3905.948	3893.728	3920.357
3961.255	3968.232	3924.008	3982.713	3970.325	3993.26

4038.143	4044.983	4007.201	4059.479	4046.922	4066.163
4115.031	4121.734	4090.394	4136.244	4123.52	4139.067
4191.919	4198.485	4173.587	4213.01	4200.117	4211.97



ISO VELOCITY GRAPH

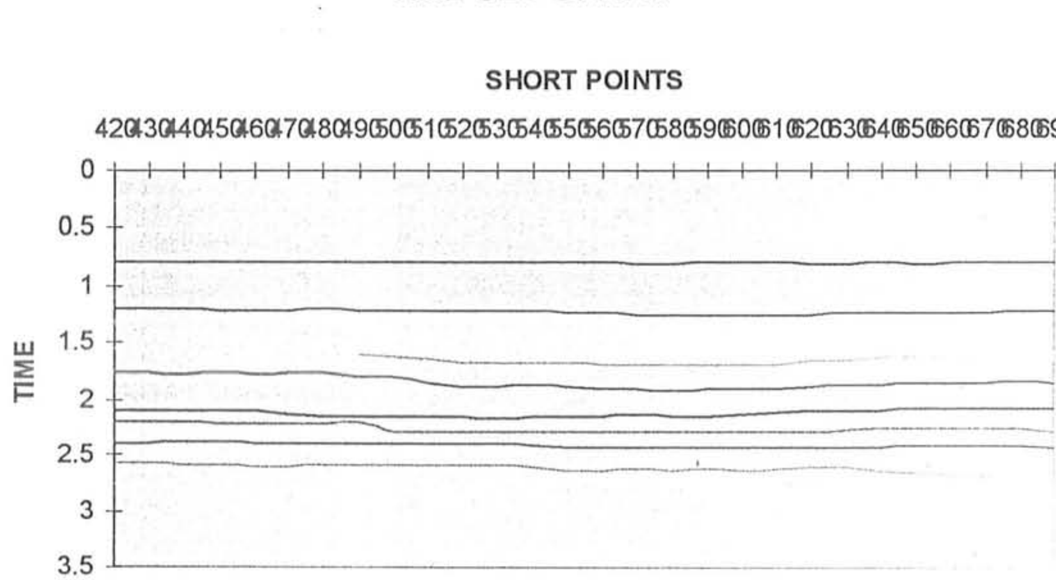
6.3 Time Section

Time Section is actually the reproduction of seismic section. The time section actually consists of two scales. One is horizontal scale, which consists of "Shot Points" while the vertical scale consists of "time". The reflectors in the given time section are marked on the basis of dominant reflection-coefficients. The time for each reflector is read from the seismic section and the times of marked reflectors prepared the time section.

DATA FOR TIME SECTION

SPs	R1	R2	R3	R4	R5	R6	R7	R8	R9
420	0.8	1.2	1.55		1.75	2.1	2.2	2.39	2.56
430	0.8	1.2	1.55		1.76	2.1	2.2	2.39	2.56
440	0.8	1.2	1.55-		1.77	2.1	2.2	2.38	2.58
450	0.8	1.21	1.55		1.75	2.1	2.22	2.38	2.58
460	0.8	1.21	1.56		1.78	2.1	2.22	2.39	2.6
470	0.8	1.22	1.55		1.75	2.13	2.22	2.39	2.6
480	0.8	1.2	1.56		1.75	2.14	2.21	2.4	2.59
490	0.8	1.22	1.58	1.6	1.79	2.14	2.2	2.4	2.58
500	0.8	1.21	1.58	1.62	1.8	2.15	2.28	2.4	2.58
510	0.8	1.21	1.6	1.63	1.85	2.15	2.28	2.39	2.58
520	0.8	1.21	1.61	1.67	1.88	2.15	2.29	2.4	2.59
530	0.8	1.21	1.61	1.67	1.88	2.17	2.29	2.4	2.59

540	0.8	1.22	1.6	1.67	1.86	2.14	2.28	2.41	2.
550	0.8	1.23	1.61	1.67	1.88	2.14	2.28	2.42	2.6
560	0.8	1.23	1.62	1.68	1.9	2.14	2.28	2.42	2.6
570	0.81	1.25	1.62	1.68	1.9	2.13	2.28	2.42	2.6
580	0.81	1.25	1.64	1.69	1.91	2.15	2.28	2.42	2.6
590	0.8	1.25	1.64	1.68	1.9	2.15	2.28	2.42	2.6
600	0.8	1.25	1.64	1.68	1.9	2.13	2.28	2.42	2.6
610	0.8	1.24	1.63	1.68	1.9	2.11	2.28	2.42	2.6
620	0.81	1.24	1.63	1.66	1.88	2.1	2.28	2.42	2.61
630	0.81	1.23	1.6	1.66	1.86	2.1	2.27	2.42	2.61
640	0.8	1.23	1.59	1.62	1.86	2.1	2.25	2.42	2.6
650	0.81	1.23	1.57	1.62	1.85	2.08	2.26	2.41	2.64
660	0.8	1.23	1.57	1.61	1.84	2.08	2.25	2.41	2.67
670	0.8	1.23	1.58	1.61	1.85	2.08	2.25	2.41	2.6
680	0.8	1.22	1.57	1.63	1.83	2.08	2.25	2.41	2.6
690	0.8	1.22	1.57	1.63	1.85	2.08	2.28	2.42	2.7



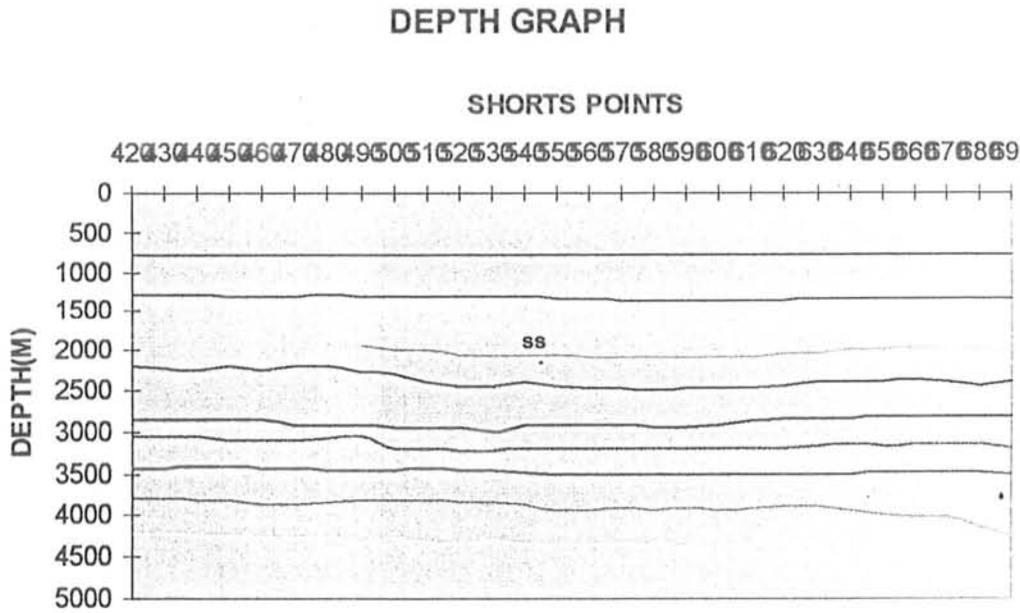
6.4 Depth Section

Generally the depth section gives the configuration of reflectors in the same way as it is in the Time Section. To determine the depth, the first step is to read times of each reflector from seismic section. Using the appropriate velocity values and time, the depth of each reflector is calculated by the formulae i.e.

Depth = V * T/2
Where:
V = the velocity of respective reflector (m/sec).
T = Two way travel time of each reflector (sec).

DATA FOR DEPTH SECTION

SPs	Depth R1	Depth R2	Depth R3	Depth R4	Depth R5	Depth R6	Depth R7	Depth R8	D R
420	779.014	1295.77	1872.266		2205.822	2862.753	3055.487	3435.538	3
430	779.014	1295.77	1872.266		2223.722	2862.753	3055.487	3435.538	3
440	779.014	1295.77	1872.266		2241.683	2862.753	3055.487	3414.944	3
450	779.014	1309.878	1872.266		2205.822	2862.753	3094.376	3414.944	3
460	779.014	1309.878	1889.075		2259.704	2862.753	3094.376	3435.538	3
470	779.014	1324.042	1872.266		2205.822	2920.426	3094.376	3435.538	3
480	779.014	1295.77	1889.075		2205.822	2939.755	3074.906	3456.184	3
490	779.014	1324.042	1922.29	1955.536	2277.785	2939.755	3055.487	3456.184	3
500	779.014	1309.878	1922.29	1989.004	2295.925	2959.137	3212.246	3456.184	3
510	779.014	1309.878	1955.536	2005.823	2387.819	2959.137	3212.246	3435.538	3
520	779.014	1309.878	1972.243	2070.908	2444.379	2959.137	3232.066	3456.184	3
530	779.014	1309.878	1972.243	2070.908	2444.379	2997.527	3232.066	3456.184	3
540	779.014	1324.042	1955.536	2070.908	2406.609	2939.756	3212.246	3476.597	3
550	779.014	1338.26	1972.243	2070.908	2444.379	2939.756	3212.246	3498.874	3
560	779.014	1338.26	1989.004	2087.298	2482.402	2939.756	3212.246	3498.874	3
570	790.9508	1367.479	1989.004	2087.298	2482.402	2920.426	3212.246	3498.874	3
580	790.9508	1367.479	2022.022	2103.735	2501.509	2959.137	3212.246	3498.874	3
590	779.014	1367.479	2022.022	2087.298	2482.402	2959.138	3212.246	3498.874	3
600	779.014	1367.479	2022.022	2087.298	2482.402	2920.426	3212.246	3498.874	3
610	779.014	1352.532	2005.823	2087.298	2482.402	2881.925	3212.246	3498.874	3
620	790.9508	1352.532	2005.823	2054.565	2444.379	2862.754	3212.246	3498.874	3
630	790.9508	1338.26	1955.536	2054.565	2406.609	2862.754	3192.476	3498.874	3
640	779.014	1338.26	1938.885	1989.004	2406.609	2862.754	3153.086	3498.874	3
650	790.9508	1338.26	1905.751	1989.004	2387.816	2824.567	3172.755	3476.597	3
660	779.014	1338.26	1905.751	1972.243	2369.092	2824.567	3153.086	3476.597	
670	779.014	1338.26	1922.29	1972.243	2387.816	2824.567	3153.086	3476.597	4
680	779.014	1327.38	1905.751	2005.823	2442.21	2824.567	3153.086	3476.597	4
690	779.014	1327.38	1905.751	2005.823	2387.819	2824.567	3212.246	3498.874	4



6.5 Method Used To Prepare the Depth Section

Depth of each reflector in given seismic section is calculated

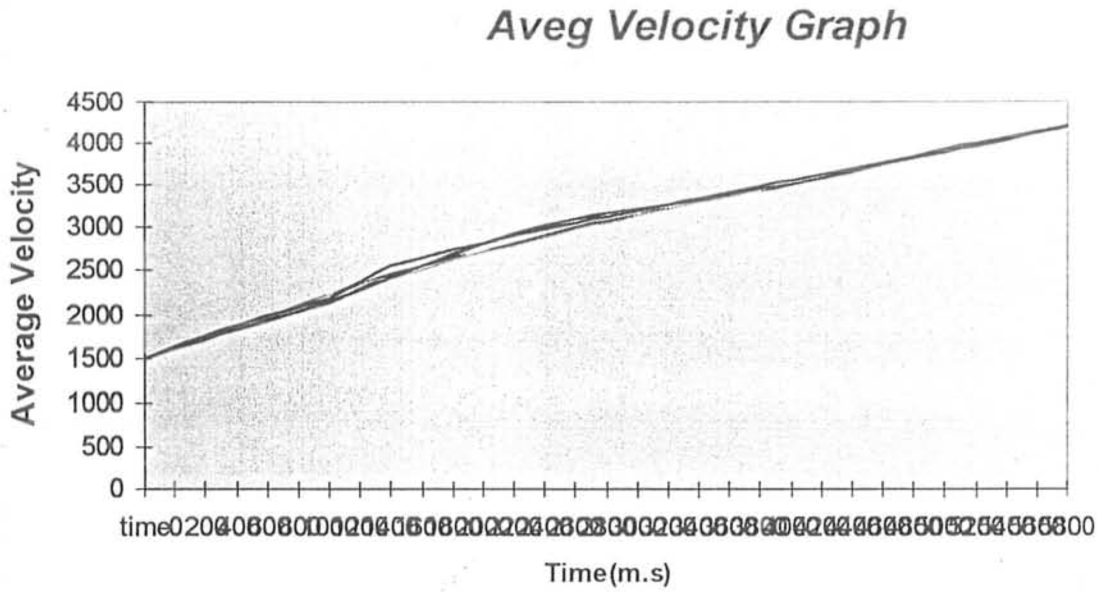
- By Using Mean Line Of Average Velocities
- By Iso Velocity contour Map
- **CONCLUSIONS.**
  From the time section and depth section it is interpreted that R4 pinch out into the R3 and depressions are present in reflectors R5 R6 and R7.

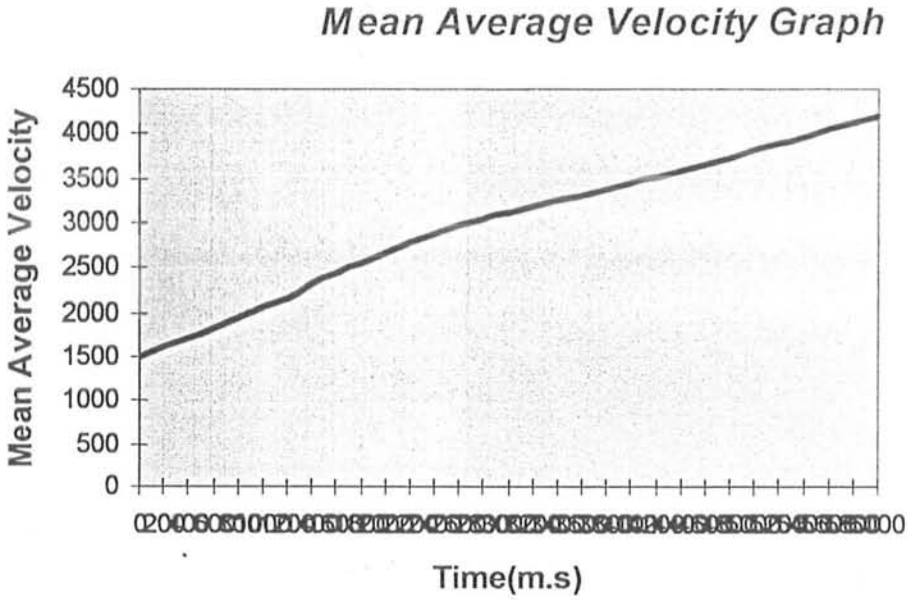
6.6.1 Average Velocities

This method employs the plotting of mean average velocity line by averaging all the average velocity-VS-time plot of each CDP window. This average velocity line is then used for the estimation of velocities under each shot point at their respective times corresponding to each particular reflector. These velocities are used in the depth estimation by putting them in the depth formula and then plotting depth of reflectors under their respective shot points generates the depth section. Data used in depth calculation for each reflector

time	*SP I*	*SP 2*	*SP 3*	*SP 4*	*SP 5*	*SP 6*
0	1500	1500	1500	1500	1500	1500
200	1600	1609.589	1600	1614.943	1605.263	1625

400	1700	1719.178	1700	1729.885	1710.526	1750
600	1800	1828.767	1800	1844.828	1815.789	1875
800	1970.812	1932.278	1900	1959.77	1922.346	2000
1000	2103.332	2029.182	1977.582	2088.124	2034.078	2084.411
1200	2219.44	2134.778	2055.164	2231.131	2148.359	2168.821
1400	2338.917	2286.038	2278.705	2345.55	2282.127	2373.064
1600	2463.21	2443.305	2360.945	2414.052	2420.296	2564.713
1800	2555.787	2547.001	2476.772	2504.563	2560.11	2661.936
2000	2642.161	2680.272	2636.675	2636.364	2703.684	2744.374
2200	2728.535	2813.576	2752.441	2720.077	2824.846	2826.812
2400	2815.721	2924.798	2882.747	2803.79	2946.008	2907.852
2600	2910.213	3007.758	3027.595	2892.543	3029.667	2979.531
2800	3002.29	3090.718	3079.225	2982.186	3103.95	3051.209
3000	3080.681	3171.942	3130.854	3061.527	3164.755	3122.888
3200	3159.073	3220.185	3182.484	3138.293	3221.067	3194.567
3400	3236.361	3268.429	3234.114	3215.058	3277.379	3266.246
3600	3305.918	3316.672	3285.743	3291.824	3333.691	3337.925
3800	3375.475	3364.915	3337.373	3368.589	3390.003	3410.032
4000	3445.032	3430.975	3389.003	3445.355	3446.315	3482.936
4200	3514.589	3507.726	3440.632	3522.12	3510.741	3555.839
4400	3584.146	3584.477	3508.043	3598.886	3587.338	3628.743
4600	3653.703	3661.228	3591.236	3675.651	3663.936	3701.646
4800	3730.591	3737.979	3674.429	3752.417	3740.533	3774.55
5000	3807.479	3814.73	3757.622	3829.182	3817.13	3847.453
5200	3884.367	3891.481	3840.815	3905.948	3893.728	3920.357
5400	3961.255	3968.232	3924.008	3982.713	3970.325	3993.26
5600	4038.143	4044.983	4007.201	4059.479	4046.922	4066.163
5800	4115.031	4121.734	4090.394	4136.244	4123.52	4139.067
6000	4191.919	4198.485	4173.587	4213.01	4200.117	4211.97





6.6 Comparison of Depths of Reflectors

REFLECTOR 1:

For R1 we get maximum depth 790.9508m at shot point 570 and minimum depth 779.014m at Shot Point420.

REFLECTOR 2:

For R2 we get minimum depth 1295.77m at shot point 420 and maximum depth 1367.449m at shot point570.

REFLECTOR 3:

For R3 we get minimum depth 1872.266m at ot point 420 and aximum depth2022.022m at shot point 580.

REFLECTOR 4:

For R4 we get minimum depth 1955.536 at shot point 490 and maximum depth 2103.735 at shot point 580.

REFLECTOR 5:

For R5 we get minimum depth 2205.822at shot point 420 and maximum depth 2501.509 at shot point 580.

REFLECTOR 6:

For R6 we get minimum depth 2824.567 at shot point 650 and maximum depth at 2997.527 at shot point 530.

REFLECTOR 7:

For R7 we get minimum depth 3055.487 shot point 420 and maximum depth 3232.066 at shot point 520.

REFLECTOR 8:

For R8 we get minimum depth 3414.944 at shot point 440 and maximum depth 3498.874 at shot point 550.

REFLECTOR 9:

For R9 we get minimum depth 3783.621m at shot point 420 and maximum depth 4231.327mat shot point 690.

Basement

we get minimum depth 4210.929m at shot point 420 and maximum depth 4477m at shot point 680.

ROCK PHYSICS

6.7 Castagna's Relationship

The most common method of shear velocity prediction is defined by Castagna et al. (1985). They derived an empirical relationship between P-Wave and S-Wave velocity, which can be written as;

$$Vp(Km/Sec)=1.16Vs+1.36$$

The parameter of the linear relationship between Vp and Vs were derived from worldwide data. This empirical relationship became known as mudrock equation or the " ARCO mudrock line". If regional shear- wave velocity is available, a local mudrock relationship can be derived.

(Castagna et al. 1985)

6.8 P-Wave Impedence

P-Wave impedence is calculated by the formula using P-wave velocity and density at regular intervals of depth. The unit of impedence is RAYLE.

$$1\,\text{Rayle} = \rho V$$

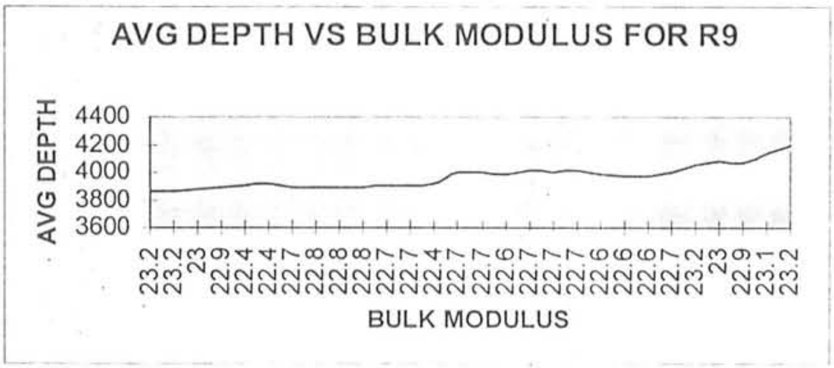
6.9 Calculation Of Bulk Modulus :(K)

Bulk modulus can be calculated using the equation,

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

Where 'k' is the compressibility coefficient.

Graph of Bulk Modulus vs depth.



(Lars Gommesen , 2003)

6.10 Shear Modulus (μ):

Shear Modulus can be calculated by density and velocity of shear wave.`

It is also called as rigidity modulus.

(Dobrin, 1976)

For liquids and gases, shear modulus (μ) =0

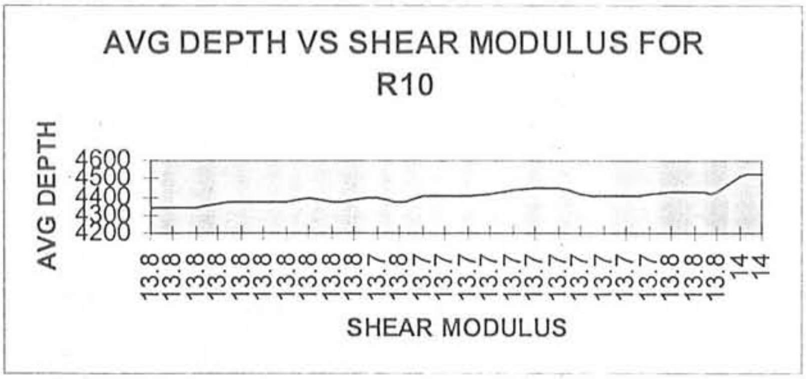
(Robinson &Coruh, 1988)

The shear modulus for the thesis work is calculated by using the formula

$$\mu=\rho\,(V_s)^2$$

(Lars Gommesen , 2003)

Graph of Shear Modulus vs depth.

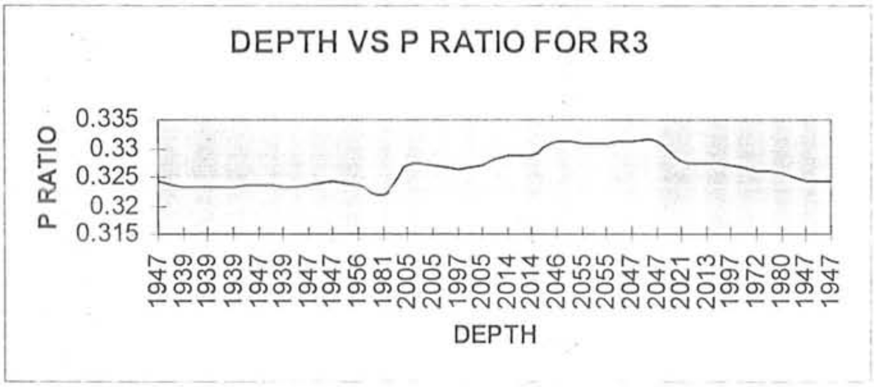


6.11 Poisson's Ratio (σ)

For the dissertation the Poisson's ratio is calculated by using the formula

$$V=1/2(Vp^2-2Vs^2)/(Vp^2+2Vs^2)$$

(Lars Gommesen, 2003)



6.12 Lame's Constant (λ)

The values for the Lame's Constant at regular depth are calculated by using the relation,

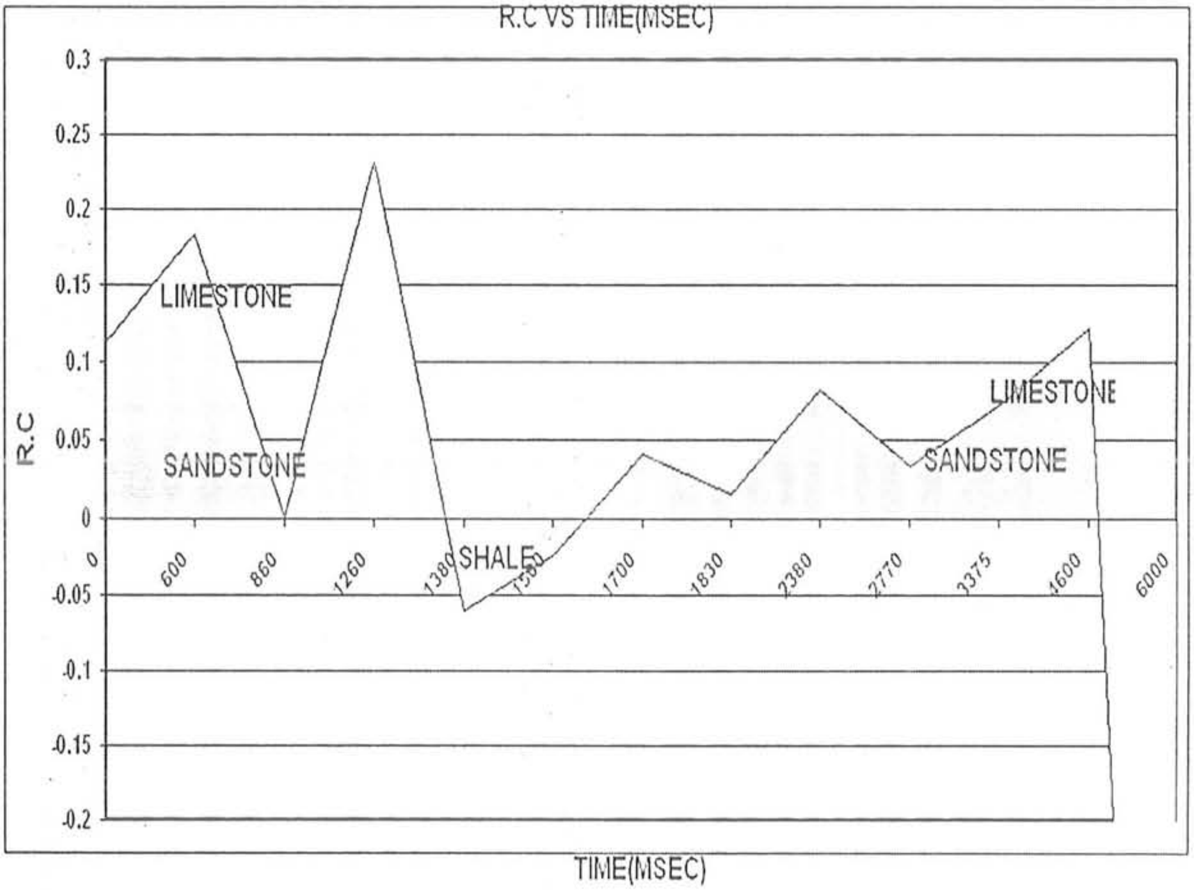
$$\alpha^2=\lambda+2\mu/\rho$$

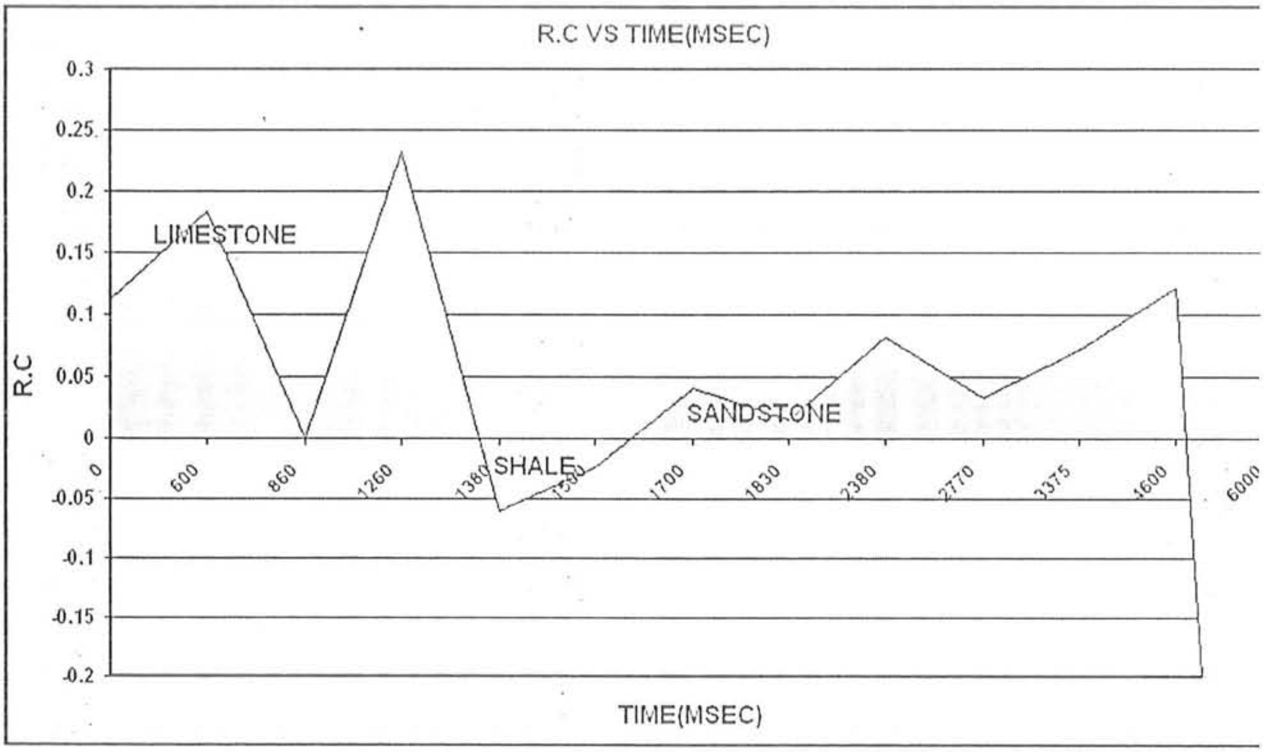
(Lars Gommesen, 2003)

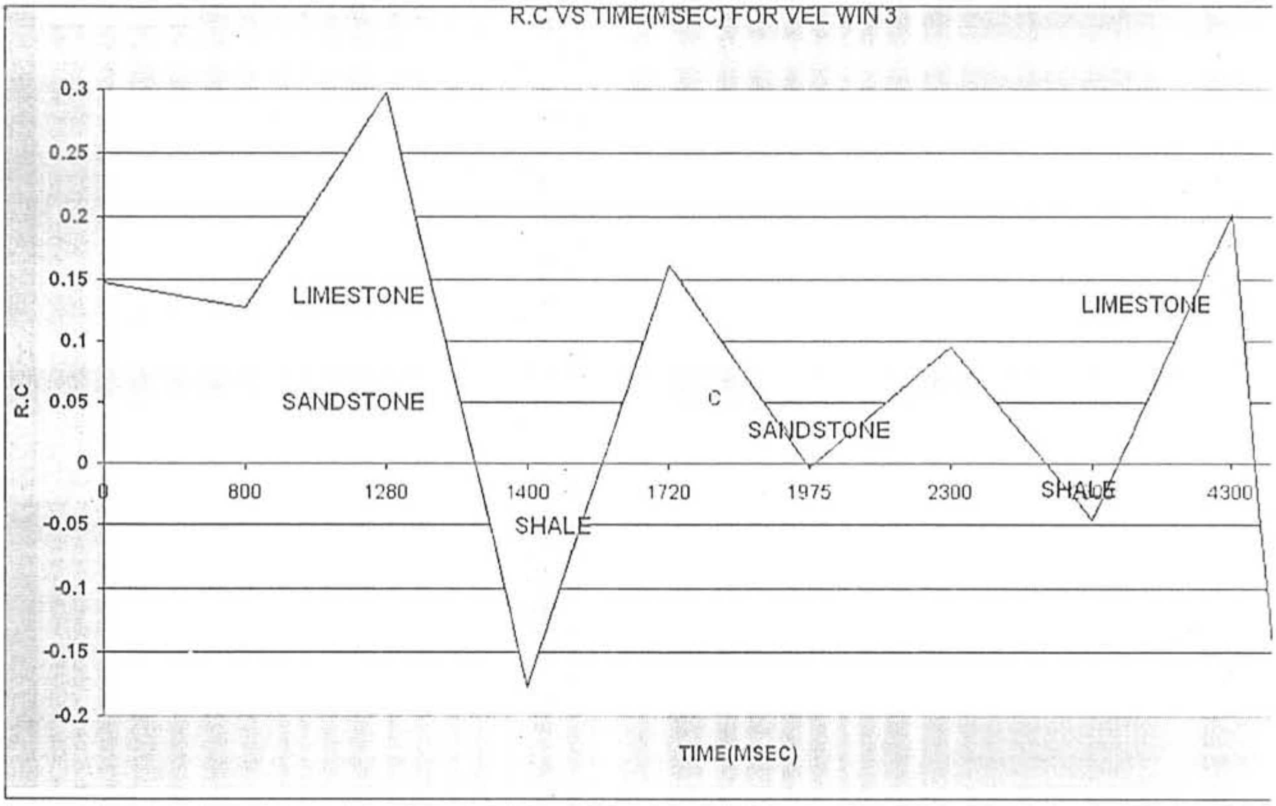
6.13Reflection Coefficient.

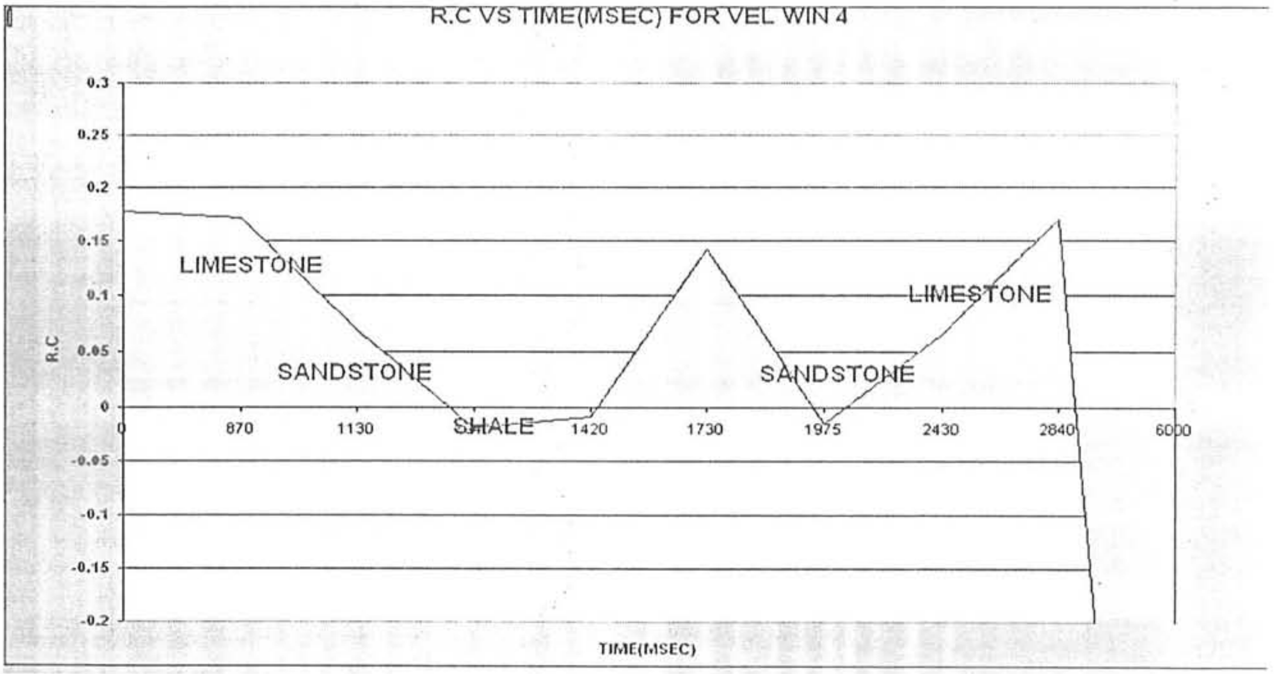
By Reflection Coefficient the lithology of formations can be interpreted by using the equation from vilocity windows by calculating the interval velocity and density

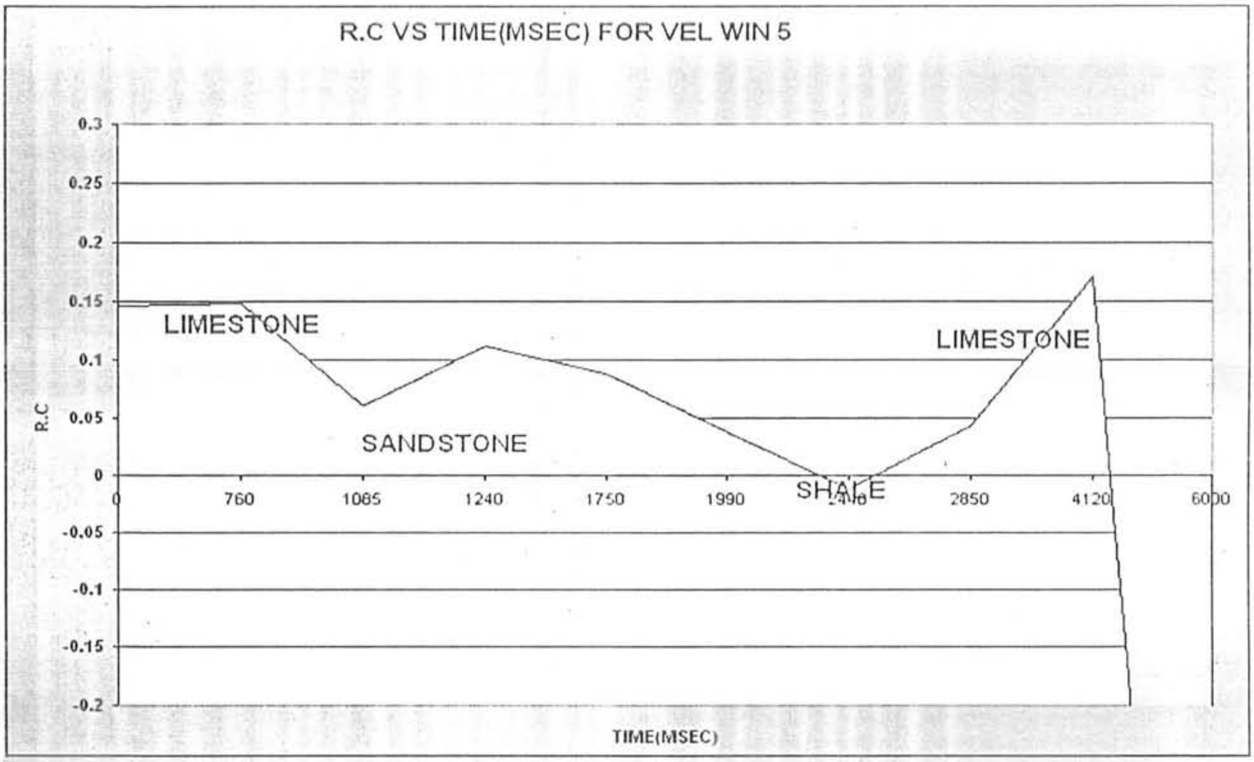
$$R.Coefficient=(\rho 2v2-\rho 1v1/\rho 2v2+\rho 1v1)$$

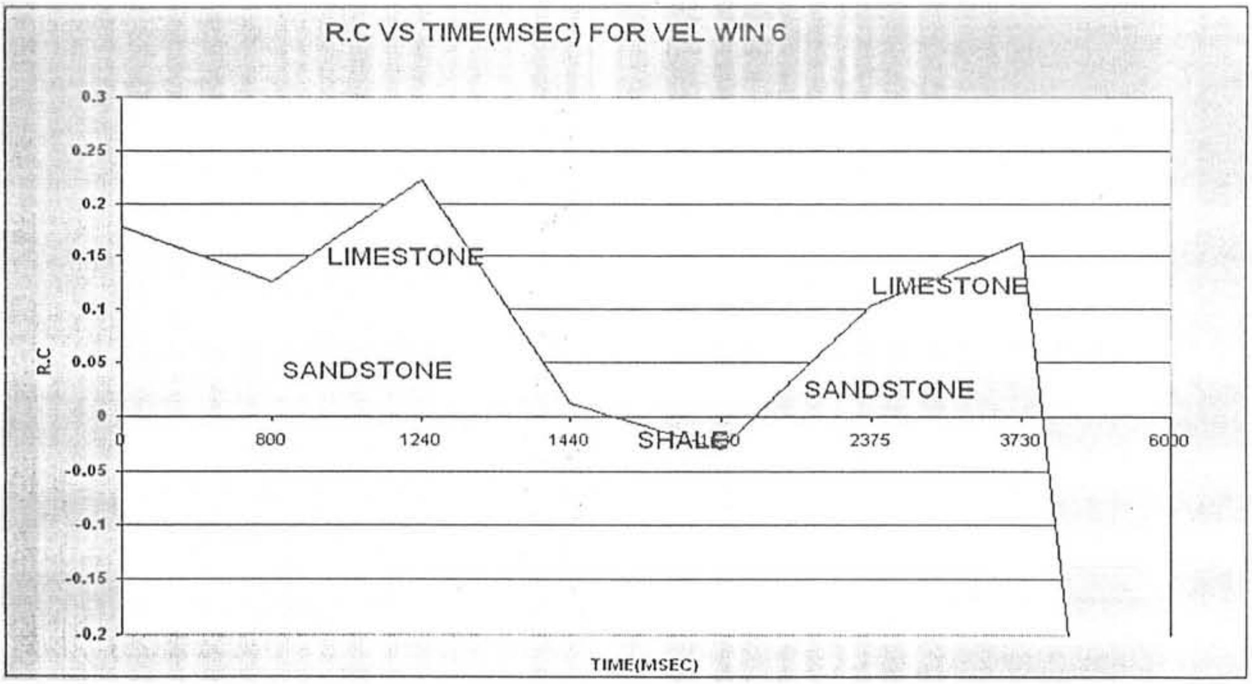



R.C VS TIME(MSEC)
R.C
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
600
860
1260
1380
1500
1700
1830
2380
2770
3375
4600
6000
LIMESTONE
SHALE
SANDSTONE
TIME(MSEC)


R.C VS TIME(MSEC) FOR VEL WIN 3
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
R.C
0
800
1280
1400
1720
1975
2300
4300
LIMESTONE
SANDSTONE
SHALE
C
SANDSTONE
SHALE
LIMESTONE
TIME(MSEC)


R.C VS TIME(MSEC) FOR VEL WIN 4
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
R.C
0
870
1130
1420
1730
1975
2430
2840
6000
LIMESTONE
SANDSTONE
SHALE
SANDSTONE
LIMESTONE
TIME(MSEC)


R.C VS TIME(MSEC) FOR VEL WIN 5
R.C
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
760
1085
1240
1750
1990
2850
4120
6000
TIME(MSEC)
LIMESTONE
SANDSTONE
SHALE
LIMESTONE


R.C VS TIME(MSEC) FOR VEL WIN 6
R.C
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
800
1240
1440
2375
3730
6000
TIME(MSEC)
LIMESTONE
SANDSTONE
SHALE
LIMESTONE
SANDSTONE

6.14 CONCLUSION

1.The Seismic Section shoes the 5.4km thick sedimentary cover. Also basement has been discovered
2.Reflector R4 pinch out in R3.
3.All reflectors are approximately horizontal.Some reflectors show small depression.
4. R10 is basement.

REFERENCES:

- "AAPG Bulletin", v 84, No 11 (Nov 2000). Pp.1833.
- Al-Sadi H.N. (1980), "Seismic Exploration Technique And Processing", Birkhauser Verlag, Boston.
- Badley M.E. (1985), Practical Seismic Interpretation". International Human Resources,
  Development Corporation, Boston.
- Dobrin M.B & Savit C.H. (1976), "Introduction To Geophysical Prospecting", 4th Edition, Megraw-Hill Book Company.
- Grant F.S. & West G.F. (1965), "Interpretation Theory In Applied Geophysics",
  McGraw-Hill Book Company.
- Roice Nelson. Jr. (1983). "New Technologies In Exploration Geophysics"Gulf
  Publishing Company, Houston.

- Kazmi, A.H. & Jan, M.Q. (1997). "Geology & Tectonics Of Pakistan", Graphic Publishers, Karachi, Pakistan.
- "PAPG-SPE Annual Technical Conference Nov 2002 (Special Publication)", Pp147-155.
- Robinson E.S., Coruh C. (1988), "Basic Exploration Geophysics", John Wiley & Sons,Inc. New York.
- Sheriff, R.E., (1973), "Encyclopedia Dictionary Of Exploration Geophysics", Society of Exploration Geophysicists, Tulsa, Oklahoma.
- Telford, W.M., Geldart, L.P., Sheriff, R.E & Keys, D.A. (1990), "Applied Geophysics", Cambridge University Press, London.
- Yilmaz, O., (1987) "Seismic Data Processing", Tulsa, USA.

DATA FOR ROCK PHYSICS

R1

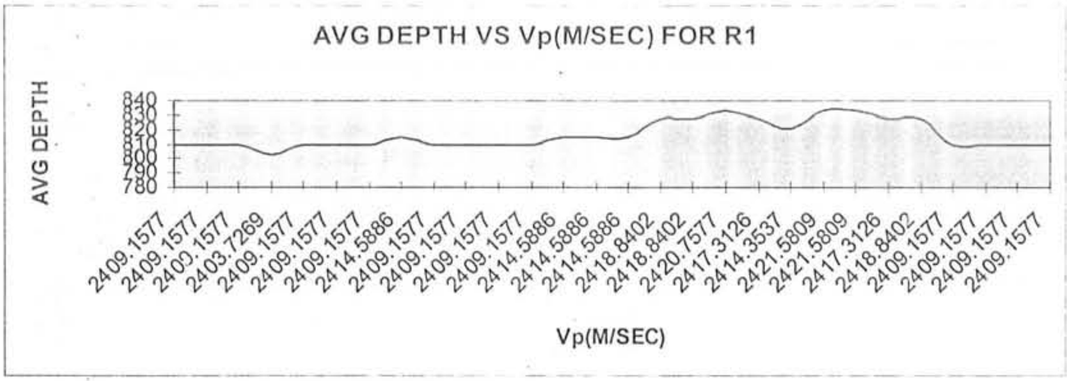
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)	D.Depth(m)
420	0.8	1947.535	779.0138	0.85	1974.689	839.2428
430	0.8	1947.535	779.0138	0.85	1974.689	839.2428
440	0.8	1947.535	779.0138	0.85	1974.689	839.2428
450	0.8	1947.535	779.0138	0.84	1969.258	827.0883
460	0.8	1947.535	779.0138	0.85	1974.689	839.2428
470	0.8	1947.535	779.0138	0.85	1974.689	839.2428
480	0.8	1947.535	779.0138	0.85	1974.689	839.2428
490	0.8	1947.535	779.0138	0.86	1980.12	851.4515
500	0.8	1947.535	779.0138	0.85	1974.689	839.2428
510	0.8	1947.535	779.0138	0.85	1974.689	839.2428
520	0.8	1947.535	779.0138	0.85	1974.689	839.2428
530	0.8	1947.535	779.0138	0.85	1974.689	839.2428
540	0.8	1947.535	779.0138	0.86	1980.12	851.4515
550	0.8	1947.535	779.0138	0.86	1980.12	851.4515
560	0.8	1947.535	779.0138	0.86	1980.12	851.4515
570	0.81	1952.965	790.951	0.87	1985.095	863.5162
580	0.81	1952.965	790.951	0.87	1985.095	863.5162
590	0.8	1947.535	779.0138	0.89	1995.389	887.9479
600	0.8	1947.535	779.0138	0.88	1990.242	875.7063
610	0.8	1947.535	779.0138	0.87	1985.095	863.5162
620	0.81	1952.965	790.951	0.88	1990.242	875.7063
630	0.81	1952.965	790.951	0.88	1990.242	875.7063
640	0.8	1947.535	779.0138	0.88	1990.242	875.7063

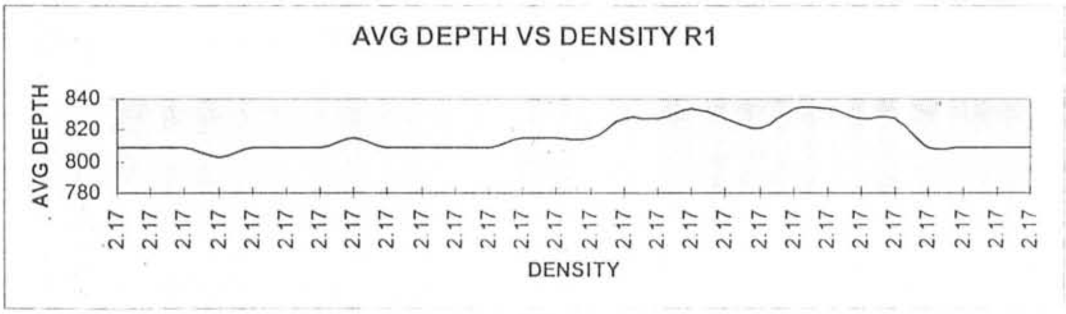
650	0.81	1952.965	790.951	0.87	1985.095	863.5162
660	0.8	1947.535	779.0138	0.85	1974.689	839.2428
670	0.8	1947.535	779.0138	0.85	1974.689	839.2428
680	0.8	1947.535	779.0138	0.85	1974.689	839.2428
690	0.8	1947.535	779.0138	0.85	1974.689	839.2428

AVG VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(Swav
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1958.396	2403.727	2.403727	2.170616	899.7645	0.899765	5.217568	1.9530
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1963.827	2414.589	2.414589	2.173064	909.1281	0.909128	5.247055	1.9755
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1963.827	2414.589	2.414589	2.173064	909.1281	0.909128	5.247055	1.9755
1963.827	2414.589	2.414589	2.173064	909.1281	0.909128	5.247055	1.9755
1963.827	2414.589	2.414589	2.173064	909.1281	0.909128	5.247055	1.9755
1969.03	2418.84	2.41884	2.17402	912.7933	0.912793	5.258606	1.9844
1969.03	2418.84	2.41884	2.17402	912.7933	0.912793	5.258606	1.9844
1971.462	2420.758	2.420758	2.17445	914.4463	0.914446	5.263818	1.9884
1968.888	2417.313	2.417313	2.173676	911.4764	0.911476	5.254455	1.9812
1966.315	2414.354	2.414354	2.173011	908.9256	0.908926	5.246417	1.9751
1971.604	2421.581	2.421581	2.174635	915.1559	0.915156	5.266055	1.990
1971.604	2421.581	2.421581	2.174635	915.1559	0.915156	5.266055	1.990
1968.888	2417.313	2.417313	2.173676	911.4764	0.911476	5.254455	1.9812
1969.03	2418.84	2.41884	2.17402	912.7933	0.912793	5.258606	1.9844
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643
1961.112	2409.158	2.409158	2.171841	904.4463	0.904446	5.232307	1.9643

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.418526	1.757279	10.19857	9.027049586
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212

0.41741	1.796067	10.27472	9.077344478
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.41741	1.796067	10.27472	9.077344478
0.41741	1.796067	10.27472	9.077344478
0.41741	1.796067	10.27472	9.077344478
0.416973	1.811375	10.30456	9.09697877
0.416973	1.811375	10.30456	9.09697877
0.416776	1.818302	10.31803	9.105824155
0.41713	1.805867	10.29384	9.089927417
0.417434	1.795224	10.27307	9.076258659
0.416691	1.82128	10.32381	9.10961964
0.416691	1.82128	10.32381	9.10961964
0.41713	1.805867	10.29384	9.089927417
0.416973	1.811375	10.30456	9.09697877
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212
0.417968	1.776616	10.23663	9.0522212





R2

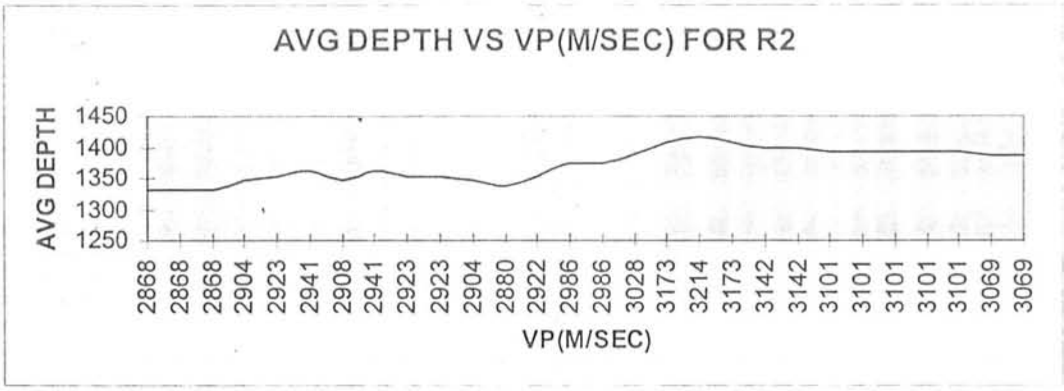
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)	D.Depth(m)

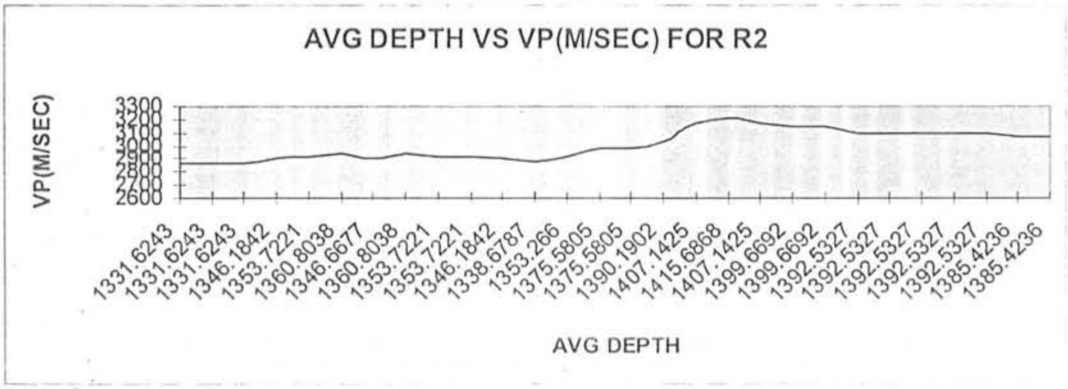
420	1.2	2159.616	1295.769	1.25	2187.967	1367.479
430	1.2	2159.616	1295.769	1.25	2187.967	1367.479
440	1.2	2159.616	1295.769	1.25	2187.967	1367.479
450	1.21	2165.088	1309.878	1.26	2194.429	1382.49
460	1.21	2165.088	1309.878	1.27	2200.891	1397.566
470	1.22	2170.56	1324.042	1.27	2200.891	1397.566
480	1.2	2159.616	1295.769	1.27	2200.891	1397.566
490	1.22	2170.56	1324.042	1.27	2200.891	1397.566
500	1.21	2165.088	1309.878	1.27	2200.891	1397.566
510	1.21	2165.088	1309.878	1.27	2200.891	1397.566
520	1.21	2165.088	1309.878	1.26	2194.429	1382.49
530	1.21	2165.088	1309.878	1.25	2187.967	1367.479
540	1.22	2170.56	1324.042	1.26	2194.429	1382.49
550	1.23	2176.032	1338.26	1.28	2207.658	1412.901
560	1.23	2176.032	1338.26	1.28	2207.658	1412.901
570	1.25	2187.967	1367.479	1.28	2207.658	1412.901
580	1.25	2187.967	1367.479	1.3	2225.855	1446.806
590	1.25	2187.967	1367.479	1.31	2234.953	1463.894
600	1.25	2187.967	1367.479	1.3	2225.855	1446.806
610	1.24	2181.504	1352.533	1.3	2225.855	1446.806
620	1.24	2181.504	1352.533	1.3	2225.855	1446.806
630	1.23	2176.032	1338.26	1.3	2225.855	1446.806
640	1.23	2176.032	1338.26	1.3	2225.855	1446.806
650	1.23	2176.032	1338.26	1.3	2225.855	1446.806
660	1.23	2176.032	1338.26	1.3	2225.855	1446.806
670	1.23	2176.032	1338.26	1.3	2225.855	1446.806
680	1.22	2170.56	1324.042	1.3	2225.855	1446.806
690	1.22	2170.56	1324.042	1.3	2225.855	1446.806

Avg VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(Swav
2173.791	2868.397	2.868397	2.268671	1300.342	1.300342	6.507448	2.9500
2173.791	2868.397	2.868397	2.268671	1300.342	1.300342	6.507448	2.9500
2173.791	2868.397	2.868397	2.268671	1300.342	1.300342	6.507448	2.9500
2179.758	2904.489	2.904489	2.275774	1331.456	1.331456	6.609961	3.0300
2182.99	2922.931	2.922931	2.279378	1347.355	1.347355	6.662466	3.0711
2185.726	2940.978	2.940978	2.282888	1362.912	1.362912	6.713923	3.1113
2180.253	2908.478	2.908478	2.276555	1334.895	1.334895	6.621309	3.0389
2185.726	2940.978	2.940978	2.282888	1362.912	1.362912	6.713923	3.1113
2182.99	2922.931	2.922931	2.279378	1347.355	1.347355	6.662466	3.0711
2182.99	2922.931	2.922931	2.279378	1347.355	1.347355	6.662466	3.0711
2179.758	2904.489	2.904489	2.275774	1331.456	1.331456	6.609961	3.0300
2176.527	2880.057	2.880057	2.270973	1310.394	1.310394	6.540531	2.9758
2182.495	2922.436	2.922436	2.279281	1346.928	1.346928	6.661055	3.0700
2191.845	2985.656	2.985656	2.291509	1401.427	1.401427	6.841658	3.2113
2191.845	2985.656	2.985656	2.291509	1401.427	1.401427	6.841658	3.2113
2197.812	3028.132	3.028132	2.299616	1438.045	1.438045	6.963542	3.3069

2206.911	3173.058	3.173058	2.326651	1562.981	1.562981	7.382597	3.6365
2211.46	3213.839	3.213839	2.334091	1598.137	1.598137	7.50139	3.7301
2206.911	3173.058	3.173058	2.326651	1562.981	1.562981	7.382597	3.6365
2203.68	3142.431	3.142431	2.321016	1536.578	1.536578	7.293631	3.5664
2203.68	3142.431	3.142431	2.321016	1536.578	1.536578	7.293631	3.5664
2200.944	3101.31	3.10131	2.313385	1501.13	1.50113	7.174526	3.4726
2200.944	3101.31	3.10131	2.313385	1501.13	1.50113	7.174526	3.4726
2200.944	3101.31	3.10131	2.313385	1501.13	1.50113	7.174526	3.4726
2200.944	3101.31	3.10131	2.313385	1501.13	1.50113	7.174526	3.4726
2200.944	3101.31	3.10131	2.313385	1501.13	1.50113	7.174526	3.4726
2198.207	3069.102	3.069102	2.307356	1473.364	1.473364	7.08151	3.3995
2198.207	3069.102	3.069102	2.307356	1473.364	1.473364	7.08151	3.3995

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.370664	3.83607	13.55118	10.9937994
0.370664	3.83607	13.55118	10.9937994
0.370664	3.83607	13.55118	10.9937994
0.366974	4.034436	13.81931	11.1296868
0.365092	4.137902	13.95673	11.1981258
0.363253	4.24053	14.09146	11.2644383
0.366567	4.056693	13.84901	11.1445458
0.363253	4.24053	14.09146	11.2644383
0.365092	4.137902	13.95673	11.1981258
0.365092	4.137902	13.95673	11.1981258
0.366974	4.034436	13.81931	11.1296868
0.369471	3.89956	13.63769	11.0379807
0.365143	4.135106	13.95304	11.1962976
0.358708	4.500521	14.42614	11.425793
0.358708	4.500521	14.42614	11.425793
0.354401	4.755545	14.7458	11.5754356
0.339817	5.683797	15.84701	12.0578152
0.335747	5.961363	16.15977	12.185532
0.339817	5.683797	15.84701	12.0578152
0.342884	5.480086	15.61295	11.9595579
0.342884	5.480086	15.61295	11.9595579
0.347015	5.21296	15.29982	11.8245127
0.347015	5.21296	15.29982	11.8245127
0.347015	5.21296	15.29982	11.8245127
0.347015	5.21296	15.29982	11.8245127
0.347015	5.21296	15.29982	11.8245127
0.35026	5.00881	15.05546	11.7162566
0.35026	5.00881	15.05546	11.7162566





R3

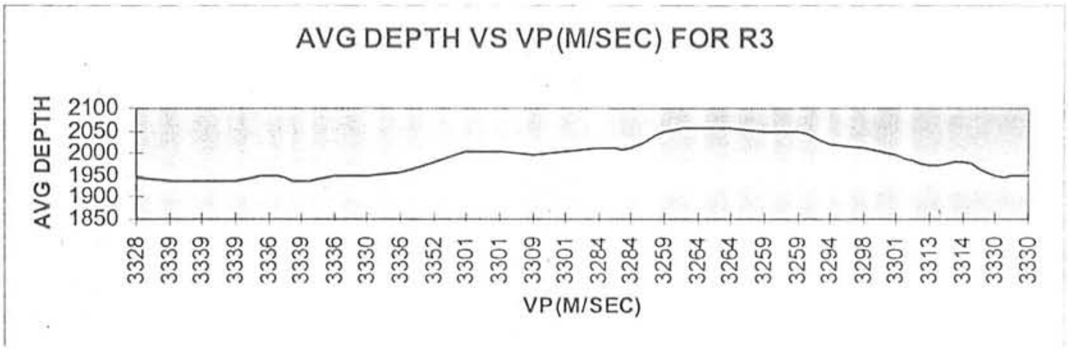
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)	D.Depth(m)
420	1.55	2415.827	1872.266	1.64	2465.881	2022.022
430	1.55	2415.827	1872.266	1.63	2461.132	2005.822
440	1.55	2415.827	1872.266	1.63	2461.132	2005.822
450	1.55	2415.827	1872.266	1.63	2461.132	2005.822
460	1.56	2421.891	1889.075	1.63	2461.132	2005.822
470	1.55	2415.827	1872.266	1.63	2461.132	2005.822
480	1.56	2421.891	1889.075	1.63	2461.132	2005.822
490	1.58	2433.279	1922.29	1.61	2449.991	1972.242
500	1.58	2433.279	1922.29	1.62	2455.561	1989.005
510	1.6	2444.42	1955.536	1.63	2461.132	2005.822
520	1.61	2449.991	1972.242	1.65	2470.63	2038.27
530	1.61	2449.991	1972.242	1.65	2470.63	2038.27
540	1.6	2444.42	1955.536	1.65	2470.63	2038.27
550	1.61	2449.991	1972.242	1.65	2470.63	2038.27
560	1.62	2455.561	1989.005	1.65	2470.63	2038.27
570	1.62	2455.561	1989.005	1.65	2470.63	2038.27
580	1.64	2465.881	2022.022	1.67	2480.129	2070.907
590	1.64	2465.881	2022.022	1.68	2484.878	2087.297
600	1.64	2465.881	2022.022	1.68	2484.878	2087.297

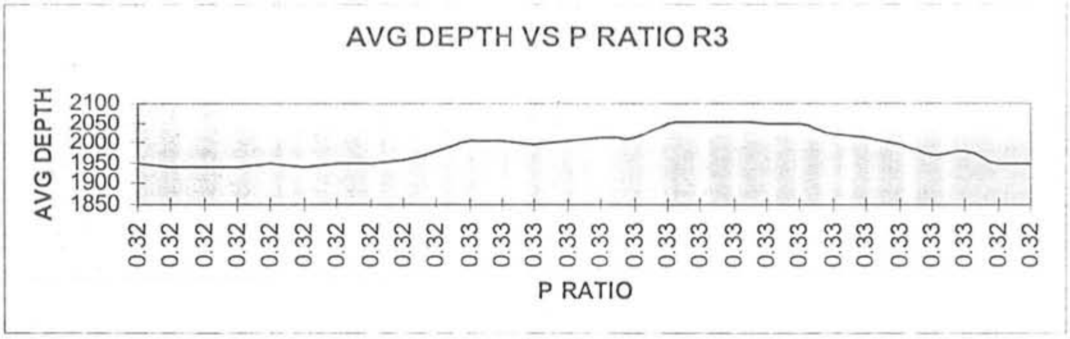
610	1.63	2461.132	2005.822	1.68	2484.878	2087.297
620	1.63	2461.132	2005.822	1.68	2484.878	2087.297
630	1.6	2444.42	1955.536	1.68	2484.878	2087.297
640	1.59	2438.849	1938.885	1.68	2484.878	2087.297
650	1.57	2427.708	1905.751	1.68	2484.878	2087.297
660	1.57	2427.708	1905.751	1.65	2470.63	2038.27
670	1.58	2433.279	1922.29	1.65	2470.63	2038.27
680	1.57	2427.708	1905.751	1.62	2455.561	1989.005
690	1.57	2427.708	1905.751	1.62	2455.561	1989.005

Avg Vel	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(Swa
2440.854	3327.926	3.327926	2.354534733	1696.488	1.696488	7.835717	3.994
2438.479	3338.917	3.338917	2.35647637	1705.963	1.705963	7.868078	4.020
2438.479	3338.917	3.338917	2.35647637	1705.963	1.705963	7.868078	4.020
2438.479	3338.917	3.338917	2.35647637	1705.963	1.705963	7.868078	4.020
2441.511	3335.646	3.335646	2.355899156	1703.143	1.703143	7.858447	4.012
2438.479	3338.917	3.338917	2.35647637	1705.963	1.705963	7.868078	4.020
2441.511	3335.646	3.335646	2.355899156	1703.143	1.703143	7.858447	4.012
2441.635	3330.149	3.330149	2.354927869	1698.404	1.698404	7.842261	3.99
2444.42	3335.72	3.33572	2.355912074	1703.207	1.703207	7.858662	4.012
2452.776	3352.431	3.352431	2.358857311	1717.613	1.717613	7.907907	4.051
2460.31	3301.375	3.301375	2.349824371	1673.599	1.673599	7.757651	3.932
2460.31	3301.375	3.301375	2.349824371	1673.599	1.673599	7.757651	3.932
2457.525	3309.358	3.309358	2.351243615	1680.481	1.680481	7.781107	3.95
2460.31	3301.375	3.301375	2.349824371	1673.599	1.673599	7.757651	3.932
2463.096	3284.356	3.284356	2.346790112	1658.928	1.658928	7.707694	3.893
2463.096	3284.356	3.284356	2.346790112	1658.928	1.658928	7.707694	3.893
2473.005	3258.995	3.258995	2.342246634	1637.065	1.637065	7.633371	3.83
2475.379	3263.744	3.263744	2.343099481	1641.159	1.641159	7.647278	3.845
2475.379	3263.744	3.263744	2.343099481	1641.159	1.641159	7.647278	3.845
2473.005	3258.995	3.258995	2.342246634	1637.065	1.637065	7.633371	3.83
2473.005	3258.995	3.258995	2.342246634	1637.065	1.637065	7.633371	3.83
2464.649	3294.034	3.294034	2.34851699	1667.271	1.667271	7.736094	3.915
2461.864	3298.047	3.298047	2.349231905	1670.73	1.67073	7.747876	3.924
2456.293	3300.845	3.300845	2.349730057	1673.142	1.673142	7.756094	3.931
2449.169	3312.977	3.312977	2.351886104	1683.601	1.683601	7.791744	3.959
2451.955	3313.707	3.313707	2.352015653	1684.23	1.68423	7.79389	3.961
2441.635	3330.149	3.330149	2.354927869	1698.404	1.698404	7.842261	3.99
2441.635	3330.149	3.330149	2.354927869	1698.404	1.698404	7.842261	3.99

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.324444	6.776517	17.04133	12.5236494
0.323362	6.858073	17.12676	12.5547109
0.323362	6.858073	17.12676	12.5547109

0.323362	6.858073	17.12676	12.5547109
0.323684	6.833751	17.10133	12.5454969
0.323362	6.858073	17.12676	12.5547109
0.323684	6.833751	17.10133	12.5454969
0.324225	6.792971	17.0586	12.5299541
0.323677	6.834295	17.1019	12.5457033
0.322033	6.95909	17.23193	12.5925371
0.327063	6.581702	16.83531	12.4475099
0.327063	6.581702	16.83531	12.4475099
0.326275	6.63995	16.8972	12.4705666
0.327063	6.581702	16.83531	12.4475099
0.328746	6.458462	16.70353	12.3978876
0.328746	6.458462	16.70353	12.3978876
0.331258	6.277177	16.50755	12.3227638
0.330787	6.31091	16.54421	12.3369389
0.330787	6.31091	16.54421	12.3369389
0.331258	6.277177	16.50755	12.3227638
0.331258	6.277177	16.50755	12.3227638
0.327789	6.528386	16.77844	12.4261836
0.327392	6.557501	16.80952	12.4378557
0.327116	6.577845	16.8312	12.4459742
0.325918	6.666446	16.92527	12.4809717
0.325846	6.671799	16.93093	12.4830672
0.324225	6.792971	17.0586	12.5299541
0.324225	6.792971	17.0586	12.5299541





R4

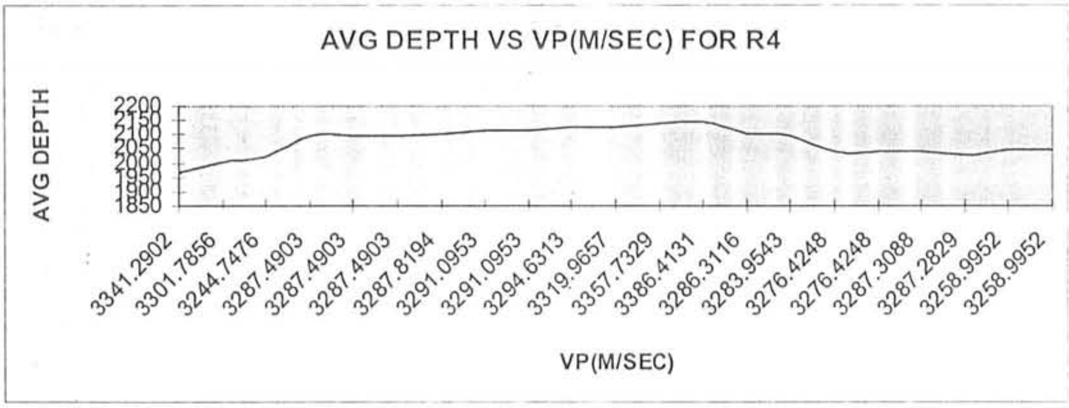
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)	D.DEPTH
420						
430						
440						
450						
460						
470						
480						
490	1.6	2444.42	1955.536	1.61	2449.991	1972.242
500	1.62	2455.561	1989.005	1.64	2465.881	2022.022
510	1.63	2461.132	2005.822	1.65	2470.63	2038.27
520	1.67	2480.129	2070.907	1.7	2494.376	2120.22
530	1.67	2480.129	2070.907	1.7	2494.376	2120.22
540	1.67	2480.129	2070.907	1.7	2494.376	2120.22
550	1.67	2480.129	2070.907	1.71	2499.022	2136.664
560	1.68	2484.878	2087.297	1.71	2499.022	2136.664
570	1.68	2484.878	2087.297	1.71	2499.022	2136.664
580	1.69	2489.627	2103.735	1.72	2503.668	2153.154
590	1.68	2484.878	2087.297	1.73	2509.013	2170.297
600	1.68	2484.878	2087.297	1.74	2514.976	2188.029
610	1.68	2484.878	2087.297	1.75	2520.939	2205.822
620	1.66	2475.379	2054.565	1.72	2503.668	2153.154
630	1.66	2475.379	2054.565	1.71	2499.022	2136.664
640	1.62	2455.561	1989.005	1.68	2484.878	2087.297
650	1.62	2455.561	1989.005	1.68	2484.878	2087.297
660	1.61	2449.991	1972.242	1.69	2489.627	2103.735
670	1.61	2449.991	1972.242	1.68	2484.878	2087.297
680	1.63	2461.132	2005.822	1.68	2484.878	2087.297
690	1.63	2461.132	2005.822	1.68	2484.878	2087.297

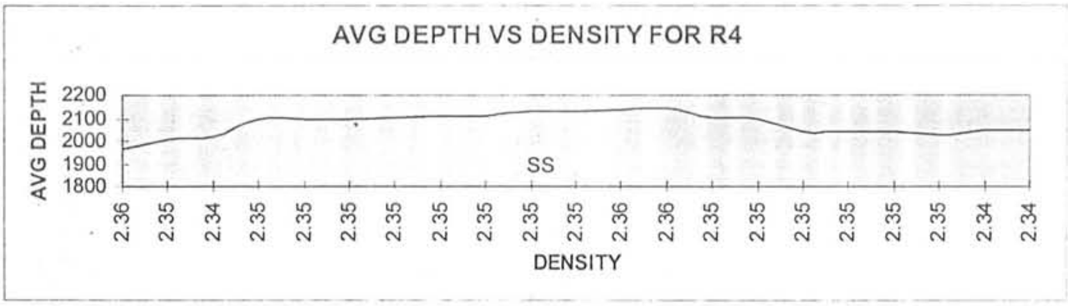
AVG VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)

2447.205	3341.29022	3.34129022	2.356895047	1708.00881	1.708009	7.87507037	4.
2460.721	3301.78558	3.30178558	2.349897452	1673.95308	1.673953	7.758857509	3.
2465.881	3244.74763	3.24474763	2.339682489	1624.78244	1.624782	7.591679206	3.
2487.252	3287.4903	3.2874903	2.347349808	1661.62957	1.66163	7.716889734	3.
2487.252	3287.4903	3.2874903	2.347349808	1661.62957	1.66163	7.716889734	3.
2487.252	3287.4903	3.2874903	2.347349808	1661.62957	1.66163	7.716889734	3.
2489.575	3287.81943	3.28781943	2.347408557	1661.9133	1.661913	7.717855469	3
2491.95	3291.09527	3.29109527	2.347993051	1664.7373	1.664737	7.727468815	3.
2491.95	3291.09527	3.29109527	2.347993051	1664.7373	1.664737	7.727468815	3.
2496.647	3294.6313	3.2946313	2.348623482	1667.7856	1.667786	7.737848434	
2496.946	3319.96571	3.31996571	2.353125517	1689.62561	1.689626	7.81229602	3.
2499.927	3357.73288	3.35773288	2.359789311	1722.18351	1.722184	7.923542149	4
2502.909	3386.41313	3.38641313	2.364812316	1746.90787	1.746908	8.008231475	4.
2489.524	3286.31162	3.28631162	2.347139376	1660.61346	1.660613	7.713431394	3.
2487.201	3283.95426	3.28395426	2.346718346	1658.58126	1.658581	7.706515706	3.
2470.22	3276.42477	3.27642477	2.345372043	1652.09032	1.65209	7.684435066	3.
2470.22	3276.42477	3.27642477	2.345372043	1652.09032	1.65209	7.684435066	3.
2469.809	3287.3088	3.2873088	2.347317407	1661.4731	1.661473	7.716357173	3.
2467.434	3287.28287	3.28728287	2.347312779	1661.45075	1.661451	7.716281094	3.
2473.005	3258.99519	3.25899519	2.342246634	1637.06482	1.637065	7.633370507	3
2473.005	3258.99519	3.25899519	2.342246634	1637.06482	1.637065	7.633370507	3

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.323128	6.875756	17.14522	12.5613836
0.327023	6.584692	16.83849	12.44869958
0.332672	6.17657	16.39766	12.2799434
0.328436	6.481063	16.72778	12.40707428
0.328436	6.481063	16.72778	12.40707428
0.328436	6.481063	16.72778	12.40707428
0.328403	6.483439	16.73033	12.40803769
0.328079	6.507111	16.75569	12.41761367
0.328079	6.507111	16.75569	12.41761367
0.32773	6.532717	16.78307	12.42792379
0.325229	6.717784	16.97951	12.50098612
0.321512	6.998937	17.27322	12.60726396
0.3187	7.216667	17.49696	12.6858457

0.328552	6.472559	16.71866	12.40362209
0.328785	6.455568	16.70042	12.39670862
0.329531	6.401464	16.64219	12.3745451
0.329531	6.401464	16.64219	12.3745451
0.328454	6.479753	16.72638	12.40654288
0.328456	6.479566	16.72618	12.40646696
0.331258	6.277177	16.50755	12.32276379
0.331258	6.277177	16.50755	12.32276379





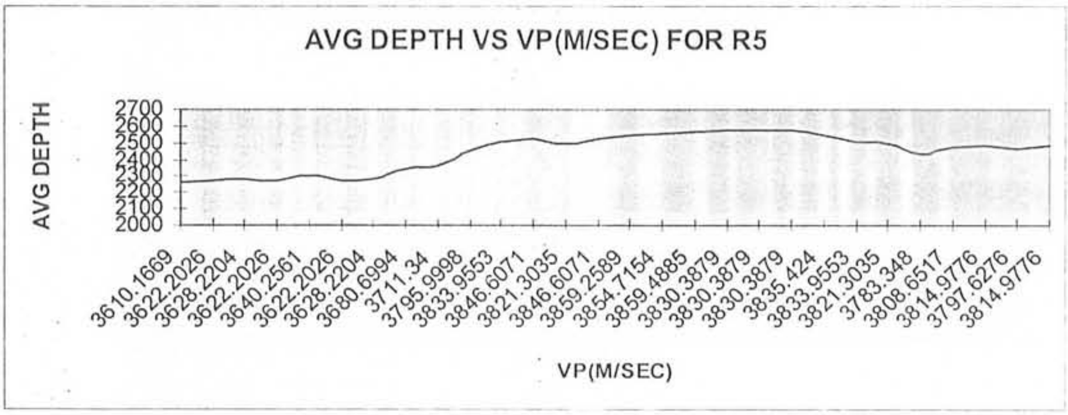
R5

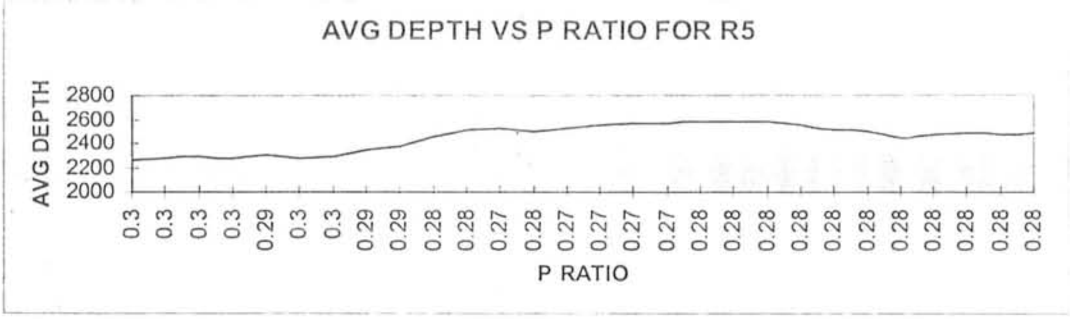
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)		Avg DEPTH
420	1.75	2520.939	2205.822	1.81	2557.046	2314.127	2259.97
430	1.76	2526.957	2223.722	1.82	2563.064	2332.388	2278.05
440	1.77	2532.975	2241.683	1.82	2563.064	2332.388	2287.03
450	1.75	2520.939	2205.822	1.83	2569.082	2350.71	2278.26
460	1.78	2538.993	2259.704	1.83	2569.082	2350.71	2305.20
470	1.75	2520.939	2205.822	1.83	2569.082	2350.71	2278.26
480	1.75	2520.939	2205.822	1.84	2575.1	2369.092	2287.45
490	1.79	2545.011	2277.784	1.86	2587.752	2406.609	2342.19
500	1.8	2551.028	2295.926	1.88	2600.403	2444.379	2370.15
510	1.85	2581.426	2387.819	1.92	2625.707	2520.679	2454.24
520	1.88	2600.403	2444.379	1.95	2644.685	2578.568	2511.47
530	1.88	2600.403	2444.379	1.97	2657.337	2617.476	2530.92

540	1.86	2587.752	2406.609	1.95	2644.685	2578.568	2492.58
550	1.88	2600.403	2444.379	1.97	2657.337	2617.476	2530.92
560	1.9	2613.055	2482.402	1.97	2657.337	2617.476	2549.93
570	1.9	2613.055	2482.402	1.98	2663.223	2636.591	2559.49
580	1.91	2619.381	2501.509	1.98	2663.223	2636.591	2569.0
590	1.9	2613.055	2482.402	2	2673.922	2673.922	2578.16
600	1.9	2613.055	2482.402	2	2673.922	2673.922	2578.16
610	1.9	2613.055	2482.402	2	2673.922	2673.922	2578.16
620	1.88	2600.403	2444.379	1.99	2668.671	2655.327	2549.85
630	1.86	2587.752	2406.609	1.97	2657.337	2617.476	2512.04
640	1.86	2587.752	2406.609	1.95	2644.685	2578.568	2492.58
650	1.85	2581.426	2387.819	1.9	2613.055	2482.402	2435.11
660	1.84	2575.1	2369.092	1.95	2644.685	2578.568	2473.8
670	1.85	2581.426	2387.819	1.95	2644.685	2578.568	2483.19
680	1.83	2569.082	2350.71	1.95	2644.685	2578.568	2464.63
690	1.85	2581.426	2387.819	1.95	2644.685	2578.568	2483.19

Avg VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(
2538.993	3610.16694	3.61016694	2.402943255	1939.79909	1.939799	8.67502631	4.
2545.011	3622.20261	3.62220261	2.404943504	1950.17466	1.950175	8.711192639	4
2548.019	3628.22044	3.62822044	2.40594176	1955.36245	1.955362	8.729287079	4.
2545.011	3622.20261	3.62220261	2.404943504	1950.17466	1.950175	8.711192639	4
2554.037	3640.25611	3.64025611	2.407934553	1965.73802	1.965738	8.765498463	4.
2545.011	3622.20261	3.62220261	2.404943504	1950.17466	1.950175	8.711192639	4
2548.019	3628.22044	3.62822044	2.40594176	1955.36245	1.955362	8.729287079	4.
2566.381	3680.69941	3.68069941	2.414594915	2000.60294	2.000603	8.887398077	4.
2575.716	3711.33996	3.71133996	2.41960447	2027.01721	2.027017	8.979974757	4
2603.566	3795.99985	3.79599985	2.433286465	2099.99987	2.1	9.236755056	5.
2622.544	3833.95529	3.83395529	2.439346277	2132.72008	2.13272	9.352344574	5.
2628.87	3846.60711	3.84660711	2.441356215	2143.62682	2.143627	9.39093817	5.
2616.218	3821.30348	3.82130348	2.437331359	2121.81334	2.121813	9.313782803	5.
2628.87	3846.60711	3.84660711	2.441356215	2143.62682	2.143627	9.39093817	5.
2635.196	3859.25892	3.85925892	2.4433612	2154.53355	2.154534	9.429563514	5.
2638.139	3854.71538	3.85471538	2.442641734	2150.61671	2.150617	9.415688666	5.
2641.302	3859.48851	3.85948851	2.443397538	2154.73148	2.154731	9.430264727	5.
2643.488	3830.38786	3.83038786	2.438778635	2129.6447	2.129645	9.341468066	5.
2643.488	3830.38786	3.83038786	2.438778635	2129.6447	2.129645	9.341468066	5.
2643.488	3830.38786	3.83038786	2.438778635	2129.6447	2.129645	9.341468066	5.
2634.537	3835.42399	3.83542399	2.439579857	2133.9862	2.133986	9.356823108	5
2622.544	3833.95529	3.83395529	2.439346277	2132.72008	2.13272	9.352344574	5.
2616.218	3821.30348	3.82130348	2.437331359	2121.81334	2.121813	9.313782803	5.
2597.24	3783.34803	3.78334803	2.431256431	2089.09313	2.089093	9.19828924	5.
2609.892	3808.65166	3.80865166	2.435311432	2110.90661	2.110907	9.275252938	5.
2613.055	3814.97757	3.81497757	2.436322024	2116.35998	2.11636	9.294513877	5.
2606.883	3797.62762	3.79762762	2.433547279	2101.40312	2.101403	9.241706355	5.
2613.055	3814.97757	3.81497757	2.436322024	2116.35998	2.11636	9.294513877	5.

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.297054	9.041844	19.2625	13.2346049
0.295905	9.146436	19.35846	13.26083277
0.295331	9.19898	19.40647	13.27381877
0.295905	9.146436	19.35846	13.26083277
0.294184	9.304562	19.50258	13.2995344
0.295905	9.146436	19.35846	13.26083277
0.295331	9.19898	19.40647	13.27381877
0.290343	9.664204	19.82624	13.38343295
0.287445	9.941668	20.07218	13.44440348
0.279492	10.73079	20.755	13.60113683
0.275952	11.09535	21.06267	13.66576257
0.274776	11.21836	21.16543	13.68652218
0.27713	10.97309	20.96	13.64461125
0.274776	11.21836	21.16543	13.68652218
0.273601	11.34212	21.2683	13.70688925
0.274023	11.29759	21.23135	13.69962022
0.27358	11.34437	21.27017	13.70725521
0.276284	11.0608	21.03371	13.65983814
0.276284	11.0608	21.03371	13.65983814
0.276284	11.0608	21.03371	13.65983814
0.275815	11.1096	21.07459	13.66819258
0.275952	11.09535	21.06267	13.66576257
0.27713	10.97309	20.96	13.64461125
0.280675	10.61076	20.65265	13.57881543
0.27831	10.85157	20.85745	13.62306905
0.27772	10.91224	20.90871	13.63388896
0.279339	10.74629	20.76817	13.60398044
0.27772	10.91224	20.90871	13.63388896





R6

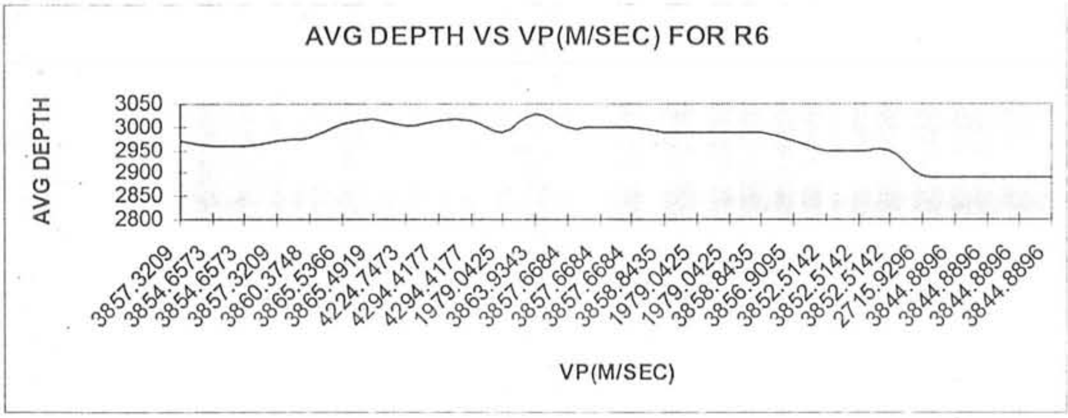
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)		Avg DEPTH
420	2.1	2726.432	2862.753	2.21	2782.72	3074.906	2968.8
430	2.1	2726.432	2862.753	2.2	2777.715	3055.486	2959.1
440	2.1	2726.432	2862.753	2.2	2777.715	3055.486	2959.1
450	2.1	2726.432	2862.753	2.21	2782.72	3074.906	2968.8
460	2.1	2726.432	2862.753	2.22	2787.726	3094.376	2978.5
470	2.13	2742.184	2920.426	2.22	2787.726	3094.376	3007.4
480	2.14	2747.435	2939.756	2.22	2787.726	3094.376	3017.0
490	2.14	2747.435	2939.756	2.2	2787.726	3066.498	3003.1
500	2.15	2752.686	2959.138	2.2	2787.726	3066.498	3012.81
510	2.15	2752.686	2959.138	2.2	2787.726	3066.498	3012.81
520	2.15	2752.686	2959.138	2.21	2731.683	3018.509	2988.82
530	2.17	2762.698	2997.527	2.2	2777.715	3055.486	3026.50
540	2.14	2747.435	2939.756	2.2	2777.715	3055.486	2997.62
550	2.14	2747.435	2939.756	2.2	2777.715	3055.486	2997.62
560	2.14	2747.435	2939.756	2.2	2777.715	3055.486	2997.62
570	2.13	2742.184	2920.426	2.2	2777.715	3055.486	2987.95
580	2.15	2752.686	2959.138	2.21	2731.683	3018.509	2988.82
590	2.15	2752.686	2959.138	2.21	2731.683	3018.509	2988.82
600	2.13	2742.184	2920.426	2.2	2777.715	3055.486	2987.95
610	2.11	2731.683	2881.925	2.2	2777.715	3055.486	2968.70
620	2.1	2726.432	2862.753	2.19	2772.709	3036.116	2949.43
630	2.1	2726.432	2862.753	2.19	2772.709	3036.116	2949.43
640	2.1	2726.432	2862.753	2.19	2772.709	3036.116	2949.43
650	2.08	2715.93	2824.567	2.18	2715.93	2960.363	2892.46
660	2.08	2715.93	2824.567	2.15	2752.686	2959.138	2891.85
670	2.08	2715.93	2824.567	2.15	2752.686	2959.138	2891.85
680	2.08	2715.93	2824.567	2.15	2752.686	2959.138	2891.85
690	2.08	2715.93	2824.567	2.15	2752.686	2959.138	2891.85

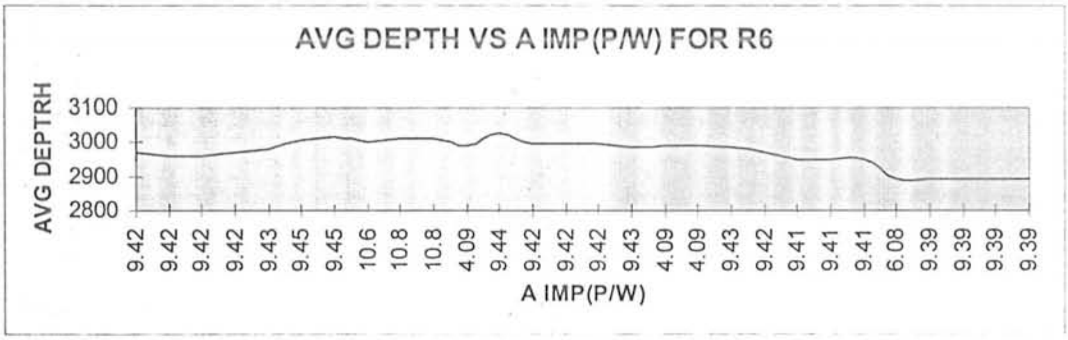
Avg VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(
2754.576	3857.3209	3.8573209	2.443054393	2152.86284	2.152863	9.423644768	5.
2752.073	3854.65731	3.85465731	2.442632535	2150.56665	2.150567	9.415511361	5.
2752.073	3854.65731	3.85465731	2.442632535	2150.56665	2.150567	9.415511361	5.

2754.576	3857.3209	3.8573209	2.443054393	2152.86284	2.152863	9.423644768	5.
2757.079	3860.37482	3.86037482	2.443537805	2155.49554	2.155496	9.432971824	5.
2764.955	3865.53656	3.86553656	2.444354213	2159.94531	2.159945	9.448740565	5.
2767.581	3865.49193	3.86549193	2.444347159	2159.90684	2.159907	9.448604223	5.
2767.581	4224.74731	4.22474731	2.499262532	2469.60975	2.46961	10.55875266	6.
2770.206	4294.41768	4.29441768	2.50950326	2529.67041	2.52967	10.77685516	6.
2770.206	4294.41768	4.29441768	2.50950326	2529.67041	2.52967	10.77685516	6.
2742.184	1979.04253	1.97904253	2.067642621	533.657355	0.533657	4.091952687	1.
2770.206	3863.93428	3.86393428	2.444100876	2158.56404	2.158564	9.443845162	5.
2762.575	3857.66845	3.85766845	2.443109422	2153.16246	2.153162	9.424706134	5.
2762.575	3857.66845	3.85766845	2.443109422	2153.16246	2.153162	9.424706134	5.
2762.575	3857.66845	3.85766845	2.443109422	2153.16246	2.153162	9.424706134	5.
2759.95	3858.84346	3.85884346	2.443295438	2154.1754	2.154175	9.428294626	5.
2742.184	1979.04253	1.97904253	2.067642621	533.657355	0.533657	4.091952687	1.
2742.184	1979.04253	1.97904253	2.067642621	533.657355	0.533657	4.091952687	1.
2759.95	3858.84346	3.85884346	2.443295438	2154.1754	2.154175	9.428294626	5.
2754.699	3856.90949	3.85690949	2.442989249	2152.50818	2.152508	9.422388429	5.
2749.57	3852.51418	3.85251418	2.442292947	2148.71912	2.148719	9.408968203	5.
2749.57	3852.51418	3.85251418	2.442292947	2148.71912	2.148719	9.408968203	5.
2749.57	3852.51418	3.85251418	2.442292947	2148.71912	2.148719	9.408968203	5.
2715.93	2715.92961	2.71592961	2.237903324	1168.90484	1.168905	6.07798791	2.
2734.308	3844.88963	3.84488963	2.441083658	2142.14623	2.142146	9.385697243	5.
2734.308	3844.88963	3.84488963	2.441083658	2142.14623	2.142146	9.385697243	5.
2734.308	3844.88963	3.84488963	2.441083658	2142.14623	2.142146	9.385697243	5.
2734.308	3844.88963	3.84488963	2.441083658	2142.14623	2.142146	9.385697243	5.

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.273781	11.32311	21.25254	13.70379488
0.274028	11.29702	21.23087	13.69952698
0.274028	11.29702	21.23087	13.69952698
0.273781	11.32311	21.25254	13.70379488
0.273498	11.35307	21.27738	13.70866677
0.273019	11.4038	21.31938	13.71684909
0.273024	11.40336	21.31902	13.71677864
0.240459	15.24293	24.28415	14.1221959
0.234313	16.05889	24.86846	14.16252822
0.234313	16.05889	24.86846	14.16252822
0.460792	0.588844	7.313023	6.920459808
0.273168	11.38804	21.30634	13.7143162
0.273749	11.32652	21.25536	13.70435048
0.273749	11.32652	21.25536	13.70435048
0.273749	11.32652	21.25536	13.70435048
0.27364	11.33804	21.26492	13.70622667
0.460792	0.588844	7.313023	6.920459808
0.460792	0.588844	7.313023	6.920459808
0.27364	11.33804	21.26492	13.70622667
0.273819	11.31908	21.24919	13.70313682

0.274227	11.27605	21.21345	13.69608037
0.274227	11.27605	21.21345	13.69608037
0.274227	11.27605	21.21345	13.69608037
0.386327	3.057734	12.43041	10.39192031
0.274935	11.20162	21.15147	13.68372708
0.274935	11.20162	21.15147	13.68372708
0.274935	11.20162	21.15147	13.68372708
0.274935	11.20162	21.15147	13.68372708





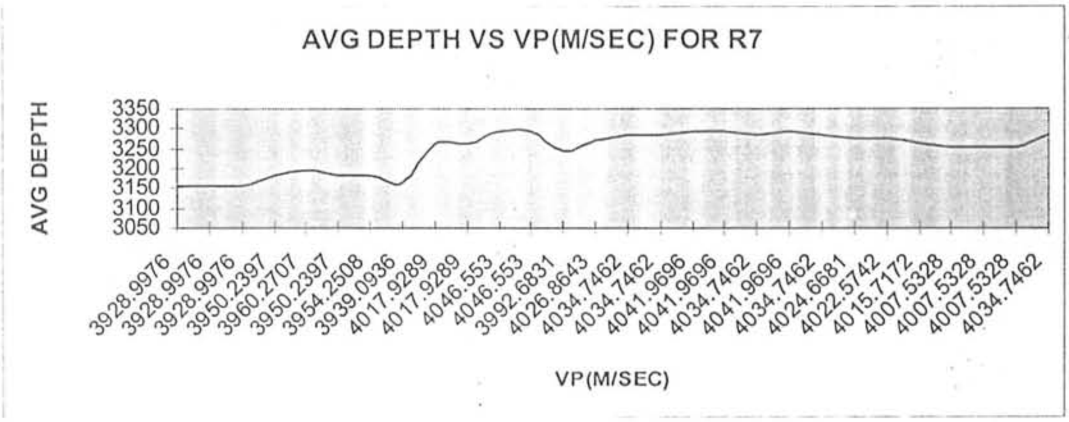
R7

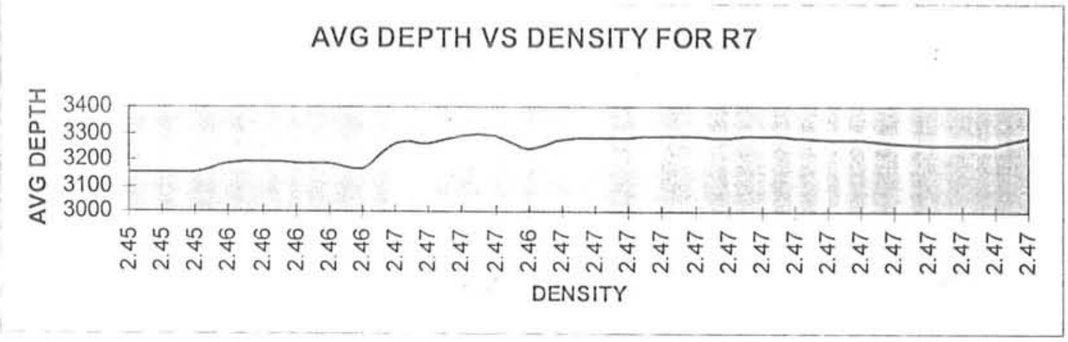
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)		Avg DEPTH
420	2.2	2777.715	3055.487	2.3	2827.771	3251.936	3153.71
430	2.2	2777.715	3055.487	2.3	2827.771	3251.936	3153.71
440	2.2	2777.715	3055.487	2.3	2827.771	3251.936	3153.71
450	2.22	2787.726	3094.376	2.31	2833.019	3272.137	3183.25
460	2.22	2787.726	3094.376	2.32	2838.267	3292.389	3193.38
470	2.22	2787.726	3094.376	2.31	2833.019	3272.137	3183.25
480	2.21	2782.72	3074.906	2.32	2838.267	3292.389	3183.64
490	2.2	2777.715	3055.487	2.31	2833.019	3272.137	3163.81
500	2.28	2817.76	3212.246	2.33	2843.515	3312.695	3262.47
510	2.28	2817.76	3212.246	2.33	2843.515	3312.695	3262.47
520	2.29	2822.765	3232.066	2.35	2854.011	3353.463	3292.76

530	2.29	2822.765	3232.066	2.35	2854.011	3353.463	3292.76
540	2.28	2817.76	3212.246	2.31	2833.019	3272.137	3242.19
550	2.28	2817.76	3212.246	2.34	2848.763	3333.052	3272.64
560	2.28	2817.76	3212.246	2.35	2854.011	3353.463	3282.85
570	2.28	2817.76	3212.246	2.35	2854.011	3353.463	3282.85
580	2.28	2817.76	3212.246	2.36	2859.259	3373.925	3293.08
590	2.28	2817.76	3212.246	2.36	2859.259	3373.925	3293.08
600	2.28	2817.76	3212.246	2.35	2854.011	3353.463	3282.85
610	2.28	2817.76	3212.246	2.36	2859.259	3373.925	3293.08
620	2.28	2817.76	3212.246	2.35	2854.011	3353.463	3282.85
630	2.27	2812.754	3192.476	2.35	2854.011	3353.463	3272.96
640	2.25	2802.743	3153.086	2.37	2864.507	3394.44	3273.76
650	2.26	2807.748	3172.755	2.35	2854.011	3353.463	3263.10
660	2.25	2802.743	3153.086	2.35	2854.011	3353.463	3253.27
670	2.25	2802.743	3153.086	2.35	2854.011	3353.463	3253.27
680	2.25	2802.743	3153.086	2.35	2854.011	3353.463	3253.27
690	2.28	2817.76	3212.246	2.35	2854.011	3353.463	3282.85

Avg VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(S
2802.743	3928.99756	3.92899756	2.454325354	2214.65307	2.214653	9.643038336	5.4
2802.743	3928.99756	3.92899756	2.454325354	2214.65307	2.214653	9.643038336	5.4
2802.743	3928.99756	3.92899756	2.454325354	2214.65307	2.214653	9.643038336	5.4
2810.372	3950.23969	3.95023969	2.457635977	2232.96525	2.232965	9.708251187	5.4
2812.996	3960.27068	3.96027068	2.459194684	2241.61265	2.241613	9.739076601	5.5
2810.372	3950.23969	3.95023969	2.457635977	2232.96525	2.232965	9.708251187	5.4
2810.493	3954.2508	3.9542508	2.458259616	2236.4231	2.236423	9.720575048	5.4
2805.367	3939.09357	3.93909357	2.455900503	2223.35652	2.223357	9.674021873	5.4
2830.637	4017.92886	4.01792886	2.468097173	2291.31798	2.291318	9.916638853	5.6
2830.637	4017.92886	4.01792886	2.468097173	2291.31798	2.291318	9.916638853	5.6
2838.388	4046.55303	4.04655303	2.472481227	2315.99399	2.315994	10.00502639	5.7
2838.388	4046.55303	4.04655303	2.472481227	2315.99399	2.315994	10.00502639	5.7
2825.389	3992.68308	3.99268308	2.464211067	2269.55438	2.269554	9.838813829	5.5
2833.261	4026.86429	4.02686429	2.469468224	2299.02094	2.299021	9.944213409	5.6
2835.885	4034.74617	4.03474617	2.470675725	2305.81566	2.305816	9.968549407	5.6
2835.885	4034.74617	4.03474617	2.470675725	2305.81566	2.305816	9.968549407	5.6
2838.509	4041.96957	4.04196957	2.471780795	2312.04273	2.312043	9.990862747	5.7
2838.509	4041.96957	4.04196957	2.471780795	2312.04273	2.312043	9.990862747	5.7
2835.885	4034.74617	4.03474617	2.470675725	2305.81566	2.305816	9.968549407	5.6
2838.509	4041.96957	4.04196957	2.471780795	2312.04273	2.312043	9.990862747	5.7
2835.885	4034.74617	4.03474617	2.470675725	2305.81566	2.305816	9.968549407	5.6
2833.382	4024.66814	4.02466814	2.46913146	2297.12771	2.297128	9.93743473	5
2833.625	4022.57424	4.02257424	2.468810244	2295.32262	2.295323	9.930972485	5.6
2830.879	4015.71724	4.01571724	2.467757469	2289.41141	2.289411	9.909816213	5.6
2828.377	4007.53282	4.00753282	2.466499125	2282.35588	2.282356	9.884576182	5.6
2828.377	4007.53282	4.00753282	2.466499125	2282.35588	2.282356	9.884576182	5.6
2828.377	4007.53282	4.00753282	2.466499125	2282.35588	2.282356	9.884576182	5.6
2835.885	4034.74617	4.03474617	2.470675725	2305.81566	2.305816	9.968549407	5.6

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.26716	12.0377	21.83721	13.81207278
0.26716	12.0377	21.83721	13.81207278
0.26716	12.0377	21.83721	13.81207278
0.265209	12.2541	22.01112	13.84171547
0.26429	12.35703	22.09334	13.85532238
0.265209	12.2541	22.01112	13.84171547
0.264842	12.2952	22.04399	13.84718662
0.266233	12.14029	21.91983	13.82630152
0.259027	12.95785	22.56721	13.92864747
0.259027	12.95785	22.56721	13.92864747
0.256428	13.26196	22.80325	13.961941
0.256428	13.26196	22.80325	13.961941
0.261327	12.69285	22.35947	13.8975689
0.258215	13.05237	22.64084	13.93926269
0.257499	13.13605	22.70583	13.94845899
0.257499	13.13605	22.70583	13.94845899
0.256843	13.21301	22.76542	13.95674912
0.256843	13.21301	22.76542	13.95674912
0.257499	13.13605	22.70583	13.94845899
0.256843	13.21301	22.76542	13.95674912
0.257499	13.13605	22.70583	13.94845899
0.258414	13.0291	22.62274	13.93667236
0.258604	13.00694	22.60549	13.93419128
0.259228	12.93452	22.549	13.92598901
0.259973	12.84836	22.48162	13.91604376
0.259973	12.84836	22.48162	13.91604376
0.259973	12.84836	22.48162	13.91604376
0.257499	13.13605	22.70583	13.94845899





R8

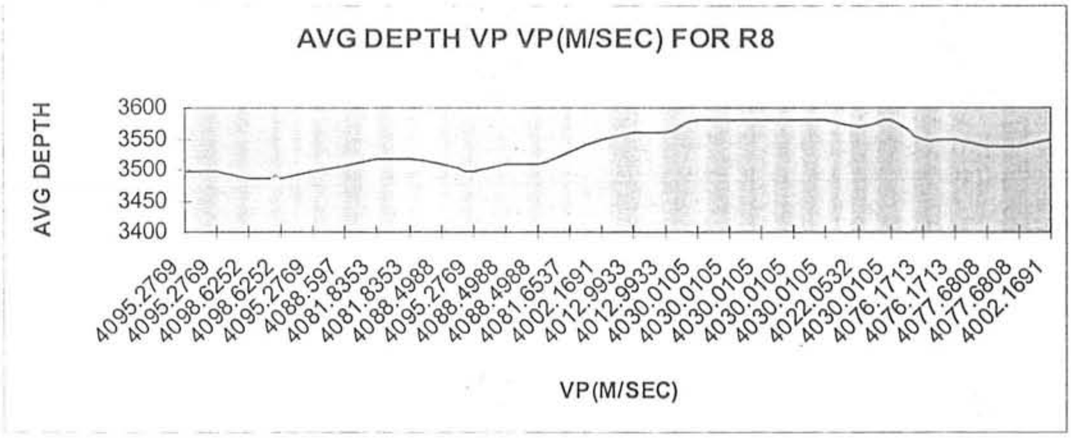
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)		Avg DEPTH
420	2.39	2874.927	3435.538	2.45	2904.813	3558.396	3496.9
430	2.39	2874.927	3435.538	2.45	2904.813	3558.396	3496.9
440	2.38	2869.701	3414.944	2.45	2904.813	3558.396	3486.
450	2.38	2869.701	3414.944	2.45	2904.813	3558.396	3486.
460	2.39	2874.927	3435.538	2.45	2904.813	3558.396	3496.9
470	2.39	2874.927	3435.538	2.46	2909.462	3578.639	3507.0
480	2.4	2880.153	3456.184	2.46	2909.462	3578.639	3517.4
490	2.4	2880.153	3456.184	2.46	2909.462	3578.639	3517.4
500	2.4	2880.153	3456.184	2.45	2904.813	3558.396	3507.
510	2.39	2874.927	3435.538	2.45	2904.813	3558.396	3496.9
520	2.4	2880.153	3456.184	2.45	2904.813	3558.396	3507.
530	2.4	2880.153	3456.184	2.45	2904.813	3558.396	3507.
540	2.41	2885.143	3476.597	2.46	2909.462	3578.639	3527.6
550	2.42	2891.631	3498.874	2.47	2914.112	3598.928	3548.9
560	2.42	2891.631	3498.874	2.48	2918.761	3619.263	3559.0
570	2.42	2891.631	3498.874	2.48	2918.761	3619.263	3559.0
580	2.42	2891.631	3498.874	2.5	2928.059	3660.074	3579.4
590	2.42	2891.631	3498.874	2.5	2928.059	3660.074	3579.4
600	2.42	2891.631	3498.874	2.5	2928.059	3660.074	3579.4
610	2.42	2891.631	3498.874	2.5	2928.059	3660.074	3579.4
620	2.42	2891.631	3498.874	2.5	2928.059	3660.074	3579.4
630	2.42	2891.631	3498.874	2.49	2923.41	3639.645	3569.2
640	2.42	2891.631	3498.874	2.5	2928.059	3660.074	3579.4
650	2.41	2885.143	3476.597	2.48	2918.761	3619.263	3547.
660	2.41	2885.143	3476.597	2.48	2918.761	3619.263	3547.
670	2.41	2885.143	3476.597	2.47	2914.112	3598.928	3537.7
680	2.41	2885.143	3476.597	2.47	2914.112	3598.928	3537.7
690	2.42	2891.631	3498.874	2.47	2914.112	3598.928	3548.9

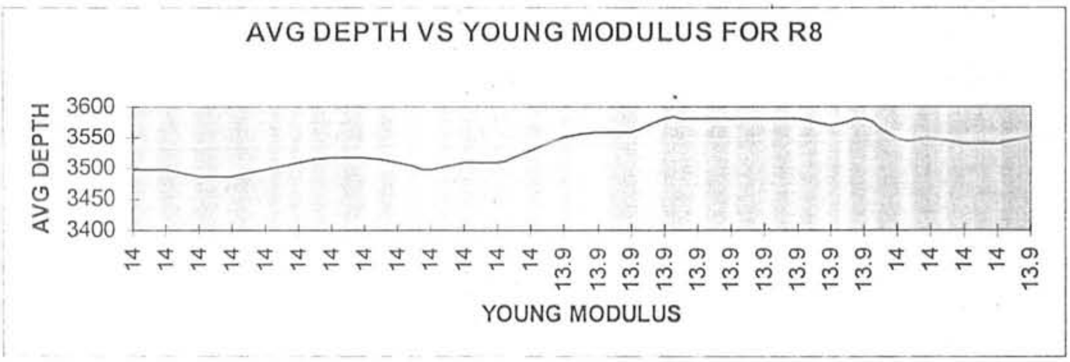
Avg VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp
2889.87	4095.27686	4.09527686	2.479890533	2357.99729	2.357997	10.15583831	5.
2889.87	4095.27686	4.09527686	2.479890533	2357.99729	2.357997	10.15583831	5.
2887.257	4098.62516	4.09862516	2.480397268	2360.88376	2.360884	10.16621866	

2887.257	4098.62516	4.09862516	2.480397268	2360.88376	2.360884	10.16621866	5
2889.87	4095.27686	4.09527686	2.479890533	2357.99729	2.357997	10.15583831	5.
2892.195	4088.59695	4.08859695	2.478878661	2352.23875	2.352239	10.13513573	5.
2894.808	4081.83528	4.08183528	2.477853139	2346.40972	2.34641	10.11418835	5.
2894.808	4081.83528	4.08183528	2.477853139	2346.40972	2.34641	10.11418835	5.
2892.483	4088.49883	4.08849883	2.478863788	2352.15416	2.352154	10.1348317	5
2889.87	4095.27686	4.09527686	2.479890533	2357.99729	2.357997	10.15583831	5.
2892.483	4088.49883	4.08849883	2.478863788	2352.15416	2.352154	10.1348317	5
2892.483	4088.49883	4.08849883	2.478863788	2352.15416	2.352154	10.1348317	5
2897.303	4081.65373	4.08165373	2.477825588	2346.25322	2.346253	10.11362605	5.
2902.871	4002.16911	4.00216911	2.465673416	2277.73199	2.277732	9.868041988	5.
2905.196	4012.99331	4.01299331	2.467338883	2287.0632	2.287063	9.901414441	5
2905.196	4012.99331	4.01299331	2.467338883	2287.0632	2.287063	9.901414441	5
2909.845	4030.01047	4.03001047	2.46995043	2301.73316	2.301733	9.953926092	5.
2909.845	4030.01047	4.03001047	2.46995043	2301.73316	2.301733	9.953926092	5.
2909.845	4030.01047	4.03001047	2.46995043	2301.73316	2.301733	9.953926092	5.
2909.845	4030.01047	4.03001047	2.46995043	2301.73316	2.301733	9.953926092	5.
2909.845	4030.01047	4.03001047	2.46995043	2301.73316	2.301733	9.953926092	5.
2907.52	4022.05323	4.02205323	2.4687303	2294.87347	2.294873	9.929364677	5.
2909.845	4030.01047	4.03001047	2.46995043	2301.73316	2.301733	9.953926092	5.
2901.952	4076.17127	4.07617127	2.476993117	2341.52696	2.341527	10.09664818	5.
2901.952	4076.17127	4.07617127	2.476993117	2341.52696	2.341527	10.09664818	5.
2899.627	4077.68076	4.07768076	2.477222405	2342.82824	2.342828	10.10132214	5.
2899.627	4077.68076	4.07768076	2.477222405	2342.82824	2.342828	10.10132214	5.
2902.871	4002.16911	4.00216911	2.465673416	2277.73199	2.277732	9.868041988	5.

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.252026	13.78857	23.20621	14.01383683
0.252026	13.78857	23.20621	14.01383683
0.251724	13.82517	23.23396	14.01718125
0.251724	13.82517	23.23396	14.01718125
0.252026	13.78857	23.20621	14.01383683
0.252628	13.7157	23.15088	14.00707924
0.253237	13.64216	23.0949	14.00012314
0.253237	13.64216	23.0949	14.00012314
0.252636	13.71463	23.15007	14.00697913
0.252026	13.78857	23.20621	14.01383683
0.252636	13.71463	23.15007	14.00697913
0.252636	13.71463	23.15007	14.00697913
0.253254	13.64019	23.0934	13.99993477
0.260462	12.79207	22.43748	13.90943463
0.259476	12.90581	22.52657	13.92269778
0.259476	12.90581	22.52657	13.92269778
0.257929	13.08574	22.66678	13.94295236
0.257929	13.08574	22.66678	13.94295236
0.257929	13.08574	22.66678	13.94295236
0.257929	13.08574	22.66678	13.94295236

0.257929	13.08574	22.66678	13.94295236
0.258652	13.00143	22.60119	13.93357222
0.257929	13.08574	22.66678	13.94295236
0.253749	13.58073	23.04803	13.99420669
0.253749	13.58073	23.04803	13.99420669
0.253612	13.59709	23.06052	13.99579144
0.253612	13.59709	23.06052	13.99579144
0.260462	12.79207	22.43748	13.90943463





R9

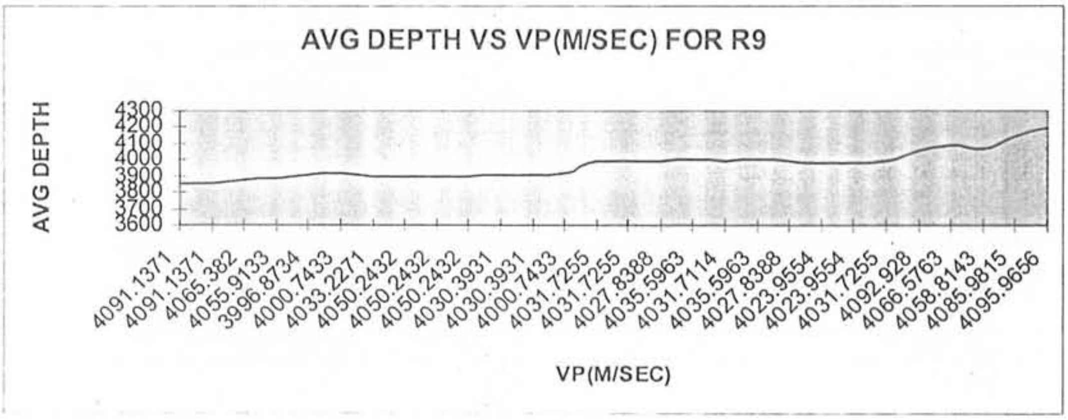
S.P	Up.Time(Sec)	Mean Vel.(m/sec)	Up.Depth(m)	D.Time(Sec)	Mean Vel.(m/sec)		Avg DEPTH
420	2.56	2955.954	3783.621	2.63	2986.168	3926.811	3855.21
430	2.56	2955.954	3783.621	2.63	2986.168	3926.811	3855.21
440	2.58	2965.253	3825.176	2.63	2986.168	3926.811	3875.9
450	2.58	2965.253	3825.176	2.64	2990.041	3946.854	3886.01
460	2.6	2974.551	3866.916	2.64	2990.041	3946.854	3906.8
470	2.6	2974.551	3866.916	2.65	2993.913	3966.935	3916.92
480	2.59	2969.902	3846.023	2.64	2990.041	3946.854	3896.4
490	2.58	2965.253	3825.176	2.65	2993.913	3966.935	3896.0
500	2.58	2965.253	3825.176	2.65	2993.913	3966.935	3896.0
510	2.58	2965.253	3825.176	2.65	2993.913	3966.935	3896.0

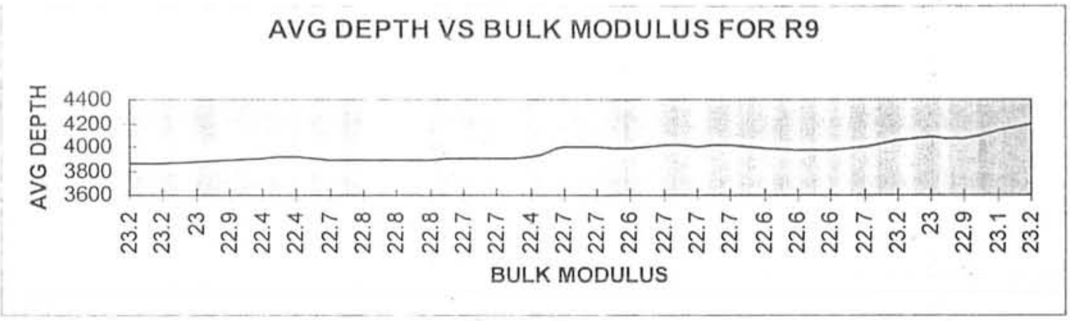
520	2.59	2969.902	3846.023	2.65	2993.913	3966.935	3906.47
530	2.59	2969.902	3846.023	2.65	2993.913	3966.935	3906.47
540	2.6	2974.551	3866.916	2.65	2993.913	3966.935	3916.9
550	2.63	2986.168	3926.811	2.7	3013.275	4067.921	3997.36
560	2.63	2986.168	3926.811	2.7	3013.275	4067.921	3997.36
570	2.62	2982.296	3906.808	2.7	3013.275	4067.921	3987.36
580	2.63	2986.168	3926.811	2.71	3017.147	4088.235	4007.52
590	2.62	2982.296	3906.808	2.71	3017.147	4088.235	3997.52
600	2.63	2986.168	3926.811	2.71	3017.147	4088.235	4007.52
610	2.62	2982.296	3906.808	2.7	3013.275	4067.921	3987.36
620	2.61	2978.424	3886.843	2.7	3013.275	4067.921	3977.38
630	2.61	2978.424	3886.843	2.7	3013.275	4067.921	3977.38
640	2.63	2986.168	3926.811	2.7	3013.275	4067.921	3997.36
650	2.66	2996.786	3985.725	2.73	3024.892	4128.978	4057.35
660	2.68	3005.53	4027.41	2.74	3028.765	4149.407	4088.40
670	2.67	3001.658	4007.213	2.73	3024.892	4128.978	4068.09
680	2.73	3024.892	4128.978	2.74	3028.765	4149.407	4139.19
690	2.78	3044.12	4231.327	2.74	3028.765	4149.407	4190.36

Avg VEL	Vp(m/sec)	Vp(km/sec)	Density(g/cc)	Vs(m/sec)	Vs(Km/sec)	A.Imp (Pwave)	A.Imp(
2971.061	4091.13714	4.09113714	2.479263595	2354.42857	2.354429	10.14300738	5.8
2971.061	4091.13714	4.09113714	2.479263595	2354.42857	2.354429	10.14300738	5.8
2975.711	4065.382	4.065382	2.475352391	2332.22586	2.332226	10.06325305	5.7
2977.647	4055.91327	4.05591327	2.473909788	2324.06317	2.324063	10.03396354	5.7
2982.296	3996.87341	3.99687341	2.464857361	2273.16673	2.273167	9.85172284	5.6
2984.232	4000.74331	4.00074331	2.465453783	2276.50285	2.276503	9.863647728	5.6
2979.971	4033.22713	4.03322713	2.470443146	2304.50614	2.304506	9.963858312	5.6
2979.583	4050.24322	4.05024322	2.47304472	2319.17519	2.319175	10.01643261	5.7
2979.583	4050.24322	4.05024322	2.47304472	2319.17519	2.319175	10.01643261	5.7
2979.583	4050.24322	4.05024322	2.47304472	2319.17519	2.319175	10.01643261	5.7
2981.908	4030.39309	4.03039309	2.470009054	2302.06301	2.302063	9.955107428	5.6
2981.908	4030.39309	4.03039309	2.470009054	2302.06301	2.302063	9.955107428	5.6
2984.232	4000.74331	4.00074331	2.465453783	2276.50285	2.276503	9.863647728	5.6
2999.722	4031.72553	4.03172553	2.470213174	2303.21166	2.303212	9.959221515	5.6
2999.722	4031.72553	4.03172553	2.470213174	2303.21166	2.303212	9.959221515	5.6
2997.786	4027.83884	4.02783884	2.469617621	2299.86107	2.299861	9.947221767	5.6
3001.658	4035.59628	4.03559628	2.470805857	2306.54852	2.306549	9.971174927	5.6
2999.722	4031.71136	4.03171136	2.470211004	2303.19945	2.303199	9.959177767	5.6
3001.658	4035.59628	4.03559628	2.470805857	2306.54852	2.306549	9.971174927	5.6
2997.786	4027.83884	4.02783884	2.469617621	2299.86107	2.299861	9.947221767	5.6
2995.85	4023.95541	4.02395541	2.469022137	2296.51329	2.296513	9.935234989	5.6
2995.85	4023.95541	4.02395541	2.469022137	2296.51329	2.296513	9.935234989	5.6
2999.722	4031.72553	4.03172553	2.470213174	2303.21166	2.303212	9.959221515	5.6
3010.839	4092.92795	4.09292795	2.479534862	2355.97237	2.355972	10.14855754	5.8
3017.147	4066.57625	4.06657625	2.475534162	2333.25539	2.333255	10.06694843	5.7
3013.275	4058.81428	4.05881428	2.474352037	2326.56403	2.326564	10.04293537	5.7
3026.828	4085.98151	4.08598151	2.478482136	2349.98406	2.349984	10.12703218	5.8

3036.442	4095.96562	4.09596562	2.479994796	2358.59105	2.358591	10.15797343	5.

P.Ratio	Shear Mod	Bulk Mod	Y MODULUS
0.252399	13.74339	23.17192	14.00966238
0.252399	13.74339	23.17192	14.00966238
0.254724	13.46413	22.9588	13.98271084
0.25558	13.36225	22.88055	13.97237845
0.260944	12.73663	22.39392	13.90283831
0.260592	12.77713	22.42575	13.90766559
0.257637	13.1199	22.6933	13.94669884
0.256094	13.30145	22.83372	13.96608238
0.256094	13.30145	22.83372	13.96608238
0.256094	13.30145	22.83372	13.96608238
0.257894	13.0898	22.66993	13.94339938
0.257894	13.0898	22.66993	13.94339938
0.260592	12.77713	22.42575	13.90766559
0.257773	13.10395	22.68092	13.94495316
0.257773	13.10395	22.68092	13.94495316
0.258126	13.0627	22.64887	13.94040826
0.257422	13.1451	22.71284	13.9494415
0.257774	13.1038	22.6808	13.94493667
0.257422	13.1451	22.71284	13.9494415
0.258126	13.0627	22.64887	13.94040826
0.258479	13.02156	22.61687	13.93582908
0.258479	13.02156	22.61687	13.93582908
0.257773	13.10395	22.68092	13.94495316
0.252237	13.76292	23.18675	14.01147357
0.254616	13.47701	22.96867	13.98399786
0.255318	13.39342	22.90452	13.97556823
0.252863	13.68723	23.12922	14.00440241
0.251964	13.79609	23.21192	14.01452713





DATA OF REFLECTION COEFFICIENT

REFLECTION COEFFICIENT

VELOCITY
WINDOW 1 1

time	vrms	vint	vave	DENSITY	DEN*Vint	R.C
0	1500	1500	1500	1.929232	2893.848	0.11346
600	1800	1800	1800	2.019202	3634.564	0.183541
860	2050	2534.493	2022.056	2.078787	5268.671	0.000469
1260	2200	2492.113	2171.28	2.116122	5273.614	0.231567
1380	2400	3926.831	2323.937	2.152374	8452.009	-0.06028
1500	2500	3447.463	2413.819	2.172891	7490.96	-0.02394
1700	2600	3253.46	2512.6	2.194788	7140.654	0.041589
1830	2675	3511.294	2583.546	2.210119	7760.378	0.015443
2380	2900	3547.344	2806.272	2.256286	8003.822	0.081983
2770	3100	4114.982	2990.531	2.292444	9433.366	0.033072
3375	3350	4313.392	3227.666	2.336597	10078.66	0.071674
4600	3800	4827.478	3653.703	2.410155	11634.97	0.121969
6000	4400	5960.345	4191.919	2.494393	14867.44	-1

VELOCITY
WINDOW 1 2

time	vrms	vint	vave	DENSITY	DEN*Vint	R.C
0	1500	1500	1500	1.929232	2893.848	0.146677
730	1900	1900	1900	2.046681	3888.693	0.107269
930	2000	2328.841	1992.224	2.071077	4823.209	0.078267
1275	2200	2665.398	2174.377	2.116876	5642.317	0.14134
1460	2400	3478.583	2339.636	2.156	7499.825	0.023623
1565	2500	3614.323	2425.158	2.175438	7862.736	-0.02649
1840	2650	3379.161	2567.74	2.206731	7456.9	0.104031
2150	2900	4079.888	2785.771	2.252154	9188.534	0.011032
2400	3050	4120.437	2924.798	2.279742	9393.532	0.015428
2990	3300	4165.048	3169.53	2.326004	9687.918	0.000794
3875	3500	4104.242	3383.006	2.364217	9703.32	0.187695
6000	4400	5685.534	4198.485	2.495369	14187.51	-1

VELOCITY WINDOW 1

3

time	vrms	vint	vave	DENSITY	DEN*Vint	R.C
0	1500	1500	1500	1.929232	2893.848	0.146677
800	1900	1900	1900	2.046681	3888.693	0.127078
1280	2100	2396.525	2086.197	2.09508	5020.911	0.297753
1400	2375	4332.123	2278.705	2.141824	9278.644	-0.17716
1720	2500	2985.97	2410.289	2.172096	6485.812	0.161695
1975	2750	4051.597	2622.205	2.218341	8987.825	-0.00359
2300	2950	3953.504	2810.323	2.2571	8923.453	0.094795
2600	3200	4693.346	3027.595	2.299514	10792.42	-0.04606
4300	3600	4137.632	3466.447	2.378663	9842.031	0.203007
6000	4400	5962.234	4173.587	2.491662	14855.87	-1

VELOCITY WINDOW 1

4

time	vrms	vint	vave	DENSITY	DEN*Vint	R.C
0	1500	1500	1500	1.929232	2893.848	0.177888
870	2000	2000	2000	2.073095	4146.19	0.170989
1130	2200	2766.002	2176.248	2.117331	5856.543	0.069499
1240	2300	3148.448	2262.492	2.138004	6731.394	-0.01915
1420	2400	2999.63	2355.932	2.159744	6478.434	-0.00919
1730	2500	2914.535	2456.028	2.182328	6360.472	0.143342
1975	2700	3825.398	2625.9	2.219122	8489.027	-0.01567
2430	2900	3643.012	2816.347	2.258308	8227.045	0.065586
2840	3100	4089.278	3000.115	2.294279	9381.943	0.170713
6000	4400	5303.08	4213.01	2.497525	13244.57	-1

VELOCITY WINDOW 1

5

time	vrms	vint	vave	DENSITY	DEN*Vint	R.C
0	1500	1500	1500	1.929232	2893.848	0.146677
760	1900	1900	1900	2.046681	3888.693	0.148743
1085	2100	2506.146	2081.565	2.093916	5247.659	0.060972
1240	2200	2801.785	2171.592	2.116198	5929.132	0.112213
1750	2600	3380.567	2523.922	2.197256	7427.972	0.087726
1990	2800	3964.215	2697.626	2.234123	8856.545	0.038015
2440	3100	4175.803	2970.24	2.288546	9556.517	-0.01167
2850	3250	4028.776	3122.521	2.317331	9336.007	0.044067
4120	3600	4282.548	3480.102	2.381002	10196.75	0.17155
6000	4400	5778.021	4200.117	2.495612	14419.7	-1

VELOCITY WINDOW 1

6

time	vrms	vint	vave	DENSITY	DEN*Vint	R.C
0	1500	1500	1500	1.929232	2893.848	0.177888
800	2000	2000	2000	2.073095	4146.19	0.126635