# INTERPRETATION OF 2D-SEISMIC REFLECTION DATA LINE# 902-SGR-782 IN SANGHAR AREA OF PAKISTAN



BY

MUHAMMAD ASIF
M.Sc. GEOPHYSICS
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DEPARTMENT OF EARTH SCIENCES
QUAID-E-AZAM UNIVERSITY
ISLAMABAD

# CERTIFICATE

This dissertation submitted by **Mr. MUHAMMAD ASIF** is accepted in the present form by the Department of Earth Sciences as the requirement for the award of M.sc degree in **Geophysics.**

## RECOMMENDED BY

**Anees Ahmed Bangash** ........................................

**(Supervisor)**

**Dr. ZULFIQAR AHMED** ........................................

**(Chairman)**

**EXTERNAL EXAMINAR** ........................................

## DEPARTMENT OF EARTH SCIENCES
## QUAID-E-AZAM UNIVERSITY
## ISLAMABAD

# DADICATED TO

## MY PARENTS, BROTHER AND SISTERS

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# ABSTRACT

The seismic section of line no. 902-SGR-782 is provided by OGDC. The data is acquired from the area Sanghar (Sindh) of Pakistan. The line extending form shot point 101-232 in SN direction. The total length of the line between these shot points is 6.5 km. Along with the seismic section the RMS and Dix interval velocities are also provided for different shot points. Using the Dix average velocities, time and shot point distance a Dix average velocity contour map is constructed. The vertical and lateral changes are studied. Also in addition to this mean average velocity map is constructed. By picking accurate velocity against time in this map a depth section is plotted, which shows the correct sub-surface structure.

Six reflectors R1, R2, R3, R4, R5 and R6 are marked on the seismic section. The depth for the each reflector were found out, by using average velocity and one way travel time the reflectors are plotted on a depth section, which represents the shapes of the reflectors. Normally the reflectors show very little dip. R1, R2, R4 and R5 are almost horizontal. A geological structure like Horst and Grabben is found in R3.

# ACKNOWLEDGEMENT

All praises for Al-Mighty **ALLAH,** who helps His being in difficulties and guides in the darkness of ignorance. And all my respect to the **Holly Prophet (PBUH).**

I offer my heart felt and cordial gratitude and feelings to present all thanks to my gracious and dignified supervisor, Mr. Anees Ahmed Bangash, for his guidance, sincere advice, courtesy, friendly encouragement and keenness in solution of problems faced during the accomplishment of this dissertation.

I also pay my humble regard to Dr. Zulfiqar, chairman of Dept. of Earth Sciences, for inspiring us to complete our dissertation in time.

I must thanks to all my other teachers of the department for their valuable advice during the dissertation. I also thanks to my class fellows for their kind help, especially Malik Mussavir, Sohail, Majid, Shaid and Nabeel.

Finally, I wish to pay my deepest gratitude to my parents, for their prayers and encouragement during my whole study.

**Muhammad Asif**

# CHAPTER 1

# INTRODUCTION

# INTRODUCTION TO THE PROJECT

## 1.1 INTRODUCTION

Seismic reflection provides the highest degree of subsurface details relative to the other methods. In this method physical measurements are made at the ground surface, which are then interpreted in terms of what might be in the surface. This dissertation based on interpretation of final stack section obtained by seismic reflection method. The final stack section of line number **902-SGR-782** is provided by OGDC of Pakistan of Sanghar (Sindh) area. This line is profiled in SN direction. It contains shot points 101 to 230.

The main objective of this dissertation is to understand and to interpret the final stacked section by studying the changes taking place in the DIX average velocity contour map to find out the depth of the different reflectors and to study the structure by plotting these depths against shot points. The acquisition and processing of 48- fold CDP data had done with the selection of the following parameters.

### 1.1.1 RECORDING PARAMETERS:

### INSTRUMENTS

| | |
|---|---|
| Hardware | VAX 11/780 |
| Software | DISCO 7.2 Release |
| | VMS 4.3 Operating System |
| Field Party | S.P. 2 |
| Date Shot | 14$^{th}$ Oct 1990 |
| Instrument | DFS V |
| No. Of Chann. | 96 |
| Notch Filter | In |
| Coverage | 4800 % |

| | |
|---|---|
| Format | SEGB |
| Sample Rate | 2 Ms. |
| Density | 1600 BPI |
| Aliasing | 125 Hz |

## SOURCE

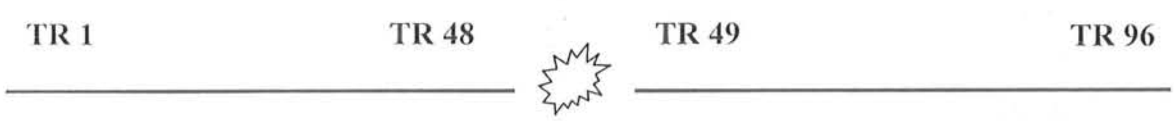
| | |
|---|---|
| Energy Source | Dynamite |
| Pattern | 9h X 1.5m X 0.5kg |
| S.P. Interval | 50 M. |

## GEOPHONE

| | |
|---|---|
| Geophone Type | Mark |
| Geophone Freq. | 10 Hz. |
| Geophone Code | 2 X 12 Linear |
| Geophone Interval | 2.08 M. |
| Group Base | 50 M. |
| Group Width | ----------- |
| Group Interval | 50 M. |

## SPREAD

The type of spread, which is used, is **Symmetric split spread**




**Source Center**

## 1.1.2 DISPLAY PARAMETERS

## SCALE

| | |
|---|---|
| Horizontal Scale | 24.0 TPI |
| Vertical Scale | 2.5 Ins./Sec |

| | |
|---|---|
| Polarity | Normal |
| Display Gain | None |
| Processed In | Feb, 1991 |
| Processed By | Saleem, Rashid |

### 1.1.3 PROCESSING SEQUENCE

1. Demultiplex Input Data
2. Geometry Definition
3. Gain Comensation (3 Db/Sec Over 5 Secs.)
4. Trace Editing
5. Datum Static Correction (Static Calculated In The Field)
6. CDP Sort
7. Spectrum Balancing
8. Filter

| TIME | BANDPASS |
|---|---|
| 0-5000 Ms | 8/12 - 60/70 Hz |

9. Predictive Deconvolution

| | |
|---|---|
| Operating Length | 120 Ms. |
| Gap Length | 4 Ms. |

1 Design/Application Window

| Near Trace | Fare Trace |
|---|---|
| 500-5000 | 700-5000 Ms. |

10. Filter

| Time | BANDPASS |
|---|---|
| 0-5000 Ms | 8/12 - 60/70 Hz |

11. MUTE

| DISTANCE | TIME |
|---|---|
| 0 M. | 0 MS. |
| 200 M. | 200 MS. |
| 800 M. | 600 MS. |

| | |
|---|---|
| 1100 M. | 1000 MS. |
| 2550 M. | 1800 MS. |

**12.** Constant Velocity Analysis (CVA)

**13.** Normal Moveout Correction

**14.** Surface Consistent Residual Statics

Maximum Allowable Static = 20 Ms.

| | |
|---|---|
| 3 | Trace Pilot For Iteration 1 |
| 5 | Trace Pilot For Iteration 2 |
| 7 | Trace Pilot For Iteration 3 |

**15.** Automatic Gain Control 750 Ms.

**16.** Constant Velocity Analysis (RCVA)

**17.** Automatic Gain Control 750 Ms.

**18.** MigratX

**19.** Stack [48 Fold]

**20.** Band Pass Filter

| TIME | BANDPASS |
|---|---|
| 0-2500 MS. | 12/16 - 50/60 HZ. |
| 3000-5000 MS. | 10/15 – 38/44 HZ. |

**21.** AUTOMATIC GAIN CONTROLS 750 MS.

## 1.2 LOCATION AND ACCESSIBILITY

Sanghar district, a part of Province Sindh, is located in the Lower Indus Basin is connected by road with the cities of Hyderabad, Karachi, and Sukkur. Sanghar is a market town and has several cotton-textile factories. The surrounding area consists chiefly of semiarid land, a part of the great Thar Desert, and some cropped areas irrigated by the Mithrao Canal system, which feeds from the Indus River.

| | |
|---|---|
| **Latitude** | $26^0$ 29' N to $26^0$ 43' N |
| **Longitude** | $68^0$ 39' E to $69^0$ 13' E |

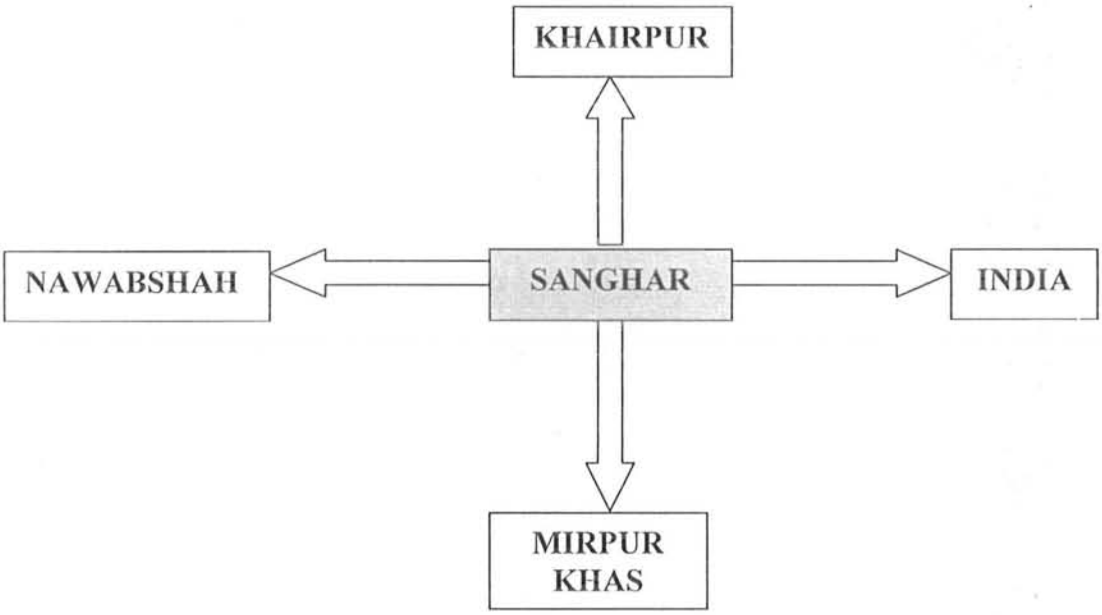



Fig 1.1

## 1.3 RAINFALL AND CLIMATE

The climate of the Sanghar area is dry almost all the year. It is one of hot areas of Pakistan. The average temperature in summer season is almost above $45^0$ C and in winter seasons it is almost $30^0$ C. Rainfall is a rarely happening events in that area. It is almost dry throughout the year and observed average annually rainfall is about 120mm.

## 1.4 Topography And Relief

Topography of the area is almost flat. As it is a part of the Indus Basin, thin sheet of sediments are overlying the bedrocks of the area. Due to the Thar Desert, sand dunes are also found which are having the maximum height of about 45 feet.

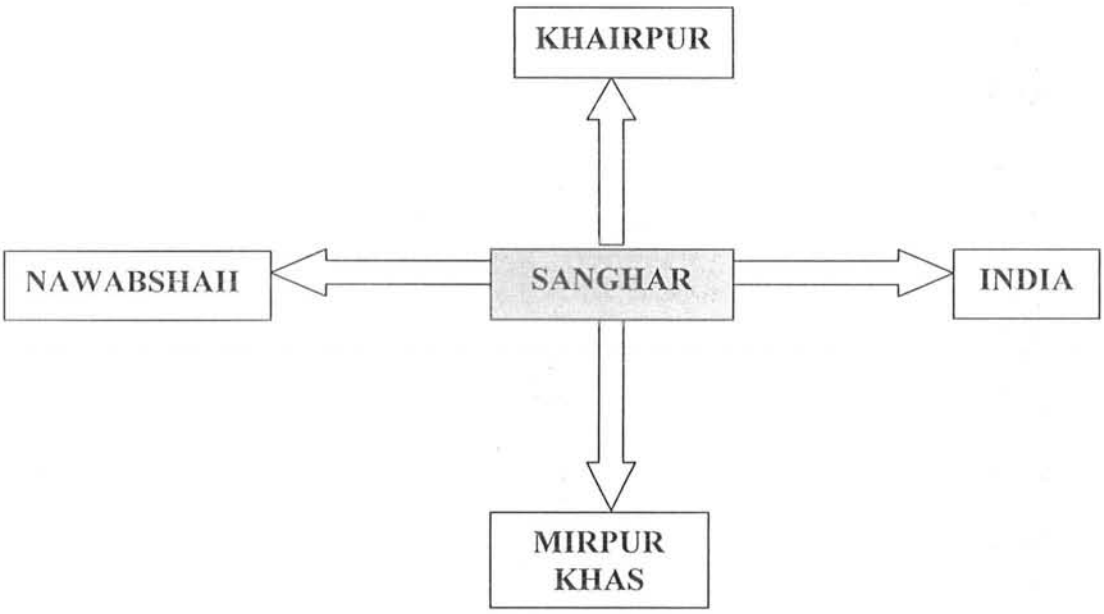



Fig 1.1

## 1.3 RAINFALL AND CLIMATE

The climate of the Sanghar area is dry all the year. It is one of hot areas of Pakistan. The average temperature in summer season is more than $45^0$ C and in winter seasons it is just about $30^0$ C. Rainfall is a rarely happening events in that area. It is almost dry throughout the year and observed average annually rainfall is about 120mm.

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Topography of the area is almost flat. As it is a part of the Indus Basin, thin sheet of sediments are overlying the bedrocks of the area. Due to the Thar Desert, sand dunes are also found which are having the maximum height of about 45 feet.

# CHAPTER 2

# GEOLOGY OF THE AREA

## 2.1 INTRODUCTION

Pakistan lies along part of the tertiary convergence zone and is involved in the interaction of three lithospheric plates. Its territorial limits straddle the Indo-Pakistan, Arabian and Eurasian plates with their triple junction located to the north west of Karachi. It has a large sedimentary area with proven petroleum potentials. The basin evaluation along the fringe of Proto-Indian Ocean and subsequent modification resulting from the continental collision can be correlated with multiple phases of tectonism. Pakistan is endowed with two major sedimentary basins, covering more than 2/3$^{rd}$ of its total area. These basins are the **Indus Basin** and the **Balochistan Basin**. The Indus Basin extends east and southeastward into India. The Balochistan Basin in the west continues northward into Afghanistan and westward into Iran. The two basins are separated by a north0sotuh treading Bela-Orncah-Chaman transform fault. Our project area lies in the Indus Basin.

Indus Basin contains Upper Proterozoic to Cenozoic sedimentary rocks that are relatively simply structured, compared with equivalent rocks in the adjacent fold belts; these rocks lay on Middle Proterozoic and older crystalline basement rocks of the Indian Shield. The basin belongs to the class of producing Extra-continental Downwarp Basins. The Indus can conveniently be delineated into the following sub-basins and fold belts; Kohat-Potwar sub-basin, Punjab platform, Sulaiman fold belt, Sukkur rift sub-basin, Sibi foreland sub-basin, Kirthar fold belt, Sindh platform, and Indus offshore basin.

Lower Indus Basin is further divided into three distinct geomorphic units.

| | | | |
|---|---|---|---|
| 1. | Western high lands | i. | Kirthar Mountains |
| | | ii. | Sindh Kohistan Section |
| 2. | Lower Indus Valley | i. | Western Valley Section |

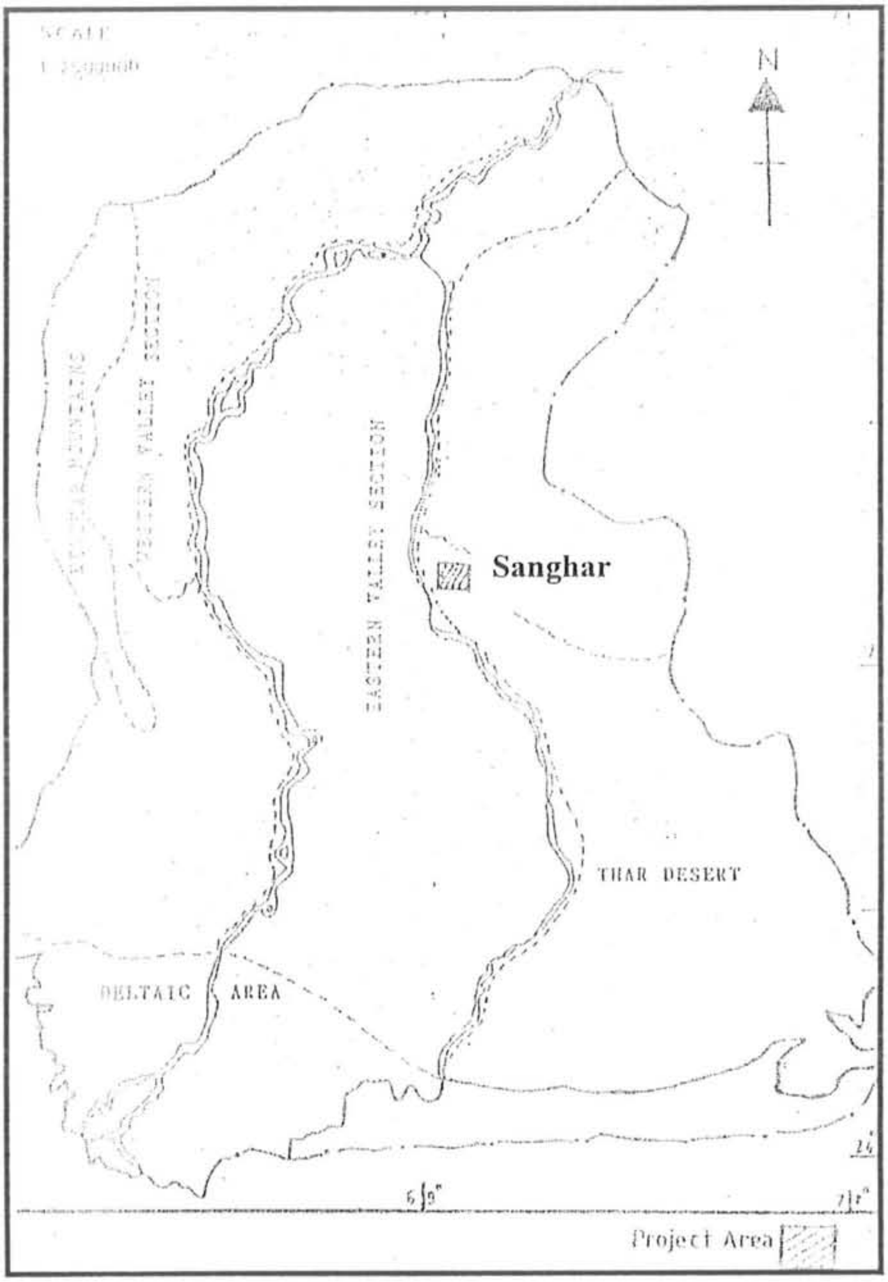
SCALE
N
WESTERN VALLEY SECTION
EASTERN VALLEY SECTION
Sanghar
THAR DESERT
DELTAIC AREA
Project Area

**Figure 2.1**

| | | | |
|---|---|---|---|
| | | ii. | Eastern Valley Section |
| | | iii. | Deltaic Area |
| 3. | Desert Province | i. | The Pat |
| | | ii. | The Thar |

## 2.2 GENERAL GEOLOGY

In general the entire area is covered by Pliocene to Holocene alluvium flood plain deposits of the rivers of the Indo-Gangatic system. The deposition of this complex commenced after the final phase of Siwalik and has been contained through the Pliocene up the recent.

The alluvium consists of the mixture of clastic sediments like sand, silt and clay with sand being dominant. The nature of soil composition varies in composition from place to place on account of vigorous flow of Indus River and Nara Canal forming belts of course and sand underlies the whole area.

## 2.3 STRATIGRAPHY

The wells so far drilled in this basin show extreme lateral variation both from north to south and west to east. This variation regards the rate and direction of sedimentation (Iqbal B. Kadri, 1994).

The stratigraphic succession, which shows the most representative of the offshore platform area, is

- Soan Formation — Pliocene
- Gaj Formation — Miocene
- Nari Formation — Oligocene
- Kirthar Formation — Eocene

| | |
|---|---|
| • Laki Formation | --- |
| • Ranikot Formation | Paleocene |
| • Pab Sandstone | Cretaceous |
| • Fort Munro Formation | --- |
| • Moghalkot Formation | --- |
| • Parh Formation | --- |
| • Goru Formation | --- |
| • Sember Formation | --- |
| • Chiltan Limestone | Jurassic |

### 2.3.1 JURASSIC FORMATION

The Jurassic is represented by the enormous thickness of sedimentary rocks including shales, limestones and sandstones. In Lower Indus Basin, Jurassic is mostly nonclastic. Shirinab, Chiltan and Mazardirk formations are the formations of that age. Chiltan limestone is typically a massive, thick bedded, dark limestone and contains pisolitic limestone beds locally. There are some indications of the development of porosity in Chiltan limestone at deeper levels. So it may act as a reservoir rock (Iqbal B. Kadri, 1994).

### 2.3.2 CRETACEOUS FORMATIONS

The early cretaceous Sember/Goru formations are the oldest rock units penetrated by well drilled so far. Sember formation is over 1900 meters thick and consists of interbedded shale, siltstone, and sandstone. The upper Goru is almost entirely a shaly facies. Lower Goru formation is composed of sand and it has the great petroleum potential as it contains all the hydrocarbons in Sindh monocline. Overlaying the Goru is Parh limestone that is about 136 meters thick.

The Moghal Kot formation consists mainly of limestone interbedded with shale. Upper most Cretaceous Pab formation is poorly developed in offshore Indus. It is either absent or where present, it is not more than 50 meters thick as observed in some of the wells (Iqbal B. Kadri, 1994).

### 2.3.2 PALEOCENE FORMATIONS

The Ranikot formation of Paleocene age is present in the Karachi offshore platform. However the upper Ranikot has only been contoured in one of the platform wells and consist mainly of interbedded shale and limestone. The Lower Ranikot consists of sandstone interbedded with shale and reaches a maximum thickness of about 1300 meters in the subsurface. It consists of 2-3 meters of net interval of coal (Iqbal B. Kadri, 1994).

### 2.3.3 EOCENE FORMATIONS

Laki Formation of Lower Eocene age is laterally extends to the Karachi offshore Platform as well as in the offshore depression. This formation is consisting shaly facies with bands of carbonate rocks. It has the maximum thickness of 445 meters in the Offshore Platform areas. Kirthar formation consists mainly of limestone interbedded with marlstone and calcareous shale and has a maximum thickness of about 1300 meters. It contains 20-meter thick interval of organic rich shales having the potential for generation of light oil or gas (Iqbal B. Kadri, 1994).

### 2.3.4 OLIGOCENE FORMATIONS

Nari formation consists mainly of limestone interbedded with marlstone and calcareous shale, commonly with bands of calcareous sandstone, especially in the upper part. Its maximum thickness is about 1700 meters. It has thin silt beds with very good potential for gas generation (Iqbal B. Kadri, 1994).

### 2.3.5 MIOCENE FORMATIONS

Lower Miocene Gaj formation is about 60-70 meters thick in the offshore platform areas. In the depression area maximum thickness of over 2700 meters was encountered in the southern most offshore well. This formation comprises carbonate facies with intercalations of calcareous clastics (Iqbal B. Kadri, 1994).

# CHAPTER 3

# THEORY OF SEISMIC WAVES

## 3.1 INTRODUCTION

Seismic reflection surveying is a geophysical method commonly used in the oil industry for imaging potential oil and gas reserves. Since the 1980's, high-resolution seismic reflection surveying has been increasingly used in shallow environmental and engineering site characterization projects.

The predominance of the Seismic method over other geophysical method is due to various factors, the most important of which are the high accuracy, high resolution and great penetration of which the method is capable. The widespread use of seismic method is principally in Exploration of petroleum.

The seismic method involves creating seismic waves at the surface via dynamite or vibrosise trucks or accelerated weight drop. The seismic waves travel through the subsurface at a velocity dependent on the density of the soil/rock. When the seismic wavefront encounters an interface where seismic velocity and material density is different, a portion of the wave is reflected back to the surface. A series of seismic receivers, geophones are laid out along the survey line and receive the reflected or refracted wave energy. The geophones send the wave information back to the seismograph via long geophone cables. The seismograph measures the time it takes for the energy to travel from the source reflects and returns to the surface. The raw seismic record, called common shot gathers, contains all recorded seismic events within the user-specified time window. When seismic survey lines come across a water body such as a small river or lake, hydrophones may be used to continue data collection.

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 towards the source. (Telford et al, 1976).

If the rock layers are horizontal or gently dipping seismic waves follow uncomplicated path. The two kinds of paths are followed by reflection seismic waves and refraction seismic waves. The reflected waves have traveled downward to borders between rock layers where they bounce or echo back to the surface. In contrast, the refracted waves follow paths that bend at each border (Robinson & Coruh, 1988).

In seismic method actually a relation is developed between the Seismic velocity and the subsurface lithology. The results obtained are interpreted in geological terms and the lithology of subsurface is studied.

## 3.2 TYPE OF SEISMIC METHODS

There are two types of seismic methods:

### 3.2.1 REFRACTION METHOD

The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity. Seismic energy is provided by a source (shot) located on the surface. Energy radiates out from the shot point, either traveling directly through the upper layer (direct arrivals), or traveling down to and then laterally along higher velocity layers (refracted arrivals) before returning to the surface. This energy is detected on surface using a linear array of geophones. Observation of the travel-times of the refracted signals provides information on the depth profile of the refractor.

### 3.2.2 REFLECTION METHOD

Seismic reflection profiling involves the measurement of the two-way travel time of seismic waves transmitted from surface and reflected back to the surface at the interfaces between contrasting geological layers. Reflection of the transmitted energy will only occur when there is a contrast in the acoustic impedance (product of the seismic velocity and density) between these layers. The strength of the contrast in the acoustic impedance of the two layers determines the amplitude of the reflected signal. The reflected signal is detected on surface using an array of high frequency geophones. As with seismic refraction, the seismic energy is provided by a 'shot' on surface. For shallow applications this will normally comprise a hammer and plate, weight drop or explosive charge.

## 3.3 PRINCIPLE OF REFLECTION METHOD

This method involves the generation of waves from a point source. The earth consists of different layers. These layers are different in terms of density and velocity. The product of density and velocity is called acoustic impedance, which is represented as

$$Z = \rho V$$

Whenever a seismic wave strikes the interface of two layers with different acoustic impedance, it is reflected back. According to Robinson and Coruh, (1988) greater the contrast in the value of acoustic impedance, the greater the reflection becomes.

## 3.4 GEOMETRY OF THE REFLECTED RAY PATH

### 3.4.1 REFLECTION FROM HORIZONTAL REFLECTORS

The equation for the travel time " T " of the reflected ray from a shot point to a detector at a horizontal offset is given as:

$$T^2_x = T^2_o + X^2 /2T_oV^2 1$$

Where

$T_x$ = travel time of reflected wave at a distance "x from the source.

X = Geo-phone interval.

$V_1$ = Velocity of the 1st layer.

$T_o$ = Zero offset time and is given as $T_o = (2H_1) / V_1$.

$H_1$ = Depth of 1st Reflector.

The above-mentioned equation is used in various ways in the processing and interpretation of reflected data. The depth $H_1$ to the first reflector from zero offset time is given as;

$$H_1 = T_o V_1 / 2$$

And the depth $H_n$ to the deepest reflector by:

$$H_n = V_{n,avg.} T_{o,n} / 2$$

Time Distance Relation of Waves Reflected from a horizontal Surface at the Depth of "Z" in a Medium of constant Velocity "V1" (Zia-ur-Rehman, 1989).

## 3.4.2 REFLECTION FROM DIPPING REFLECTOR

The reflectors are not horizontal in nature, and we also have dipping reflectors. The mathematical expression for finding travel time is;

$$T^2=T^2_o [1+X^2+4hx \text{ Sin } x] / 4 V^2 To$$

Other parameters can be obtained from the following equations

| | |
|---|---|
| $To=2h / V$ | Zero Offset Time |
| $T \min = 2h \text{ Cos}\alpha / To$ | Minimum Travel Time |
| $\text{Cos}\alpha = T_{min} / To$ | Angle of Inclination |
| $H = X_{min} / 2$ | Sin X Angle of Reflector |

$D = hTo/T_{min}$ Depth (D) beneath the Reflector

$V = 2h\ Cos\alpha / T_{min}$ Velocity of the Layer

$V = 2\ Tmin\ d / To$

# 3.5 THEORY OF ELASTICITY

As a seismic wave propagates through any given medium, certain changes take place in that part of the medium, which are traversed by the wave. The type and amount of these changes depend largely on the energy content of the wave and on the physical properties of the medium (Al-Sadi, 1980).

The principal types of change experienced by a medium due to passage of a seismic wave are re-distribution of the internal forces and modification of the geometrical shape. The *theory of elasticity* deals with the analysis of these principal effects and the related features (Al-Sadi, 1980).

## 3.5.1 STRESS

"A force that is acting on a finite area occupying an arbitrary position within the medium represents **stress"** Or "It is the force per unit area. "

Thus when force is applied to a body, the stress is the ratio of the force to the area on which the force is applied (Al-Sadi, 1980).

$$T = F/A$$

## 3.5.2 STRAIN

When an elastic body is subjected to stresses, changes in shape and dimension occur. These changes are called strain.

It has different types such as longitudinal strain, transverse strain, shear strain and volume strain (Al-Sadi, 1980).

## 3.5.3 THE ELASTIC MODULI

The elastic properties of isotropic materials, which obey Hook's Law, are satisfied by elastic moduli. These include the following:

### I- YOUNG'S MODULUS (E):

It is also called stress modulus. When a rod is pulled or compressed then the Young's Modulus is given by

$$\text{Young's Modulus } (\mathbf{E}) = (\Delta F/A) / (\Delta L/L)$$

Where,

| | | |
|---|---|---|
| F | = | Stretching force, |
| ΔL | = | Change in length, |
| A | = | Cross-sectional Area |
| L | = | Original length |
| ΔF/A | = | Longitudinal Stress |
| ΔL/L | = | Longitudinal Strain |

#### II- BULK MODULUS (K)

The modulus expresses the Stress Strain ratio in case of a simple hydrostatic pressure 'P ' applied to a cubic element, the resultant volume strain being the change of volume "ΔV" divided by the original by the original volume V (Al-Sadi, 1980).

$$\text{Bulk Modulus } (\mathbf{K}) = (\text{Volume Stress } p) / (\text{Volume Strain } \Delta V / V)$$

The bulk modulus is some times called *incompressibility* and its reciprocal is called *compressibility* (Al-Sadi, 1980).

### III- SHEAR MODULUS (M)

It is defined as the ratio of shearing stress (t) to resultant shear strain also called the rigidity modulus (Al-Sadi, 1980).

Shear Modulus ($\mu$) = (shearing stress T) / (shear strain)

### IV- POISSON RATIO

The ratio of transverse or lateral strain to longitudinal strain is known as Poisson ratio. When a rod of length L is pulled it elongate by $\Delta L$ and its width w is contracted by $\Delta W$. It is denoted by $\sigma$ (Al-Sadi, 1980).

$$\sigma = (\Delta W / W) \; / \; (\Delta L / L)$$

Its value ranges from 0.05 for very hard, rigid rock to about 0.45 for soft poorly consolidated material.

## 3.6 Seismic Wave Laws

There are three fundamental laws obeyed by the seismic waves. They are described here in brief.

### 3.6.1 HUYGEN'S PRINCIPLE

This law states that waves in homogeneous medium out from a point source in expanding sphere, so that every point is source of a new wave that travels out from it in spherical shells (Al-Sadi, 1980).

### 3.6.2 FERMAT'S LAW

This law explains that time required for a wave to travel from one point to another is less than the time taken to do this journey by any other route.

### 3.6.3 SNELL'S LAW

The direction of reflected and refracted waves traveling away from a boundary depends upon the direction of the incident waves and speed of the waves. (Figure 3.1)

$$Sin_i\, i / Sin_r = V_o / V_1$$

| | | | |
|---|---|---|---|
| Where, | i | = | angle of incidence |
| | r | = | angle of refraction |
| | $V_0$ | = | velocity of 1st medium |
| | $V_1$ | = | velocity of 2nd medium |

### 3.6.3 CRITICAL ANGLE

The angle of incidence "i" for which angle of refraction is $90^0$, is called the "Critical Angle" and for refraction is denoted by $i_c$. (figure 3.2)

$$Sin\, i_c = V_0 / V_1$$

## 3.7 TYPES OF SEISMIC WAVES

The Seismic wave is corner stone in all the seismic activities. These are messengers that convey information about the earth's interior. The Seismic wave is basically a sound wave, which is mechanical motion in an elastic medium (Zia-ur-Rehman, 1989).

As a seismic wave propagates through a given medium, certain changes take place in that part of the medium. The type amount of these changes depends largely on the energy, content of wave and on the physical property of the medium itself (Al-Sadi, 1980).

Waves are of different types and of many wave types only four: compressional, shear, Raleigh and Love waves directly concern the interpreter in

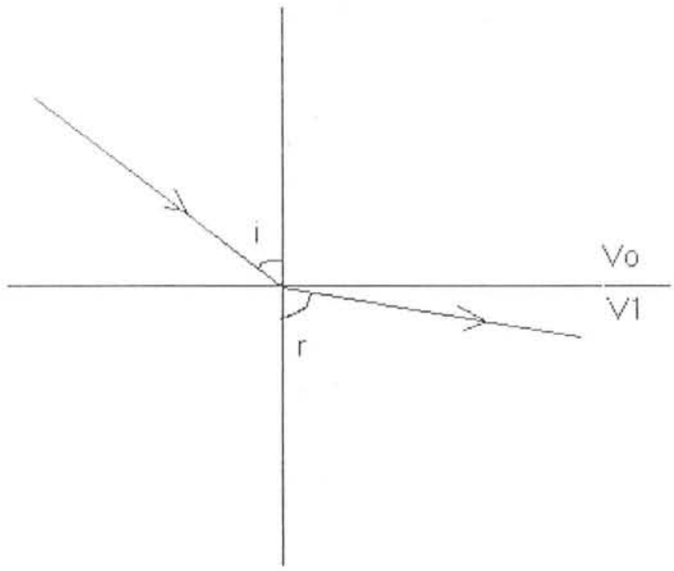


Figure: 3.1 Snell's law

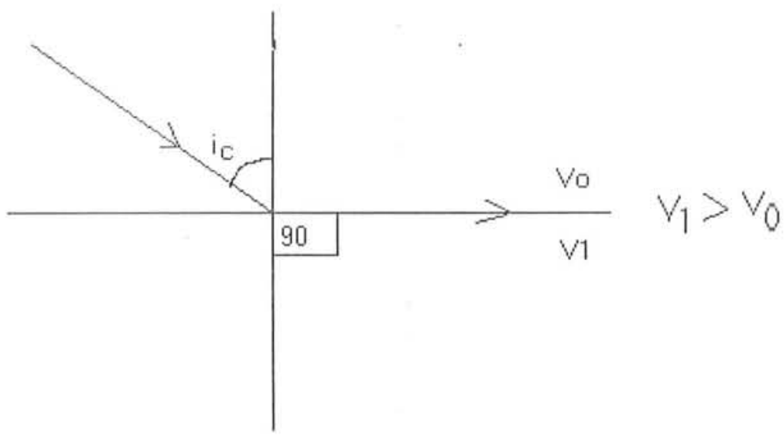


Figure: 3.2 Critical Refraction

conventional exploration. These waves are distributed in two main types (Al-Sadi, 1980).

### 3.7.1 LONGITUDINAL WAVE

This type of wave is also known as compressional or primary wave. The traveling disturbance in this case is cubical dilation or "volume deformation". Thus the wave path traversed by a P-wave

Consists of a sequence of alternation zones of compressions and rarefactions. The particles of medium oscillate about their zero-positions in a direction coincident with the ray path at those positions (Al-Sadi, 1980).

P-wave is the fastest wave for a given medium and, therefore, it is the earliest phase normally detected on earthquake seismograms. Its velocity, $v_p$ is given by,

$$V_p = [(K+4\mu/3)/\rho]^{1/2}$$

| | | |
|---|---|---|
| $K$ | = | Bulk's Modulus |
| $\mu$ | = | Shear Modulus |
| $\rho$ | = | Density of material |

### 3.7.2 TRANSVERSE WAVES

The traveling disturbance in this case is the shearing strain or "shape deformation." The medium, which is traversed by an S-wave, experiences no volume changes. A consequence of the shearing strain is transverse displacement of the path particles relative to the propagation direction. In view of these characteristics, this type of wave is called shear or *transverse wave* (Al-Sadi, 1980).

An S-wave moving in a horizontal direction, which is so polarized that the particle motion is confined to the horizontal plane, is known as SH-wave. When the polarization plane is vertical it is called SV-wave (Al-Sadi, 1980).

The velocity of s-waves, $v_s$ is given by:

$$V_S = (\mu/\rho)^{1/2} = [Y/2\rho(1+\sigma)]^{1/2}$$

### 3.7.3 RALEIGH WAVE

These waves develop at the free surface of a semi-infinite medium. The wave amplitude decays rapidly with the increasing depth (Al-Sadi, 1980).

The traveling deformation is the sort of combination of both dilation and shear strain. The particle motion takes place in a vertical plane parallel to the direction of propagation and has elliptical retrograde orbit. The minor axis is about two-third of the major vertical axis (Al-Sadi, 1980).

Raleigh waves travel with a velocity $V_R$ given by

$$V_R=0.92V_c$$



"Ground roll" normally seen in reflection recording is made up mainly of Raleigh-wave type (Al-Sadi, 1980).

### 3.7.3 LOVE WAVE (L)

This kind of waves is develops in a low-velocity surface layer, which overlies a semi-infinite medium (Al-Sadi, 1980).

The particle motion is transverse and in the horizontal plane. This type of wave travels by multiple reflections between the top and bottom boundaries of the surface layer (Al-Sadi, 1980).

Since it possesses no vertical component, Love waves are not detected by the geophone or by another vertical-component instrument (Al-Sadi, 1980).

## 3.8 APPLICATIONS OF SEISMIC METHODS

Seismic methods are used:

- To find out the structural traps (such as anticlines, faults, salt domes and reefs).
- To investigate the Stratigraphic features like discontinuous layers.
- Imaging top of bedrock
- Imaging sub-bedrock strata
- Reflection data can be used to determine the average velocities of seismic waves provide a good indication of lithology (Dobrin and Savit, 1988).
- Seismic method is also used in search for ground water, in civil engineering, mineral exploration and locating subsurface features (Robinson and Coruh, 1988).
- Imaging faults and fracture zones
- Cavity detection.
- Mapping abandoned coal mines

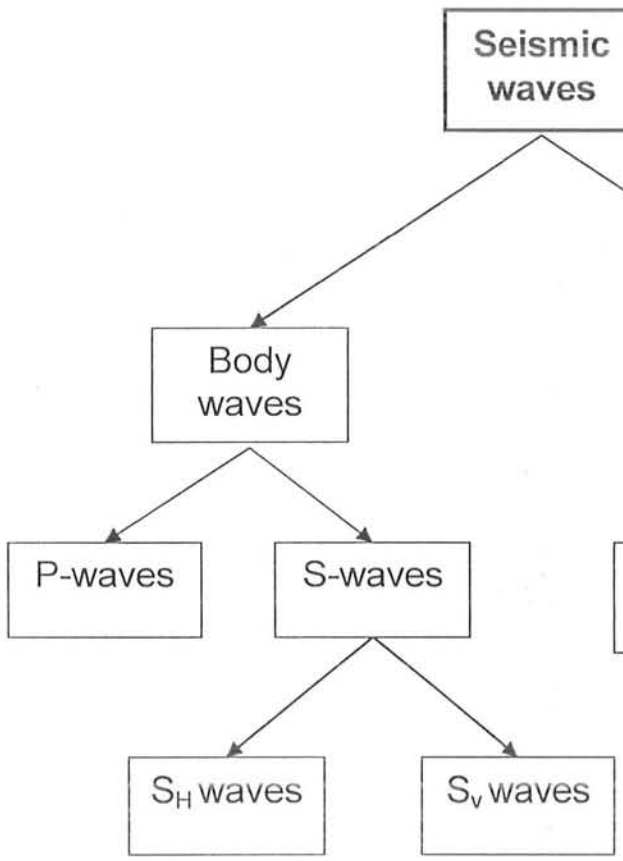


**Figure: 3.3 Flow chart of the types of seismic waves**

# CHAPTER 4

# SEISMIC DATA ACQUISITION

## 4.1 INTRDUCTION

Fundamental purpose of seismic data acquisition is to record the ground motion caused by a known source in a known location.

- First step in seismic data acquisition is to generate a seismic pulse with a suitable source.
- Second is to detect and record the seismic waves propagating through ground with a suitable receiver (geophone/seismometer), digital or analogue form.
- Third is the registration of data on a chart or tape recorder.

(Kearey et al, 2002)

The record of ground motion with time is called as seismogram. It is the basic information to be used in seismic data interpretation. During the seismic data acquisition certain operations are to be applied, such as conversion of the ground motions into electrical signals, amplification of these signals and filtering of the signals as well.

Prior to seismic data acquisition, control points in the area under study are established using the satellite and local ellipsoid datum. These control points are used to control the exact orientation of seismic lines.

After this survey layout procedure is decided. Surveyor starts to lay out the seismic line according to the prescribed program. While doing this surveyor has to mention the pickets and shot points as well. Numbers are assigned to these pickets. Pickets are the small heaps of soil or stones on the ground at some constant distance. In seismic survey these pickets represents the seismic channels.

Shot points are those pickets on which shots are recorded. Distance between pickets and shot points is selected by QC geophysist in crew.

While doing seismic data acquisition, chainage sheets (surveyor's log) are also prepared. This sheet contains information about vegetation, water resources, etc. These sheets are very useful for geometry development of the survey area in seismic data processing.

Another important aspect of seismic data acquisition is drilling up of the shot holes. This drilling can be done with

(1) Rotary rigs.

(2) Flushing unit.

These holes can be used for shooting as well as for well velocity surveys (Down hole and Up hole surveys).

(Al-Sadi, 1980)

## 4.2 ACQUISITION SETUP

### 4.2.1 THE SPREAD CONFIGURATION

The spread is defined as the layout on the surface of the detectors gives recorded output for each source. The number of detectors in a single spread is determined by the recording channels of the employed recording equipment. The most common practice followed now a day is to record 48 detectors-outputs for each source (Al-Sadi, 1980).

For reflection surveys, the source and the detectors are called the **shotpoint** and the **trace** respectively. The trace is normally made up of a group of geophones arranged in a certain geometrical configuration so that it gives the best reception response. However, for computational purposes, the location of the trace is represented by its centroid (Al-Sadi, 1980).

| 12-Trace-Spread | | 24-Trace-Spread | |
|---|---|---|---|
| Move Up Rate | Coverage Fold | Move Up Rate | Coverage Fold |
| 1 | 12 | 1 | 24 |
| 2 | 6 | 2 | 12 |
| 4 | 3 | 4 | 6 |
| 12 | 1 | 12 | 3 |
| | | 24 | 1 |

There are different types of spread configuration used according to the given conditions and objectives which are:

(1) Split Spread
(2) End Spread
(3) In Line Spread
(4) Cross Spread
(5) L-Spread

Along with these basic spreads, another technique called as Fan shooting can also be used. In this technique, geophones are arranged in an arc, fanning out in different directions from the source (Robinson & Coruh, 1988).

Fan shooting is used in Transmission method. Transmission method differs from normal refraction method in the sense that it does not involve critical incidence of waves over the interface. In Transmission method, source and detector are on opposite sides of the investigated interface. Other techniques used in transmission method in velocity logging (well shooting, continuous velocity logging (CVL) and uphole survey).

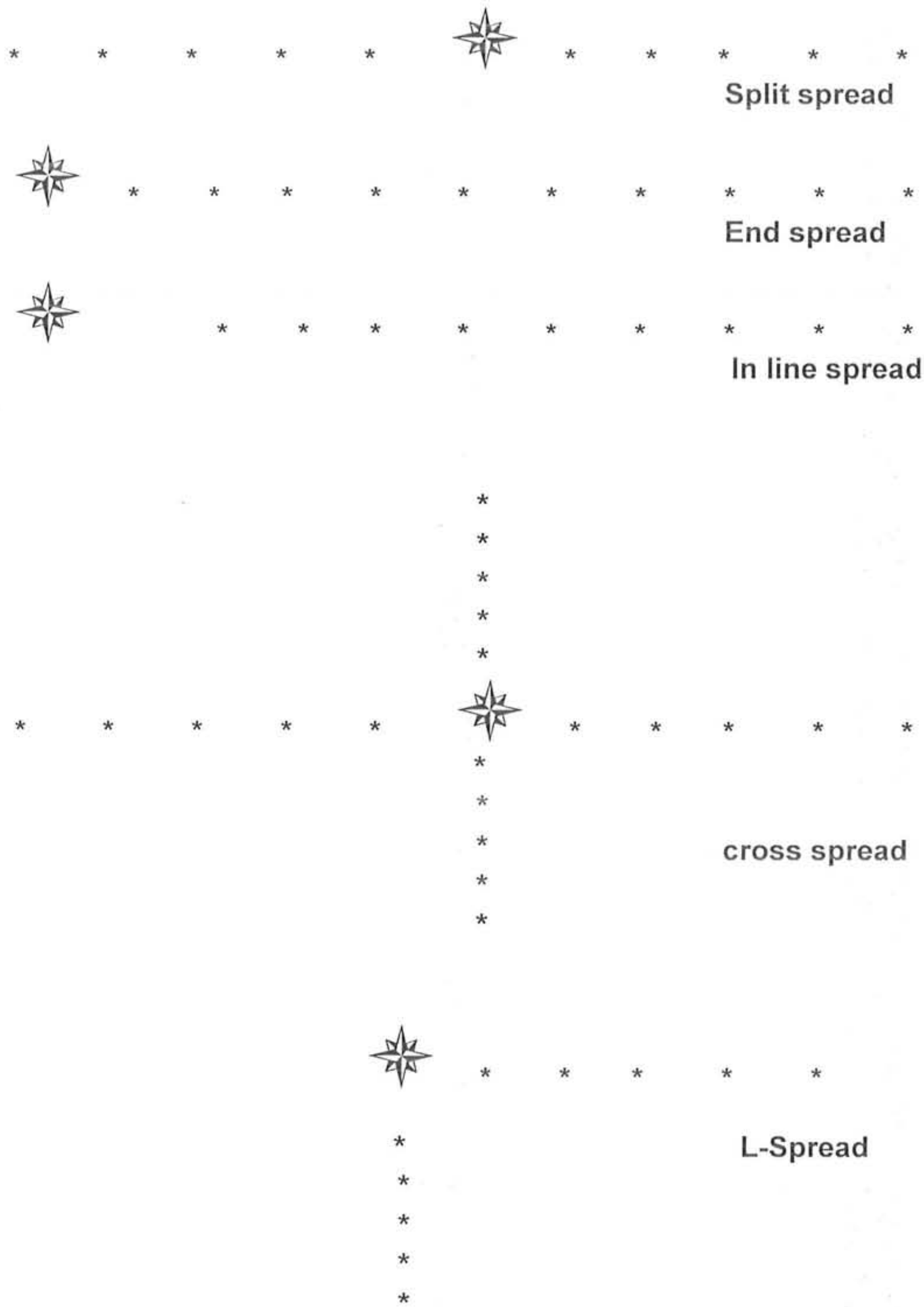


**Fig. 4.1 Spread Configuration**

Fan shooting is used for determination of the dimensions of velocity anomalous structures (Al-Sadi, 1980).

### 4.2.2 SHOOTING TYPES

There are different types of shootings used in the field. These types are:

(1) Symmetric shooting.

(2) Asymmetric shooting.

(3) End shooting.

(4) Roll in

(5) Roll out shooting.

Symmetric shooting is one in which the number of channels on sides of source is same.

Asymmetric shooting is one in which the number of channels on sides of source is not same.

End shooting is one in which source is at one end of the spread.

Roll- in shooting is one in which we have to add receivers in the spread while shooting in the source along the spread.

Roll-out shooting is one in which we have to remove the receivers from the spread while shooting out along the spread.

### 4.2.3 SHOOTING PARAMETERS

Shooting parameters include

(1) Source size.

(2) No. of holes.

(3) Hole depth.

(4) Shot at or between the pickets.

### 4.2.4 RECORDING PARAMETERS

There is a set of parameters that define a given recording operation. These parameters are normally kept constant during a survey of a given area. (Al-Sadi) The most important parameters are the following,

#### (1) GROUP INTERVAL

Group is defined to be as combination of a certain no of geophones. Group interval is the interval between the mid points of two-consective group.

#### (2) GROUP BASE

It is the total length of that collectively feed a channel. Group base can act for the suppression of noise.

#### (3) NO. OF CHANNELS

Total no. of recording units used in the survey.

#### (4) NO. OF GEOPHONES IN A GROUP

Total no. of geophones in a group.

#### (5) GEOPHONE ARRAY

It can be linear, weighted or arial. Linear array means that all geophones are arranged along a line. Weighted array means that geophones in a group are arranged in form of parallel lines. In this array sensitivity of each geophone is made different. In arial array, geophones are laid over an area around the line.

#### (6) SAMPLE RATE

The time in digital recording during which discrete samples are recorded.

#### (7) RECORD LENGTH

The total length of for recording one short is called as record length.

### (8) COVERAGE

Coverage means how many fold data will be obtained from the multifold profiling survey. No of folds from a survey can be determined as follows

**No of Folds = $(N*\Delta X)/2*\Delta S$**

N: the number of recording channels along a spread.

$\Delta$ X: the geophone interval.

$\Delta$ S: the source interval.

(Robinson &Coruh, 1988)

### (9) NEAR AND FAR OFFSET

The minimum possible distance between source and first active channel is called as near offset. The distance from the source to last active channel is called as far offset.

Along with these basic parameters certain other parameters which are kept constant throughout a survey of an area.

These are

(1) The initial gain.

(2) The filter setting.

(3) The trace to channel relationship.

(4) The recording format.

## 4.3 SHOOTING & RECORDING PARAMETERS

The initial stage of seismic survey involves field trails in the survey area to determine the most suitable combination of source, offset, recording range, array geometry and detector spacing to produce good seismic data.

Quality of field data can be achieved if field parameters (shooting and recorder) are appropriately selected. Conducting different experiments in field does this selection. This selection of parameters is dependent on four variables.

These variables are source size, source depth, no. of holes and group base. By changing these Variables, the best combination is selected for recording and shooting parameters.

## 4.4 TYPES OF ENERGY SOURCES

The most common method applied in generating seismic waves is exploding dynamite in shot-holes. But there are different methods which have been introduced as alternative seismic sources. Depending on the field conditions prevailing in a given survey, one of these methods may be more suitable then the rest (Al-Sadi, 1980).

### 4.4.1 DYNAMITE

This is the most common energy source used in seismic prospecting. Normally it is exploded inside a drilled hole at a depth depending on the thickness of weathered layer. The deeper the charge the less intensive the generated surface waves are. Charge is usually sealed with water or mud to increase charge coupling with the surrounding medium.

The amount of charge per shot-point depends on whether it is a single hole or a pattern shooting. Generally the charge estimate is 10-50 kg of dynamite (Al-Sadi, 1980).

### 4.4.2 GEOGRAPH

This method involves the method of dropping a weight of about 3 tons from a height of about 3 meters on to the ground. Since the generated energy is weak in comparison with dynamite shooting, *vertical stacking* is carried out. Thus, the records of 30 to 50 drops made at the one location are stacked together for signal enhancement (Al-Sadi, 1980).

### 4.4.3 VIBROSEIS

This method is based on the use of a mechanical vibrator that is hydraulically or electrically driven to exert a force of an oscillation magnitude. The source function (the sweep) consists of force pulses generated at a frequency that is increasing linearly with time from about 6 Hz to 65 Hz during a time span of say 6-16 seconds.

Since the source is active during a time interval of a defined length, each reflection has a record length which is equal to the sweep duration. Thus, the obtained record represents the superposition resultant of all the wave trains, which correspond to the individual reflections. To extract the actual reflection time, the recorded signal is cross-correlated with the applied sweep (Al-Sadi, 1980).

### 4.4.4 DINOSEIS

In this method weight is not dropped freely. Here it is power-driven against the ground surface.

Here exploding the gas mixture contained in a chamber generates energy. The bottom of which is a moveable plate (Al-Sadi, 1980)

### 4.4.5 GEOFLUX

It consists of an explosive cord, which is buried in the ground at a shallow depth. It is not advisable to use geoflux in areas where the surface layer is too thick and unconsolidated, because in this way transmitted energy will be much weakened (Al-Sadi, 1980).

### 4.4.6 AIR GUN

It is most commonly used method. It discharges a highly compressed air into the water.

### 4.4.7 STREAM GUN

It is same as that of the air gun with the only difference that here hot steam instead of air is used.

### 4.4.8 GAS-GUN

It is also a similar marine source. It is an explosion of a mixture of propane and oxygen contained in a steel chamber.

## 4.5 DETECTION AND RECORDING

The most important and necessary step of data acquisition is detection and recording of data. It is described as follow:

### 4.5.1 SEISMIC DETECTORS

Similar to the source, special receiver/detectors are used for the measurement of the seismic waves on land and in water:

(1) Geophones - on Land.

(2) Hydrophones - in Water.

### (1) GEOPHONE

Most of the geophones are based on the principle of a moving coil. The cylindrical coil is suspended in a magnetic field by a leaf-spring. The passage of a seismic wave at the surface causes a physical displacement of the ground, which moves the geophone case and magnet in sympathy with the ground but relatively to the coil because of its inertia. This relative movement of the magnet with respect to the coil results in a small voltage being generated across the terminals of the coil in proportion to the relative velocity of the two components. Geophones thus respond to the rate of movement of the ground (i.e. particle velocity) not to the amount of movement or displacement (Al-Sadi, 1980).

To amplify the wanted signals and to suppress the unwanted signals like surface waves, more geophones are used in one group. The signal of the separate geophones is added to one signal for the whole geophone group (Al-Sadi, 1980).

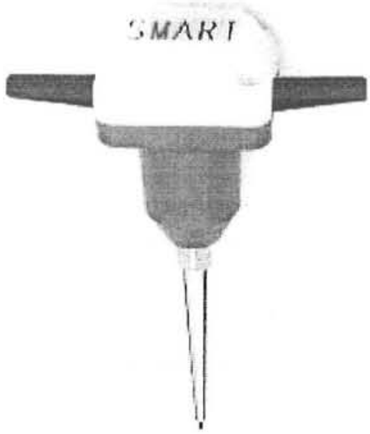


Figure 4.2 Vertical Geophone

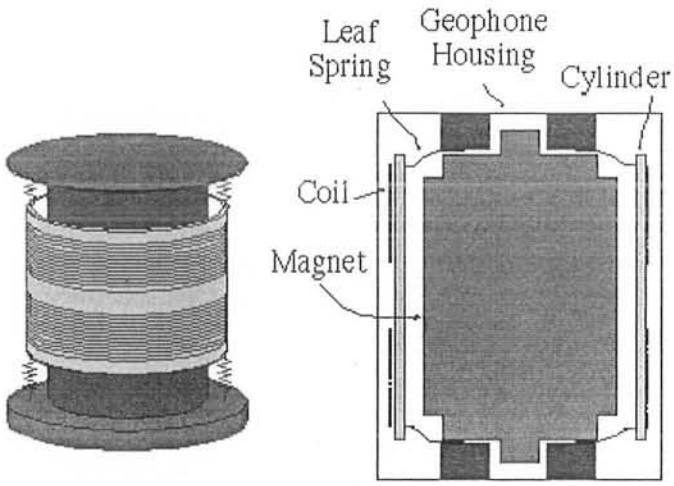


Figure 4.3 Internal Structure of Geophone

## (2) HYDROPHONE

Hydrophone/Pressure Phone is the standard receiver in Marine Seismic Survey and responds to variations in pressure. Principle of the measurement is the measurement of the change in pressure with a piezoelectric crystal placed in the hydrophone. Due to the bending of the crystal, a voltage occurs (Robinson & Coruh, 1988).

### 4.5.2 SEISMIC RECORDING

There are two types of recording system.

(1) Analogue-recording system.

(2) Digital-recording system.

### (1) ANALOGUE-RECORDING SYSTEM

This system is made up of an assembly of electronic unit normally housed in a specially adapted truck called as *recording station or dog house.* The function of the system may be divided into two main stages.

(1) The amplification stage.

(2) The recording stage.

*THE AMPLIFICATION STAGE:*

In this stage amplifier is used to amplify the seismic signals. Amplifier is capable to handle voltage amplitudes covering arrange comparable to100db. Amplification is done by a special technique called as *automatic gain control.* The amplification stage usually includes filtering facilities for certain optional bandwidths.

*THE RECORDING STAGE:*

Task of this stage is to make permanent record of the amplifier output on magnetic tapes. (Al-Sadi, 1980)

#### (2) DIGITAL RECORDING SYSTEM

In addition to basic amplification and magnetic recording, a digital station is equipped with the facility to convert a continuous signal into a digital form. The sample value is expressed in terms of binary numbers. Process of digital recording is done in three stages.

1. The amplification stage
2. The A-D conversion stage
3. The recording stage

## 1. THE AMPLIFICATION STAGE

Here along with gain-controlled amplifiers, another amplifier called as binary gain- ranging amplifier is used. The dynamic range is defined as the ratio between the smallest and largest amplitude that can be distinguished. The dynamic range is given in db (Al-Sadi, 1980).

It amplifies the signal in 6db steps rather than continuous amplification as in AGC Amplifier. The amplification stage normally includes *low-cut, high cut, notch, and anti-aliasing filter* (Al-Sadi, 1980).

## 2. THE A-D CONVERSION STAGE

It is much easier to apply mathematical operations on digital data than on analog data. Therefore an analog signal has to be converted into a digital signal. All seismic signals recorded digitally are registered in the form of binary numbers, each representing a sample value for an individual channel. The A-D Converter compares the analogue signal with the different voltage steps and add these in such a way that the smallest error between the analogue and digital signal occurs .The coordination between A-D unit and numerous channel inputs is effected through the use of the multiplexer. For a measurement, the gain must be set such that the amplitude of the measured data lies in the range of the A-D Converter. The required switching rate of A-D converter is determined by the required digital sampling interval and number of channels to be multiplexed.

The multiplexed digital data are recorded in a standard tape format. This formatting process involves distribution of the bits of each binary word on a defined number of information tracks.

## MULTIPLEXER

Older systems with many separate channels do not have channel a separate A-D Converter or enough writing capacity for each separate channel to save all data from one shot. To solve this problem, all the traces from each channel are sampled for a certain sample rate. This process is repeated for all traces for the whole sample length. These sampled values are in time sequential form and are saves on the magnetic tape.. This data is not ordered for each channel trace (channel trace 1, channel trace 2 channel trace 3 etc.), but is ordered for each time sample for all channel traces (Time sample1 - all channels, Time sample 2 - all channels, etc.). For data processing all channel traces are to be sorted out from this multiplexed data by the process called as Demultiplexing.

## THE RECORDING STAGE:

The output of formatting unit is fed to the magnetic recording system (Al-Sadi, 1980).

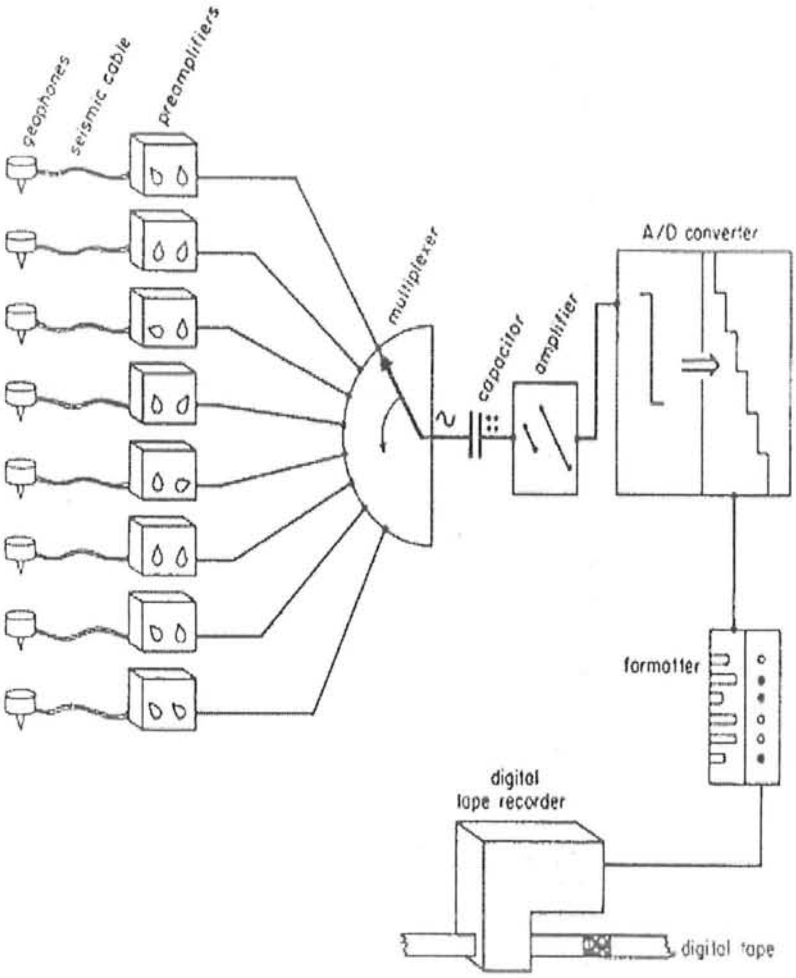


**Figure 4.3 Schematic Illustration of Digital Recording System**

# CHAPTER 5

# SEISMIC DATA PROCESSING

## 5.1 INTRODUCTION

Seismic data are recorded in the field on magnetic tape. About three to six weeks latter the information is transmitted to the interpreter as a seismic section. All of the intervening steps comprise the data processing phase of seismic exploration. The primary problem arises because different types of events can arrive at the geophone at the same time and so confuse each other. Surface waves, shallow refractions, multiples, converted waves from different horizons or other type of waves may all arrive at the same time as primary reflection and be supper imposed on the seismic record. The problem then is to separate the primary reflections, seismic, which have been refracted only once by bedding underneath the seismic line. To effect this separation, we need a discriminate that is, a respect in which the signal and noise amplitude, normal move out, or some other regards.

In data processing the data is analyzed to determine how the noise differs from the signal and the process is applied which utilizes this difference to attenuate the noise.

Processing seismic data consists of applying a sequence of computer programs each designed to achieve one step along the path from field tape to record section.

As an input-output system, processing may be schematically represented in figure 5.1.

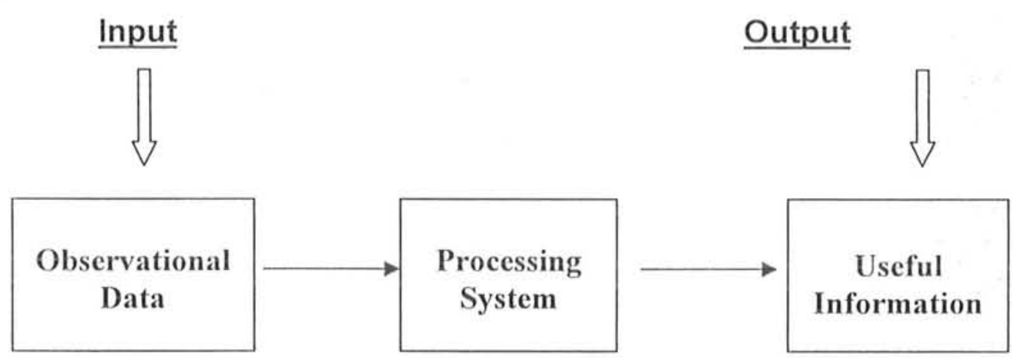


**Figure 5.1**

Modern data processing does not eliminate the need for judgments by seismologists. But it does not provide the means to assemble far more information in forms that can be examined more systematically and efficiently than would be possible without digital technology. This means that more informed judgments can be made (Robinson E.S, Coruh C. 1988).

Naturally, the computer system forms the backbone of any modern processing center. The computer hardware and associated programs, known as software, make up the physical and practical bulk of the computer. The particular software mainly controls the type of processing.

In general, the selection of the processing sequence for a given set of field data depends upon the following factors:

- Intrinsic quality of the raw data
- Geological environment
- Processing philosophy
- Personal preference
- Cost

## 5.2 PROCESSING TECHNIQUE

The basic steps involved in processing are described below,

### 5.2.1 DEMULTIPLEXING

Field seismic data is recorded on the magnetic tape, using formats as SEGA, SEGB, and SEGC. Unlike analog seismograms, which are recorded in a form suitable for analysis, digital seismograms must be assembled from the digital tape by a sorting process. This sorting process is called Demultiplexing.

"The process of sorting data from the magnetic tape into individual is called Demultiplexing".

Demultiplexing, first step in seismic data processing according to Yilmaz (1978) is to transpose the matrix in such a manner that columns of the resulting matrix can be read as seismic traces representing different offsets related with a shot point. In a recording system of 'n' channels where each channel has been sampled 'm' times, values are put in the following manner:

A11, A12, A13,....................A12,A22,A23,.........,

.......................A1 n,A2 n,A3 n,.....................A n m

A computer program used for the purpose of demultiplexing arranges the data in the following order to prepare a digital seismogram:

A11,A12,A13,...................,A 1 m

A21,A22,A23,...................,A 2 m

...........................................

...........................................

A n 1,A n 2,A n 3,....................A n m

### 5.2.2 VIBROSEIS CORRELATION

On a Vibroseis record, each reflection is as long as the input sweep. Each reflection is the near a duplicate of the sweep itself and so the refractions in the Vibroseis record overlap and are generally indistinguishable. To make the Vibroseis record useable, the reflections are compressed in to short wavelets. This is done by cross correlating, the data with the original input sweep. Thus correlated Vibroseis data looks similar to impulsive source data.

### 5.2.3 BINARY GAIN RECOVERY

Modern digital recording systems use various gain ranging techniques to increase their dynamic range. Gain ranging instruments apply a gain to the signal before recording it and also keep a record of what gains were applied. The processing center "degain" the data, that is, remove the gain applied by the field instruments. The "degain" process is often called the "true amplitude gain recovery". After de-gaining the trace, the original signal is obtained.

Again there is problem of very rapid decay of amplitude due to spherical divergence effect and attenuation losses. To correct for the rapid decay of signal energy, a gain function may be applied. A gain function is a smoothly time varying gain applied to the data to being the overall amplitude up to the fairly constant level. This is referred to as gain recovery.

### 5.2.4 AMPLITUDE ADJUSTMENT

A gain recovery function is applied on the data to correct for the amplitude effects of wave front divergence. This amounts to applying a geometric spreading function, which depends upon travel time, and an average primary velocity function, which is associated with primary reflections in a particular survey area. There are two broad types of amplitude gain programs: Automatic gain control and Relative true amplitude gain.

### 5.2.5 TRACE EDITING

Raw seismic data inevitably contains some unwanted noise and perhaps some dead traces. If obviously useless information is to be removed from the processing stream it must first be identified and then blanked or muted by assigning zero values to all samples in the affected time interval. Unwanted data are usually identified by visual examination of raw field traces although obvious cases (dead traces, strong noise bursts, etc) can be detected and edited automatically.

The raw field traces used in this editing procedure can be obtained from field monitor records.

### 5.2.6 CDP SORTING

Seismic data acquisition with multifold coverage is done in shot receiver coordinates (s,g). On the other hand, seismic data processing is done in midpoint-offset (y,h) coordinates. The required coordinate transformation is achieved by sorting the data in to CMP gethers. Each individual trace is assigned to the mid point between the shot and receiver location associated with that trace. Those traces with the same mid point location are grouped together, making up a CMP gather.

CDP gather is equivalent to the CMP gather only when reflectors are horizontal and velocities do not vary horizontally. However, when there are dipping reflectors in the subsurface, these two gathers are not equivalent and only the term CMP gather should be used. In common depth-point gather, the traces reflecting from the same point are collected. Traces are routinely gathered in to groups having same common element. The types of gathers usually made are

- Common Source Point
- Common Depth Point
- Common Receiver
- Common off-set

### 5.2.7 CONVOLUTION

The convolution the interaction of the signal and filter, such that the filter coefficient are time reversed with respect to the signal and then it cross correlated with the signal. The convolution is a concept with wide practical applications in the time series analysis. Convolution of two functions f (t) and h (t) is defined by the operation

$$f(t) * h(t) = \int f(t)\ h(t-\tau)\, d\tau$$

### 5.2.8 DECONVOLUTION

De convolution may be defined as a certain process, which counteracts a previous convolution action. Consider the following convolution operation

$$Y (t) = f (t) * h(t)$$

Where,

f(t) are two convolved functions and Y(t) is the convolution output function. Now suppose Y(t) and f(t) are given then the processes of finding h(t)is called deconvolution and the system which does that it is called inverse filter (Sadi, 1980).

The earth itself acts as filter. It expends an impulsive in to a wavelet in to several wavelets by reflection and refraction. Deconvolution has been developed as a mean off partially reversing the effect of the earth filter. Deconvolution has two objects

- It seeks to compress the wavelet in to a shorter impulse.
- It seeks to shift same wavelets produced by the incident wavelets that produced them.

In other words, deconvolution is designed to shape the pulse and attenuate multiples.
The desired signal is obtained by convolving the record trace with another specially designed trace (operator).

There are two types of deconvolution relatively common.

- Deterministic deconvolution
- Predictive deconvolution.

In predictive deconvolution the gape interval or prediction length is the length of trace unaffected by the deconvolution. For example, if the gape is 32 ms, then the deconvolution will not change the pulse shape over this interval.

The operator length is the length of trace over which the deconvolution is effective as it is moved down each trace, and it should be long enough to cover the period of the longest multiple that is to be attenuate (Zia-ur-Rehman,1989).

### 5.2.9 STATIC CORRECTIONS

Static corrections are constant for an entire trace. They consist of weathering corrections and elevation corrections.

The material near the surface of the earth is highly variable in velocity and thickness and reflection arrivals may vary because of near surface variations than because of the subsurface relief in which we are interested. This low velocity zone is called weather layer.

The properties of this weather layer erect important effect on seismic data. The large velocity contrast at the base of the weathered layer bends ray path considerably.

This contrast is also a strong produce of multiples.

The effect of weathered layer is removed by applying a weathering correction.

$$WC=dw\ (1/Vw - 1/Vc)$$

Where,

DW: thickness of weathered layer.

Vw: Velocity in weathered layer.

Vc: velocity in underline layer.

Since seismic sources and receivers are usually at or near the earth surface, raw reflection times are influenced by topographic effects. These effects are removed by elevation corrections.

$$Ecs = (Z-Zo)/Vc$$

Where,

Zo: Datum surface elevation

Z: Source or receiver elevation

Vc: Velocity in below layer

Elevation correction is normally computed in two stages. First for all, source-points then for receivers.

(Zia-ur-Rehman, 1989)

### 5.2.10 NORMAL MOVEOUT

The distance from shot to geophone is gradually increasing for successive traces of a gather, so that the reflected energy takes a bit longer for successive traces. The delay time for reflections from a flat reflecting interface is called normal move out (NMO).

Multiple energy usually has more move out than the normal move out of the primary reflection.

### 5.2.11 DYNAMIC CORRECTION

After the application of the static correction the reduced record time represents the two-way stint time where both the source and detector are effectively on the same datum. Now if we examine a reflection event on all the contributors of one CDP, We find these events falling on a hyperbola. This is due to dependence of travel time on the trace-offset, expressed by the NMO equation.

$$T^2x = T^2o + X2/V2\ NMO$$

(Zia-ur-Rehman, 1989)

### 5.2.12 MUTING

Trace muting is special type of data editing. The term is usually applied for the process of zeroing the undesired part of a trace. In order to avoid the stacking non-reflection events such as first arrivals with reflection, the first part of the trace is normally muted before carrying out the stacking process. This is occasionally reoffered to as first break suppression.

#### i. INITIAL MUTING

It removes the large energy bursts associated with first arrivals.

#### ii. SURGICAL MUTING

It is applied to remove ground roll and airwaves present in the recorded data.

(Zia-ur-Rehman, 1989)

### 5.2.13 AUTOMATIC RESIDUAL STATIC

Due to un-predicted variation of the velocity and thickness of the surface layer, a small but significant error may be committed in the computed remote sensing. These errors in the value of static correction of each seismic trace result in a deteriorating S/N ratio of the CDP stack section. Statistical processes called residual statistical analysis estimate these residuals. The residuals are estimated by summing the number of statically and dynamically corrected traces, which belong to one CDP. The summation out put called the model trace is cross-correlated with each of the contributing traces in turn. The residual is then represented by the correlation log-time corresponding to the peak of the correlation function.



### 5.2.14 VELOCITY ANALYSIS

It is the process of calculating seismic velocity, typically by using common mid point data; in order to better process the seismic data. Successful stacking, time migration and depth migration all require proper velocity inputs. Velocity or stacking velocity can be calculated from NMO. Before the traces can be stacked, normal moveout corrections have to be applied to shift reflection on all traces to a common arrival time.

## 5.2. 15 CDP STACKING

Following static and NMO corrections the traces are ready for the next, and main, step in the processing sequence, in which all the values corresponding to a particular reflection time on each trace in a CDP are added together. This sum of the traces forms one composite trace in which reflections are preserved at full strength, while all other energy is reduced. This procedure is known as staking, or compositing. Stacked data is also referred to as CDP or CRP data.

Stacking not only enhances the reflection from true reflectors but also attenuate multiple reflections.

## 5.2.16 FILTERING

A filter is a system, which discriminates against some of its input. Seismic data always contains some signal information, which we want to preserve everything else is called noise, and we want to remove or reduce it. These systems, which are generally, called filters work either by convolution in the time domain or by spectral shaping in the frequency domain.

The most common types of filters are the following:

- Low pass frequency filters
- High pass frequency filters
- Band pass frequency filters
- Notch filters
- Inverse filters
- Velocity filters

## TIME VARIANT FILTERS

The frequency content of the initial source signal changes in a time-variant manner as it propagates through the earth. In particular high frequencies are more rapidly absorbed than low frequencies. This is because of the intrinsic attenuation in rocks. It is possible to estimate the maximum frequency to be expected at the particular depth. Removal of unwanted frequencies above those maximum expected, one, is accomplished using a time variant filter whose pass band decreases in frequency with increasing reflection time. Use of a time-variant filter increases signal-to-noise ratio.

## 5.2.17 MIGRATION

Migration moves dipping reflectors into their true subsurface positions and collapses diffractions, thereby delineating detailed subsurface features such as fault planes. So in this respect migration can be viewed as a form of spatial deconvolution that increased the spatial resolution. Migration does not displace the horizontal events; rather, it moves dipping events in the up dip direction and collapses diffractions, thus enabling us to delineate faults.

The goal of migration is to make the stacked section appear similar to the geologic cross section along the seismic line.

## 5.2.18 MIGRATION TECHNIQUES

Conventional migration techniques are based on Huygens's principle. There are two alternative methods, which are both based on this principle. These are:

- Wave front common-envelope method.
- Diffraction hyperbola method.

### i. WAVE FRONT COMMON-ENVELOPE METHOD

A dipping reflector is, according to reflection laws, perpendicular to the reflection rays in our model of source-receiver common position. This means that the reflector is defined by the tangent surface (or common envelope) to all the wave fronts drawn for an incident seismic ray.

According to Huygen's principle, the superposed wave fronts will destructively interfere at all points except at the true reflection point.

#### ii. DIFFRACTION HYPERBOLA METHOD

This method is based on the assumption that a reflector is made up of a packed series of diffraction points or scatters.

The diffraction hyperbola method is also known as the diffraction summation method, was the first compute implementation of migration.

Diffraction summation is a straightforward summation of amplitudes along the hyperbolic trajectory whose curvature is governed by the velocity function. It is also known as the Kirchhoff Migration.

### 5.2.19 HEADER GENERATION

After all of the samples from a given field trace are assembled into an array a large amount of archival information is placed in a reserved block called a trace header which is located on the tape just ahead of the data samples. Trace header information may include location and elevation of source and receiver field, record number, trace number, etc. A real header block is also placed at the head of each reel, for recording line number, reel number etc.

### 5.2.20 DISPLAY

At the end of the processing sequence and some time at intermediate stages it is necessary to convert the digital data to analog format so that they can be displaced and then examined visually.

There are several methods for plotting digital data in analog form. The most common method is to pass the digital trace through a sample and hold device which produces an out put voltage proportional to each sample and which holds the voltage constant until the next sample arrives. This procedure produces a "stair step" type of analog, which can then be smoothed into a continuous trace by passing through low pass filter. The analog signal is then displaced on paper or film by means of recording oscillograph (camera) or plotter.

## 5.3 PROCESSING OBJECTIVES

The improvement of the signal to noise ratio either by enhancing the signal or attenuating the noise. This is the object of most seismic data processing, which is generally designed to attenuate specific type of noise.

The repositioning of data elements (migrating). This data on unmigrated seismic sections are referenced to the locations of the source and receivers usually being plotted at the midpoint between them, migration repositions data to the locations of the reflecting points.

The measurement of the "attributes" of the data, including velocity, amplitude, frequency, polarity and other measurements.

The display of the data in a manner easily understandable by an interpreter, display parameters include the use of optimum scale for the particular interpretation objectives and displays that combine various types of measurements such as color displays.

# CHAPTER 6

# INTERPRETAITON

## 6.1 INTRODUCTION

The objective of seismic reflection interpretation is to study the subsurface structures that help in discovering the hydrocarbon accumulation in the subsurface sedimentary rocks using the reflection data. As science has not yet discovered the direct method of finding the oil and gas, or of assessing the quantities of hydrocarbons in the subsurface, so the seismic reflection method only indicate the geological situations where the hydrocarbons can accumulate.

However, due to limitations of the available data, the interpretation is restricted only to identify the reflectors, calculating their depth and discussing the possibilities of depositional and geological setting of the subsurface in the study area (seismic line).

## 6.2 DISCUSSION ON THE SEISMIC LINE

The processed seismic section is provided with the information about the RMS and DIX interval velocities. Where Dix average is calculated by the following formula

$$V_{n,\,ave} = \frac{V_{int}(T_n - T_{n-1}) + V_{n-1,\,ave}\,T_{n-1}}{T_n}$$

These velocities are estimated from shot points Sp-101 to Sp-232. The total six horizons are marked represented by R1, R2, R3, R4, R5 and R6. From top to bottom as shown in the seismic section. The reflectors are marked on the basis of change in acoustic impedance between the interfaces.

## 6.3 ROLE OF VELOCITY IN SEISMIC INTERPRETATION

Velocity is the key factor in the processing and interpretation of seismic data. Khattri, et al (1980) suggested that effectiveness of seismic survey will provide true information about the subsurface structure, lithology and fluid content is critically dependent on accurate knowledge of velocity of subsurface layers.

## 6.4 DIX AVERAGE VELOCITY CONTOUR MAP

The main function of contouring is just to make a numerical data more visual so that high and low area may be recognized quickly with out peering at individual numbers Dix average velocity as calculated from given RMS and interval vary from 1800 m/s to 4500 m/s for 5 second data and have been taken into account to prepare an iso-velocity contour map at an interval of 100 m/s. this contour map shows vertical as well as lateral variation.

i. Vertical changes are due to structural changes or lithology variation.
ii. Lateral variations are supposed to be the result of slow change in the physical properties or due to the change in the lithology.

## 6.5 SEISMIC TIME SECTION

Time section is actually the production of the reflectors marked on the given processed seismic section. Time section shows the general trend of the reflectors in the study area and is considered as the representative of the given seismic section. Time of each reflector is read and then plotted against the shot points to draw seismic time section. On the seismic time section we see six reflectors R1, R2, R3, R4, R5 and R6 as shown in appendixes.

## 6.6 DEPTH SECTION

The application time-depth conversion transforms the seismic reflection data into a structural depth picture. Conversion is very sensitive to velocity variation. There are a number of identified reflections present on the given stacked section, out of which six prominent reflectors have been chosen for interpretation.

The seismic time section is converted into depth section using approximate velocity values taken from Dix average velocity map and one way travel times.

Use the following formula for this purpose.

Depth= V.T/2

Where,

V= Velocity (m/sec)

T= Two way travel Time (Sec)

The depths calculated by Dix average are less than the depth calculated by RMS velocity but reflectors are showing the same trend as shown in appendixes.

## 6.7 DEPTH ESTIMATION

Various techniques are used in the construction of a depth section that might give a picture close to reality. Velocity determination is of prime importance in the construction of a depth section. Following methods are applied for the depth determination.

## 6.8 MEAN AVERAGE VELOCITY METHOD

In this method, each seismic processing velocity at different CDP are plotted between time and average velocities and used for the generation of average velocity function plotting which define the average velocity distribution for selected reflectors across the section.

## 6.9 DEPTH SECTION BY USING AVERAGE VELOCITY METHOD

From the mean average line, average velocity is find out against the time, where as the time is read from seismic section. Now depth is again finding out. This depth section is shown in appendixes. There are six reflectors R1, R2, R3, R4, R5 and R6. All the reflectors start from Sp-101 and terminate at Sp-323.

### 6.9.1 REFLECTOR 1

The reflector R1 varies between SP-101 to SP-230 at the time range of 0.58-0.62 sec in the time section. By average velocity method, minimum depth of reflector is 597 m at Sp-185 and maximum depth is 645m at Sp120. Average depth of the reflector is 616 m. By using Iso-velocity method, minimum and maximum depths are 599m and 645m respectively. The reflector is almost straight.

### 6.9.2 REFLECTOR 2

The reflector R2 varies between SP-101 to SP-230 at the time range of 1.18 to 1.22 sec in the time section. By average velocity method, minimum depth of reflector is 1353m at Sp-185 and maximum depth of 1430m at Sp120. Average depth of the reflector is 1382 m. By using Iso-velocity method, minimum and maximum depths are 1335m and 1403m respectively. The reflector is straight and regular.

### 6.9.3 REFLECTOR 3

The reflector R3 varies between SP-101 to SP-230 at the time range of 1.5 to 1.76 sec in the time section. By average velocity method, minimum depth of reflector is 1898 m at Sp-110 and maximum depth of 2375m at Sp-225. Average depth of the reflector is 2323 m. By using Iso-velocity method, minimum and maximum depths are 1942m and 2352m respectively. Reflector has a normal fault.

### 6.9.4 REFLECTOR 4

The reflector R4 varies between SP-101 to SP-230 at the time range of 2.5 to 2.52 sec in the time section. By average velocity method, minimum depth of reflector is 3940 m at Sp-110 and maximum depth of 4081m at Sp-225. Average depth of the reflector is 4006 m. By using Iso-velocity method, minimum and maximum depths are 3911m and 4105m respectively. The reflector is almost straight.

### 6.9.5 REFLECTOR 5

The reflector R5 varies between SP-101 to SP-230 at the time range of 3.06 to 3.12 sec in the time section. By average velocity method, minimum depth of reflector is 5301m at Sp-110 and maximum depth of 5465m at Sp-230. Average depth of the reflector is 5408 m. By using Iso-velocity method, minimum and maximum depths are 599m and 645m respectively. The reflector is almost straight.

### 6.9.6 REFLECTOR 6

The reflector R6 varies between SP-101 to SP-230 at the time range of 3.46 to 3.7 sec in the time section. By average velocity method, minimum depth of reflector is 6552 m at Sp-110 and maximum depth of 6993m at Sp-125. Average depth of the reflector is 6599 m. By using Iso-velocity method, minimum and maximum depths are 599m and 645m respectively. Reflector has four normal faults and horst and graben structure is formed in that reflector.

Depth section based on the Average Velocity method represents the true picture of the area, which is very similar to the time section of the area. Also the shape and dimensions of the reflectors resemble the reflectors marked on the provided seismic section.

On the other hand, the depth section based on the Iso-Velocity method has some upwards and downwards variations in reflectors and it resembles less accurately than the depth section prepared by average velocity method, to the time section.

## 6.10 STRUCTURAL ANALYSIS

It is the study of reflector on the basis of reflection times. The main purpose of structural analysis of seismic section is search for the structural traps having hydrocarbons.

Interpretation use two way reflection times rather than depth and time. Structural maps are constructed to display the geometry of selected reflection events.

The project area (Sanghar) is located in the Lower Indus Basin. Sanghar is actually an irrigated area and we find no outcrop structure in this area. The Southern Indus Basin covers a large area. It is bounded by the Indian shield in the east and highly folded and up thrusted mountain that constitutes the Arial belt in the west. The Jacobabad arch approximately delimits the southern basin from the central Indus basin. Subsurface geology of the area includes sediments from Triassic to Pliocene. Rifting of Madagascar form the Indian tectonic activity was removed in that area during companion and mastantation.

Normal faulting NNW-SSE and renewed clastic deposition from southern east. The western margin of India currently passed over a mantle thermal in the late cretaceous to early Paleocene and this may have contribution to the wide spread uplift and faulting. The basalt formed by heating, was deposited and Deacon during the early Paleocene (Kazmi & Jan, 1997 & Ahmad, 1974).

## 6.11 CONCLUSION

From the overall discussion of the area it is concluded that:

- The area is an irrigated land and no outcrop feature is found in the area.

- There are six kinds of reflectors shown in the seismic section. Reflector
- Mean average velocity method is more accurate method for finding the structures of subsurface and is widely used by OGDC.
- Observed reflectors are nearly horizontal showing very slight undulations with horst and graben geometry.
- R3 has a normal fault.
- The last reflector (R6) has four faults which combined together and form Horst and graben structure.
- As that area lies in extensional regime, so normal faulting is present in that area.
- Well data is not provided without whom names to different reflectors could not be given. For the better interpretation of given seismic line, well data should also be provided along the seismic section.
- On the basis of Stratigraphic interpretation, it is concluded that there may be the Stratigraphic traps in this study area for the accumulation of hydrocarbons.
- Sanghar area has many producing well in tilted fault blocks, so the Horst and Graben structures are given prime important as for as hydrocarbon are considered major reservoir rocks are mainly of lower Cretaceous age

# APPENDICES

## APPENDIX 1 TIMES AND VELOCITY

| VELOCITY | CDP-240 | CDP-290 | CDP-340 | CDP-390 | CDP-440 |
|---|---|---|---|---|---|
| **1800** | 0 | 0 | 0 | 0 | 0 |
| **1900** | 280 | 310 | 300 | 300 | 340 |
| **2000** | 422 | 482 | 477 | 480 | 500 |
| **2100** | 669 | 663 | 661 | 655 | 658 |
| **2200** | 953 | 946 | 939 | 863 | 840 |
| **2300** | 1214 | 1217 | 1197 | 1054 | 1040 |
| **2400** | 1317 | 1393 | 1337 | 1234 | 1241 |
| **2500** | 1415 | 1493 | 1504 | 1424 | 1441 |
| **2600** | 1508 | 1691 | 1647 | 1574 | 1601 |
| **2700** | 1963 | 1840 | 1767 | 1684 | 1751 |
| **2800** | 2240 | 1945 | 1900 | 1794 | 1945 |
| **2900** | 2329 | 2145 | 2029 | 1957 | 2150 |
| **3000** | 2402 | 2295 | 2172 | 2138 | 2299 |
| **3100** | 2479 | 2445 | 2378 | 2348 | 2439 |
| **3200** | 2548 | 2608 | 2577 | 2560 | 2602 |
| **3300** | 2694 | 2788 | 2756 | 2730 | 2832 |
| **3400** | 2897 | 2968 | 2935 | 2900 | 3047 |
| **3500** | 3094 | 3126 | 3092 | 3061 | 3207 |
| **3600** | 3283 | 3285 | 3229 | 3221 | 3376 |
| **3700** | 3472 | 3445 | 3593 | 3457 | 3546 |
| **3800** | 3662 | 3770 | 3833 | 3727 | 3716 |
| **3900** | 3851 | 3942 | 3998 | 3920 | 3904 |
| **4000** | 4040 | 4115 | 4163 | 4092 | 4048 |
| **4100** | 4229 | 4288 | 4327 | 4265 | 4264 |
| **4200** | 4419 | 4419 | 4492 | 4437 | 4444 |
| **4300** | 4608 | 4608 | 4657 | 4609 | 4624 |
| **4400** | 4797 | 4797 | 4821 | 4781 | 4804 |
| **4500** | 4986 | 4986 | 4986 | 4954 | 4984 |

## APPENDIX 2.A TIME SECTION DATA

| SP. # | R1(sec) | R2(sec) | R3(sec) | R4(sec) | R5(sec) | R6(sec) |
|---|---|---|---|---|---|---|
| 110 | 0.6 | 1.19 | 1.5 | 2.5 | 3.06 | 3.53 |
| 115 | 0.6 | 1.2 | 1.5 | 2.52 | 3.07 | 3.54 |
| 120 | 0.62 | 1.22 | 1.53 | 2.52 | 3.1 | 3.53 |
| 125 | 0.62 | 1.21 | 1.51 | 2.54 | 3.08 | 3.7 |
| 130 | 0.6 | 1.22 | 1.53 | 2.53 | 3.08 | 3.7 |
| 135 | 0.6 | 1.2 | 1.52 | 2.53 | 3.08 | 3.7 |
| 140 | 0.6 | 1.2 | 1.76 | 2.52 | 3.09 | 3.64 |
| 145 | 0.6 | 1.19 | 1.76 | 2.53 | 3.08 | 3.64 |
| 150 | 0.6 | 1.19 | 1.76 | 2.53 | 3.1 | 3.65 |
| 155 | 0.6 | 1.18 | 1.74 | 2.52 | 3.11 | 3.55 |
| 160 | 0.6 | 1.19 | 1.75 | 2.52 | 3.11 | 3.55 |
| 165 | 0.6 | 1.18 | 1.74 | 2.51 | 3.1 | 3.55 |
| 170 | 0.6 | 1.18 | 1.74 | 2.52 | 3.1 | 3.54 |
| 175 | 0.59 | 1.18 | 1.74 | 2.53 | 3.1 | 3.55 |
| 180 | 0.59 | 1.18 | 1.74 | 2.53 | 3.1 | 3.55 |
| 185 | 0.58 | 1.17 | 1.74 | 2.53 | 3.11 | 3.55 |
| 190 | 0.58 | 1.18 | 1.74 | 2.54 | 3.11 | 3.46 |
| 195 | 0.59 | 1.18 | 1.75 | 2.54 | 3.11 | 3.47 |
| 200 | 0.6 | 1.19 | 1.74 | 2.53 | 3.11 | 3.47 |
| 205 | 0.59 | 1.18 | 1.74 | 2.53 | 3.11 | 3.47 |
| 210 | 0.59 | 1.18 | 1.74 | 2.53 | 3.12 | 3.48 |
| 215 | 0.59 | 1.18 | 1.75 | 2.53 | 3.11 | 3.48 |
| 220 | 0.59 | 1.18 | 1.76 | 2.54 | 3.11 | 3.47 |
| 225 | 0.59 | 1.19 | 1.77 | 2.56 | 3.11 | 3.48 |
| 230 | 0.59 | 1.19 | 1.74 | 2.55 | 3.12 | 3.48 |

## APPENDIX 2.B TIME SECTION DATA

| SP. # | F1(sec) | F2(sec) | F3(sec) | F4(sec) | F5(sec) |
|---|---|---|---|---|---|
| 115 | | 3.4 | | | |
| 120 | | 3.58 | | | |
| 125 | | 3.7 | | | |
| 130 | | 3.81 | | | |
| 135 | 1.45 | | 3.77 | | |
| 140 | 1.7 | | 3.55 | | |
| 145 | 1.9 | | | 3.8 | |
| 150 | | | | 3.65 | |
| 155 | | | | 3.5 | |
| 160 | | | | | |
| 165 | | | | | |
| 170 | | | | | |
| 175 | | | | | |
| 180 | | | | | 3.64 |
| 185 | | | | | 3.52 |
| 190 | | | | | 3.4 |

APPENDIX 3.A DEPTH SECTION DATA

| SP. # | R1(m) | R2(m) | R3(m) | R4(m) | R5(m) | R6(m) |
|---|---|---|---|---|---|---|
| **110** | 621 | 1383 | 1898 | 3940 | 5301 | 6552 |
| **115** | 621 | 1398 | 1898 | 3977 | 5326 | 6577 |
| **120** | 645 | 1430 | 1935 | 3977 | 5410 | 6552 |
| **125** | 645 | 1414 | 1916 | 4036 | 5356 | 6993 |
| **130** | 621 | 1430 | 1951 | 4010 | 5356 | 6993 |
| **135** | 621 | 1398 | 1933 | 4010 | 5356 | 6993 |
| **140** | 621 | 1398 | 2252 | 3977 | 5383 | 6836 |
| **145** | 621 | 1383 | 2358 | 4010 | 5365 | 6836 |
| **150** | 621 | 1383 | 2358 | 4010 | 5410 | 6866 |
| **155** | 621 | 1368 | 2323 | 3977 | 5436 | 6603 |
| **160** | 621 | 1383 | 2339 | 3977 | 5436 | 6603 |
| **165** | 609 | 1368 | 2323 | 3966 | 5410 | 6603 |
| **170** | 609 | 1368 | 2323 | 3977 | 5410 | 6577 |
| **175** | 609 | 1368 | 2323 | 4010 | 5410 | 6603 |
| **180** | 609 | 1368 | 2323 | 4010 | 5410 | 6603 |
| **185** | 597 | 1353 | 2323 | 4010 | 5436 | 6530 |
| **190** | 597 | 1368 | 2323 | 4036 | 5436 | 6372 |
| **195** | 609 | 1368 | 2339 | 4036 | 5436 | 6399 |
| **200** | 621 | 1383 | 2323 | 4010 | 5436 | 6399 |
| **205** | 609 | 1368 | 2323 | 4010 | 5436 | 6390 |
| **210** | 609 | 1368 | 2323 | 4010 | 5465 | 6424 |
| **215** | 609 | 1368 | 2339 | 4010 | 5436 | 6424 |
| **220** | 609 | 1368 | 2358 | 4036 | 5436 | 6399 |
| **225** | 609 | 1383 | 2375 | 4081 | 5436 | 6424 |
| **230** | 609 | 1383 | 2323 | 4058 | 5465 | 6424 |

## APPENDIX 3.B DEPTH SECTION DATA

| SP. # | F1(m) | F2(m) | F3(m) | F4(m) | F5(m) |
|---|---|---|---|---|---|
| 115 | | 6214 | | | |
| 120 | | 6678 | | | |
| 125 | | 6993 | | | |
| 130 | | 7306 | | | |
| 135 | 1810 | | 7191 | | |
| 140 | 2235 | | 6603 | | |
| 145 | 2622 | | | 7277 | |
| 150 | | | | 6862 | |
| 155 | | | | 6475 | |
| 160 | | | | | |
| 165 | | | | | |
| 170 | | | | | |
| 175 | | | | | |
| 180 | | | | | 6838 |
| 185 | | | | | 6523 |
| 190 | | | | | 6214 |

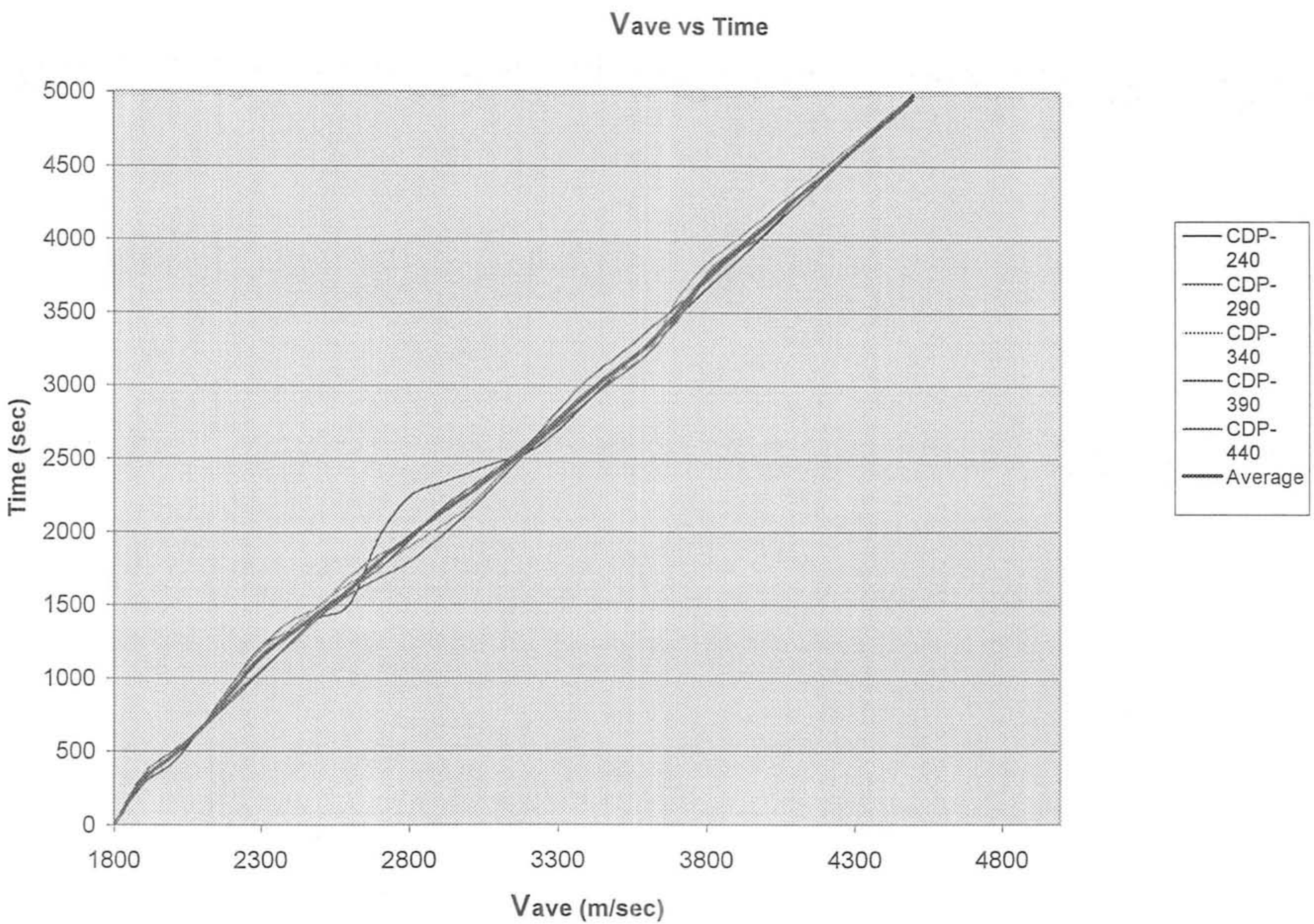
Vave vs Time
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Time (sec)
1800
2300
2800
3300
3800
4300
4800
Vave (m/sec)
CDP-240
CDP-290
CDP-340
CDP-390
CDP-440
Average

Figure 6.1

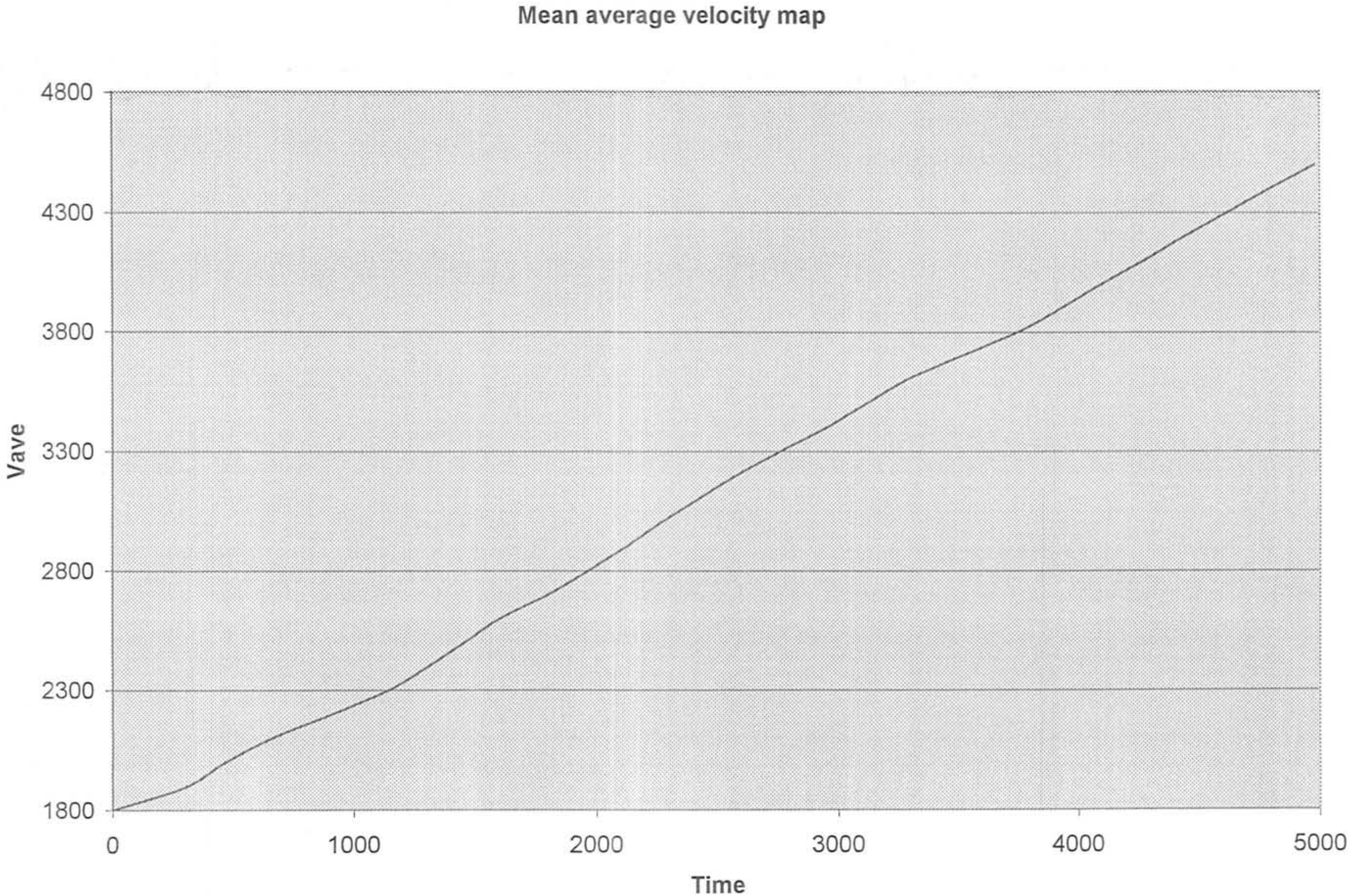
Mean average velocity map
4800
4300
3800
3300
2800
2300
1800
Vave
0
1000
2000
3000
4000
5000
Time

Figure 6.2

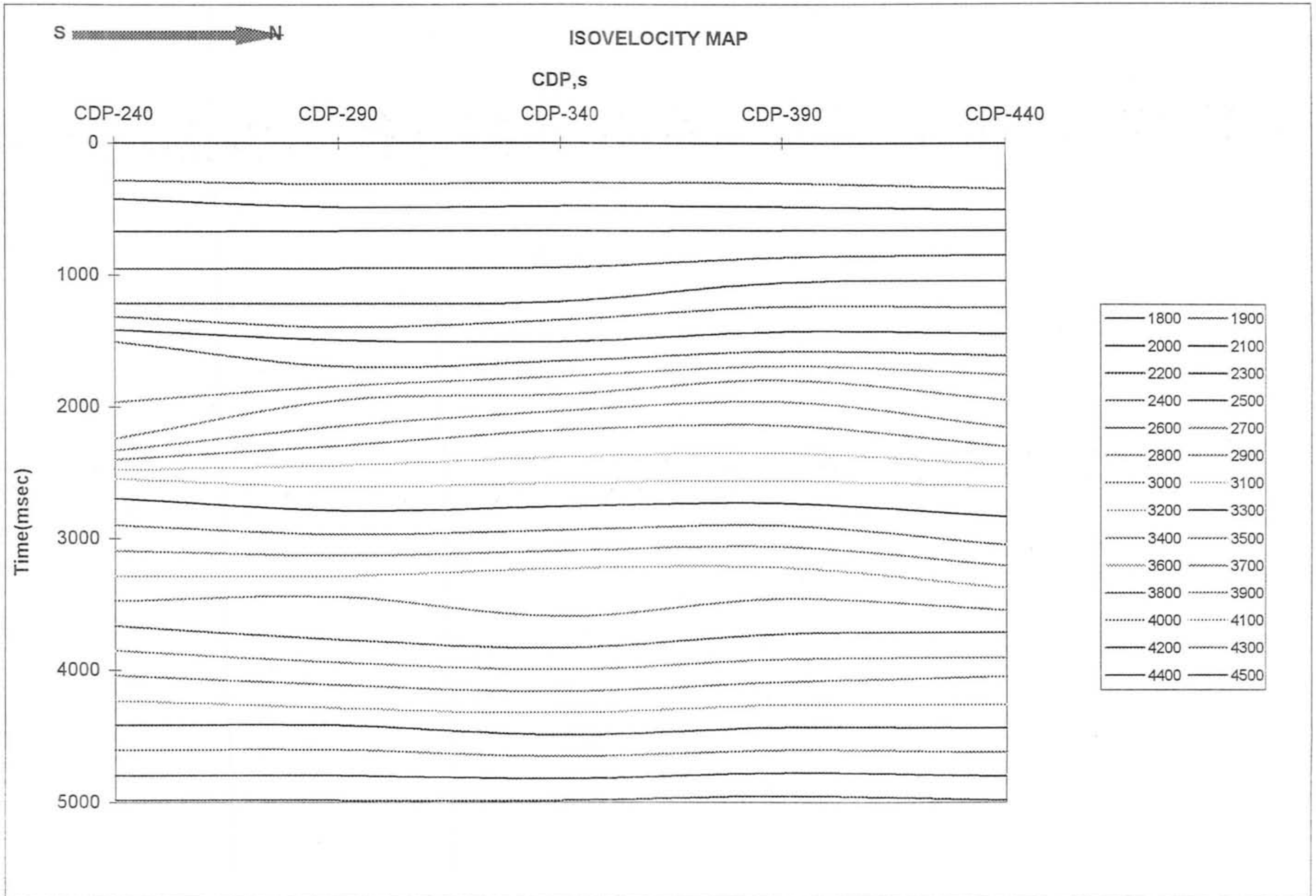
S N
ISOVELOCITY MAP
CDP,s
CDP-240
CDP-290
CDP-340
CDP-390
CDP-440
0
1000
2000
3000
4000
5000
Time(msec)
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
4400
4500

Figure 6.3

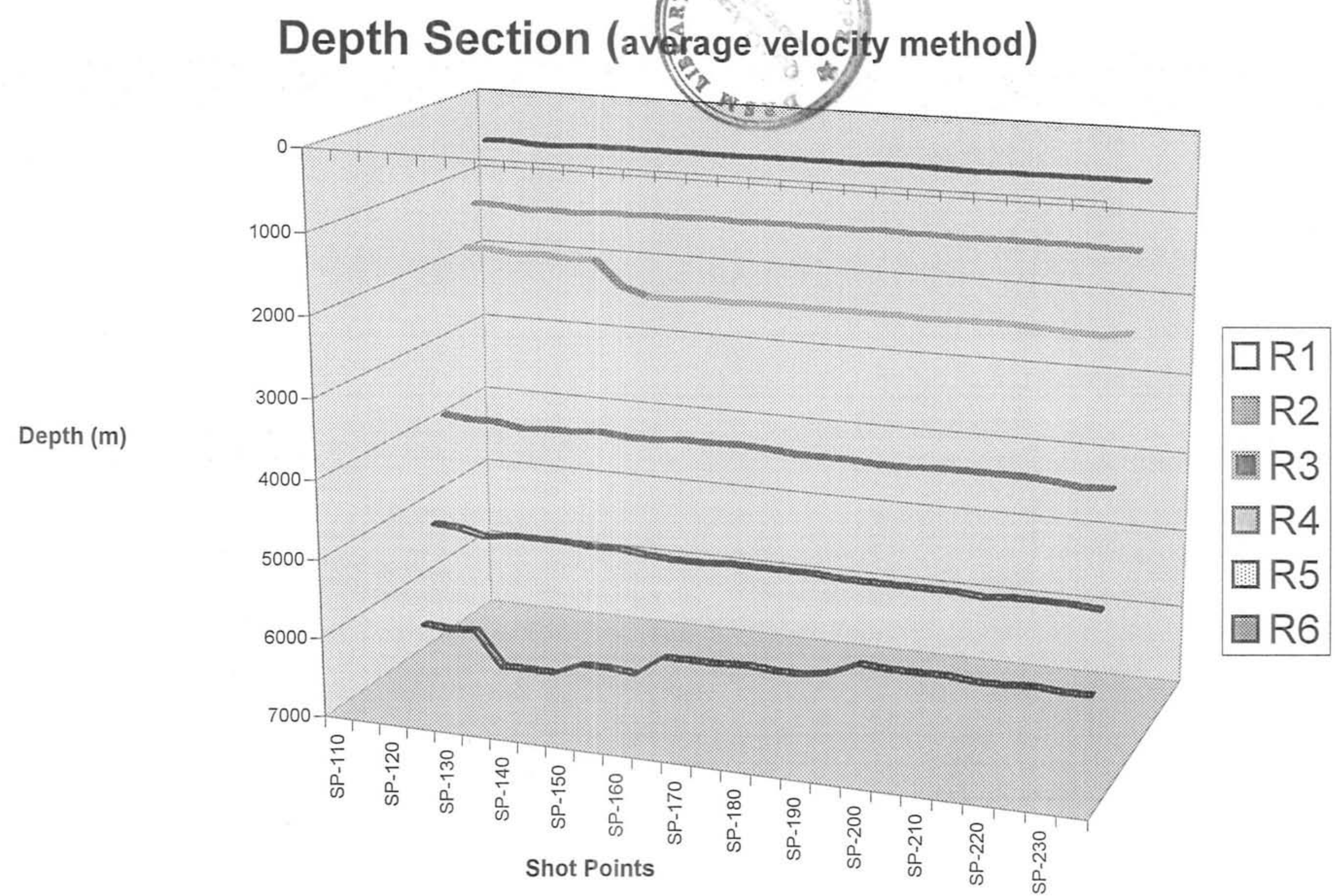
Depth Section (average velocity method)
Depth (m)
0
1000
2000
3000
4000
5000
6000
7000
SP-110
SP-120
SP-130
SP-140
SP-150
SP-160
SP-170
SP-180
SP-190
SP-200
SP-210
SP-220
SP-230
Shot Points
R1
R2
R3
R4
R5
R6

Figure 6.5