2-D SEISMIC REFLECTION DATA INTERPRETATION OF KABIRWALA AREA

BY

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INTRODUCTION

1.1 INTRODUCTION:

This dissertation mainly describes the procedure of the seismic reflection interpretation. Applied on the seismic reflection data of Line 857- KBR-111 Kabir Wala area provided by the department of Earth Sciences, Q.A.U. Islamabad. This data is being acquired and processed by Oil and Gas Development Corporation (OGDC). This dissertation is based on the interpretation of single line.

The following latitude and longitude bound the area of prospects.

Latitude	30^0 24 North
Longitude	71^0 52 East

1.2 OBJECTIVE:

The main objective of this dissertation is

1) To interpret the seismic time section by marking the prominent reflectors.
2) To study the behavior of Dix average velocities.
3) To find the depths of the marked reflectors and of the probable sequences.
4) To plot the depth section against the shot point positions for different prominent reflectors.
5) By using this we find the possible structure and correlating it with stratigraphy of the area.

1.3 GEOLOGY OF THE AREA:

Tectonically this area is stable. It is the part of Punjab Plain and has almost no structural deformation accept some normal faulting. This area falls in the middle Indus Basin, which is bounded by Jacobabad High in south, the Indian Shield in the east, Sarghodha High in the north and Suliaman fore deep in the west. (Kazmi & Jan, 1997)

1.4 STRATIGRAPHY:

The stratigraphically this area includes all the major formations of ages from Pre-Cambrian to Pliocene described below.

Formation	Lithology	Age
Nagri	**Sandstone and Clay**	**Early Pliocene**
Chingi	**Red Clay and Sandstone**	**Late Miocene**
Sakesar	**Limestone, Marl & Chert**	**Eocene**
Nammal	**Shale and Limestone**	**Eocene**
Sui Main Limestone	**Limestone and Shale**	**Paleocene**
Dunghan	**Nodular, massive Limestone, Shale & Marl**	**Paleocene**
Ranikot	**Yellow brown Sandstone & Shale**	**Paleocene**
Lamshiwal	**Sandstone & Silty Shale**	**Early Cretaceous**
Chichali	**Silt Sandstone with Sandy Shale**	**Middle Jurassic**
Samanasuk	**Limestone with subordinate Marl & Shale**	**Middle Jurassic**
Shinwari	Thin bedded gray Limestone, Marl & Shale	Middle Jurassic
Datta	Shale with Limestone and Sandstone	Early Jurassic
Kingriali	Dolomite and Dolomatic Limestone	Late Jurassic
Tredian	Sandstone and Shale	Middle Jurassic
Mianwali	Marl, Sandstone, Limestone & Dolomite	Early Jurassic
Chidru	Calcareous Sandstone & Sandy Limestone	Late Permian
Wargal	Limestone and Dolomite	Late Permian
Amb	Limestone, Sandstone & Shale	Late Permian
Sardhai	Clay with beds of Sandstone and Siltstone	Early Permian
Warcha	Sandstone With interbedded Clay and Shale	*Early Permian*
Dandot	Sandstone with subordinate Shale	Early Permian

Tobra	Sandstone, Siltstone and Shale	Early Permian
Baghanwala	Pseudomorph and flaggy Sandstone	Cambrian
Khisor	Dolomite and Gypsum	Cambrian
Jutana	Sandstone and Dolomite	Cambrian
Kussak	Greenish Sandstone and Siltstone	Cambrian
Khewra	Brown yellowish Sandstone	Cambrian
Salt Range	Red Gypseous Marl with Rock Salt	Pre-Cambrian

1.4 ACQUISATION PARAMETERS

Following parameter has been taken during this survey.

RECORDING PARAMETER

Instruments	SN-358
Energy source	Dynamite
Format	9 Track Seg B
Record length	5-sec
Sample rate	2 ms
No-channels	96
Fold of stack	24
Coverage	2400 %
Low cut filter	cut
Notch filter	in
High cut filter	128

GEOMETRY

Cable layout	2650m
Geophone Station interval	50m
Types of geophone	PE-3
Geophone code	031205
Geophone frequency	10 Hz
Geophone interval	5m
Group length	105m

SOURCE

Short interval	100m
Charge size per hole	0.5Kg
Charge depth	2m
No: of hole per shot	9
Shot hole base	100m

DISPLAY PARAMETERS

Horizontal scale	1:123625
Vertical scale	10 cm/sec
Plotting polarity	68 db

SEISMIC METHODS

2.1 INTRODUCTION

Seismic method is one of the commonly used Geophysical techniques. It is better than other method due to greater penetration, higher revolution and accuracy. The basic technique of seismic exploration consists of generating seismic waves. These waves are propagated through the earth interior and measuring the time required for the waves to travel from the source to series of detector planted on the surface. After reflection from the subsurface discontinuities, these travel time may be converted into depth value. There are two types of methods in seismic prospecting.

1: REFRACTION
2: REFLECTION

2.2 SEISMIC REFLECTION METHOD

A property of every substance is its acoustical impedance, which is product of density and seismic velocity. Seismic waves reflect from every boundary, where the acoustic impendence changes. In seismic reflection method arrival time of P-waves are calculated after using appropriate field parameters. After the application of certain correction and data processing these arrival reflection time are converted to two-way travel time and time section is obtained. The time section is converted to depth section by the use of velocities and final subsurface geological picture is mapped.

2.3 IMPORTANCE OF SEISMIC WORK

The wide spread use of seismic method is principally use for exploring the petroleum. The location of exploratory rarely is being made with out seismic information. Seismic method is also important for ground water search and in civil engineering, especially to measure the depth of bedrock, in connection to construction of large buildings, dams and high ways. Seismic techniques have found little application and direct exploration for minerals because they do not produce good definition, where interfaces between different rock types are highly irregular. According to Telford et al (1976) they are useful in locating features such as buried channels in which heavy minerals may be accumulated.

2.4 BASIC THEORY OF ELASTICITY

The waves traveling in the subsurface depend upon the elastic properties of material through they pass. There for the knowledge of elastic modulii is very necessary, these are

describe as follow
A force applied on the surface of an object is called stress. It is measured in the unit of force divided by area. The SI unit of stress is called Pascal.

1 Pa= 1N/m

The deformation (change in size or shape) of an object due to apply stress is called strain. Robinson & Coruh, (1988) have describe three type of strain,

Elastic strain
Plastic strain
Rupture

Elastic strain is proportional to the applied strees and disappears, when the stress ceases. The permanent deformation is evidenced by the plastic strain. If the stress exceeds the strength of material than rupture is occurred.

2.5 ELASTIC MODULI

The linear relationship between the stress and strain in the elastic field is specified by its various elastic moduli, each of which expresses the ratio of particular type of stress to the resultant strain elastic moduli are the following.

2.5.1 BULK MODULUS

The bulk modulus expresses the stress-strain ratio in the case of simple hydrostatic pressure 'P, applied a cubic element, the resultant volume strain being the change of volume divided by original volume.

Bulk Modulus K=volume stress P/volume strainρV/V

2.5.2 YOUNG'S MODULUS

Consider a rod of original length L and having a crossectional area and extended by an increment 'ρL, through the application of force F to its ends. The relevant elastic moduli is Young's modulus E define by

Young's modulus E=longitudinal stress (F/A)/longitudinal strain (ρL/L)

2.5.3 SHEAR MODULUS

It is define as the ratio of shearing stress (τ) to the resultant shear strain tanθ, also called the rigidity modulus or lam's constant.

Shear modulus μ=shearing stress τ/shear strain tanθ

2.5.4 POISSION 'S RATIO

The ratio of transverse are lateral strain to the longitudinal strain is known as

Possion's ratio. When a rod of length L is elongated by ρLand its width W is contracted by ρW.

σ = ρW/W / ρL/L

2.5.5 AXIAL MODULUS

It is defined by Kearey & Brooks,(1991)define as the ratio as longitudinal stress to the longitudinal strain in the case when there is no lateral strain, that is when the material is constrain to deform uniaxially.

2.6 SEISMIC WAVES

The theory of elasticity reveals the energy propagated through the earth in the different form of seismic waves.

2.6.1 TYPES OF SEISMIC WAVES

There are two types of seismic waves

BODY WAVES

These waves travel directly through the mass of substance in any direction, according to Robinson &Coruh, (1988). These waves are two types.

LONGITUDINAL WAVES (Compressional or primary waves)

These are the waves for which the motions of the particle of the medium are parallel to the direction of propagation (like those sound waves in air). The speed of propagation of such a waves is

$$V_p = \sqrt{\frac{K + \frac{4\mu}{3}}{\rho}}$$

Where,

K = bulk modulus

μ = shear modulus

ρ= density of the material

TRANSVERSE WAVES (shear or secondary waves)

These are the waves for which the particles of the medium are perpendicular to the direction of propagation (like waves on a vibrating string). Individual particle motion involves oscillations about a fixed point in a plane at right angle to the angles to the direction of the wave propagation. The velocity of S waves is given by

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

SURFACE WAVES

The amplitude of these waves is greatest at the surface, at the depth of the wavelength; the displacement at any point is only a fraction of what is at the surface, such waves called surface waves. Can occur in a solid in that case they are controlled by elasticity these are the waves can travel only near the surface of such a mass are close to the border between two different substances. These are two types

RAYLEHGH WAVES

These types of waves developed at the semi-infinite elastic solid. The motion is sort of combination of longitudinal and transverse waves vibration giving rise to elliptical Motion of the particles (the major axis of ellipse is perpendicular to the surface and the direction of propagation). Velocity of Rayleigh waves is

$$VR = (.92\mu/\rho)^{1/2}$$

LOVE WAVES

These are the transverse waves propagated in a surface layer having elastic property differ from those of underling semi-infinite elastic solid. The velocity of propagation of love a wave depend on the wavelength and varies between that of transverse waves in the surface layer (which is approach is the wavelength approaches zero), the trans verse waves in lower medium (which is approached as wavelength approaches infinity).

2.7 LAWS GOVERNING THE PROPAGATION OF SEISMIC WAVES

When seismic waves created by an explosive source these are emanating outward from the shot point in all directions (in three dimensional sense).
According to Al-Sadi (1980) that the certain principle are formulated to add and visualizing the manner by which the wave propagate, especially an complicated situation.

2.7.1 FERMAT'S PRINCIPLE

It states that the rays (which is perpendicular to the wave front) reaching a point from given source at the given point by minimum time, path between source and point.

2.7.2 HUYGEN'S PRINCIPLE

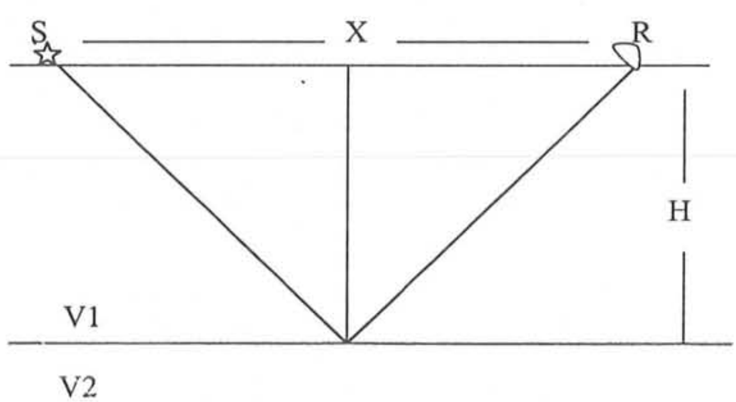
According to this principle each point on wave front can consider as the source point of secondary wave front.

2.7.3 Snell's Law

It states that" direction of refracted and reflected waves traveling away form a boundary depend upon the direction of the incident waves and the speed of the waves i.e. Sin i/ Sin r = Vi/Vr

2.8 HORIZENTAL REFLECTOR

In single horizontal layer in which the seismic waves velocity is "V1" and the thickness is "h" which lies above the deeper material in which the velocity is "V2".
In the reflection method this boundary is referred to as reflector.
The part of the reflected waves from source at "S" to the receiver "R" is given in the figure



In this case the angle of incidence is equal to the angle of reflection. Due to this the down going and up going parts of path will be also be equal, in as much as wave travel with velocity at velocity "V1". The travel time along the path, distance of 2r is

$$t_{x=2r/V1}$$

and

$$r=[(x/y)^2+(h1)^2]^{1/2}$$

Where 'X' is the distance between the source and the receiver and h is the depth to the reflector.
Hence

$$t_{x=[(x/y)^2+(h1)^2]^{1/2}/V1}$$

Squaring both sides

$$t^2_{x}= x^2/V1^2+4h1^2/V1^2$$

Dividing by $4h1^2$ and rearranging, we get

$$t_x^2/4h1^2/V1^2-x^2/4h1^2=1$$

As 'h1' and 'V1', are the constant properties of structure, so above equation is hyperbola; that is symmetric about $\alpha=0$.
These results explain why the reflection arrival times are plot along a curve. Travel time varies with receiver distance. If the source and receiver are placed at the same location $\lambda=0$, then

$$to=2h1/v1$$

Where 'to' is called zero off-set time, it is the travel time of the reflected waves along a vertical path. If we now express "h1" in term of "to" and V1 and substitute the value in eq-4, we get

$$t_x^2/t0^2-x^2/_{t0}^2V1^2=1$$

The above relationship again shows that the reflection arrival time varies hyperbolically with distance.
(Robinson & Coruch, 1988) have describe a common practice in reflection seismology is to express the reflected waves travel time "tx" as the sum of zero off-set time "to" and the additional increment of time "Δt", that is needed because the receiver is off-set at a distance X from the source. The time increment "Δt" is called the normal move-out (NMO) time. It provide us with a way to express travel time as

$$tx=t0+\rho t$$

That is more convenient for some methods of analyzing reflection data. The normal move-out (NMO) is also called dynamic correction and after applying the dynamic correction the reflection from the reflecting horizon is brought along straight line.
Velocity V1 and reflected depth (h1)

The depth h1 to the reflector is given from zero-offset time

h1=t0V1/2

Depth

Hn=Vn2arcT0n/2

Where to is the zero-offset time of the reflection from that boundary

2.8 DIPPING REFLECTOR

The reflector is not horizontal usually due to the tectonic forces. So, it is dipping as shown in fig. The time-distance equation having dip angle θ is given as,

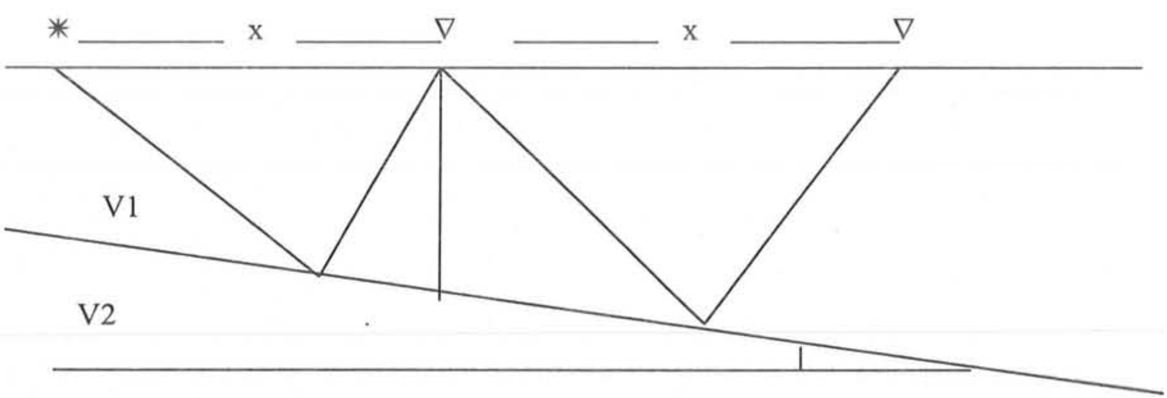
$$t=(x^2+4x^2+4xzsino/V)^{1/2}$$

t=t0{1+x2+4xzsin/4V2t02}

TRAVEL TIME (t_x)

It is the function of seismic waves reflected from an interface, which is dipping by angle in the direction of source to receiver.

$$t_x=1/V1$$



DIPPING REFLECTOR

2.10 CDP SHOOTING OR MULTIFOLD REFLECTION

It is difficult to recognize the weak reflected pulses on a seismogram. A very common practice is used to enhance these weak pulses by multifold reflection surveying. Multifold reflection are obtain by combing many reflections from the source point on the reflector that where recorded separately with different source. The different source receiver combinations have path reaching the same point on the reflector, this point of reflection is called the " Common depth point ", and because of the different source receiver spacing all the reflection travel time will be different.
According to Robinson & coruch, (1988) applying the normal move-out adjustment, we obtain corrected seismogram traces on which the reflection should be appear at identical times. Therefore by adding all the traces together to form a single composite trace. We hope to obtain a large pulse from the sum of the reflections at the identical times, the other pulses would act to cancel one another, now we have obtain a multifold composite trace. The name multifold come from the fact that we have a multiple traces combination and that making the normal move-out adjustment we are in a sense folding. The down going and up going parts of each path into a vertical path. We can assign a fold number that tells how many individual traces were used to obtain the composite.
The process of adding together the adjusted traces is called the stacking. The CDP traces are combined together to obtain an enhanced primary reflection. Common depth point stacking is effectively used for attenuation for multiple reflections. The reflection that arrive at the same time.

No of fold=N. ρY/2.ρX

(i) Zero-offset time is given by

t=2h/V1

(ii) Minimum travel time is given by

tmin=2hcoso/V1

(iii) Angle of inclination is given by

coso=tmin/t0

(iv) Angle of Reflector is given by

h=Xmin/2sino

(v) Velocity of the layer is given by

V1=2hcoso/tmin=2tmind/t0

(vi)Depth beneath the reflector is given by
d=ht0/tmin

SEISMIC DATA ACQUISTION

3.1 INTRODUCTION

In seismic data acquisition reflection from different sedimentary layers considered as primary signal. Almost all other types of events are commonly regarded as noise. The aims of all the recording system and field layout are essentially design to improve the signal and reduce the noise.
The basic field activity is collection of seismogram, which may be defined as analogue, or digital time series that register the amplitude of ground motion as function of time, during the passage of seismic waves. The acquisition of seismogram involves conversion of seismic ground motion into electrical signals, amplification and filtering of signal and registration on a tape record.
There are two types of methods in Acquiring seismic data i.e.

3.2 CONVENTIONAL ACQUISTION Vs CDP ACQUISTION

Conventional technique of data acquisition has been replaced by CDP technique, in which shooting pattern and acquisitions layouts are used to cut down the noise that can be encountered in the field. Conventional technique being single fold coverage giving continuous subsurface coverage but signal to noise ratio is affected by the presence of multiples and ground roll.
Conversely, CDP shooting infect offers cancellation of coherent and random noises, and enhancement of primary reflection signals. Variation in velocities do not remain as problem, because in CDP stacking the summing of all traces (from different source point and different receiver) related to the same reflection point in subsurface, reduces significantly the effect. This summation of traces from single reflection point is regarded as CDP fold, resulting as increase in fold increase signal to noise ratio.

3.3 SEISMIC SURVEYING

Seismic surveying consists of placing some receivers at different location and than using them to detect vibration produced by an energy source. The receiver converted the mechanical vibration into electric current that are transmitted to preserve the information in the form that can displaying and analyzed. The receiver used to detect the ground vibration is called "Geophone".
The Geophone signal, which is the electric current, produced by vibration, is transmitted to seismic cable, each Geophone required two wire conductor. Therefore number of conductor in seismic cable depends upon the number of Geophone being used in the survey.

3.4.1 IMPULSIVE ENERGY SOURCE

According to Al-sadi,(1980) this is most common energy source used in seismic prospecting; normally it is exploded inside a drilled hole at a depth ranging from few meters to several tens of meters. The charge weight is 10-50 Kg of Dynamite is rough estimate. Dynamite is now replaced by safe explosives, mostly ammonium nitrate. Several one- pond cans of ammonium nitrate are threaded at the ends, so that they can be sewed together to form large charges. An electric blasting cap is a small capsule of fulminated mercury, which can be exploded by electric current. Explosive charge is loaded in a hole.

3.4.2 NON IMPULSIVE ENERGY SOURCE

VIBROSEIS

In vibroseis system energy is produced by a pad pressed firmly to the ground, which vibrate in a carefully controlled way. The pad, which is about of one square meter and is attached beneath the truck by hydraulic jacks. Extended these jacks allow part or all the weight of truck to be used to press the pad to the ground. The pressure fluctuations driving pad are carefully monitored by an electric oscillator. It produces oscillations of continuously varying frequency for a specified interval of time. During the duration of vibration, which can range from few seconds to more than 30 sec. The frequency vary from low to high or from high to low, one sequence of vibration is called sweep. It can be up sweep or down sweep, depending on whether the frequency increase or decreases. The duration of vibration is called sweep time. The choice of using the vibrators is dynamite depending upon field working condition.

3.5 INSTRUMENTS FOR SEISMIC SURVEYING

Seismic surveying is consist of placing some receivers at different locations and than using them to detect vibrations produced by an energy source. The receiver converts the mechanical vibration into electric signal, which is transmitted to the recorder, the recorder is designed to preserve the information in form that can be displayed and analyzed. Seismic surveying can be done on land or at sea. These instruments are receiver and seismic cables.

3.5.1 GEOPHONE

The receiver used to detect ground vibration is called a geophone or a seismometer.

It is used for surveying on land and it can be operated on the ocean floor if mounted and suitable container. In geophone a magnetized mass fixed to the container is surrounded by a wire coil suspended on spring. When the ground vibrates, the coil move back and forth around the magnetic mass. From the principle of electromagnetisms that the motion of coil around the magnetic produced induced electric current in coil. The strength of current depends on the speed of coil motion. The electric current emanating from a geophone tends to proportional to the velocity of ground motion. The frequency at which geophone response is maximum is known as natural frequency. Geophone commonly have natural period in the range of 5 to 40 Hz.

3.5.2 SEISMIC CABLE

The geophone signal is transmitted to the recording system by means of seismic cable. Each geophone requires two wire conductors. The number of conductor in the seismic cable depends on the number of geophone. The point where the geophone is connected to pair of conductor is takeout. Seismic cable is manufacture with 6,12,24,48 and even 96 takeouts. It is more convenient to used segmented cable. Each segment is usually few tens to hundred of meters long, has one takeout point, and multiprony plugs on both ends for connecting the adjacent segments. A single cable segment and geophone can be moved from one end of a line to the other without disconnecting all other geophones.

3.6 MULTIPLE REFLECTED WAVES

These waves reflect more than one time from the same boundary. Multiple reflections can occur at any boundary, land play important role in downward reflection of the waves.

Robinson & Coruh,(1988) have been suggested that the first few multiples possess enough energy to produce a distinguishable pulse on a seismogram. The multiple possess sufficient amplitude to be detected on seismogram, can cause interpretation problems. These problems specially occur for seismic survey at sea because of the large acoustic impendence contrast between the water and the underlying sediment or rock, especially large multiple can be recorded. Multiple reflections can be distinguished from the primary reflection coming from deeper boundary. The arrival time of multiple reflection on seismogram is calculated and prepare travel time graph, by which identical velocity V1 and reflector depth is calculated, which we would also been obtain from the analysis of the primary reflection. The multiple would indicate a second layer of equal thickness and velocity. Therefore multiple can be detected by the analysis of the primary reflection and comparing with the result of multiple reflections.

3.7 NOISE

Seismic data being recorded in the field include seismic signal and noise. There are many types of noise. But two important types are

3.7.1 COHERENT NOISE

According to Robinson & Coruh, (1988) it display of some regular pattern on a seismogram, often it consists of recognizable waves such as surface waves and multiples that are produced by the source. Examing the pattern of coherent noise, we can devise field procedure to reduce it.

3.7.2 INCOHERENT NOISE

It is also known as random noise, it displays of an irregular patterns, it may arrive simultaneously from many source such as wind blowing on trees and passing traffic.
The basic tools are available for controlling the noise in the field includes source size, source depth, electronic filtering, receiver arrays, source array and electronic mixing.

3.8 GLOBAL POSITIONING SYSTEM

This is used to locate any point on the earth i.e. find longitude, latitude height and temperature. It is based on the constellation of 24 satellites orbiting the earth at very high altitudes. These are man made stars used for navigation purposes.
The satellite are high enough that they avoid the problems encountered by the land based systems and they use technology accurate enough to really given point position, anywhere in the world in 24 hours.

3.9 RECORDING SYSTEM

These are two major types of recording systems

3.9.1 ANALOG RECORDING SYSTEM

When the ground is vibrating, it is in continuous motion. A geophone responding to this motion produces a continuously varying electric signal. A seismogram is a graph that shows how the amplitude of this signal varies with time. It is a permanent record that how the ground was vibrating during that interval of time at the receiving location.

Different techniques can be used to obtain a seismogram. One such technique is a recording device that draws a continuous graph at the same time as it is recorded the geophone signal. Analog magnetic type with magnetizable coating is also use for recording. As the tap advances and passing by the recorder head. The geophone signals are continuously magnetized.
Robinson & Coruh, (1988) have been described the techniques, which produce continuous graphs were named as Analog recording system.
Each geophone, amplifier, galvanometer unit of the system functions independently of the other. Such a unit is known as one channel, which produces the traces on the seismogram that is independent of other traces.
Analog seismic recording systems with 24 or 48 channels used for the petroleum exploration.

3.9.2 DIGITAL RECORDING SYSTEMS

Digital recording system is modern computer technology and the capability of computer processing of digital data is essential for the purpose of exploration seismology.
According to Robinson & Coruh,(1988). A digital recording makes use of binary number to store the measurement of Geophone signal strength. Any binary number can be expressed with only two symbols "0" and "1". Therefore the binary number can be store on magnetic tap by means of successive of small area that are either magnetized (1) or un- magnetized (0). Each square on a magnetic tap is called "bit" and each rows of square is crossing the tap is called the "byte". One bit is used to store the one digit.
In multi-channel system each geophone signal is first amplified and filtered by analog electronic components, then the signal is change to digital form by the unit is called the analog to digital converter or "A/D" converter. Only one A/D converter is needed to process the signals of all geophones. A procedure accomplished by mean of a high spread, which is called multiplexer. The multiplexer first connects to channel "1" for a period of about one microsecond, which is sufficient time to charge a computer to the voltage of the channel "1", amplifier output at that moment; this signal is then amplified and transmitted to A/D converter. In A/D converter, different combination of standard voltages is generated and tests to find the particular combination that exactly balanced the signal. These signals are transmitted to the formatting unit. Here, the voltage pulses are converted to control signals that activate the recorder heads to magnetize the appropriate bits on the magnetic tap, the entire sequence of step required less than 30 microseconds.
Then multiplexer return to channel "1" and again began to sample the signals of all geophones in a second time and so on.
Now we have the sequence of binary numbers that were recorded on the tap. The tap is sent to a data processing center where computers are available for demultiplexing and for preparing digital seismogram.

SEISMIC VELOCITIES

4.1 INTRODUCTION

Seismic Velocities are the most important parameter in Seismic technique for interpretation processing. Seismic velocities are generally needed for the inspection of Lithology, physical nature of the rocks and also for the calculation of dip and depth interfaces.

The Seismic interpretation has been described as the process of solving for a velocity distribution from the data measured in terms of time, which must be presented in geologic terms (as in structural & lithological interpretation). Velocity varies both in lateral position and with depth, depending upon the medium.

According to Dobrin & Savit, (1988) Seismic velocities vary largely in sedimentary rocks as compared to igneous and metamorphic rocks.

In terms of lithology, whenever there is a change in grain size and mineralogical composition of the sock, velocity behavior changes. An increase in grain size will result in the increase in velocity.

The Seismic velocities in rocks are affected by several factors.

- Density of rock.
- Overburden pressure or depth of burial
- Porosity / fracturing
- Fluid content is pores.
- lithology and mineralogical composition of rock.

The relation between porosity (ϕ) and velocity (V) has been defined by the following relations,

$$1/v = \phi/VF + (1-\phi)/Vm$$

Where

Vf = Velocity of pore fluid

Vm = velocity of rock matrix

The relationship between velocity and depth/age of rock particularly for the shale and sandstone section, which is

$$V = 125.3 \ (ZT)^{1/2}$$

Where

V = velocity in feet per second

Z = Depth in feet

T = Age in years

4.2 DEPENDCES OF SEISMIC VELOCITIES UPON THE PHYSICAL PROPERTIES OF THE ROCKS

The velocities of propagating waves depend upon the following physical characteristics of rocks

POROSITY

Porosity decrease with depth as the result velocity increases.

AGE OF ROCKS

Seismic velocity increases to one-sixth power of age.

TEMPERATURE

Seismic velocity decreases slightly with temperature but freezing of pores fluids increase the velocity.

NATURE OF INTERSTITIAL FLUIDS:

Sand containing water in pore space has higher seismic velocity then containing the oil and if containing gas has lower velocity.

SHALE CONTENT AND SAND CONTENT:

Shale content tends to have lower seismic velocity and more in sand content.

DOLOMITIZATION:

It tends to increase s-wave velocity.

LIME CONTENT:

It increases the seismic velocity.

4.3 P-wave velocities of different rocks.

Type of Medium	Velocity Rang (m/Sec)
Air	330
Water	1400-1600
Shale	1100-3000
Sandstone	2000-3500
Limestone	3500-4500
Dolomite	3500-6900
Granite	4200-6000
Gabbro	6450-6700
Dunite	7500-8100
Basalt	5500-6300

4.4 TYPE OF VELOCITY

In Seismic prospecting, we deal with a medium, which is made of a sequence of layers of different velocities, so it is necessary to specify the kind of velocities. Those are used for structural and lithological interpretation.

4.4.1 AVERAGE VELOCITY(Vavg)

The average velocity is simply obtained by dividing the depth' Z, of reflecting surface by the observed one-way reflection time 't, from the datum to the surface.

$$V_{avg} = Z / T$$

If Z represents the sum of the thickness of layers $Z_1, Z_2, Z_3, \ldots\ldots Z_n$.
Then the average velocity is defined as

$$V_{avg} = Z_1 + Z_2 + Z_3 \ldots\ldots Z_n / t_1 + t_2 + t_3 \ldots\ldots t_n$$

The average velocity is used for time to depth conversion and for migration.
Robinson & Coruh, (1988) have described that the average velocity is used for depth conversion, because it is true vertical velocity in the ground. It should never be used NMO calculation.

4.4.2 INTERVAL VELOCITY (Vint)

According to Dobrin & Savit, (1984) that the velocities within the interval defined by the interfaces are called the interval velocities. If two reflection at depth Z_1 and Z_2 give reflections having respective one-way times of t_1 and t_2. The interval velocities 'Vint, between Z_1 and Z_2 defined as

$$V_{int} = Z_2 - Z_1 / t_2 - t_1$$

Interval velocity depends not only upon the lithology but also depend upon depth of burial and the same formation at a greater depth will usually have a greater velocity.

4.4.3 ROOT MEAN SQUARE VELOCITY (Vrms)

If the section consists of horizontal layers with respective interval velocities of V_1, V_2, and V3 .... V_n and one-way interval travel times $t_1, t_2, t_3 \ldots\ldots t_n$. the root mean Square (rms) velocity is obtained form the relation.

$$V^2_{rms} = V_1^2 t_1 + V_2^2 t_2 + \ldots\ldots + Vn^2 tn / \ t_1 + t_2 + \ldots\ldots t_n.$$

The RMS velocity gives a better result them the average velocity, when single layer case is used for $\triangle$ t Calculation. Infect RMS velocity differ form the average velocity more and more as the layer become complex.

4.4.4 INSTANTANEOUS VELOCITY (Vinst)

The velocity varies continuously with depth, its values at particular depth, is

$$Vinst = d_z / d_t$$

Where

$$dz = Z_2 - Z_1$$
$$dt = t_2 - t_1$$

For shallow horizons, Vavg and Vint are same and interval velocity measurements are meaningless, when reflectors are not horizontal.

4.4.5 STACKING VELOCITY (Vst)

It is velocity obtained from the application of normal move out (NMO) correction to common depth point (CDP) gather. So stacking velocity (Vst) is based on the relation,

$$Tx^2 = To^2 + X^2 / Vst^2$$

Where

X = Source – reciver offset
To = Two way travel time of reflection at zero offset.
Tx = Two way travel time of reflection at X.
Vst = Stacking velocity.

Stacking velocities are always greater then average and interval velocities.

$$Vave \leq Vrms < Vst$$

Different Values of Vst are tested to obtain Δ T (NMO time).

4.5 DIX FORMULA FOR VELOCITY

There is a simple but accurate formula for quick calculation of interval velocities from the velocities determined by the known $X^2 - T^2$ technique.
According to Badley, (1985) that Dix interval velocity can be obtained form RMS velocities.

V^2_{int12} (interval velocity) = $[(V^2_{rms})_2T_2 - (V^2_{rms})_1T_1 / T_2 - T_1$

T_2 = Two –way travel time to deeper level.
T_1 = Two –way travel time for shallows level.
The dix velocities are correct only for the horizontal strata and are layer then the true interval velocities for dipping reflectors.

4.6 METHOD OF VELOCITY DETERMINATION

In Seismic prospecting two main approaches are used for velocity measurement.

- By use of exploration oil well, which is a direct method. A velocity function is computed form the continuous velocity survey.
- By use of reflection travel time during processing, which is as indirect method.

4.7 T^2-X^2 METHOD

This method is based on the equation

$$T^2 = X^2 / V^2_{rms} + To^2$$

When we plot 'T^2, as function of X^2, we get a straight line whose slope is $1/V^2_{rsm}$ whose intercept is To^2 form which determine the corresponding depth.

SEISMIC DATA PROCESSING

5.1 INTRODUCTION

Processing of seismic data consists of applying a sequence of corrections and filters to recorded digital data. The main purpose of processing is to remove signal to noise ratio for making the interpretation more depending and reliable. In addition to field acquisition parameters, seismic data processing results also depend
on the tool used for processing.

According to Dobrin & Savit, (1988) Seismic data processing is the approach by which raw data recorded in the field is enhanced to the extent that can be used for geological interpretation. The seismic reflection coming from the depth is generally weak and need to strength by digital processing of field data. This approach involves the sequences of operation for improving the signal to noise ratio. The seismic field recorder generally record the data on magnetic taped. These taps are then transferred to the data processing center, where the seismic data are processed. Processing of seismic data consists of applying a sequence of computer programs. The steps involves from demultiplexer of field data to the preparation of final time section are briefly describe as follow

5.2 DEMULTIPLEXING

The seismic data recorded on a magnetic taps is "demultiplexed" form. Now to record that data, we have four types of formats.

SEGA, SEGB, SEGC, these three format are used to record the data in multiplex form.

SEGD, this is the only format that record the data in the both multiplex and Demultiplexing form.

Robinson & Coruh, (1988) have described the processes of sorting the data form magnetic tape into individual channel sequences, which are known as Demultiplexing. Multiplexing of data is used for preparation digital seismogram. The recording system used for acquisition of this data has 120 channels with a sampling rate of 2 m sec. The digital recording system puts the values in the following order

A1,1, A2,1, A3,1 ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,

In this sequence, the first subscript represent the channel number and the second subscript represent the number of point in the sequence of values obtained, from that channel.

Data in this form was demultiplexed by a computer program and sorts these values into a sequence for separate channel.

First the computer reads the entire digital tap, then it repeatedly sort a value, until the following sequence have been complied separately

Time Sequential →

Trace Sequential ↓				
	A1,1	A1,2	A1,3 ----------	A1,1800
	A2,1	A2,2	A2,3 -----------	A2,1800
	A120,1	A120,2	A120,3 ----	A120,1800

In this way digital seismogram for each channel is form.

5.3 VIBROSEIS CORRELATION

The seismogram results from the refraction and reflection of vibroseis source wavelet along the many paths leading to geophone. Since the wavelet lasts so long that all the reflected and refracted arrival overlap one another. None of this arrival can be distinguished on the seismogram recorded in the field.

Since we know the precise form of input signals, we can use a processing technique called "correlation". For computer processing of the digital magnetic taps after it has been sent from field site to data processing center where correlation is take place.

It have been suggested by Rehman, (1989) that the vibroseis data is made useable by cross correlating the data with the original input sweep. By this reflection are compressed into short wavelets.

According to Robinson & Coruh, (1988). The vibroseis correlation enables us to extract from each of the long overlapping sweep signals, a short wavelet, much like those obtained with impulsive source. The frequency of resulting wavelet is equal to the middle frequency of the sweep signal.

The particular form of wavelet produced by vibroseis correlation is called a Klauder wavelet. These Kaluder wavelet is the autocorrelation of a vibroseis sweep. The important of vibroseis correlation is that correlating the data with field sweep, cancel out the phase changed and lags in the data caused by recording instrument

5.4 EDITING

Editing is the process of removing or correcting any traces or records. Automatic editing and user selected editing is done during Demultiplexing.

Rehman, (1989) have been described that the data editing involves complete removal of all undesired data through setting to zero, the trace samples.

After multiplexing the data, the trace of each channel under its respective number is plotted. The time plotting the demultiplexed data is termed as "Shot Pack".

Shot pack is useful for quality control and it enabled us to identify, dead channels, noising channels, channels with reverse polarity, and disturbance due to high-tension wire, Asymmetric/symmetric shooting. Hence the channel with above characteristic is further process with special techniques to the actual data (Zia, 1989).

5.4 AMPLITUDE ADJUSTMENT

The amplitude of the reflected waves diminishes with offset distance because it is effect of geometric spreading and absorption. So a gain recovery function is applied on the data to correct for the amplitude effect of wave front (spherical) divergence.

There are two adjustments, which are as follows

1 Trace normalization is amplitude adjustment applied to entire trace and enhances the appearance of continuity.

2 Traces balancing is the "amplitude, within the trace. The process is also called automatic gain control (AGC), time variant scaling or equalization. AGC attempts to make amplitude similar for all offset times and all mid points.

5.6 COMMON MID POINT (SORTING AND GATHER)

In processing of selecting the sets of traces to be stacked is called sorting. The trace same mid point location are grouped together for stack is called mid point stacking gather. Common mid point stacking is widely used in seismic reflection data processing.

The steps involves are the following.

1: First the traces are sorted from seismogram.

2: Static correction is apply to remove the weathering surface and elevation effect

3: Amplitude adjustment

4: Normal move out adjustment.

after applying the following steps, the traces are stacked and prepare the seismic section.

According to Yilmaz (1987), CDP gather is equivalent to a CMP gather only when the reflector are horizontal and velocities do not vary horizontally. However, when there are dipping reflectors in the subsurface, these two gather are not equivalent Therefore only CMP gather is use (Yilmaz, 1987).

5.7 TIME CORRECTION

Two main types of correction are needed to apply to reflection times, on individual seismic traces. Then the resultant seismic section gives true representation of geological structures. These two types correction are

5.7.1 STATIC CORRECTION

Surface elevation varies from shot point to shot point and from geophone group to geophone group. The near surface layer above the bedrock is low velocity and varies in its thickness.

To see the correct subsurface picture, we bring all shots and receivers groups on the same elevation level, generally called datum plane.

Thus removing these surface effects requires two corrections.

5.7.1.1 WEATHERING CORRECTION

Up hole survey are performed to find out the correct thickness and velocity of weathering layer, to calculate the weathering correction (t_w).

$$tw=h_0 (1/v_o-1/v_1)$$

Where

h_o = weathering layer theickness

Vo= weather layer velocity

V1=velocity in bed rock

5.7.1.2 ELEVATION CORRECTION

Elevation correction is for elevation differences between individual shot and detectors, which introduce time difference of seismic traces. All the receivers are brought to the same datum plane.

$$t_0 = Z\text{-}Zo/V1$$

Z=elevation of source

Zo= elevation of datum surface

According to Robinson & Coruh, (1988) the static correction of trace is the sum of its weathering and elevation correction (Δt)

$$\Delta t = t_w + t_e$$

It is applied to traces by shifting the source and receivers, which are lying above the datum plane. The static correction is subtracted from the arrival time of that trace and the receiver lying below, static correction is added for that traces. Thus shot and receiver corrections are applied to all traces, so as to remove the effect of weathering layer and all shots and receivers are assumed to be present on the same datum plane.

The static correction can be viewed

(a) Replacing the weathering zone velocity v_o with bed rock velocity v_1 and
(b) Then reducing the source and receiver points to the same horizontal datum.

5.7.2 DYNAMIC CORRECTION

The final step is to preparing a CDP gather is normal move out adjustment. This adjustment is called dynamic time correction.
Robinson & Coruh, (1988) have been described that the reflected wavelets on unadjusted traces lie on hyperbolic arc. The idea of normal move out or dynamic time correction is to shift these wavelets to the common arrival time, equal that on zero offset trace.

$\Delta t = \sqrt{[(t_o)2 + X2/Vrms]} - t_o$

to= zero offset time

X= offset distance

T=source receiver reflection

That shows as '$_{to}$' increased then (Δt) normal move out adjacentment will be less. it means that Δt value is decreased for deep reflection. Since we know the 't, and X offset, thus velocity on the reflector can be determined, i.e the velocity required to correct for normal move out is called the normal move out velocity. Therefore the normal move out adjacentment is actually for velocity analysis. Since NMO is time varying so it is called the dynamic correction.

5.8 DECONVOLUTION OR INVERSE FILTERS

The earth filter expands an impulse into a wavelet and divides it into several wavelets by reflection and refraction. Inverse filter is used to reversing the effect of earth filter.
Robinson & Coruh, (1988), have been describe that inverse filter have two objections

1. It seeks to compress the wavelet into shorter impulse that is similar to initial impulse, to approximately a spike.
2. It seeks to shift some wavelet produced by reflection and refraction back into incident wavelet. Long reflected wavelet overlap on one another. So it is desired to obtain the shortened wavelet, to easily separate from one another.

The stronger multiples override the deeper reflection then multiple are shift back into the wavelets from which they produced.
Therefore removing the multiples can recognize the deeper reflector. Deconvolution is mostly applied in the processing of marine seismic data to remove the strong multiple reflected signals from ocean floor.
Because primary reflection from ocean floor is strong and easily recognized.

5.9 SPKING DECONVOLUTION

Yilmaz, (1987) have been described the process by which the seismic wavelet is compressed into zero spike is called the spiking deconvolution. This goal is achieved by making use of various filters. Their performance depends upon the filter length, but also on whether the input wavelet is minimum phase. The amplitude spectrum of the operator is the inverse of the amplitude spectrum on minimum phase. Therefore the one way to extract the seismic wavelet provided. It is minimum phase is to compute the spiking deconvolution operator and find its inverse. In conclusion, if the input wavelet is not minimum phase then spiking deconvolution cannot convert into a perfect zero lag spikes.

5.10 MINIMUM PHASE

Let us consider three wavelets with different phase lag spectra. As a result, there shape differ.

(1) A wavelet that has more energy concentrated at the onset.
(2) The wavelet has energy concentrated in the center.
(3) Also the wavelet having most of all energy concentrated at the end. The shape of a wavelet can be altered by changing the phase spectrum without modifying the amplitude spectrum. A wavelet is minimum phase, if the energy is maximally concentrated at its end. Finally in all in between situation, the wavelet is mixed phase, whereas the wavelet having a maximum amplitude at t=0, is termed as the zero phase wavelet.

5.10 MUTING

We have determined the NMO, which is time shift in particular time. At a given offset, NMO decrease with time, thus earlier part of a wavelet is greater time shift than the later part. As a result of NMO correction, traces are stretched in a time varying manner, causing their frequency content to shift towards the lower end of spectrum, this effect is called the NMO-stretch. Frequency distortion increase at traces. The solution to NMO stretch at earlier time is to apply "MUTE" to the corrected gather, i.e. the distortion zone is detected, so that the reflection with unacceptable number of stretch are not include n the summation.

5.11 RESIDUAL STATIC'S CORRECTION

On extra step is needed before stacking for most land data, that the events in some gathers are not as flat as they are in other gather.

According to Yilmaz,(1987) the normal move out in CMP gathers does not always conform to a perfect hyperbolic trajectory. This is often because near surface velocity irregularities cause static or dynamic distortion problems. Lateral velocity variation due to complex overburden can cause move out that could be negative i.e. reflection events arrives on long offset traces before it arrive on short offset traces.

Close experiment of the velocity spectra indicates that the some are easier to pick than others. To improve stacking quality residual static corrections are performed on the move out corrected CMP gather. The time shifts are depending only on shot and receiver location, not on the ray path from source to receivers. The estimated residual corrections are applied to original CMP gather with no NMO correction. Velocity analysis is often repeated to improve the velocity picks, with this improved velocity the CMP gathers are NMO corrected. Finally the gather are stacked and shows a comparison between the stack without the residual static correction and with residual static correction.

5.12 STACKING

It is used to improve the quality of seismic data and to reduce the noise. "Stacking" is the process of compression or the process of combining the seismogram traces, which are obtained by different source and receiver position. First normal move out correction apply to the traces to reduce mid point time at zero offset for each CDP gather and then by summing traces along the offset axis "stack section "is obtained. In the corrected gathered the traces have been gathered into depth point order, both static and dynamic correction has been applied and the traces are muted. Therefore to stack the data all the traces sum in each depth point, that result single the stacked traced for each depth point.

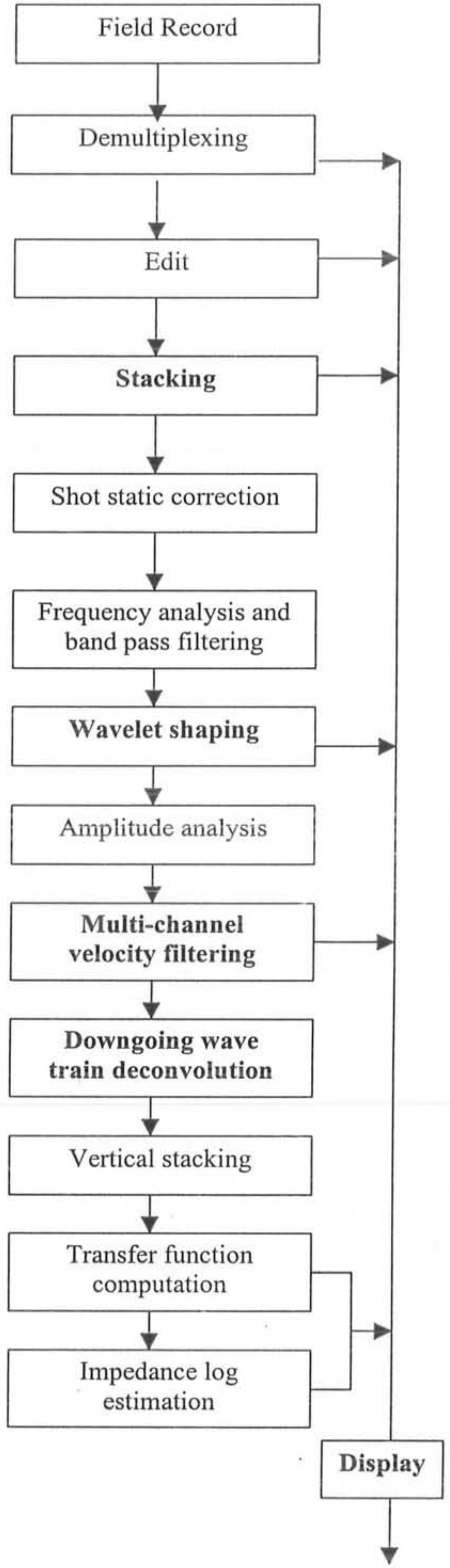
5.13 MIGRATION

The process of shifting or repositioning the reflection event the position that is corrected image of reflector. Irregularities on reflector produce diffraction wavelets, which interfere with the reflection on the seismogram. On the seismic section, this diffraction is produced arc like pattern. When CDP stacked traces plotted to prepare the seismic section, the diffracted wavelet create an image has the shape of hyperbola. Where the diffracted wavelets superposed on the reflection. It is desirable to remove the diffracted signal from the seismic section. Robinson & Coruh, (1988) have been described that the Migration procedure generally has two tasks.

1 it must reposition the reflection that were displaced because of dip.

2 it removed the diffracted images.

Computer programmers are prepared to the implementation of these ideas. The needs to apply migration can usually be judge by examining the seismic section, where the diffraction and dipping image are seen.



A typical VSP data processing Sequences.

SEISMIC INTERPRETATION

6.1 FUNDAMENTALS OF INTERPRETATION

Interpretation is the transformation of seismic reflection data into geological structural picture by the application of corrections, migration and time depth conversion.

It is done objectively to extract from the seismic data the maximum amount of geological information, especially the structural and stratigraphic history.

Dobrin& Savit (1988) have described that the following assumptions are taken into account for interpretation.

1) The coherent events seen on seismic records or on processed sections are reflections from acoustic impedance contrasts in the earth.

2) These contrasts are associated with bedding which represents the geological structure.

3) The seismic details of wave (shape, amplitude) are related to geologic details i.e stratigraphy and the nature of the interstitial fluids.

For making the interpretation more reliable the following data is considered essential.

6.1.1 SEISMIC VELOCITIES

In interpretation the seismic velocity information play sensitive role.

The seismically derived velocities i.e. stacking velocities and average velocities are commonly obtained during processing at intervals along the section and are found to change vertically form one formation to the other. These are more reliable at shallow part of the section than at the deeper Part, may be due to uncertainty of picking stacking velocities. So in practice rather than using velocities form one velocity analysis alone, average velocities from several nearby points are preferred. Because velocity analysis generally are not very accurate due to false geometric assumptions and departure from the assumption of horizontal layering of the earth. Thus, velocities functions are matched with depth information obtain from well or any other source. A time depth chart is made from this information.

6.1.2 WELL DATA

If well data is available, it is an invaluable aid interpretation procedure. It provides the link between lithology, seismic reflections and stratigraphic sequences.

Sonic log are used to make an overall correlation between the well and section, but discrepancies may occur in detailed correlation.

To overcome these inherent uncertainties of sonic logs, check-shot or velocity surveys are done. In present case no well data was available for correlation.

6.1.3 LITHOLOGICAL DATA

The study of actual rock samples from the well is another source of well information. The rock samples and wire line logs (resistivity, gamma, S.P caliper, dip etc form the basis of subsurface correlations, facies analysis, stratigraphic studies and geochemistry etc. the results of these studies are often summarized in composite log, which comprises of lithological description the interpreted formation identification and details, of hydrocarbon.

6.1.4 SYNTHETIC SEISMOGRAMS

Synthetic seismogram helps the tie between well and the seismic section, whereas inverse modeling derives synthetic acoustic impedance or sonic logs from seismic data and aids in seeing the geological significance of seismic wave shape variations near the well, especially in locating nearby stratigraphic changes suggested by the well data.

6.1.5 VERTICAL SEISMIC PROFILES

A more sophisticated comparison between the seismic section and the well results is obtained by converting velocity check-shot data into a vertical seismic profile (VSP). The reflections are identified on the VSP from geologist's picks of formation tops in the well logs. Then the VSP can be correlated with a regular seismic section from a line that crosses the well.

6.1.6 OUTCROP GEOLOGY

Relevant outcrop geology provides much detailed information, which can be extrapolated and used to model the subsurface geology. Outcrop geology gives details of stratigraphy, lithology. facies relationships and associations. All these informations are required for a good interpretation, but we have only seismic section and the velocity information. So on the basis of these limited informations we do our best to have a good interpretation of the given section, on the basis of stratigraphic information only.

6.2 INTERPRETATION OF GIVEN SEISMIC SECTION

6.2.1 DEPTH DETERMINATION

There are two basic tools for the preparation of the depth section.

1. Contour Average Velocity Method 2. Mean Average Line Method

6.2.1.1 CONTOUR AVERAGE VELOCITY METHOD

The following steps are involved in this method,

a. Using the interval velocities, the average velocities were calculated by using formula given below.

$$Vavg2 = \frac{Vint2\ (T2-T1)+Vavg1\ (T1)}{T2}$$

Where,

$$Vavg1 = Vrms2$$

b. Then these average velocities under given Shot points are plotted along their respective times given in Table (6.2).

c. Interpolating the average velocities at an interval of 100m/sec an iso-velocities contour map (Fig.a) was prepared.

d. Then times of each reflector are plotted on this contour map.

e. The reflector velocities at each Sp with reference to the above and below lying contours are calculated.

f. Then the depth of each reflector is calculated, plotted along the shot points to form depth section (Fig.b).

Three reflectors have been observed in this depth section, which is explained below.

***i)* Reflector R1:**

R1 varies between **SP-250** to **SP-360** at the time range of **0.83 sec** to **0.81 sec.** in the time section and at the depth range of reflector **1** is **752.80m** to **780 m** in the depth section are shown in Table (6.3-a)

***ii)* Reflector R2:**

The reflector R2 varies between **SP-250** to **SP-360** at the time range of **1.43 sec.** to **1.40 sec.** in the time section and depth ranges **1623.05 m** to **1580 m** in the depth section are shown inTable (6.3-b).

***iii*) Reflector R3:**

The reflector R3 varies between **SP-250** to **SP-360** with the time ranges between **2.37 sec.** to **2.36 sec.** in the time section and depth ranges from **3436.50 m** to **3435.11 m** in the depth section are shown in Table (6.3-c)

6.2.1.2 MEAN AVERAGE VELOCITY LINE METHOD

Following steps are involved in this method,

a. The calculated average velocities are plotted along their respective times of each CDP shown in (Fig.d).

b. A mean Average Velocity line (Fig.e) is plotting by averaging all the average velocity Vs time of each CDP window.

c. Using mean average velocity line noted the average velocities of each reflector under the shot point at their respective times.

d. These velocities are used to calculate the depth of each reflector.

g. Then the depth of each reflector is plotted along the shot points Vs depth to form depth section shown in (Fig.f).

Three reflectors have been observed in this depth section, which is explained below.

***i*) Reflector R1:**

The reflector varies between **SP-250** to **SP-360** with the time ranges between **0.830 sec.** to **0.810 sec.** in the time section and depth ranges from **784.98 m** to **767.88 m** in the depth section are shown in Table 6.4(a).

***ii*) Reflector R2:**

The reflector varies between **SP-250** to **SP-360** with the time ranges between **1.43sec.** To **1.40 sec.** in the time section and depth ranges from **1630.20m** to **1582 m** in the depth section are shown in Table 6.4(b).

***iii*) Reflector R3:**

The reflector varies between **SP-250** to **SP-360** with the time ranges between **2.37 sec.** to **2.36 sec.** in the time section and depth ranges from **3495 m** to **3383.06 m** in the depth section are shown in Table 6.4(c).

6.3 COMPARISON OF DEPTH SECTION

We plotted two-depth sectionsby using two methods as described earlier. These graphs show somewhat similar trend.

1. Contour Average Velocity Method:

Reflector	Depth Range (m)
R1	752.81-780
R2	1623.05-1580
R3	3436-3435.11

2. Mean Average Velocity Line Method:

Reflector	Depth Range (m)
R1	784.98-767.88
R2	1630.20-1582
R3	3400.95-3383.06

6.4 STRUCTURAL ANALYSIS

In this seismic section there is no indication of faults. Reflector R_1 is slightly dipping, Reflector R_2 is also dipping slightly with same trend as reflector R_1, Reflector R_3 is dipping steeper than other two reflectors. This gentle dip of strata is an indication of stable area.

6.5 STRATIGRAPHIC ANALYSIS

The stratigraphy of the area is related to middle Indus Basin having age of Pre-Cambrian to Recent. During the Cretaceous the basin tilted to the north due to shift in basin axis therefore all the horizons are up going to the north.

In the first portion of seismic section, the reflections are not clear and give the indication of alluvium deposit. In middle part, due to more change in the acoustic impedance give the strong reflections. Reflector R_1 represents the sequence of Siwaliks to recent. Below this conformable strata are present, as regional unconformity occur in base tertiary (Base Paleocene). Reflector R_2 represents the Jurassic to Paleocene sequences. After this a strong reflector R_3 is shown which give the indication of top of Salt Range Formation. Between R_3 and R_2 lies the Cambrian to Jurassic sequences. Below R_3 are the Salt Range Formation and the basement.

6.6 CONCLUSIONS

1. The average iso-velocity contour map shows smooth horizontal contours indicating little variation in velocity. Therefore the area is tectonically stable and no major structural deformation exists.

2. A truncation of the strata was also observed below reflector R_1 that is the indication of an unconformity at the base tertiary (Base Paleocene).

3. On the basis of structural and stratigraphic correlation, reflector R_1 marks the boundary between the Siwaliks to recent sequence. Reflector R_2 represents the sequences of Jurassic to Paleocene and R_3 marks the top of Salt Range Formation.

4. The area is tectonically stable and the strata are dipping very gently towards north.

TABLE#6.1(a)

CDP258			
Time	Vint	Vave	Depth
0.004	1497	1497.00	2.99
0.61	1651	1649.99	503.25
0.71	2711	1799.43	638.80
0.82	2117	1842.03	755.23
1.01	2444	1955.27	987.41
1.21	3009	2129.44	1288.31
1.41	3043	2259.02	1592.61
1.54	3744	2384.38	1835.97
1.86	3308	2543.28	2365.25
2.21	3485	2692.42	2975.13
2.31	5879	2830.37	3269.08
2.42	4118	2888.90	3495.57
2.54	5278	3001.77	3812.25
2.73	5308	3162.28	4316.51
4	7328	4484.89	8969.79

TABLE#6.1(b)

CDP288			
Time	Vint	Vave	Depth
0.004	1497	1497.00	2.99
0.545	1742	1740.20	474.21
0.705	2142	1831.39	645.57
0.885	2326	1931.99	854.91
1.045	2635	2039.63	1065.71
1.205	2284	2072.07	1248.43
1.305	3164	2155.75	1406.63
1.415	3606	2268.49	1604.96
1.605	3403	2402.79	1928.24
1.855	3500	2550.66	2365.74
2.205	2837	2596.11	2862.22
2.305	4991	2700.01	3111.77
2.405	5742	2826.50	3398.87
4	7000	4490.68	8981.37

TABLE#6.1(c)

CDP 323			
Time	Vint	Vave	Depth
0.004	1497	1497.00	2.99
0.525	1742	1740.13	456.79
0.705	2298	1882.57	663.61
0.885	2133	1933.50	855.58
1.005	2798	2036.73	1023.46
1.185	2816	2155.10	1276.90
1.315	2827	2221.52	1460.65
1.476	2849	2289.97	1689.99
1.605	4948	2503.60	2009.14
1.805	3224	2583.42	2331.54
2.205	3235	2701.62	2978.54
2.305	5651	2829.58	3261.09
2.405	4546	2900.95	3488.39
2.705	5247	3161.14	4275.44
4	7283	4495.59	8991.18

TABLE#6.1(d)

CDP353			
Time	Vint	Vave	Depth
0.004	1497	1497	2.99
0.655	1742	1740.50	570.02
0.705	2394	1786.85	629.87
0.875	2143	1856.05	812.02
1.105	2472	1984.25	1096.30
1.185	3534	2088.88	1237.66
1.345	2731	2165.26	1456.14
1.595	3002	2296.41	1831.39
1.725	4735	2480.19	2139.17
1.965	2900	2531.47	2487.17
2.305	4592	2835.41	3267.81
2.505	4496	2967.99	3717.41
2.605	6664	3109.87	4050.61
4	7077	4493.41	8986.81

TABLE # 6.2

Time and Average Velocity of Contour Map at Each CDP				
Average Velocity m/sec	Time at CDP-258 (sec)	Time at CDP-288 (sec)	Time at CDP-323 (sec)	Time at CDP-253 (sec)
1600	0.4	0.21	0.21	0.21
1700	0.63	0.42	0.42	0.42
1800	0.7	0.63	0.58	0.58
1900	0.9	0.77	0.74	0.74
2000	1.05	0.93	0.93	0.99
2100	1.16	1.23	1.05	1.16
2200	1.31	1.34	1.24	1.29
2300	1.45	1.44	1.41	1.44
2400	1.53	1.59	1.5	1.57
2500	1.72	1.73	1.59	1.68
2600	1.95	2.2	1.9	1.95
2700	2.21	2.3	2.19	2.08
2800	2.27	2.38	2.28	2.21
2900	2.41	2.47	2.4	2.34
3000	2.5	2.57	2.48	2.5
3100	2.62	2.66	2.55	2.57
3200	2.74	2.76	2.64	2.66
3300	2.84	2.86	2.75	2.76
3400	2.93	2.95	2.85	2.86
3500	3.03	3.05	2.96	2.97
3600	2.13	2.14	3.06	3.07
3700	2.22	3.24	3.17	3.17
3800	3.33	3.34	3.27	3.27
3900	3.43	3.44	3.38	3.38
4000	3.52	3.53	3.48	3.48
4100	3.62	3.63	3.59	3.59
4200	3.72	3.72	3.69	3.68
4300	3.82	3.82	3.79	3.78
4400	3.91	3.91	3.9	3.89

DIX VELOCITY CONTOUR MAP

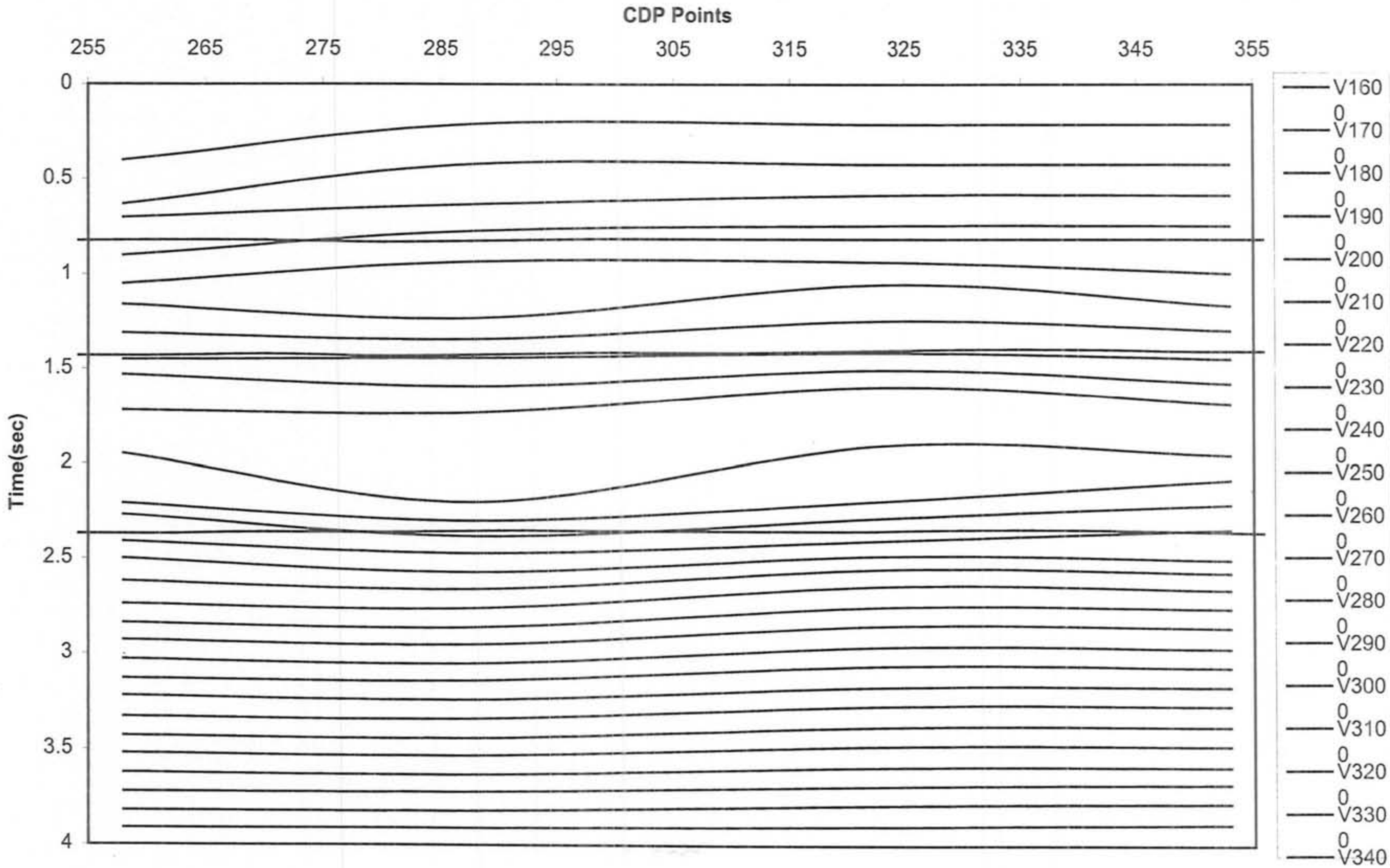


Fig. a

Time and depth of Reflector by Dix Method

Reflector.1			
S.P	Time(sec	Vavg	Depth
250	0.83	1825.00	752.81
260	0.82	1865.00	764.65
270	0.82	1888.23	774.17
280	0.83	1921.42	797.39
290	0.82	1937.5	794.38
300	0.81	1935.29	783.79
310	0.81	1936.84	784.42
320	0.81	1936.84	784.42
330	0.81	1935.00	783.68
340	0.81	1933.33	783.00
350	0.81	1929.13	781.30
360	0.81	1925.92	780.00

TABLE 6.3(a)

Time and depth of Reflector by Dix Method

Reflector.2			
S.P	Time(sec)	Vavg	Depth
250	1.43	2270.00	1623.05
260	1.43	2285.71	1634.28
270	1.42	2276.92	1616.61
280	1.43	2286.95	1635.17
290	1.42	2280.00	1618.80
300	1.41	2283.00	1609.52
310	1.41	2289.65	1614.20
320	1.40	2294.04	1605.83
330	1.39	2284.21	1587.53
340	1.39	2283.33	1586.91
350	1.40	2278.78	1595.15
360	1.40	2257.14	1580.00

TABLE 6.3(b)

Time and depth of Reflector by Dix Method

Reflector.3			
S.P	Time(sec)	Vavg	Depth
250	2.37	2900.00	3436.50
260	2.37	2864.24	3394.12
270	2.36	2833.33	3343.33
280	2.36	2788.88	3290.88
290	2.35	2762.50	3245.94
300	2.35	2785.71	3273.21
310	2.35	2816.66	3309.58
320	2.35	2852.00	3351.10
330	2.34	2869.00	3356.73
340	2.34	2883.33	3373.50
350	2.35	2900.00	3407.50
360	2.36	2911.11	3435.11

TABLE 6.3(c)

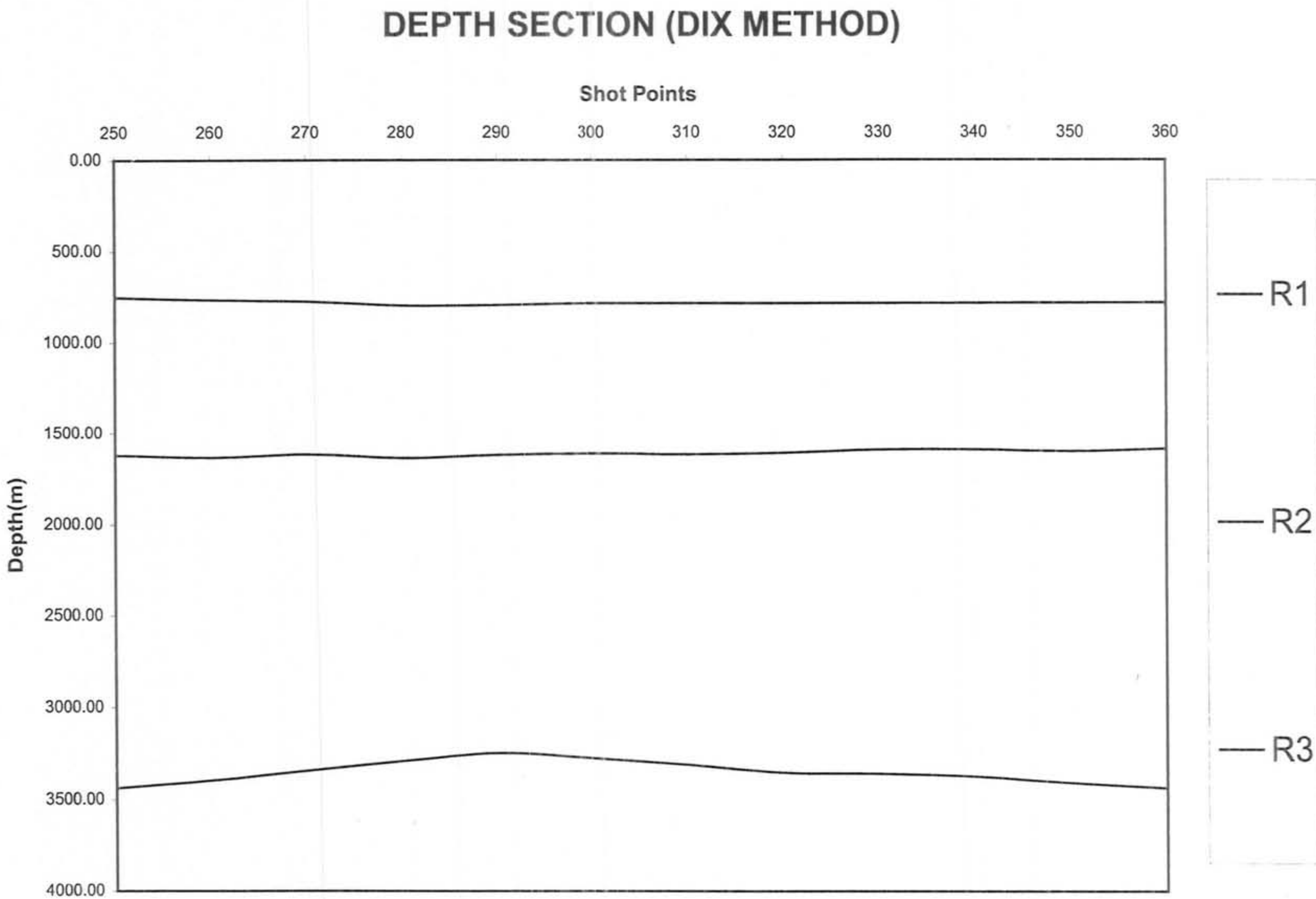

DEPTH SECTION (DIX METHOD)
Shot Points
250
260
270
280
290
300
310
320
330
340
350
360
Depth(m)
0.00
500.00
1000.00
1500.00
2000.00
2500.00
3000.00
3500.00
4000.00
R1
R2
R3

Fig. b

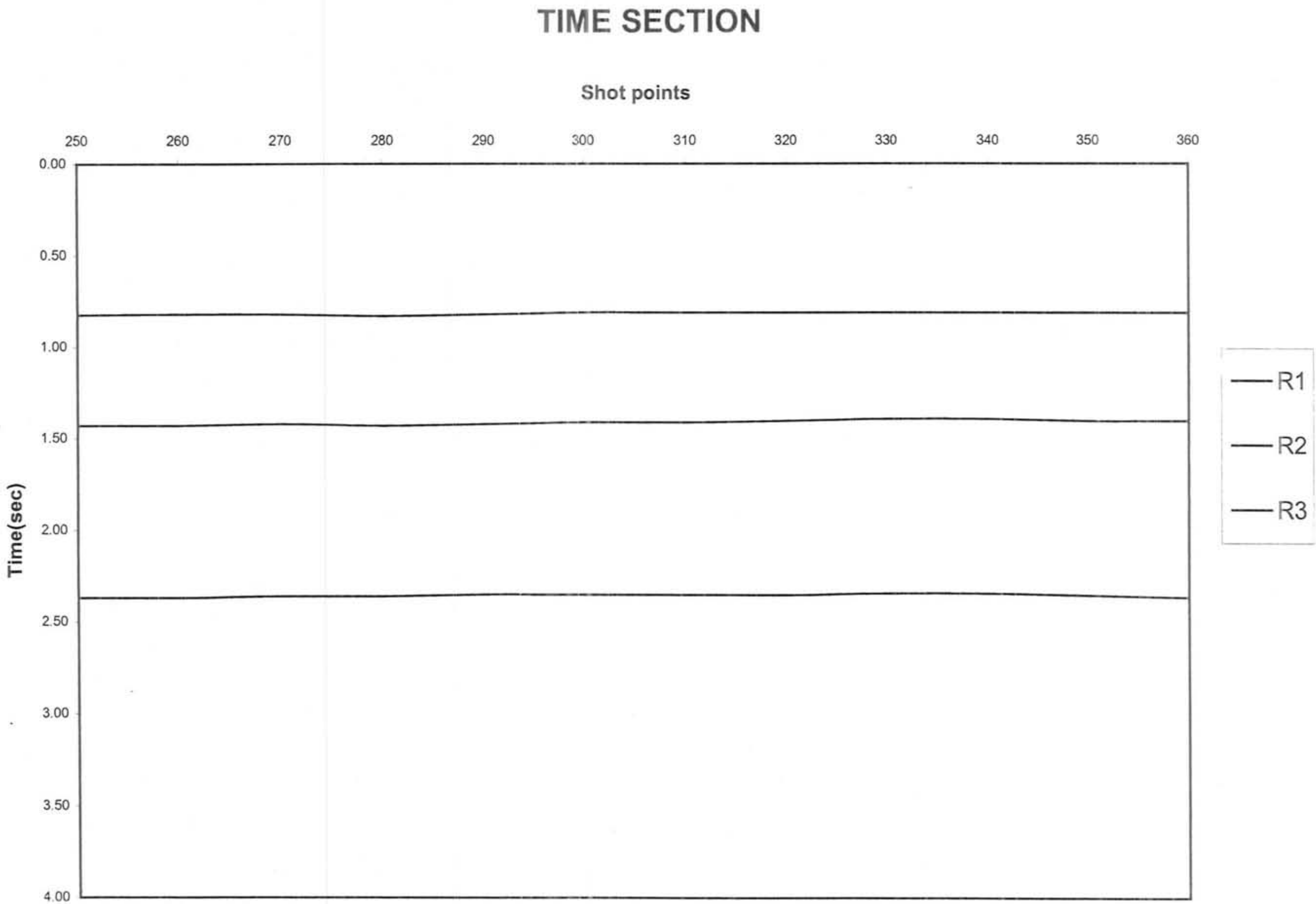

TIME SECTION
Shot points
250
260
270
280
290
300
310
320
330
340
350
360
Time(sec)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
R1
R2
R3

Fig. c

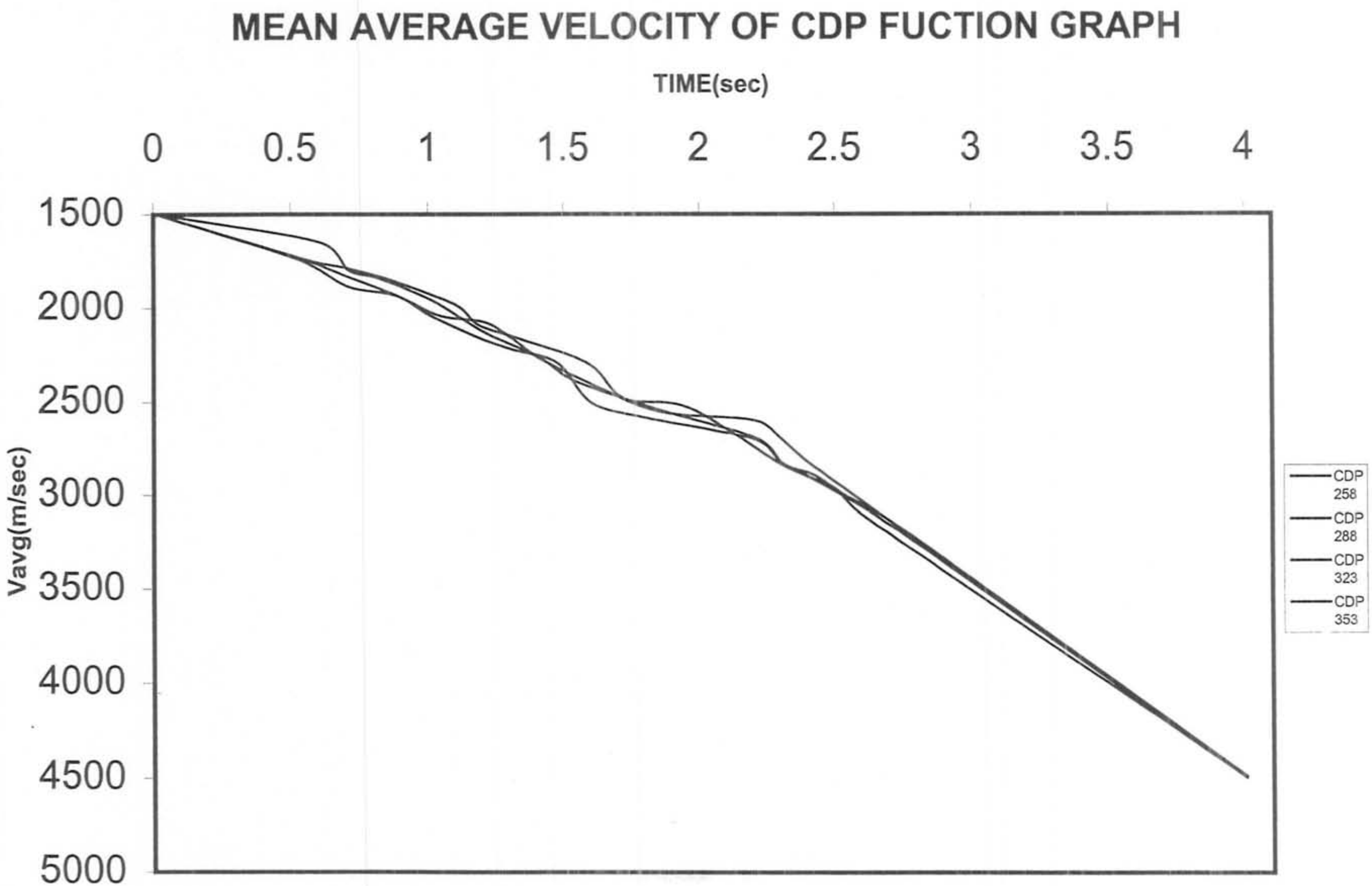

MEAN AVERAGE VELOCITY OF CDP FUCTION GRAPH
TIME(sec)
0
0.5
1
1.5
2
2.5
3
3.5
4
Vavg(m/sec)
1500
2000
2500
3000
3500
4000
4500
5000
CDP 258
CDP 288
CDP 323
CDP 353

Fig. d

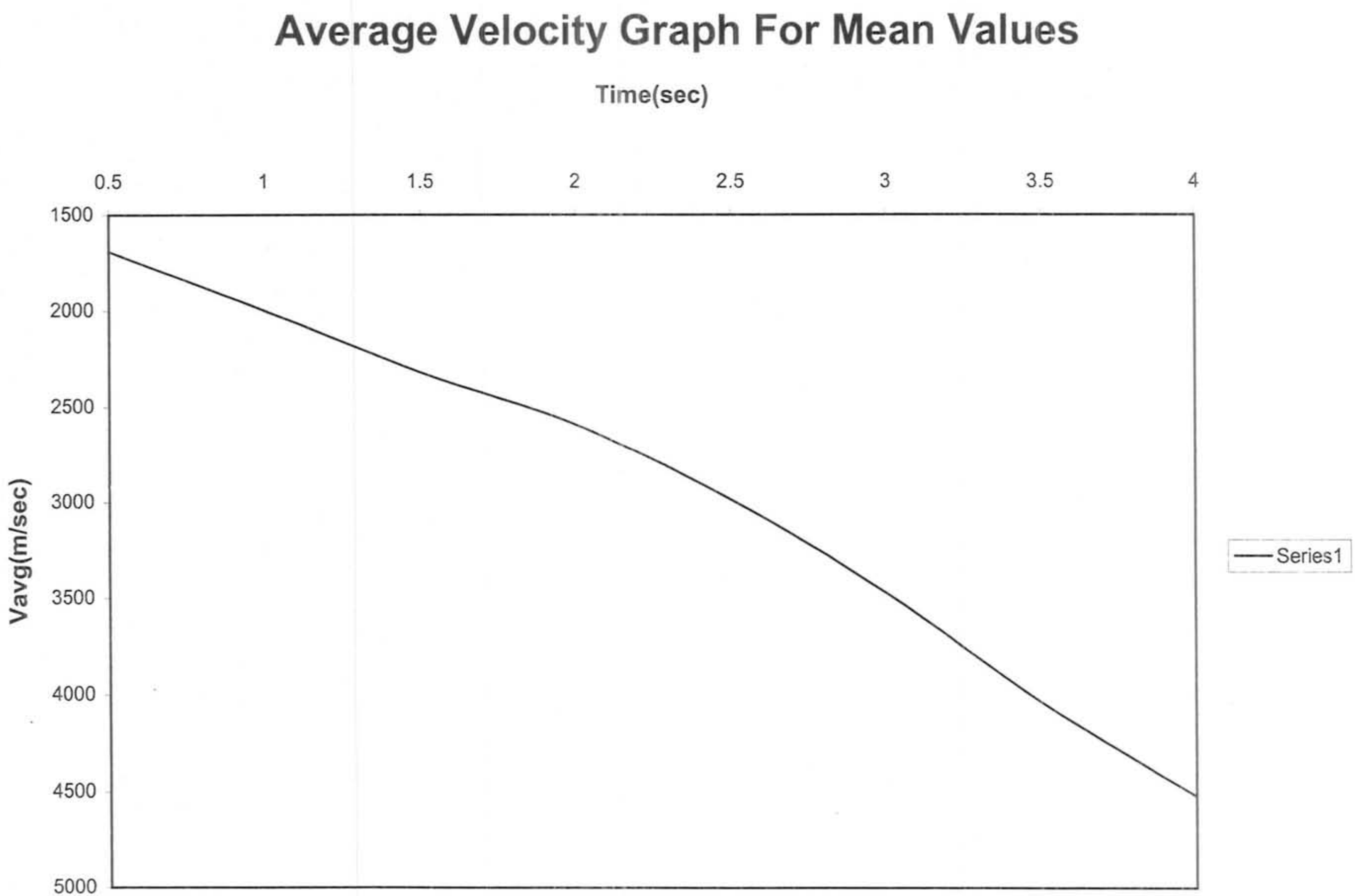

Average Velocity Graph For Mean Values
Time(sec)
0.5
1
1.5
2
2.5
3
3.5
4
Vavg(m/sec)
1500
2000
2500
3000
3500
4000
4500
5000
Series1

Fig. e

Calculation of Depth (Mean Vavg Method)

Reflector.1			
S.P	Time(sec)	Vavg	Depth
250	0.825	1903	784.988
260	0.82	1900	779.000
270	0.82	1900	779.000
280	0.83	1905	790.575
290	0.82	1900	779.000
300	0.81	1896	767.880
310	0.81	1896	767.880
320	0.81	1896	767.880
330	0.81	1896	767.880
340	0.81	1896	767.880
350	0.81	1896	767.880
360	0.81	1896	767.880

TABLE 6.4(a)

Calculation of Depth (Mean Vavg Method)

Reflector.2			
S.P	Time(sec)	Vavg	Depth
250	1.43	2280	1630.20
260	1.43	2270	1623.05
270	1.42	2280	1618.80
280	1.43	2270	1623.05
290	1.42	2280	1618.80
300	1.41	2265	1596.83
310	1.41	2265	1596.83
320	1.4	2260	1582.00
330	1.39	2250	1563.75
340	1.39	2250	1563.75
350	1.4	2260	1582.00
360	1.4	2260	1582.00

TABLE 6.4(b)