2D INTERPRETATION OF SEISMIC LINE # CNW 87-A2
OF
DADU BLOCK OF PAKISTAN

QUAID-I-AZAM UNIVERSITY
ISLAMABAD

BY

ABDUL BASIT
M.Sc (Geophysics)

DEPARTMENT OF EARTH SCIENCES
QUAID-I-AZAM UNIVERSITY
ISLAMABAD

بسم الله الرحمن الرحيم

In the name of Allah, The most compassionate, The merciful

And with Him are the keys of the invisible. None but He knoweth them. And He knoweth what is in the land and the sea. Not a leaf falleth but He knoweth it, not a grain amid the darkness of the earth, naught of wet or dry but (it is noted) in a clear record. (Al-Anaam)

Dedicated

To My

Loving Parents

CERTIFICATE AND APPROVAL

This dissertation by Abdul Basit is accepted in its present form by the department of Earth Sciences, Quaid-I-Azam University, ISLAMABAD as satisfying the requirement for the award of degree of M.Sc Geophysics.

RECOMMENDED BY

1) Mr. Ghulam Rasool Ghazi:........................
(Course Supervisor)

2) Prof. Dr. Zulfiqar Ahmad:..........................
(Chairman)

3) External Examiner:.................................

Dated:........................

CONTENTS

ABSTRACT

This dissertation is based on the seismic section of the line # CNW 87-A2 provided by the Department of Earth Sciences, QAU Islamabad. The seismic reflection survey was carried out by " VERITAS SEISMIC" in the DADU Province Pakistan. A 60 fold data was acquired along a 7.5 km long. Oil and Gas Development Corporation (OGDC) provided the migrated seismic section along with RMS, DIX Interval and DIX average velocity are also provided for different shot points . Using the Dix average velocities, time and shot point distance a DIX average contour map is constructed. This line contains a total of 150 shot points numbered as SP# 150, 160,,,,,,,,,,,,,,,300.

Three reflectors R1, R2, R3 are marked, due to their prominent reflection on the seismic section. The depth for each reflector is found by DIX average velocity and travel time. Two methods are used for the estimatation of velocities to construct two depth sections to represent the shape of reflectors. These methods are explained in the last chapter and the resulted depth sections are displayed in figures in the same chapter. Three faults are observed in the area. This shows that the area is highly deformed. Lateral as well as vertical variations in the velocities are observed in the DIX average velocity contour map and men average velocity contour map that may attribute to structural and physical variations in the subsurface material.

PRINCIPLES OF GEOPHYSICS

1.1 INTRODUCTION:

The science of "geophysics" applies the principles of "Physics" to the study of the earth. Geophysical investigations of the interior of the Earth involve taking measurements at or near the Earth's surface that are influenced by the internal distribution of physical properties. Analysis of these measurements can reveal how the physical properties of the Earth's interior vary vertically and laterally.

By working at different scales, different geophysical methods may be applied to a wide range of investigations from studies of the entire Earth to exploration of a localized region of the upper crust. In the geophysical exploration methods, measurements with in geographically restricted areas are used to determine the distribution of physical properties at depths that reflect the local subsurface geology.

To meet the challenge, Earth scientists have developed more and more sophicated techniques of exploration. Until well into the twentieth century, the search for oil and solid minerals was confined to deposits directly observable on the surface in the form of seeps and outcrops or other exposures. When all accumulations in the area that could be discovered by such simple means had been found, it was necessary to deduce the presence of buried deposits indirectly by downward projection of geological information observable on the surface. As this approach reached the point of diminishing returns, new methods of studying the subsurface were needed. They did not require any geological observations, but they did involve physical measurements at the Earth's subsurface that would give information on the structure or composition of concealed rocks that might be useful for locating desired deposits.

1.2 Geophysics and Geology:

we designate the study of the earth using physical measurements at or above the surface as "Geophysics" while it is not easy to establish a meaningful border line between geology and geophysics, the difference lies primarily in the type of data with which one beings. "Geology" involves the study of the earth by direct observations on rocks, either from surface exposure or bore holes, and the deduction of its structure, composition or history by analysis of such observations. "Geophysics" on other hands involves the study of those parts of the earth hidden from direct view by measuring their physical properties with appropriate instruments, usually on or above the surface. It also includes interpretation of measurements to obtain useful information on the structure and composition of the concealed zones. The distinction between the two branches of "Earth Science" is not clear-cut. "Well-Logs" for example are widely used in geological studies.

"Geophysics" provides the tools for studying the structure and composition of the earth's interior. The existence and properties of the earth's crust, mantle and core have been determined by observations upon seismic waves from earthquakes as well as by measurements of the earth's gravitation, magnetic and thermal properties. The tools and techniques developed for such studies have been used in exploration for hydrocarbons and minerals. At the same time, geophysical methods devised for prospecting applications have been put to use in more academic research on the nature of the Earth's interior.

1.3 SEISMIC SURVEY:

Like any geophysical survey, a seismic survey normally comprises three steps.

a) Data Acquisition:

It is achieved by the use appropriate emission, detection and recording systems in the field. It uses the latest electronics techniques for the digital recording of the data with considerable speed and accuracy.

b) Processing:

It is designed to enhance the signal-to-noise ratio and to enable interpretation of the data. Modern computerized data processing methods have led to the development of increasingly effective software systems.

c) Interpretation:

It aims to determine and to characterize the geophysical layers in the subsurface. It is carried out by geologists, and summarizes the overall geological, drilling and geophysical data.

1.4 Relation To earthquake Seismology:

The fundamental principles of the seismic methods of the geophysical exploration for "OIL" are the same as those of much older science of Seismology, which has developed over many years of study of natural Earthquakes. Instruments for detecting and recording the tremors of the earth caused by natural forces have been used since around the middle of the last century. Careful study of the times of travel of different types of waves or phases, as recorded on these records, has led to the development of fairly definite theories of the constitution of the earth and of the propagation of elastic waves through it. Infect, our most definite ideas of the nature and physical properties of the earth at great depths have been obtained from the analysis of the travel times of earthquake shocks, which have been transmitted through the interior of the earth. As worked out from such studies, the earth is now believed to consist of a quite definite series of concentric shells of material with different elastic properties.

Although the general background of seismic prospecting has much in common with "Earthquake Seismology". The nature of the seismic waves is somewhat different in the two cases. This difference is principally in the period or frequency. Earthquake waves have periods ranging from a few seconds to as long as 60 seconds, but the waves used in seismic prospecting are of very much shorter wavelength with periods of the order of 0.01 to 0.1 sec. The fundamental principles of the instruments used are generally the same, but the details of construction are greatly different on account of the difference in the frequency to which they are designed to respond. Also of course, the instruments used in seismic prospecting have to be designed with careful consideration of their portability and there use under exposed conditions in the field.

1.5 Geophysics In Oil Exploration:

The hydrocarbons now being extracted from petroleum to meet the demand for energy need not come from conventional sources, because they can be extracted from tar sands or oil shale's or be synthesized from coal. But the technological, economic and environmental problems of changing over to such alternative sources are so formidable that we shell be almost entirely dependent on oil and gas in their present form for many years.

Even when capacity for large scale conversion of other fossil fuels is achieved, there will be demand for all the conventional petroleum that can be produced as long as the costs of exploration and production do not become so great that other sources can be exploited moiré cheaply.

1.6 Geophysical Surveying Methods:

Method	Measured parameter	"Operative" physical property
Seismic	Travel times of reflected / refracted seismic waves	Density and elastic moduli, which determines the propagation velocity of seismic waves
Gravity	Spatial variations in the strength of the gravitational field of earth	Density
Magnetic	Spatial variations in the strength of the geomagnetic field	Magnetic susceptibility and remanence
Resistivity	Earth Resistance	Electrical conductivity
Induced Polarization	Polarization voltage or frequency-dependent ground resistance	Electrical capacitance
S.Potential	Electrical Potentials	Electrical Conductivity
Electro-Magnetic	Response to electromagnetic radiation	Electrical conductivity and Inductance
Radar	Travel times of reflected radar pulses	Dielectric constant

1.7 Geophysical Surveying Applications:

Application	Survey Methods*
Exploration for fossil fuels (oil, gas, coal)	S, G, M, (EM)
Exploration for metalliferous mineral deposits	M, EM, E, SP, IP, R
Exploration for underground water supplies	E, S, (G), (Rd)
Exploration for bulk mineral deposits like sand and gravel	S, (E), (G)
Engineering / construction site investigation	E, S, Rd, (G), (M)

NOTE: *

G = Gravity
M = Magnetic
S = Seismic
E = Electrical Resistivity
SP = Self Potential
IP = Induced Polarization
EM = Electro-Magnetic
R = Radiometric
Rd = Ground – Penetrating Radar
( ) = Subsidiary Methods

INTRODUCTION TO THE PROJECT

2.1 INTRODUCTION:

Seismic reflection provides the highest degree of the subsurface details relative to the other geophysical methods. In this method physical measurements are made at the ground surface, which are then interpretated in terms of what might be in the subsurface.

The dissertation chiefly describes the interpretation procedure of the seismic reflection. The project is based on the seismic reflection survey carried by **VERITAS SEISMIC** in the **DADU** province Pakistan. A part of **line CNW 87-A2** is provided by the Department Of Earth Sciences Quaid-I-Azam University Islamabad. The data given is acquired along a 7.5 Km long South East oriented profile (CNW 87-A2). The department provided the Normal Polarity Migrated Seismic Section along with velocity information regarding this line. The acquisition and processing of 60 fold (CDP) data has been done carefully with a selection of appropriate field and processing parameters. The line contains a total of 150 shot points numbered as SP-150 to SP-300.

2.2 OBJTECTIVES:

The main objectives of this dissertation are as follows

a) To understand the processing and interpretation migrated section to obtain a picture of subsurface.

b) To fined the depths of reflectors and preparation of depth section.

c) To correlate reflectors with the Stratigraphy of the area.

d) To study the effect of the velocity variation along the profile and its distribution in the subsurface.

e) To analyze the structure if any, using the time section and average velocity contour map.

2.3 LOCATION:

Dadu Block comprising an area of about 3981.5 Sq.Km. is located in Dadu District of the Sind Province. Dadu city serves as a rail link with Karachi in the South of Quetta city in the northwest. Good infrastructure of roads exists in the DADU Area. Hydrabad city at a distance of about 200 km, in the south provides air link with Karachi International Airport. Indus river flows with in the block along its eastern limit. Landscape is nearly flat and covered with alluvium. The mean annual rain fall in the area is about 85 mm. The region experiences severe summers with average temperature of 38^0C and moderate with temperature averaging 16^0C.

2.4 GEOLOGICAL SETTING:

Before discussing the particular area we will take the overview of all geological settings of Pakistan, (Kazmi, A.H & Jan, M.Q. 1997.)

TECTONIC ZONES OF PAKISTAN:

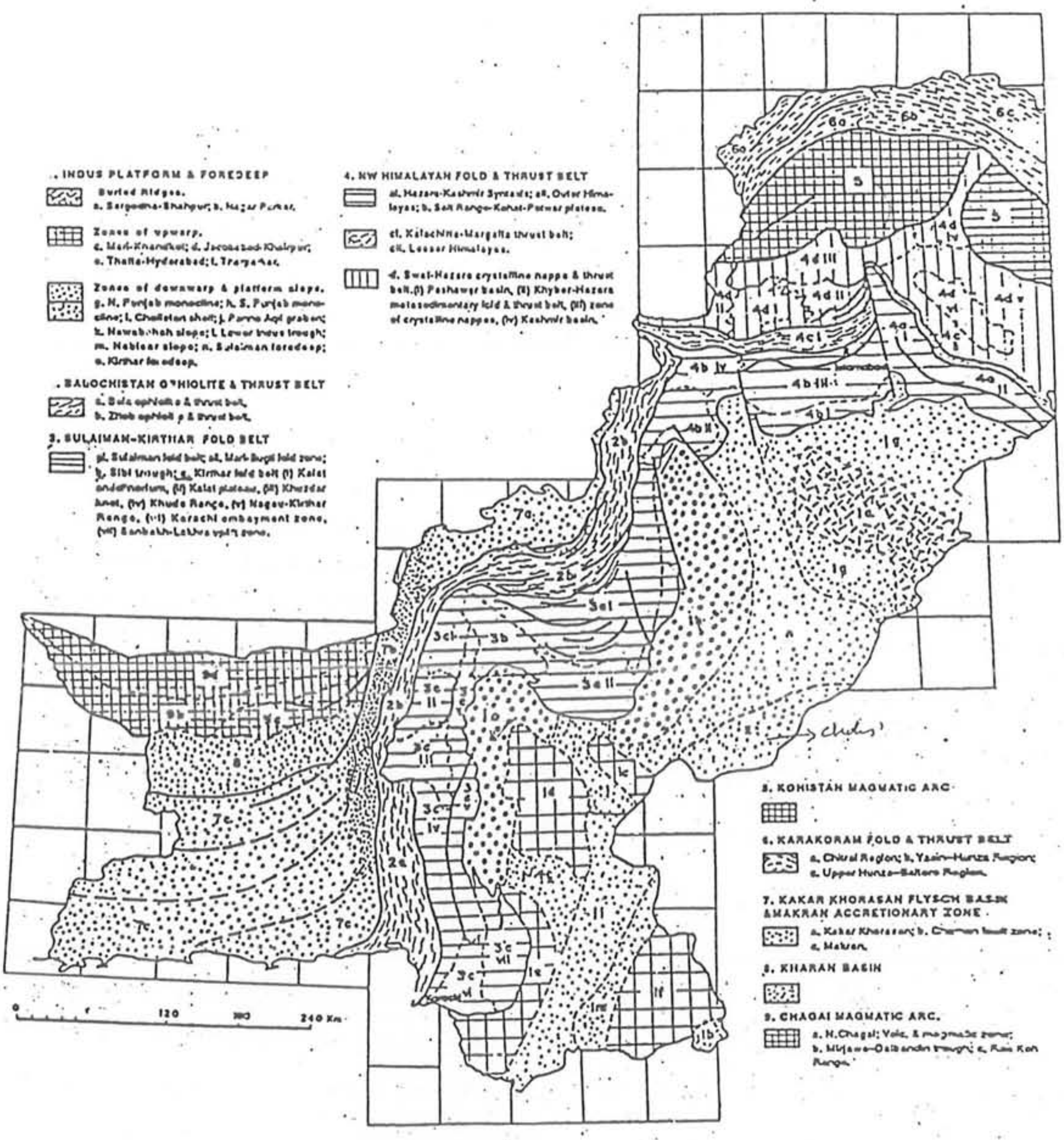
The geology of Pakistan is divided into regions, which are given below,

Goundwanian Domain:

Tethyan Domain:

The southern part of Pakistan belongs to Goundwanian Domain and is sustained by the Indo-Pakistan crustal plate. The northern most and western regions of Pakistan fall in Tethyan Domain and present a complicated geology and complex crustal structures. On the basis of plate tectonic features, geological structures, orogenic history and lithofacies Pakistan may be subdivided into the following broad tectonic zones,

- **Indus Plateform and foredeep**
- **East Balochistan fold and thrust belt**
- **Northwest Himalayan fold and thrust belt**
- **Kohistan ladakh magmatic arc**
- **Karakoram block**
- **Kakar khorasan flysch basin and Makran accretionary zone**
- **Chagai magmatic arc**
- **Pakistan offshore**



INDUS PLATFORM & FOREDEEP
Buried Ridges.
a. Sargodha-Shahpur; b. Nagar Parkar.
Zones of upwarp.
c. Mari-Khandkot; d. Jacobabad-Khairpur;
e. Thatta-Hyderabad; f. Tharparkar.
Zones of downwarp & platform slope.
g. N. Punjab monocline; h. S. Punjab monocline; i. Cholistan shelf; j. Panno Aqil graben;
k. Nawabshah slope; l. Lower Indus trough;
m. Nabisar slope; n. Sulaiman foredeep;
o. Kirthar foredeep.
BALOCHISTAN OPHIOLITE & THRUST BELT
a. Bela ophiolite & thrust belt.
b. Zhob ophiolite & thrust belt.
3. SULAIMAN-KIRTHAR FOLD BELT
aI. Sulaiman fold belt; aII. Mari-Bugti fold zone;
b. Sibi trough; c. Kirthar fold belt (i) Kalat anticlinorium, (ii) Kalat plateau, (iii) Khuzdar knot, (iv) Khude Range, (v) Kirthar Range, (vi) Karachi embayment zone, (vii) Sonbakh-Lakhra uplift zone.
4. NW HIMALAYAN FOLD & THRUST BELT
aI. Hazara-Kashmir Syntaxis; aII. Outer Himalayas; b. Salt Range-Kohat-Potwar plateau.
cI. Kalachitta-Margalla thrust belt;
cII. Lesser Himalayas.
d. Swat-Hazara crystalline nappe & thrust belt. (i) Peshawar basin, (ii) Khyber-Hazara metasedimentary fold & thrust belt, (iii) zone of crystalline nappes, (iv) Kashmir basin.
5. KOHISTAN MAGMATIC ARC
6. KARAKORAM FOLD & THRUST BELT
a. Chitral Region; b. Yasin-Hunza Region;
c. Upper Hunza-Baltoro Region.
7. KAKAR KHORASAN FLYSCH BASIN & MAKRAN ACCRETIONARY ZONE.
a. Kakar Khorasan; b. Chaman fault zone;
c. Makran.
8. KHARAN BASIN
9. CHAGAI MAGMATIC ARC.
a. N. Chagai; Volc. & magmatic zone;
b. Mirjawa-Dalbandin trough; c. Ras Koh Range.
Islamabad
Karachi
0 120 240 Km

Pakistan comprises two sedimentary basins

a) Balochistan basin

b) Indus basin

BALOCHISTAN BASIN:

This basin comprises the Makran accretionary zone and Makran offshore trench; contain 5000 – 15000 m thick flysch type terrigenous slope and shelf sediments and turbidities. This is the least explored region of Pakistan. Very limited seismic survey has been done and only six wells have been drilled in this vast basin of over 300,00 km^2.

INDUS BASIN:

The Indus basin covers an area of about 533,500 km^2 and contain more than 15,000 m thick sediments ranging in age from the Precambrian to recent. Oil and gas fields have been discovered in the inner folded zones of the Sulaiman and Kirthar ranges, Kohat- potwar plateau, Sulaiman Kirthar depression (foredeep), Karachi depression, and the Indus Plateform (Punjab monocline, Sukkur rift and Sindh monocline). The Jacobabad-Khairpur high and Mari-Khandkot highs (Sukkur rift zone) and the Sargodha high (Sargodha- shahpur buried ridge) divide the Indus basin into three main tectono-stratigraphic zones. These zones are given below,

1. NORTHERN INDUS BASIN:

This basin is characterized by complex structural styles and stratigraphic sequence ranging from Precambrian to recent. A number of oil fields occur in this zone. The Dhurnal oil field is the largest and has reserves of about 52 million barrels of oil and 0.13 TCF of gas.

2. CENTRAL INDUS BASIN:

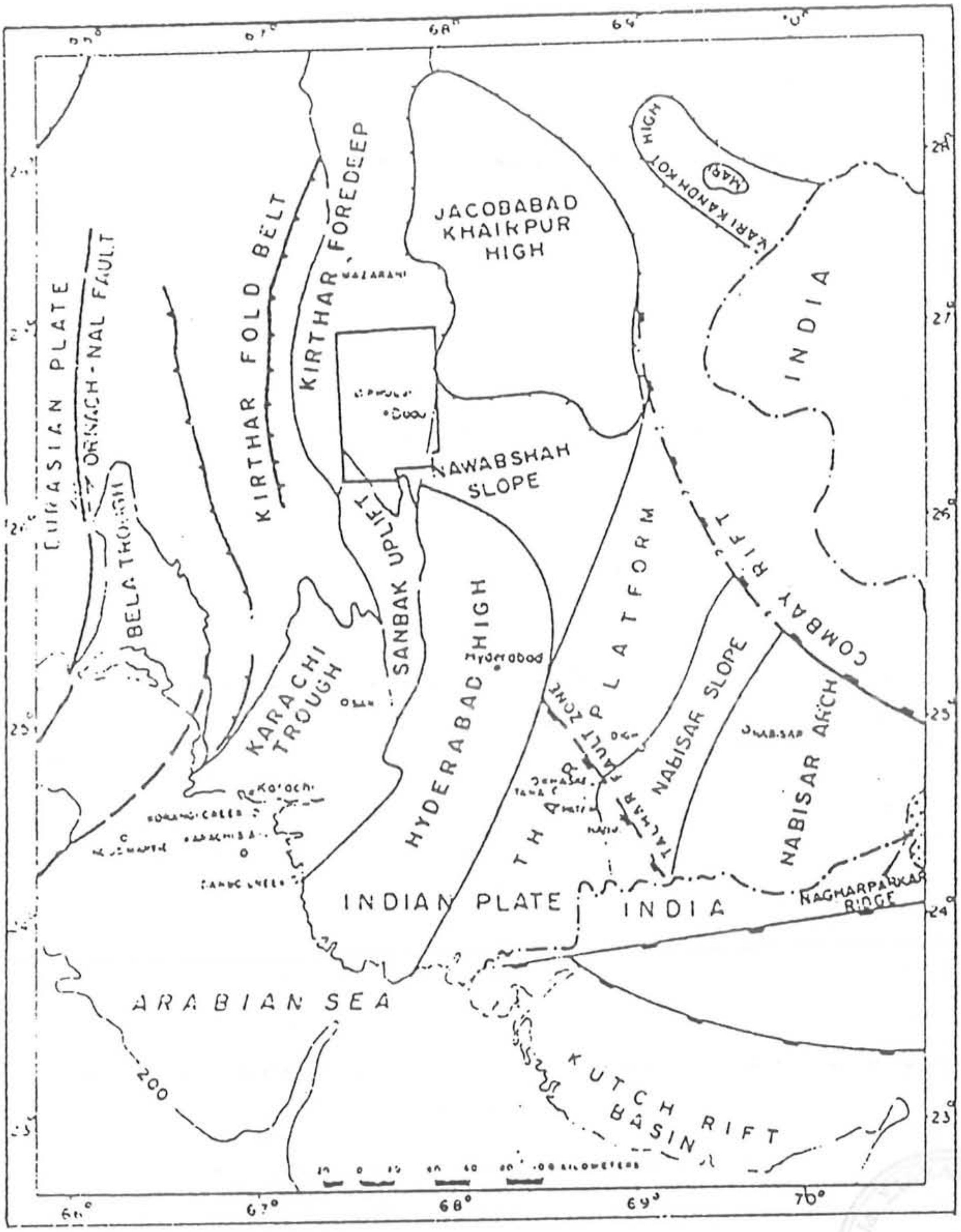
This basin is comprised of duplex structures characterized by large anticlines and doom in the passive roof sequence of Sulaiman fold belt followed eastward by gently dipping strata of Punjab monocline which has few tectonic folds and faults. The basin contains a sedimentary sequence ranging from Precambrian to recent. It is essentially a natural gas bearing zone and contain nine gas fields, including one giant field (Sui) with 8.6 TCF recoverable reserves and one large field (Pirkoh) with 2.6 TCF recoverable reserves. The main producing strata range in age from Cretaceous to Eocene. The main gas fields of Mari, Khandkot, Sui, Uch, Loti, Zin, Pirkoh and Jandran are concentrated in this region. Central Indus basin is bounded by Jacobabad high in south, Sargodha high in north, Sulaiman foredeep in west and Indian shield in east.

3. SOUTHERN INDUS BASIN:

This basin is characterised by passive roof duplex type structure and passive backthurst along the Kither fold belt, a passive roof thrust forming a frontal culmination wall along the margin of the fold belt, and the kither depression and out of syncline intra-molasse detachment in the Kither depression sequence. The Kither and Karachi depressions contain several large anticlines and domes and some of these contain small gas fields (Mazarani, Sari, Hundi, and kothar). The main reservoir rocks in the Sindh monocline are the cretaceous lower goru sand stone.

2.5 DADU BLOCK

Dadu Block lies towards the southern margin of Kirthar foredeep in the lower Indus basin, which is located on the continental margin of the Indo-Pakistan Craton. This margin originated by rifting and drifting of Indo-Pakistani plate from Gondwanaland in early Mesozoic. In early tertiary, as a consequence of collision of collision of Indo-Pakistani plate with Eurasia, severe deformation of sediments took place in the vicinity of plate boundaries. Kirthar Fold Belt evolved during this period with simulation creation of Frontal depression. The Kirthar Foredeep along its eastern fringe. Kirthar Fore Deep is a N-S trending downwarps south of the Sibi Depression. Southwards, the Sunbak Uplift and Hydrabad High correspond to the southern boundary of the Kirthar Fore Deep, which separates it from the Karachi Trough. It has a faulted eastern boundary with the Thar Slope, where as it gently rises northeastward to the Jacobabad High. Seismic data reveals that folding of thick Tertiary molasse sediments resulted from the Plio-Pleis-tocene compressional tectonics.



TECTONIC ELEMENTS-LOWER INDUS BASIN

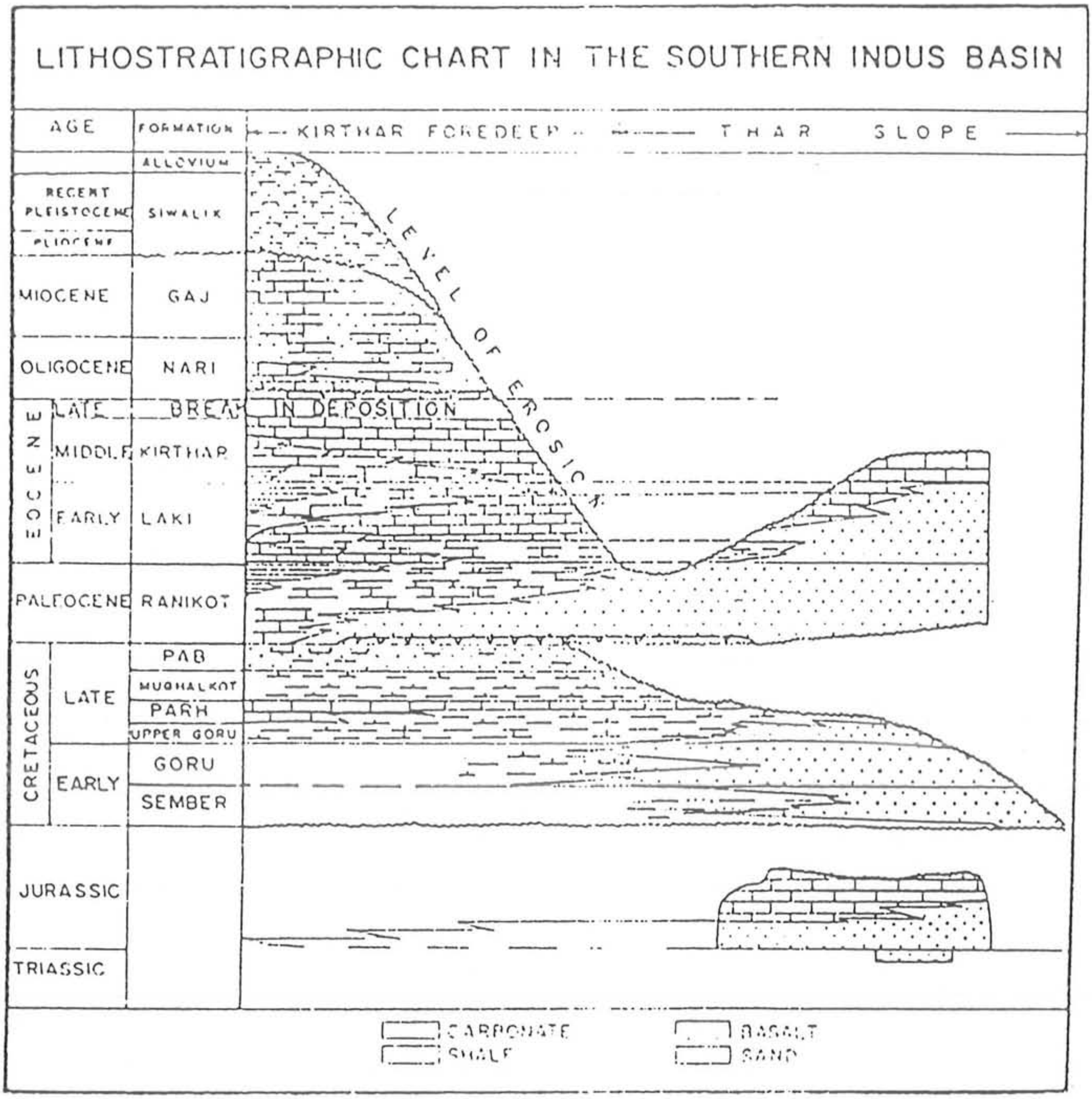
2.6 STRATIGRAPHY:

The stratigraphic intervals in the Kirthar Foredeep area spans over the Lower Cretaceous to Recent and were deposited over the trailing edge of the Indo-Pakistani Plate. Lower Cretaceous sediments comprise the Sembar and Goru Formations. These siliciclastic sequences were deposited in the deltaic environments.

Geometry of these sequences demonstrates an easterly clastic provenance with a succession of Progradational wedges, building successively Basinward to the west. Upper Goru is overlain by Parh Limestone, deposited in a shallow marine environment. Mughal Kot Formation consisting of alternating marls, Mudstones, Limestones and Sandstones, is overlain by a Sandy Sequence of the Pab Formation. These sands correspond to channel and bar type deposits.

Paleocene Ranikot Formation marks the base of Tertiary and represents an overall transgressive phase that commenced in Early Paleocene and culminated in the Late Eocene. By the end of Paleocene a shallow sea covered most of the area and Carbonate/Shale units with rare sands of Laki and Kirthar Formations were deposited during Early to Middle Eocene. After a short break in Late Eocene, Nari and Gaj Formations were deposited as progradtional sequences, in shallow marine to near-shore environments. The Molasse sediments of Siwaliks, unconformably overlie the Miocene Gaj Formation.

S.

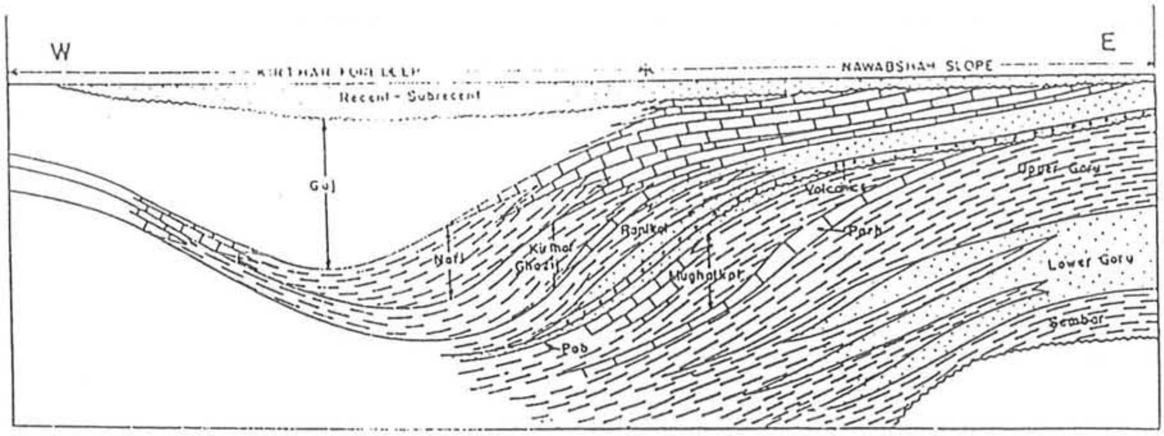

LITHOSTRATIGRAPHIC CHART IN THE SOUTHERN INDUS BASIN
AGE
FORMATION
KIRTHAR FOREDEEP
THAR SLOPE
ALLUVIUM
RECENT
PLEISTOCENE
SIWALIK
PLIOCENE
MIOCENE
GAJ
OLIGOCENE
NARI
EOCENE
LATE
BREAK IN DEPOSITION
MIDDLE
KIRTHAR
EARLY
LAKI
PALEOCENE
RANIKOT
CRETACEOUS
LATE
PAB
MUGHALKOT
PARH
UPPER GORU
EARLY
GORU
SEMBER
JURASSIC
TRIASSIC
LEVEL OF EROSION
CARBONATE
SHALE
BASALT
SAND

2.7 STRATIGRAPHIC SEQUENCE OF THE AREA:

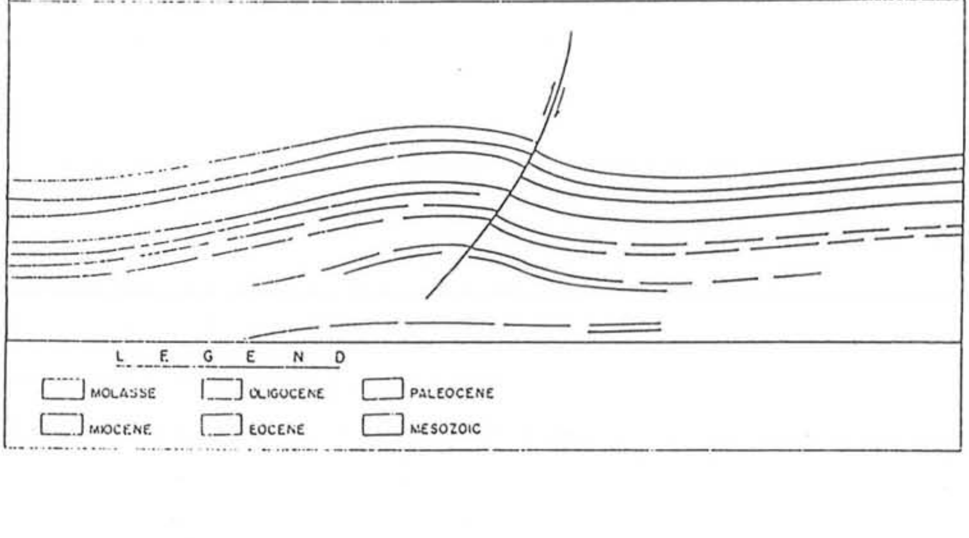
Stratigraphic Sequence of the area is as under

<table>
<tr><th colspan="2">AGE</th><th colspan="2">Lithostratigraphic Unit</th><th>LITHOLOGY</th></tr>
<tr><td colspan="2" rowspan="3">Recent
Pleistocene</td><td colspan="2">ALLOVIUM</td><td>River Deposit</td></tr>
<tr><td rowspan="4">SIWALIK Group</td><td>Soan</td><td>Conglomerates, S.Stone</td></tr>
<tr><td>Dhok Pathan</td><td>Clastic sediments, Clay, Sand stone</td></tr>
<tr><td colspan="2" rowspan="2">Pliocene</td><td>Nagri</td><td>Sand stone, Clay.</td></tr>
<tr><td>Chinji</td><td>Clay and sand stone</td></tr>
<tr><td colspan="2">MIOCENE</td><td colspan="2">GAJ</td><td>Gypreous Shale, Sandstone</td></tr>
<tr><td colspan="2">OLIGOCENE</td><td colspan="2">NARI</td><td>Brown sand stone, Shale</td></tr>
<tr><td rowspan="3">E
N
E
C
O
E</td><td>Late</td><td colspan="2">UNCONFORMITY</td><td>Break in Deposition</td></tr>
<tr><td>MIDDLE</td><td colspan="2">KIRTHAR</td><td>Massive beds of Limestone, Shale and Marl.</td></tr>
<tr><td>EARLY</td><td colspan="2">LAKI</td><td>Gray limestone, Marl, Sandstone.</td></tr>
<tr><td colspan="2">PALEOCENE</td><td colspan="2">RANIKOT</td><td>Coal beds, Basaltic lava, shale, Mudstone</td></tr>
<tr><td rowspan="6">S
U
O
E
C
A
T
E
R
C</td><td rowspan="4">LATE</td><td colspan="2">PAB</td><td>Quartzose, Shale,</td></tr>
<tr><td colspan="2">MUGHAL KOT</td><td>Arkosic Sandstone, L.Stome</td></tr>
<tr><td colspan="2">PARH</td><td>Pink to Maroon Shale, Marl</td></tr>
<tr><td colspan="2">UPPER GORU</td><td>Olive-Green Shale, Siltstone</td></tr>
<tr><td rowspan="2">EARLY</td><td colspan="2">GORU</td><td>Gray Shale, Limestone,</td></tr>
<tr><td colspan="2">SEMBER</td><td>Lime stone, Shale, Siltstone</td></tr>
</table>

DEPOSITIONAL MODEL



PLAY TYPE



2.8 PETROLEUM GEOLOGY:

Shale of Lower Cretaceous Sembar and Lower Goru formations, Paleocene Lower Ranikot and Lower Eocene Ghazij formations have good source rock potential in the area. Oil shows in the wells drilled in neighboring areas signify Paleocene and lower Eocene shales as potential source rocks for liquid hydrocarbons.

Good reservoir potential is present at different stratigraphic levels in the area. Cretaceous Pab Sandstone with good intergranular porosity and permeability is an important gas and condensate producer in Sulaiman range to the north. It also bears good reservoir qualities and hydrocarbon shows in the wells drilled in Hydrabad High and Karachi trough, south of the block. Overlying lower ranikot shales provide the effective seal. Pab formation is estimated to lie at a drillable depth of about 4000-4500 meters. Multilayered sandstones and limestones of ranikot Formation of Paleocene age posses excellent reservoir qualities with porosity ranging up to 30% in the surrounding regions. These reservoirs are producing in the Karachi Trough area. An effective seal is provided by the Upper Ranikot shales. The Sui Main Limestone of Lower Eocene Age is producing gas in the immediate northwest of the Block at Mazarani and also in the Middle Indus Basin. Log porosities in the surrounding areas range between 15-20%. Thick Shales of Ghazij formation would act as seal at this stratigraphic level

At all stratigraphic horizons, the entrapment is mainly structural. Seismic data reveals that effect odf compressional tectonics in Plio-Pleistocene times, gave rise to N-S trending asymmetrical anticlines with a steeper, generally faulted eastern flanks. Reefal buildups in Paleocene sequences can also provide potential stratigraphic plays.

Elements of Seismic Surveying

3.1 INTRODUCTION!

The seismic method is one of the most important geophysical methods in the investigation of subsurface geological structure of the earth. Its importance is due to high resolution, high accuracy, greater subsurface scanning and lesser number of variables involved. The methods are particularly well suited to the mapping of the layered sedimentary sequence and therefore, it is widely used in the search of oil and gas.

In seismic surveying, the seismic waves are propagated through the earth's interior and the travel times are measured of waves that return to the surface after refraction or reflection at geological boundaries within the ground. These travel times may be converted into depth values and, hence, the distribution of subsurface interfaces of geological interest may be systematically mapped.

Seismic surveying was first carried out in the early 1920s. It represented a natural development of the already long established methods of earthquake seismology in which the travel times of earthquake waves recorded at seismological observatories are used to drive information on the internal structure of the earth. Earthquake seismology provides information on the gross internal layering of the earth, and measurement of the velocity of earthquake waves through the various Earth layers provides major clues as to their composition and constitution. In the same way but on the smaller scale, Seismic surveying provides a clear and detailed picture of subsurface geology.

The basic technique of seismic method consists of generating seismic waves with the help of a source (Dynamite, Vibrosies) lying on the ground surface and in measuring the time required for the waves to travel from the source to a series of detectors (Geophones) planting on the ground surface after refraction or reflection from subsurface discontinuities. These travel times may be used to calculate the depths of the subsurface geological interfaces. This gives the picture of the earth's interior.

The seismic method utilizes the propagation of elastic waves through the earth and is based on the following fundamental postulates.

The waves are propagated with different velocities in different geological strata.
The contrast between the velocities is large.
The strata velocity increases with depth.
Principally the seismic method is used in exploration for petroleum and gas but these methods are also well suited, on a smaller scale, to the mapping of near-surface sediment layers, the location of water table and in engineering context, site investigation of foundation conditions including the determination of bedrock. Seismic surveying can be carried out on land or at sea, and it is used extensively in offshore geological surveys and the exploration for offshore resources.
The two types of seismic prospecting methods are:
Seismic refraction method.
Seismic reflection method.

3.2 Elastic Properties Of Solids:

The elastic properties of matter are described by certain elastic constants. These constants are idealized for "Perfectly Elastic" bodies and for determination within the "elastic limit". In general, this involves the assumption that the displacements are small and that the body returns exactly to its original form or condition after the displacing force is removed.
As a seismic wave propagates through a given medium, certain changes take place in that part of a medium that is traversed by the wave. The type and amount of these changes depends largely on the energy content of the wave and on the physical properties of the medium itself.
The principal types of change experienced by a medium due to the 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 two principal effects and the related features. (Al-Sadi 1980)

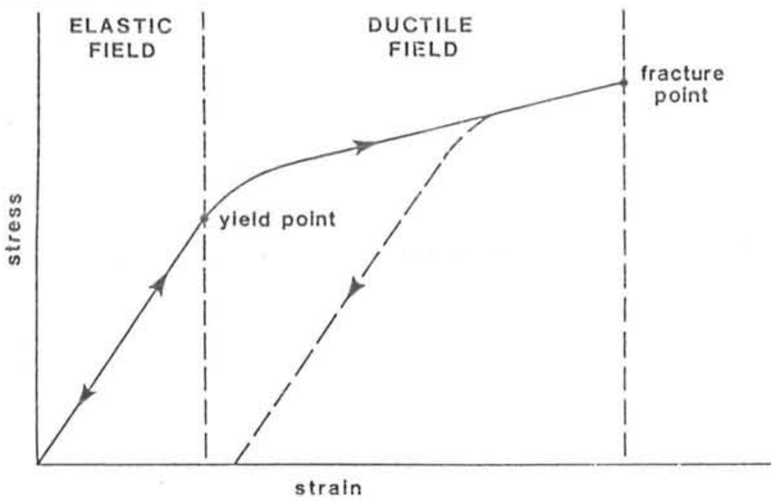


Fig. 3.1 A typical stress–strain curve for a solid body.

Elastic Material:

By elastic material we mean, material that re-gains its original shape when the force causing deformation is removed. The phenomenon of elastic compression or expansion is a displacement of the material such that the original condition is restored when the stress is removed. As larger and larger stresses are applied the elastic limit is eventually reached beyond which the material cannot return to its original configuration when the stress is removed. (Zia-1988)

STRESS:

Stress is represented by a force, which is acting on a finite area occupying an arbitrary position within the medium. The stress is a limiting value of force acting on an elementary area which is diminishing to zero, thus:

$$T = \lim_{\Delta A \rightarrow 0} F/\Delta A$$

Where F = force
ΔA = elementary area
T = stress

(Al-Sadi 1980)

STRAIN:

When an elastic body is subjected to stress to stresses, the changes in shape and dimension occur. These deformations are called strains. The strain depends on the strength and direction of stress and the nature of the substance being deformed. When the strain is proportional to the applied stress, and it disappears when that stress ceases, it is called " Elastic Strain".

Exploration seismologists are concerned principally with the elastic strain. To be sure, plastic deformation and rupture are ceased by explosions or movements along faults that generate seismic waves. But this severe deformation is confined to a small zone close to the point of energy release. As the seismic waves travel away from this small source zone, they produce only elastic strain. Therefore, it is important for us to examine the formal ways of describing elastic strain. (Al-Sadi 1980)

Poisson's Ratio (σ):

It is not a measure of a stress-strain relation but it is a measure of a geometric change in shape. Suppose that a cylindrical shaped test piece of original length L is compressed elastically to a length L-ΔL. its original diameter D will be increased to D+ΔD. Poisson's ratio is the ratio of the fractional change in length to the fractional change in the diameter. Mathematically

$$\sigma = -\frac{\Delta D/D}{\Delta L/L}$$

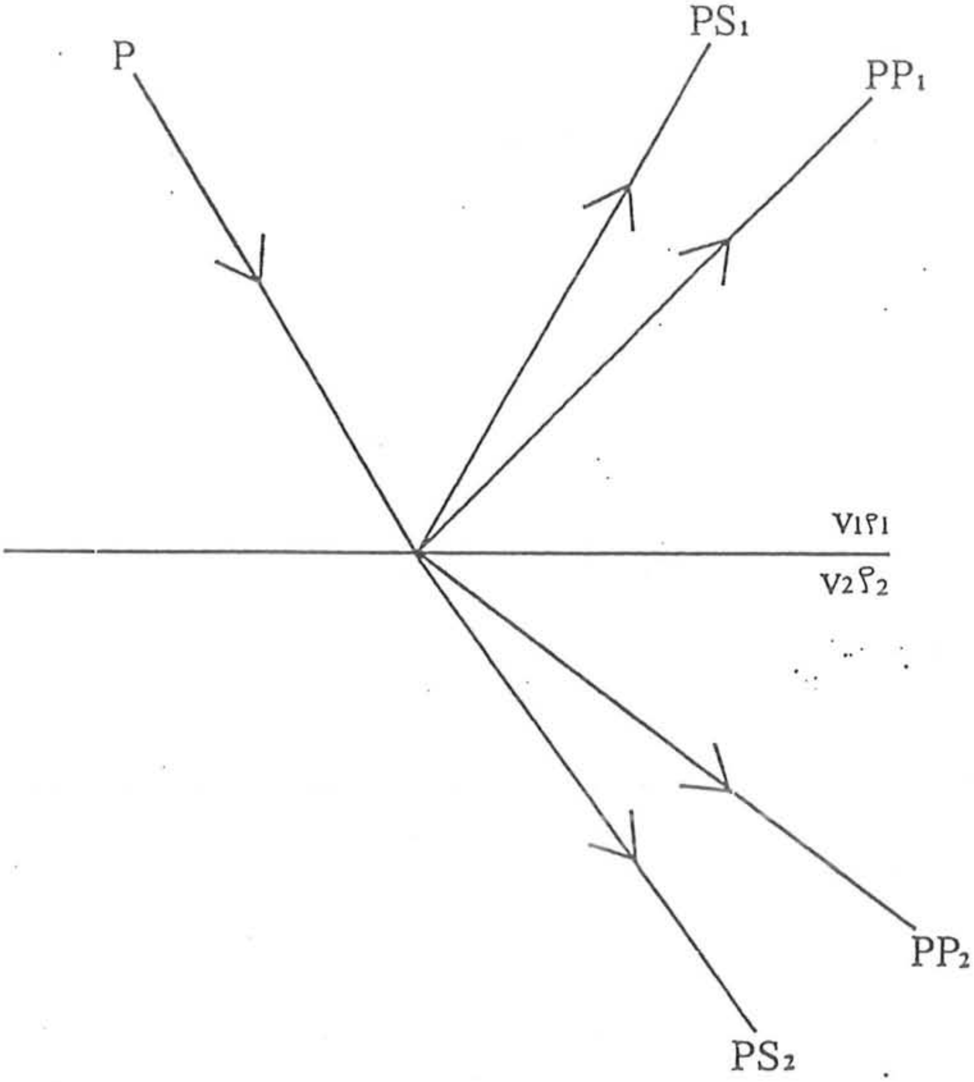
(Nettleton 1940)

3.3 SEISMIC REFRACTION METHOD:

Refraction or a change in direction occurs whenever a wave crosses a boundary between wave-transmitting media of different physical properties (except when the wave path is normal to the boundary). Refraction method is based on the study of elastic waves refracted along the geological boundaries. This method is generally used for determining low velocity zone (weathering layer), which is helpful in the interpretation of seismic data. Before1930, this method was used for oil prospecting, but now we use reflection method. Now refraction method is mainly used in civil engineering projects for bedrock investigation in connection with dam sites, hydroelectric power stations and large-scale building construction etc.(Nettleton 1940)

3.4 SEISMIC REFLECTION METHOD:

Reflection occurs whenever a wave encounters a discontinuity where there is a change in the physical properties of the wave-transmitting medium. The amount of wave energy reflected and its phase relative to the incident wave depend upon the contrast of the physical properties of the media on the two sides of the contact. The seismic reflection method is based on the study of elastic waves, which are reflected from the subsurface between two geological



Refracted And Reflected transverse And Longitudinal Waves

Fig.2.3

layers. These layers differ from each other in densities and velocities and the product of density and velocity is called "Acoustic Impedance". When a seismic wave strikes with the interface of two layers having acoustic impedance contrast, it is reflected back. The seismic reflection survey is most commonly carried out in the areas of shallowly dipping sedimentary sequence. The reflections are measured with instruments (geophone, seismometer) laid along the ground at some estimated distance from the source. Variations in the reflection times from place to place on the surface usually indicate structural features in the subsurface. So in seismic methods firstly a relation is established between the seismic velocity and the lithology and then results are interpreted in terms of geology.(Nettleton1940)

3.5 SEISMIC WAVES:

The seismic wave is the 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 a mechanical motion in an elastic medium.

Seismic waves are parcels of elastic strain energy that propagate outwards from a seismic source such as an earthquake or an explosion. Sources suitable for seismic surveying generate short-lived wave trains, known as pulses that typically contain a wide range of frequencies. Expect in the immediate vicitinity of the source, the strains associated with the passage of a seismic pulse are minute and may be assumed to be elastic. On this assumption the propagation velocities of seismic pulses are determined by the elastic moduli and densities of the material through which they pass. There are two groups of seismic waves, Body Waves and Surface Waves.(Kery & Brooks)

3.6 TYPES OF SEISMIC WAVES:

There are two types of seismic waves:

a) Body Waves.

b) Surface Waves.

a) BODY WAVES:

The waves that can travel within the medium (body). Body waves of two types can propagate through the body of an elastic solid. The velocity of propagation of a body wave in any material is given by

$$V = \left[\frac{\text{Appropriate elastic modulus of material}}{\text{Density } \rho \text{ of material}} \right]$$

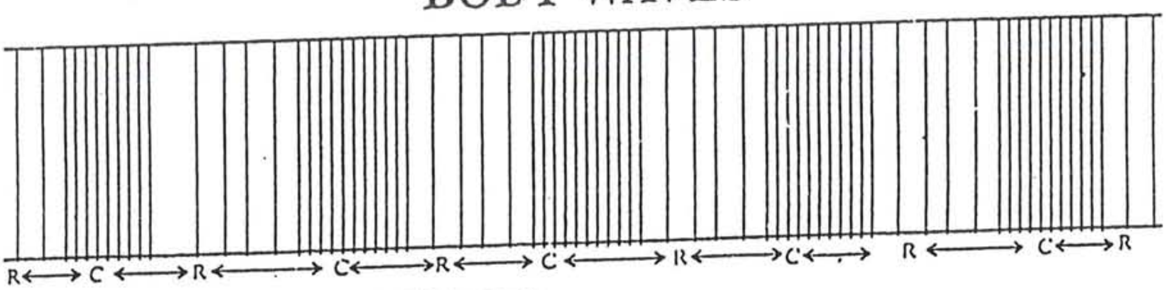
Both P and S waves are called body waves.(Kery & Brooks 1991)

i. P-Waves:

These are produced by compression. Particle motion associated with the passage of a compressional wave involves oscillations about a fixed point in the direction of wave propagation. We use these waves in exploration seismology.

If a pressure is suddenly applied, as by an impact, at a point inside an homogenous elastic medium of infinite size, the region of compression will move outwards from the disturbance as an expanding spherical shell, the increase of radius having the compressional wave velocity. Behind this we observe another expanding expanding shell, representing maximum rarefaction and later, at an approximately equal distance, the second compressional pulse as shown in fig. These waves are also known as Longitudinal or Primary waves.(Dobrin 1976)

BODY WAVES



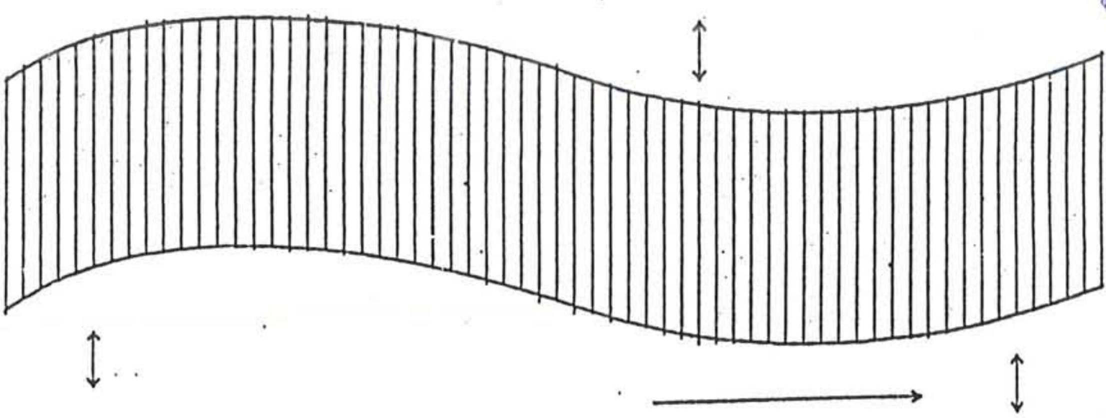
P-WAVES

R is Rarefaction

C is Compression

⟶ Direction of Wave Motion

⟷ Direction of Particle Motion



S-WAVES

↕ Direction of Particle Motion

⟶ Direction of Waves Motion

Figure 2.1

ii S-Waves.

The particle motion of these waves are at right angle to the direction in which the wave is moving. When shear deformation propagates in an elastic solid, the motion of individual particles is always perpendicular to the direction of wave propagation. In S-Waves the individual particle motions involve oscillation, about a fixed point in a plane at right angles to the direction of wave propagation. These S-Waves are also some times called Transverse, Shear or Rotational waves, because they cause an angular deformation at constant volume. They are called S-Waves or Secondary Waves because they arrival "Secondly" following the longitudinal waves. So P-Waves have greater velocity than S-Waves.

If we had already measured the elastic properties of the specimen, we can establish the following relationship between elasticity, density and S-Wave speed.

$$Vs = [\mu / \rho]^{1/2}$$

We know that U = 0 for ideal liquids and gases, so S-Waves do not travel in fluids. These vibrations travel only in solids.(Robinson & Coruh 1988)

B) SURFACE WAVES:

These waves are propagated along the boundary of the solid. If a pebble is thrown into a pond or a strong wind blows across an open stretch of water, the surface of water is disturbed and waves that travel away from the source are set up. The amplitude of the wave is greatest at the surface. Such waves are called surface waves. There are two types of surface waves in solids.

i RAYLEIGH WAVES:

Rayleigh waves propagate along the boundary between two dissimilar solid media. Rayleigh waves occur as ground roll along the air rock interface. These waves travel along only the free surface of an elastic solid. The motion of a particle is in a vertical plane. The orbital particle motion is in the opposite sense to the circular particle motion associated with an oscillatory water wave and is therefore sometimes described as retrograde. The amplitude of the motion

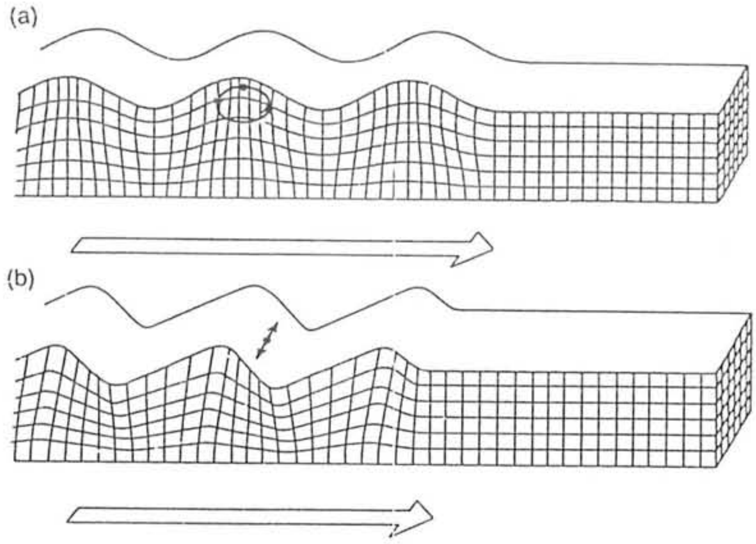


Fig. 3.4 Elastic deformations and ground particle motions associated with the passage of surface waves. (a) A Rayleigh wave. (b) A Love wave. (From Bolt 1982.)

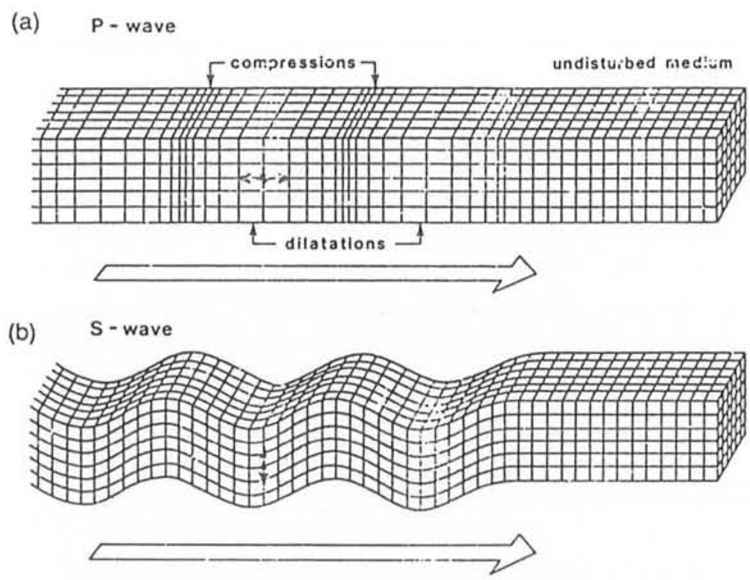


Fig. 3.3 Elastic deformations and ground particle motions associated with the passage of body waves. (a) A *P*-wave. (b) An *S*-wave. (From Bolt 1982.)

decreases exponently with depth below the surface. The velocity of Rayleigh waves is slower than for body waves in the same medium, being about nine-tenths that of shear waves in the same medium. The Rayleigh waves can be identified by low-velocity and low frequency.
When a low speed surface layer overlies a much thicker material in which the speed of elastic waves is higher. The Rayleigh waves velocity varies with frequency. Rayleigh waves are believed to be the principal component of ground roll, the common designation for low velocity, low frequency surface waves which often obscure reflections on seismic records obtained in oil exploration.(Dobrin 1976)

ii LOVE WAVES:

Love waves are surface waves, which are observed only when there is a low-speed layer overlying a higher speed substratum. The wave motion is horizontal and transverse. The British mathematician A.E.H.LOVE demonstrated that these waves propagate by multiple reflections between the top and bottom surface of the low-speed layer.
All LOVE waves are dispresive, the velocity increasing with wavelength. The Love-wave speed is equal to that of shear waves in the upper layer for very short wavelengths and to the speed of shear waves in the lower medium for very long wavelengths. Because there particle motion is always horizontal. Love waves are seldom recorded in the course of seismic prospecting operations for which the detectors respond to vertical ground motion only. They are used extensively in earthquake seismology to study the earths near surface layering. (Dobrin & Savit 1988)

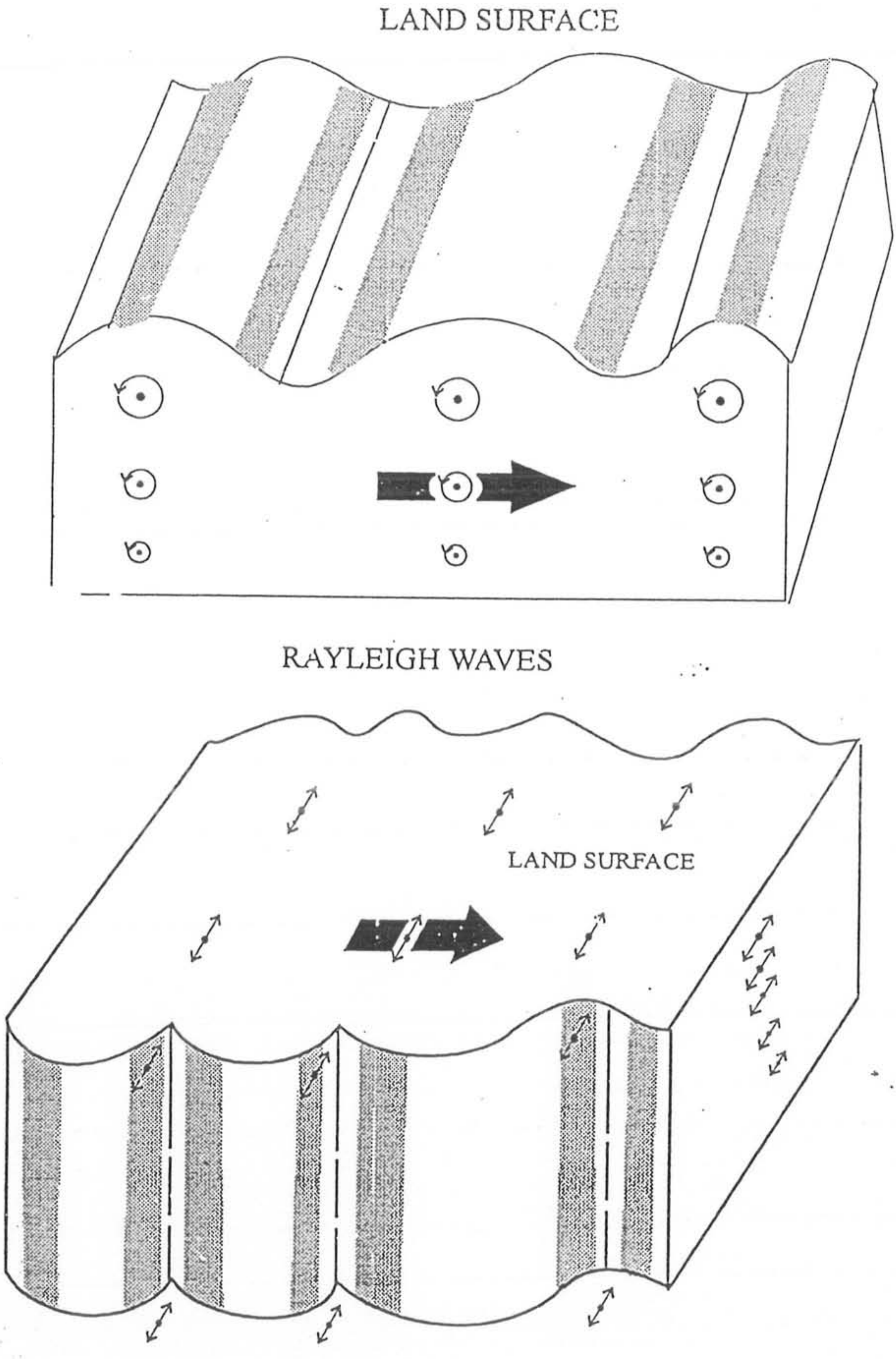


Fig.2.2

3.7 LAWS GOVERNING THE SEISMIC WAVES:

Laws governing the seismic waves are

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

Huygen's principle

Waves in a homogeneous medium spread out from a point source as expanding spheres. Huygen's Principle states that every point on a wave front is the source of a new wave that also travels out from it in spherical shells. If the spherical waves have a large enough radius, they can be treated as planes. Lines perpendicular to the wave fronts are called wave paths or rays. (Dobrin & Savit 1988)

Snell's law

The wave traversing a boundary between two media of velocity V1 and V2 is refracted in such a way that:

$$\frac{\text{Sin } i}{\text{Sin } V1} = \frac{\text{Sin } r}{V2}$$

When Sin i = V1/V2 , then Sin r becomes equal to one and the refracted angle becomes 90^0 . It means that the refracted wave path does not penetrate in the medium but travels just below or along the interface and such an angle is called the critical angle. There is no refraction in the second layer and the wave is totally reflected as shown in the figure. (Zia 1988).

Fermat's Principle

A wave propagating along a ray path for which the travel time is minimum. The laws of reflection and refraction follows follow from the application of Fermat's Principle. By using Fermat's principle it is possible to define the geometrical shape of the ray path. As a consequence of this principle, the ray paths of a wave traveling within a homogeneous medium take the form of a straight line.
(Al-Sadi 1980)

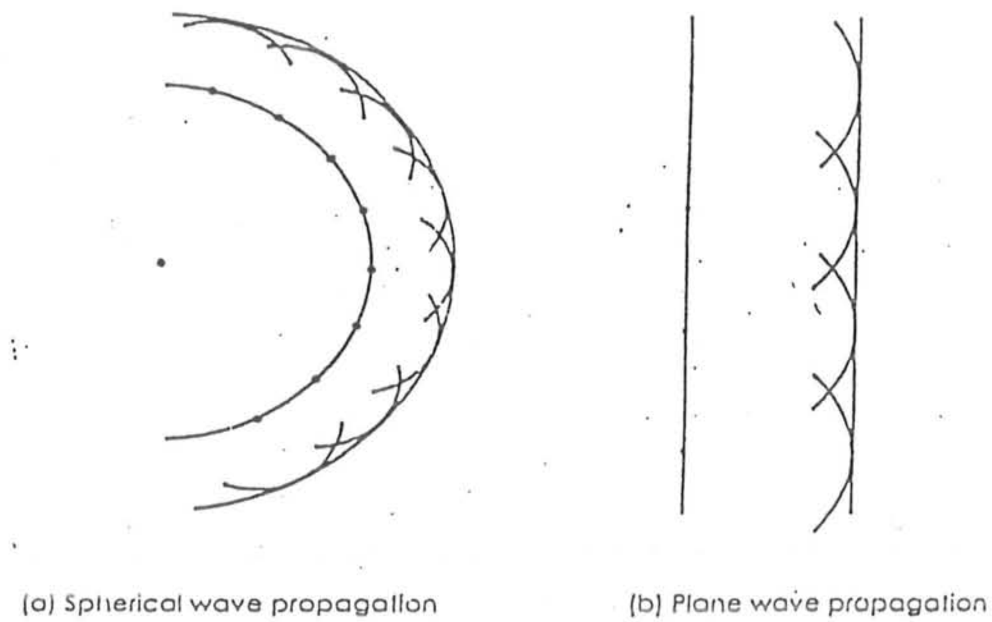
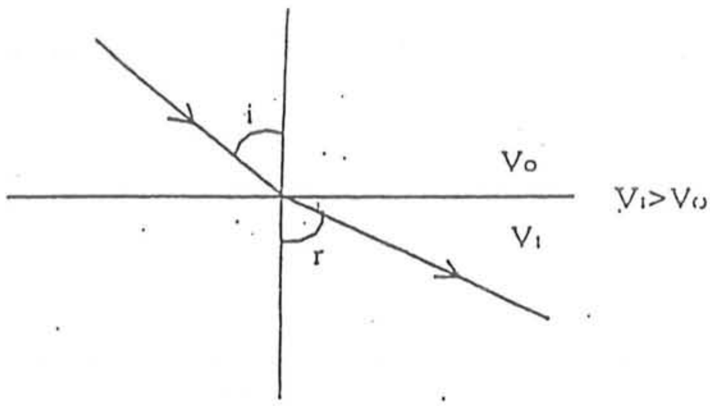


Figure 2.3 Huygen's Principle



Snell's Law

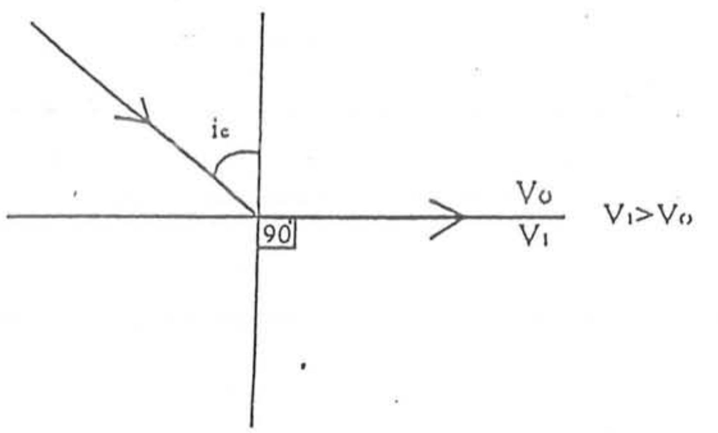
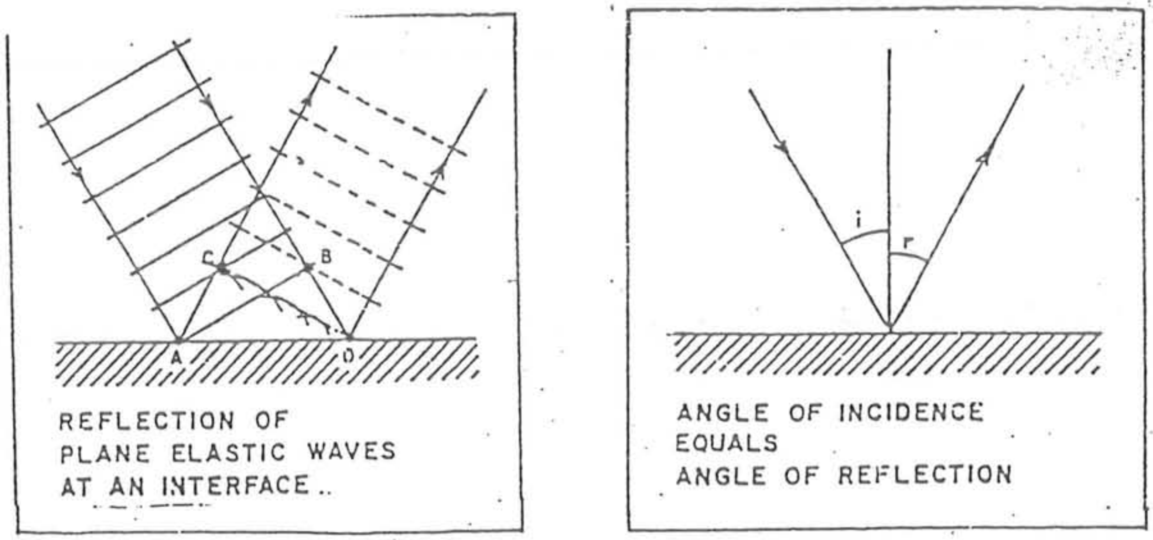
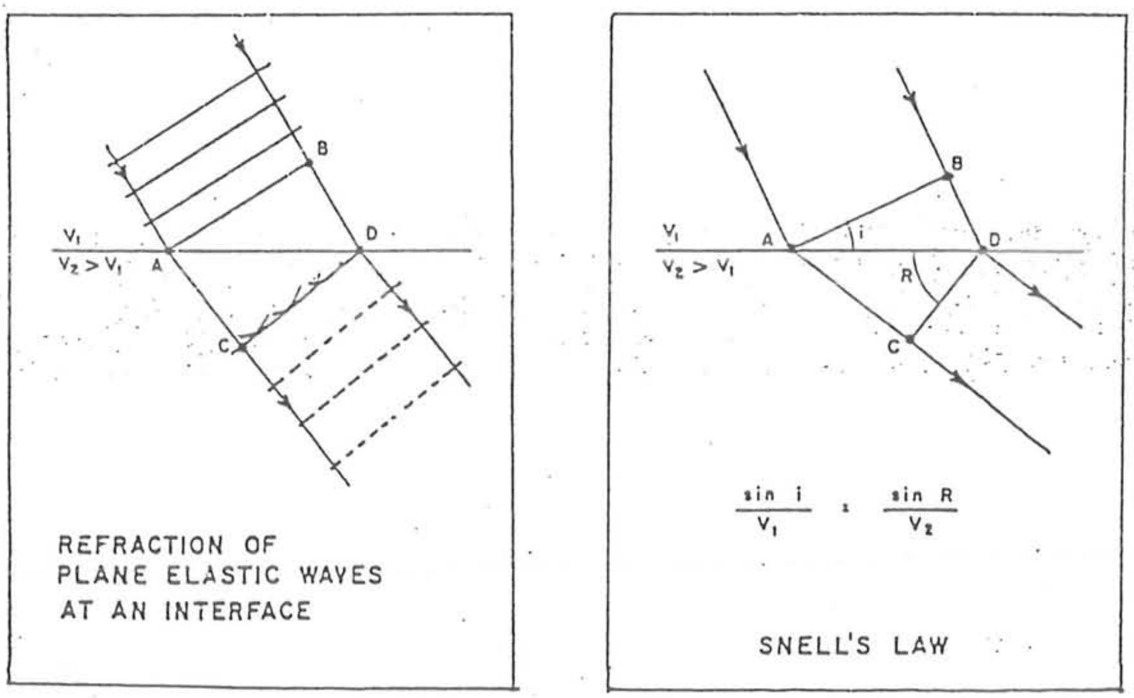


Figure 2.2 Critical refraction



(a) (b)

Reflection of Waves
Fig. 1.17



(a) (b)

Reflection of Waves
Fig. 1.18

3.8 DIFRACTION:

When the seismic waves strike any irregularity along a surface such as a corner or a point where there is a sudden change of curvature, the irregular feature acts as a point source for radiating waves in all directions in accordance with the Huygen's Principle. Such radiation is known as Diffraction.

A diffracted wave will reach the surface first at a point directly above the edge, because the path is shortest to this point. The event will be observed at successively later times as one moves along the surface away from the point. The amplitude of the diffracted wave falls off rapidly with distance from the nearest point to the source.(Dobrin & Savit 1988)

3.9 VELOCITIES OF SEISMIC WAVES IN ROCKS:

The velocities of seismic waves depend mainly on the elastic properties of the materials making up the rocks. In most sedimentary rocks the actual velocity is dependent upon the porosity, the pressure, and fluid filling the pore spaces .

In general igneous rocks have seismic velocities, which show a narrow range of variation than sedimentary or metamorphic rocks. The average velocity for igneous rocks is higher than those for sedimentary and metamorphic rocks. The fastest rock is Dunite, an ultra basic rock that some believe may be an important constituent of the earth's mantle, for which, the speeds measured for five samples range from 22,000 to 28,500 ft/sec.

Most type of metamorphic rocks shows a wider range of variations in velocities. Gneiss for example has speeds ranging from 11,600 to 24,800 ft/sec and Marbel velocities range from 12,400 to 23,000 ft/sec. Dependence of velocity on depth and geological age is expressed by an empirical formula given by Faust (1951). This formula also helps in large-scale statistical study of sedimentary rock velocities i.e.

$$V = KZ^{1/6}T^{1/6}$$

Where $K = 125.3$ when Z is in feet, T in year, and V in feet per second

Z = depth of burial

T = age of formation

A linear relationship between the reciprocal of the velocity and porosity has been found by Wyllie et al. to be valid for water-saturated sand stones at depth greater than a few thousand feet:

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

Where

V = velocity in saturated sand rock

Φ = fractional porosity

Vf = velocity of fluid in pore space

Vm = velocity of solid material making up rock matrix

The above equation is referred to as the time average relationship.

A similar equation developed from theoretical considerations by Pickett is

$$1/V = A + B\Phi$$

where A and B depend on lithologic parameters and depth of burials. This equation appears to be valid for a wider range of sedimentary rocks.

(Dobrin & Savit 1988)

APPLICATIONS OF SEISMIC METHODS:

To find out the structural traps such as anticlines, faults, salt domes and reefs.

To investigate the stratigraphic features like discontinuous layers.

Reflection data can be used to determine the average velocities of seismic waves to provide a good indication of lithology.

Seismic data is also used in search for ground water, in civil engineering, in mineral exploration and locating subsurface features.

(Kearey & Brooks 1991)

FIELD PARAMETERS:

SOURCE TYPE	DYNAMITE
SOURCE INTERVAL	50 Meters
SOURCE LAYOUT	7 Holes
AVERAGE CHANGE	7 X .525 Kg
INSTRUMENTATION	Serial SN-348
FIELD FILTER	OUT-125 Hz, Notch Out
RECORD LENGTH	5 Sec
SPREAD TRACE	1 – 60 – 61 – 120
DISTANCE	3175 – 225 , 225 – 3175 M
GEOPHONE FREQUENCY	SM4U –10 Hz
GROUP INTERVAL	50 M
GEOPHONE LAYOUT	18 – 0.4M
AVERAGE HOLE DEPTH	2M
GAIN MODE	I.F.P
COVERAGE	5000 %
SAMPLE INTERVAL	2mm

DISPLAY PARAMETERS:

TRACES / INCH	24
INCHES / SECONDS	5.0

11- Statics – Automatic Surface Constant:
Window 100 –2000 mm.
Lag 24mm. 7 tr . CDP Model
Filter 10 / 15 – 50 / 60 Hz
12- Filter – Digital Band pass:
Filter 1 pass Band 10 / 15 – 50 / 60 Hz
Appl. Gate 0 – 3000 Ms
13- Amplitude Equalization – AGC
Size of Window 500 Ms
14- First Break Mutes – data Dependent

Distance	325	375	975	3175	4000 m
Mute	0	310	700	1600	1700 mm

15- Trim Statics – Cross Corelation:
Window 100 – 2000 mm
Lag 14 mm . . 5 tr . CDP model
Filter 10 / 15 – 50 / 60 Hz
16- Stack 60 Fold
17- Filter – Digital Band pass
Filter 1 Pass Band 10 / 15 – 50 / 60 Hz.
Appl. Gate 0 – 3000 Mz
18- Amplitude Wquilization – AGC:
Size of Window 500 Ms
19- FK – Coherency
Powering exponent 1.35
20- Manual Scaling:
100 % 0.00 Sec. 150% 3.00 Sec.
21- Finite Difference Migration:
110 % of Stacking Velocities
22- Filter – Digital Band Pass:
Filter 1 Pass Band 10 / 15 – 50 / 60 Hz
Appl. Gate 0 – 3000 Mz

SEISMIC DATA ACQUISATION

4.1 INTRODUCTION:

Data acquisition in geophysical prospecting is the collection of data in the field for desired purpose. Seismic data acquisition consists of placing some receivers at different locations and then using them to detect vibrations produced by an energy source. The receivers convert the mechanical energy into electrical energy that is transmitted to a recorder, the recorder is designed to preserve the information in the form that can be displayed and analyzed.

4.2 SEISMIC SURVEYING:

The basic field activity in seismic surveying is the collection of seismograms which may be defined as "analogue" or digital time series that register the amplitude of the ground motions as a function of time during the passage of a seismic wave train. The acquisition of seismograms involves the conversion of the seismic ground motions into electrical signals, amplification and filtering of the signals and their registration on a chart recorder and/or tape recorder. The conventional seismic survey procedure is to monitor ground motions at a large number of surface locations; thus multichannel recording systems are usually employed with, exceptionally, up to several hundred separate recording channels. Except in the simplest recording systems the data are tape recorded to facilitate subsequent processing. Modern recording systems utilize digital tape recording so that that the data are available in a suitable form for input to computers. A block diagram of a seismic recording system is shown in the figure.(Kery & Brooks 1991)

4.3 ENERGY SOURCES:

The most common method applied in generating seismic waves is exploding dynamite in shot holes. There are, however, other 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 than the rest.(Al-Sadi 1980)

Here is a short description of each of these methods:

a) Dynamite
b) Geograph
c) Dinoseis
d) Geoflex
e) Vibroseis

a) Dynamite:

This is the most common energy source used in seismic prospecting. Normally it is exploded inside a drilled hole at a depth ranging from a few meters to several tens of meters. The deeper the charge, the less intensive the generated surface waves are. Since the weathered surface layer absorbs high frequency components, so it is always advisable to place the charge below the base of this weathered zone. As a field procedure the charge is usually sealed with water or mud to increase the charge coupling with the surrounding medium. The amount of the charge per shot point depends on weather it is a single hole or a pattern (multi-hole) shooting. As a rough estimate, the charge weight is 10-50 kg of dynamite. (Al-Sadi 1980)

b) Geograph:

The geograph method or thumper involves dropping a weight of about 3-tons from a height of about 3 meters on to the ground. Since the generating energy is weak as compared to the dynamite energy source. In this method vertical stacking is carried out. Thus the records of 30 to 50 drops made at the one location are stacked together for a single enhancement.
The effective generated energy depends on the strength of the impact and the nature of the surface material. The geograph is a high frequency source, very safe, fast in operation and cheap as compared to other type of the energy sources. The drawback of this method is the development of strong surface waves, and because of the filtering effect of the surface layer, the high frequency components are severely attenuated. This lowers the resolution capability of the method. (Al-Sadi 1980)

c) Dinoseis:

The impact energy is generated by exploding a gas mixture (propane and oxygen) contained in a chamber, the bottom of which is a movable plate. The generated pressure-impact on the plate provides the necessary seismic energy. (Al-Sadi 1980)

d) Geoflex:

The seismic source consists of an explosive cord, which is buried in the ground at a shallow depth. It is laid down by a hydraulically operated plough that is especially designed for the purpose.
The main advantage of this method is the speed with which the explosive cord is laid down in the field and certain attenuation of the generated surface waves. However, it requires especially favourable field conditions, such as soft ground, which is penetrable by the plough and open country. Geoflex is not used in the areas, where the surface layer is too thick and unconsolidated, since in such circumstances; the transmitted energy will be much weakened.(Al-Sadi 1980)

e) Vibroseis:

This is based on the use of a mechanical vibrator, which is hydraulically, or electrically driven to exert a force of an oscillating magnitude. The source function (called the sweep) consists of force pulses generated at a frequency, which is increased linearly with time from about 6Hz to 60 Hz during a time span of say 6-16 seconds. The main problem met with in Vibroseis work is the low energy level of the source. (Al-Sadi 1980)

4.4 THE SPREAD CONFIGURATION:

The method of seismic reflection is by far the most widely applied method in geophysical prospecting, especially in the search for oil-bearing structures. The spread is defined as the lay out on the surface of the detectors, which give the recorded out puts for each source.

In 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. (Al-Sadi 1980)

Basic Spread:

The arrangement of geophones that is used to record seismic waves is called a spread. In 2d reflection surveys the source and the receivers will be on the same line while in 3d surveys the source and receivers will be in different lines. Basic spreads are given below,

(Robinson & Coruh)

a) Split Spread:

The most commonly used spread before the introduction of digital recording is the split spread. In this type of spread the source is at the center of the line of geophones. In a symmetrical split spread the live offsets are the same in both direction. In an asymmetrical split spread the offsets are not the same in both directions and usually the number of traces differs in two directions.

```
* * * * * * * * * * * * * * * *
```

b) End Spread:

In this type of spread the source is placed at one end of the line of geophones.

```
* * * * * * * * *
```

c) Cross Spread:

In this type of spread the source is at the center of two lines of geophones.

```
         *
         *
         *
*  *  *  *  *  *  *
         *
         *
         *
```

d) L Spread:

In this type of spread the source is at the corner of two lines of geophones.

4.5 COMMON DEPTH POINT (CDP) PROFILING:

In common depth point profiling, it is arranged that a set of traces recorded at different offsets contain reflections from a common depth point (CDP) on the reflector. The shot point and detector locations for such a trace, known as CDP gather, have a common mid point (CMP), below which the common depth point is assumed to lie. The CDP principle breaks down in the presence of the dip, because the CDP then no longer directly underlies the shot-detector midpoint and the reflection point differs for rays traveling to different offsets.(Kearey & Brooks 1991)

Advantages Of CDP:

1-The CDP gather represents the best possible data set for computing velocity from the normal movement effect (NMO).

2- with accurate velocity information the moveout can be removed from each trace of a CDP gather to produce a set of traces that may be summed algebraically to produce a CDP stack in which the reflected arrivals are enhanced relative to the seismic noise.

4.6 NORMAL MOVE OUT:

Move out is defined as the difference between the travel time t1 & t2 of reflected ray arrivals recorded at two offset distances x1 & x2.
Normal moveout (NMO) at an offset distance x is the difference in travel time ΔT between reflected arrival at x and at ZERO offset. NMO is a function of offset, velocity and reflector depth. The concept of moveout is fundamental to the recognition, correlation and enhancement of the reflection event, and to the calculation of the velocities using reflection data. (Kearey & Brooks 1991)

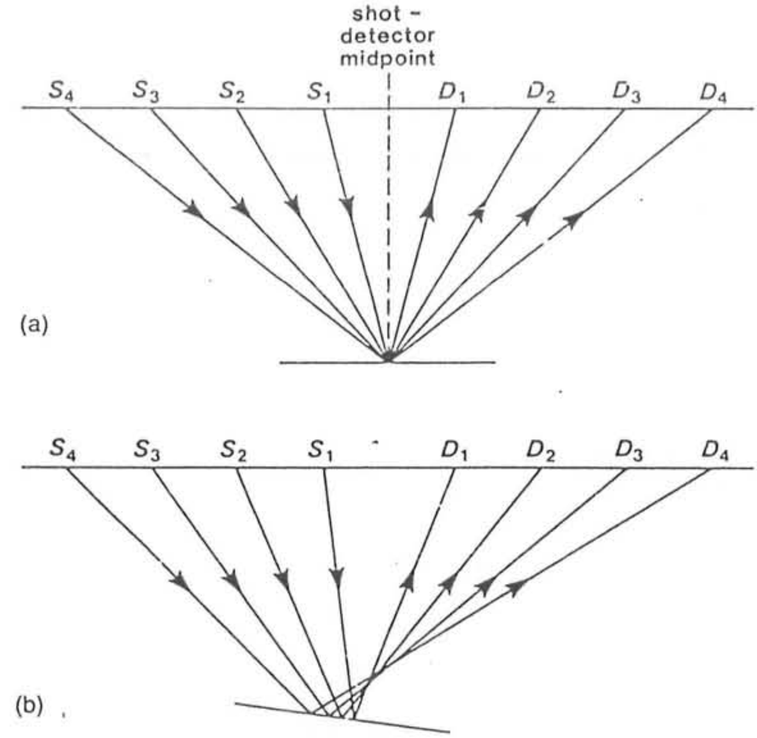


Fig. 4.15 Common depth point (CDP) reflection profiling. (a) A set of rays from different shots to detectors all reflected off a common point on a horizontal reflector. (b) The common depth point is not achieved in the case of a dipping reflector.

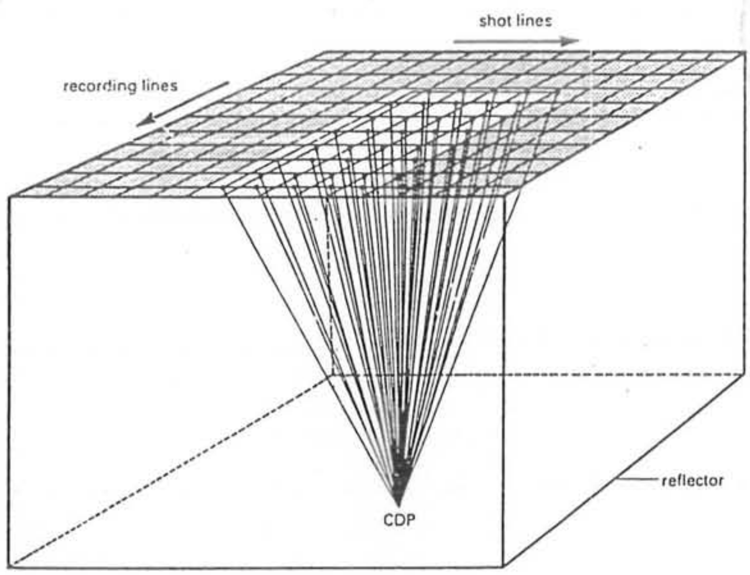


Fig. 4.16 Reflected ray paths defining a common depth point from an areal distribution of shot points and detector locations in a three-dimensionl survey.

4.7 SEISMIC DETECTION :

Earth movement due to the arrival of the seismic wave is generally very small. In seismic detection, it is necessary to detect the vibration amplitudes as small as 10^{-8} inch. In addition to the high sensitivity requirements, the seismic equipment must cope with amplitudes covering a very wide range of about 100db. Thus seismic equipment of adequate sensitivity, large dynamic range and suitable frequency response is the aim of all development programs taking place in the field of seismic detection.(Al-Sadi 1980)

GEOPHONE:

The geophone is an electromechanical instrument, which produces an electrical output, which is linearly dependent on the vertical component of the motion of the ground in which it is planted. There are several types of the geophone depending on the particular physical principle applied in functioning.
The most commonly used type (the electromagnet) operates on the principle of voltage generation due to different ional movement of a coil in a magnetic field. The generated voltage is proportional to the rate of change in the magnetic flux due to the movement of one part relative to the other. A schematic representation of an electromagnetic geophone is shown in figure. .(Al-Sadi 1980)
The output of a moving coil geophone is proportional to the velocity of the coil. Note that the coil velocity is related to the very low particle velocity associated with the seismic ground motion and not to the much higher propagation velocity of the seismic energy. The sensitivity of the geophone is determined by the number of windings in the coil and the strength of the magnetic field. The immature geophones used in commercial reflection surveying typically have a sensitivity of about 10V per ms^{-1}. Moving coil geophones are sensitive only to the component of ground motion along the axis of the coil. Vertically traveling compress ional waves from subsurface reflectors cause vertical ground motions and are therefore best detected by geophones with an upright coil as illustrated in fig. (Kearey & Brooks)

Hydrophones:

Hydrophones are composed of ceramic piezo-electrical elements, which produce an output voltage proportional to the pressure variations associated with the passage of a compress ional seismic wave through water. The sensitivity is typically 0.1mV pa^{-1}. for multi channel seismic surveying at sea, large number of individual hydrophones are made up into hydrophone streamers by distributing them along an oil-filled plastic tube. The tube is arranged to have neutral buoyancy and is manufactured from materials with an acoustic impedance close to that of water to ensure good transmission of seismic energy to the hydrophone elements. Since piezo-electric elements are sensitive to accelerations, hydrophones are often composed of two elements mounted back to back and connected in series so that the effects of accelerations of the streamer as it is towed through the water are canceled out in the hydrophone out-puts. As with the geophone deployment in land seismic surveying, groups of hydrophones may

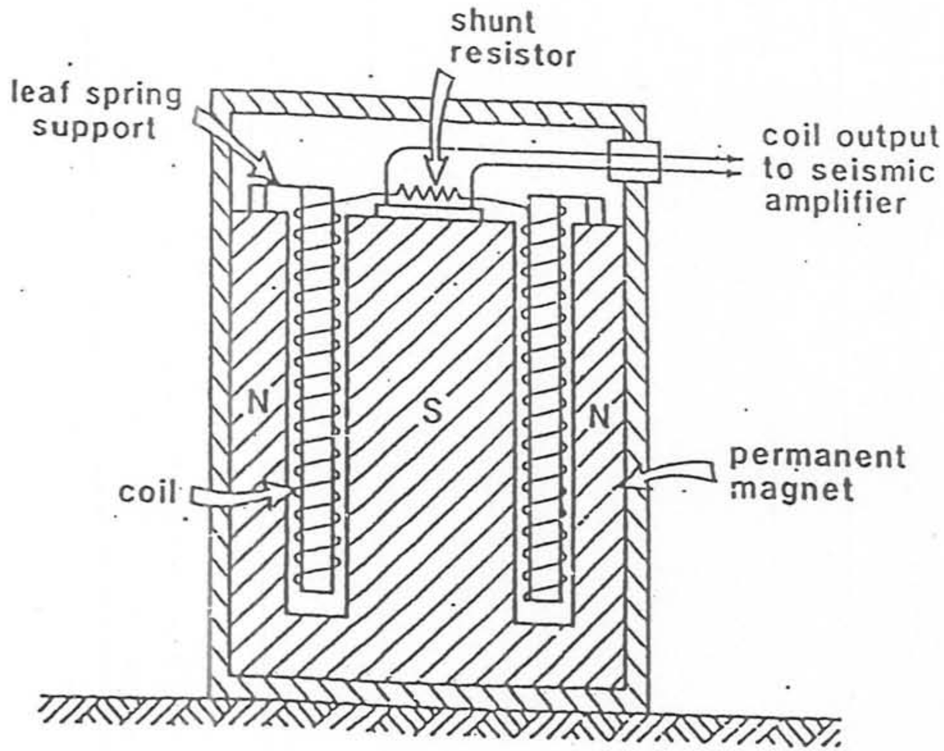


Figure 3.1 Schematic cross-sections through a moving coil geophone.

be connected together into linear arrays to produce detectors with a directional response. (Kearey & Brooks)

Seismic Cable:

The geophone signal, which is the electric current produced by ground vibration, is transmitted to the recording system by means of the seismic cable. Each geophone requires two wires conductors. Therefore the number of conductors in the seismic cable depends upon the number of the geophones being used in the survey. For small-scale engineering surveys, cables usually have 24 conductors which carry the signals of 12 geophones.

At regular intervals along the cable are "takeout" points where a geophone can be connected to its pair of conductors. Seismic cables come with takeout interval as short as a few meters and as long as several hundred meters. Manufactures can ordinarily supply cables with 6, 12, 24, 48 and even 96 takeouts.

For certain survey procedures, it is more convenient to use a segmented seismic cable. Each segment, which is usually a few tens to a few hundreds of meters long, has one takeout point and multiprong plugs on both ends for connecting to adjacent segments. With this arrangement, a single cable segment and geophone can be moved from one end of a line to the other without disconnecting all the other geophones.(Robinson & Coruh 1988)

4.8 SEISMIC RECORDING:

When the seismic wave hits the geophone, the electrical out put of the geophone is recorded by the following two recording systems.

a) Analogue Recording System
b) Digital Recording System

a) Analogue Recording System:

The analogue recording system is made up of an assembly of electronic units normally housed in a specially adapted truck called the recording station. When the ground is vibrating it is a continuous motion. A geophone responding to this motion produces a continuous varying electric signal. Before the geophone signal is recorded by an analog system, it can be electronically amplified and filtered. The amplifier like the volume control on a radio is used to increase the strength of the weak geophone signal. A seismogram is a graph that shows how the amplitude of this signal varies with time. It is a permanent record of how the ground was vibrating during that interval of time at the receiver location. Different techniques may be used for obtaining a seismogram. One such technique is a recording device that draws a continuous graph at the same time that it is receiving a geophone signal. The graph is drawn by the point of light that is focused on a photographic chart by a galvanometer. This kind of system has been in use since the beginning of exploration seismology. A geophone signal continuously magnetized the portion of tap (with magnetizable coating) passing by the recorder head. (Robinson & Coruh 1988)

b) Digital Recording System:

Digital recording is an outgrowth of modern computer technology, and the capability of computer processing of digital data is essential for the purposes of exploration seismology. A digital recorder makes use of binary numbers to store the measurements of the geophone signal strength. Let us compare the binary number system and the decimal number system.

The decimal number 245 is a short way to write

$2 * 10^2 + 4*10^1+5*10^0 = 245$

$2* 100 + 4* 10 + 5* 1 \quad = 245$

$200 \quad + 40 \quad + 5 \qquad = 245$

Suppose we were to express this same value in a sequence of powers of two. Then we obtain

$1 * 2^7 + 1 * 2^6 + 1 * 2^5 + 1 * 2^4 + 1 * 2^3 + 1 * 2^2 +1 * 2^1 + 1 * 2^0 = 11110101$

Where

Binary 11110101 = Decimal 245 (Robinson & Coruh 1988)

Digital seismic recording systems are usually supplied with an auxiliary galvanometric recorded for producing an analogue seismogram at the same time that the magnetic tape is being recorded. This seismogram is sometimes called a "field monitor record". The analogue to digital (A/D) unit converts the analogue out put received from the amplification system into digital form. A digital station is normally equipped with one AD-unit to do the conversion for all the seismic channels as well as the auxiliary channels. The coordination between the one AD-unit and the numerous channel-inputs is effected through the use of the multiplexer unit.(Al-Sadi1980)

Now that miniature electronic components are available and because only one A/D converter and one tape recorder are needed to serve a multichannel system. Most systems are equipped with memory units suitable for storing individual geophone output, before it is transmitted to the A/D converter. The geophone output produced by one source can be stored in a form that can be over printed by the out produced at later times by other sources. This process of adding together the signals from more than one source is called "Summing". The summed output can then be processed through the A/D converter and recorded on the digital magnetic tape.

(Robinson & Coruh 1988)

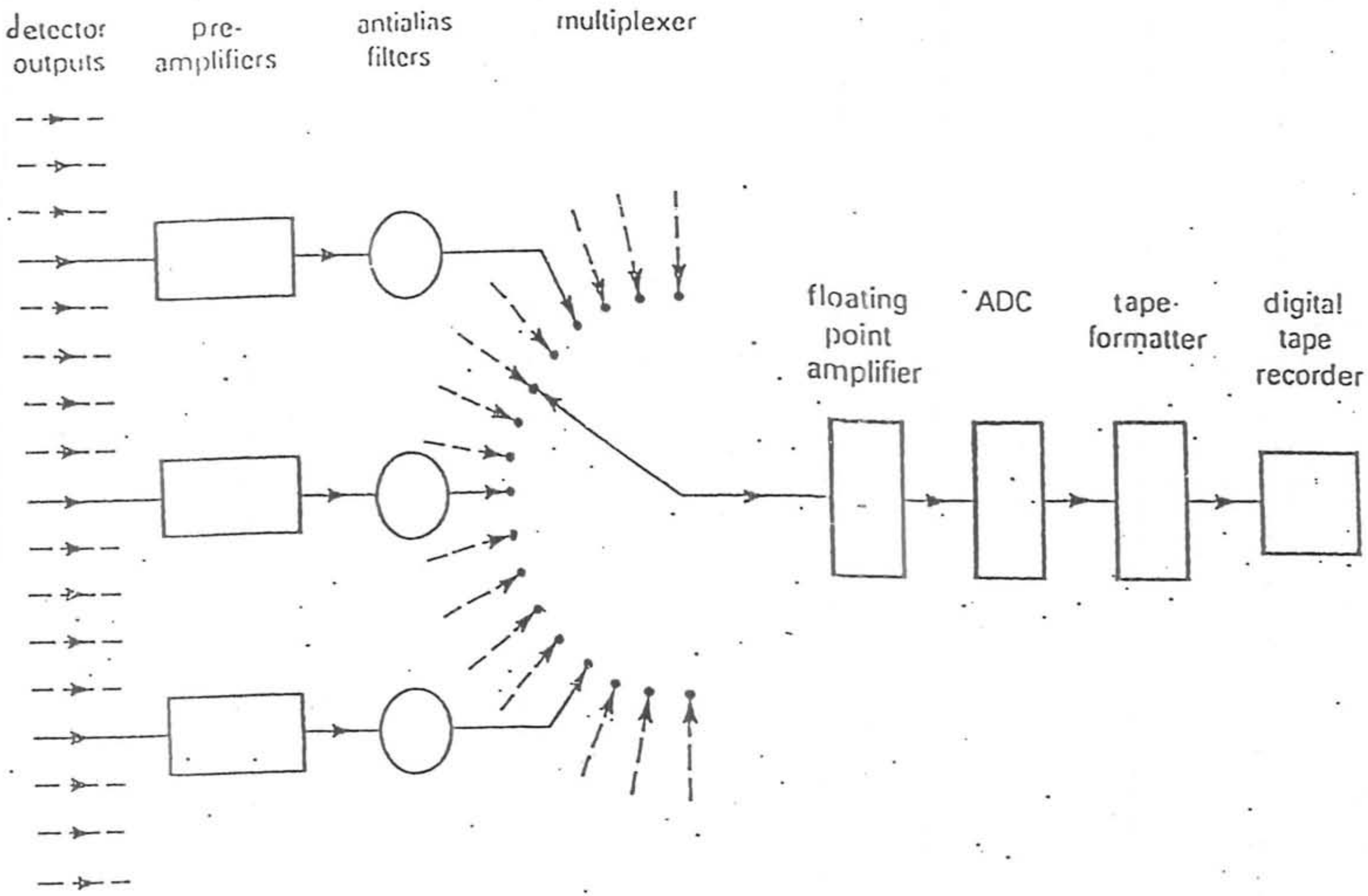


Figure 3.2 Schematic block diagram of a multichannel seismic recording system.

4.9 SEISMIC NOISE:

Noise is the information contained on a record, which one does not wish to use. For example ground rolls give information about near surface waves. Since this information is not useful to us and in petroleum exploration ground roll is consider as noise.

Noise is often divided into two categories as given below,

A) Random Noise:

It includes energy, which does not align from trace to trace or record to record. There are some sources of random noise.

- Water flow noise
- Small movements within the earth
- Local noise (People, Traffic etc.)
- Bad geophone noise
- Short wave length propagation noise
- Wind noise

B) Coherent Noise:

It is a seismic energy, which aligns from trace to trace or record to record. This type of noise is often very similar in appearance to signal and usually is more difficult to overcome than is random noise.

There are some sources of coherent noise,

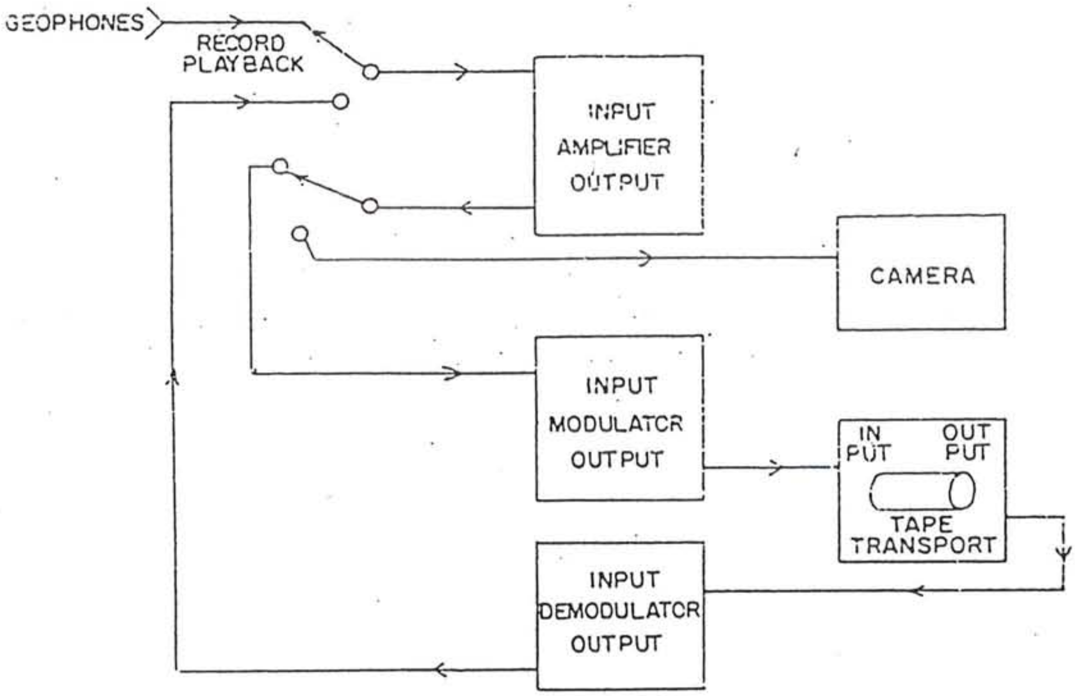
- Multiple reflections
- Refracted events
- Diffraction events
- Ground roll
- Direct waves
- Surface waves

Seismic Noise Control:

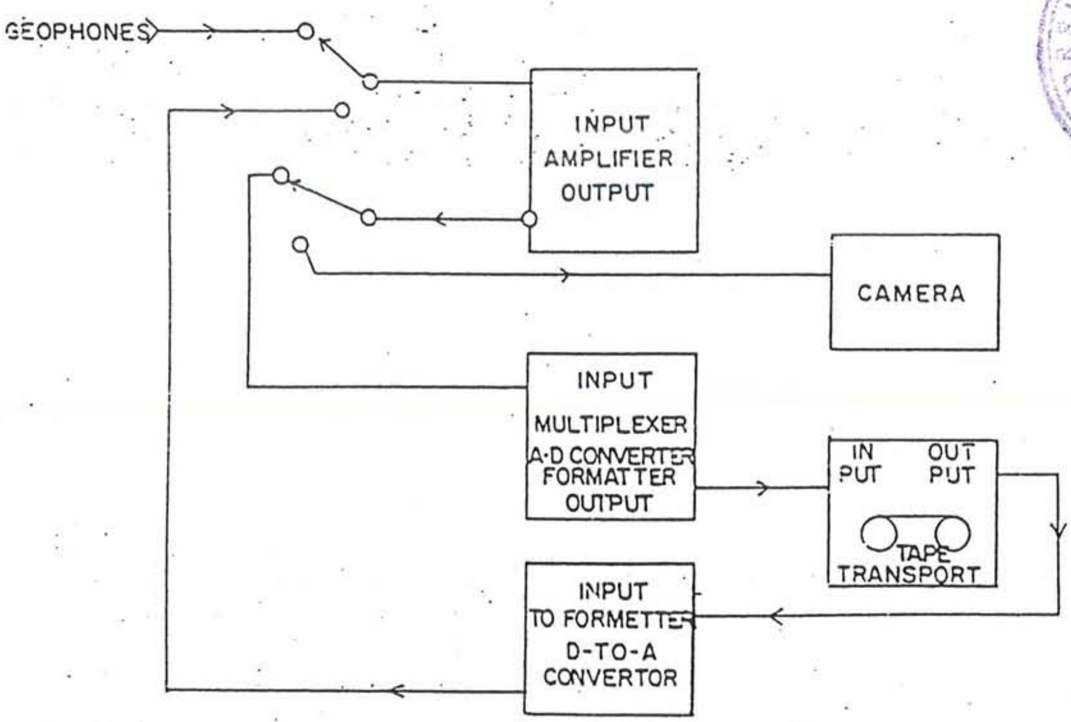
The basic tools available for controlling noise in the field are

- Source Size.
- Source Depth.
- Electronic Filtering.
- Receiver Arrays.
- Source Arrays.
- Electronic Mixing.

(Robinson & Coruh 1988)



Block Diagram of Conventional FM Recording System
Fig. 3.1



Block Diagram of Digital Recording System
Fig. 3.2

PROCESSING PARAMETERS

1-DEMULTIPLEX:

Recorded Length	5000 ms	Sample Rate	2 ms
Processed Length	3000 ms	Sample Rate	2 ms

2- Amplitude Recovery Exponential [A-1]

3- Geometry: Straight Line

4- Instrument and Geophone Dephasing Damping 0.6

5 – Deconvolution – Spiking :

Operator length = 80mm Prevhilening = 0.1%

Filter	Distance	Design Gate	Appl.Gate
1	225m	300 – 1800mm	0 – 3000 mm
2	2250m	1700 – 2700 mm	0 – 3000 mm

6- Trace Gather 60 Fold

7 – Refraction Statics :

Long-Wave not used:

Short-Wave used as indicated:

8 – Structure Statics:

Elevation only

Datum 200m. A.S.L

Replacement Velocity 3300 m/sec

9- Velocity Analysis:

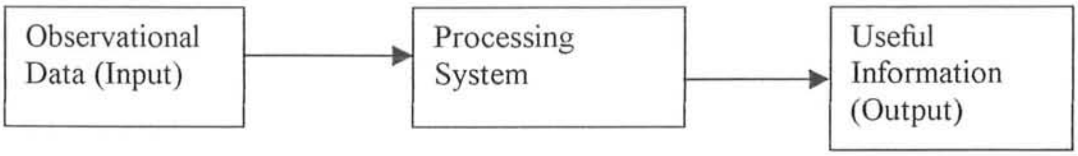
Constant Velocity Stack

10- Normal Moveout:

GEOPHYSICAL DATA PROCESSING

INTRODUCTION:

Data processing is a sequence of operations which are carried out according to a pre-defined programmed to extract useful information from a set of raw data. As an input-output system, processing may be schematically represented as shown,



The various operations carried out in processing may be summarized as follows.

- Data copying and transcription.
- Data classification and storage.
- Various types of computation and analyses.
- Display of processing results as tables, graphs or magnetic tape records.

(Al-Sadi 1980)

Much of the geophysical surveying is concerned with the measurement and analysis of waveforms that express the variation of some measurable quantity as a function of distance or time. The analysis of waveforms is an essential aspect of geophysical data processing and interpretation.(Kearey & Brooks 1991)

5.1 DIGITIZATION OF GEOPHYSICAL DATA:

Waveforms of geophysical interest generally represents continuous (analogue) functions of time or distance. Consequently the data often need to be expressed in digital form for input to a computer, whatever the form in which they were originally recorded.

A continuous, smooth function of time or distance can be expressed digitally by sampling the function at a fixed interval and recording the instantaneous value of the function at each sampling point. Thus the analogue function of time f(t) shown in figure(a) cab be represented as the digital function g(t), shown in fig(b), where the continuous function has been replaced by a series of discrete values at fixed intervals of time(t).

Basic Parameters:

The two basic parameters of a digitization system are the

a) Sampling Precision (Dynamic Range).
b) The Sampling Frequency.

a) Dynamic Range:

It is the ratio of the largest measurable amplitude A(max) to the smallest measurable amplitude A(min) in a sampled function. The higher the dynamic range the more faithfully will amplitude variations in the analogue waveform be represented in a digitized version of the waveform. Dynamic range is normally expressed in the decibel (db) scale used to define the electrical power ratios.

b) Sampling Frequency:

It is the number of the sampling points in the unit time or unit distance. Thus if a waveform is sampled every two milliseconds (sampling interval), then the sampling frequency is 500 samples per seconds (or 500 Hz). Sampling at this rate will preserve all frequencies up to 250 Hz in the sampled function. This frequency of half the sampling frequency is known as the Nyquist Frequency (fn) and the " Nyquist Interval" is the frequency range from zero to fn.

$Fn = ½ \Delta t$

Where Δt = sampling rate (Kearey & Brooks 1991)

5.2 ALIASING:

If frequencies above the Nyquist Frequency are present in the sampled function, a serious form of distortion results known as "Aliasing" in which the higher frequency components are " folded back" in to the Nyquist Interval.
Consider the figure in which a Sin wave is sampled at different sampling frequencies. At the higher sampling rate (fig 2.2(a)) the waveform is accurately reproduced but at the lower rate (fig 2.2(b)) it is rendered as a factious frequency with in the Nyquist interval. The relationship between input and output frequencies in the case of a sampling frequency of 500Hz is shown in the fig2.2c.

To overcome the problem of "Aliasing", the function must be passed through an anti-alias filter prior to digitization. The antialias filter is a low pass frequency filter with a sharp cut-off that removes frequency components above the "Nyquist Frequency" or attenuates them to an insignificant amplitude level. (Kearey & Brooks 1991)

5.3 WAVEFORM PROCESSING:

The principles of convolution, deconvolution and correlation from the common basis for many methods of geophysical data processing, especially in the field of seismic reflection surveying.

a) CONVOLUTION:

Convolution is the change in the wave shape as a result of passing through a linear filter. The process of digital filters is done by the convolution process and is a series of multiplication and summation. (Zia 1988)
Convolution Of Two digital functions is given as under:

								Cross – Product	SUM
		4	3	2	1				
1	0	2						→ 4 * 2	= 8
	1	0	2					→ 2 * 3	= 6
		1	0	2				→ 1 * 4 + 2 * 2	= 8
			1	0	2			→ 1 * 3 + 2 * 1	= 5
				1	0	2		→ 1 * 2	= 2
					1	0	2	→ 1 * 1	= 1

b) DE-CONVOLUTION:

Deconvlution is a filtering process designed to improve resolution and suppress multiple reflection. Deconvlution can be considered either in the time domain or in the frequency domain. In the time domain the object is to convert each wavelet, with its reverberations and multiples, in to a single spike. If we know the shape of the wavelet, we can design an operator which, when convoluted with the seismic trace, will convert each wavelet in to a single spike. (Zia 1989)

c) DE-MULTIPLEXING:

The output of a geophone group during field recording is a continuously varying electrical voltage. Demultiplexing is the sorting process of data samples from magnetic tape in to individual channels. In general, the early stage of processing requires channel ordered, or trace ordered data. Demultiplexing is thus the first step in processing. The data samples for shot1, group1 are assumed in the order of measuring time and output first, then the corresponding samples are for shot1, and group2 and so forth to create the output demultiplexed data set. This output organization of data is a common short gather or a field record, because the source location is common to first "N" channels of data.

Mathematically, demultiplexing is the transposing of a big matrix in such a manner that the columns of resulting matrix can be read as seismic traces recorded at different offsets.

d) EDITING:

Raw seismic data inevitably contains 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 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.(Zia 1989)

e) AMPLITUDE ADJUSTMENT:

In a seismic section the variations in the amplitudes of reflections can be important factors in the interpretation. Lateral amplitude variations, from trace to trace with in a reflection event "Bright Spot" may be the direct indications of the presence of the hydrocarbons. Vertically amplitude variations form event to event may be helpful in identifying and correlating reflection horizons. To preserve these important amplitude variations, the seismic analyst must exercise care in gain recovery and scaling (trace equalization). In some cases the amplitude variations are so great that low level events become difficult to follow or even invisible. In order to raise the level of these weak events relative to the strong ones so that geologic structure can be made visible, the analyst can apply a digital "Balance" (Automatic gain control).

(Zia 1989)

5.5 GEOMETRICAL CORRECTIONS:

A seismic trace on a field monitor shows reflected energy bursts from subsurface rock layer interfaces. However, before we use these reflected energy bursts and there energy bursts and their arrival times, we must apply several corrections to compensate for geometric effects. These corrections are of the following two types

1- STATIC CORRECTIONS:

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

There is usually a thin layer (several feet to several hundred feet thick) of low velocity material (1000 to 2500 ft/sec). Geophysics called this low velocity zone weathered layer. In this later the elements tends to decompose rock in to soil.

The thickness and velocity of the weathered layer can change along a seismic line, thereby causing changes in raw reflection time which are unrelated to subsurface structure. This effect must be removed by applying a weathering correction.

Since seismic sources or receivers are usually at or near the earth's surface, raw reflection times are influenced by topographic effects, which are also independent of subsurface structure and can be removed by applying elevation corrections. (Zia1989)

2- DYNAMIC DORRECTIONS:

In general, shot points and there associated geophone stations are separated by distances ranging up to three Kms or even more. The non-vertical component of travel time can be large and must be removed before we can attempt to relate reflection time to reflection depth. For a flat reflector, the difference between travel time to a remote geophone station and travel time to a coincident (Zero Offset) station is called the normal move out (NMO).

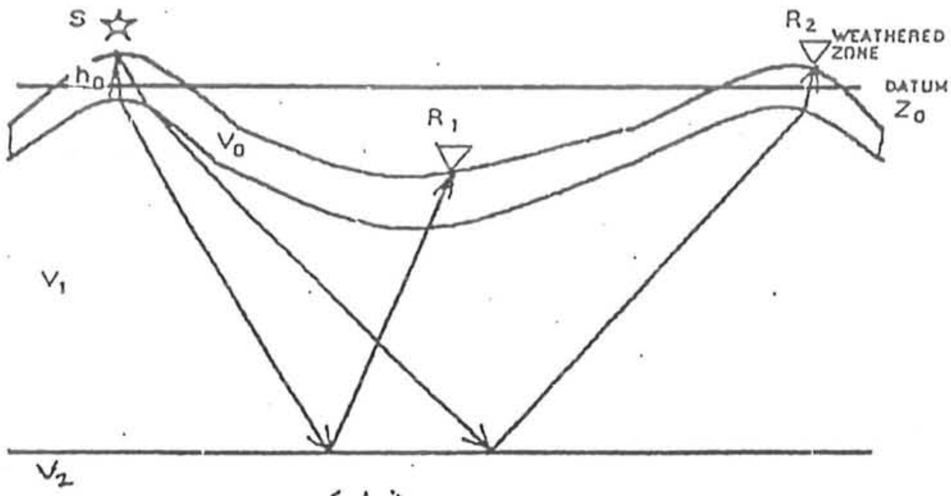
The purpose of this process is to derive normal move out functions from the velocity-time functions and apply normal moveout corrections to each trace in each CDP gather. Normal moveout is a function of reflection-time and trace offset (source to detector distance) and, thus, a normal moveout time function must be derived for each trace offset.(Zia1989)

]

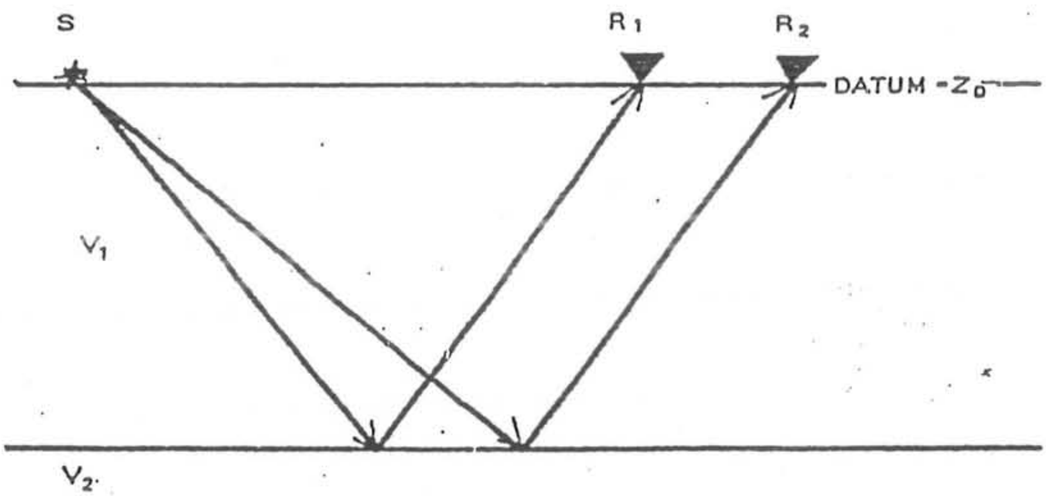
5.6 MIGRATION:

The process of replotting seismic events in their true spatial positions is called migration. A trace on a record section can be thought as an idealized field trace, recorded by one geophone station from a shot at the same station. Note that from one trace it is generally not possible to distinguish signal from noise.

When a trace is plotted vertically beneath its common shot station. A reflected event is identified by its alignment across any array of traces, and the reflection



(A)

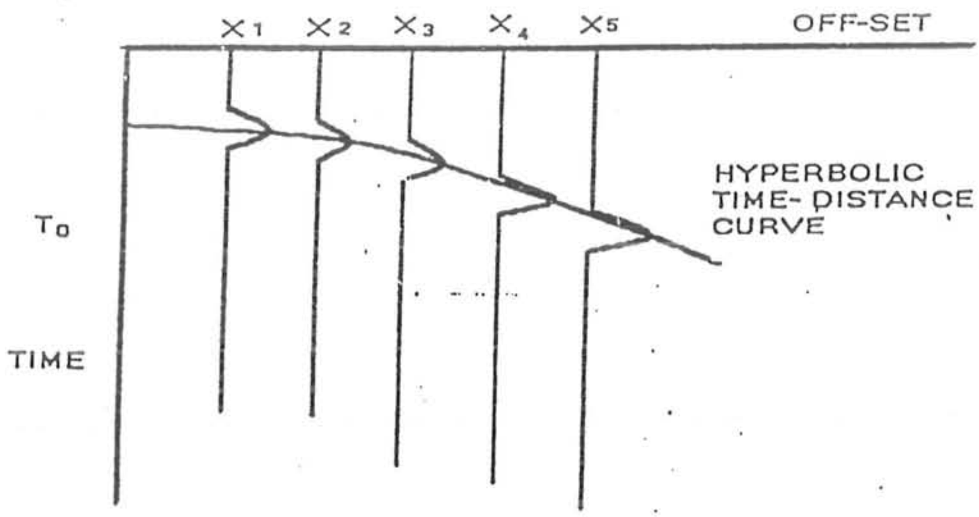


(B)

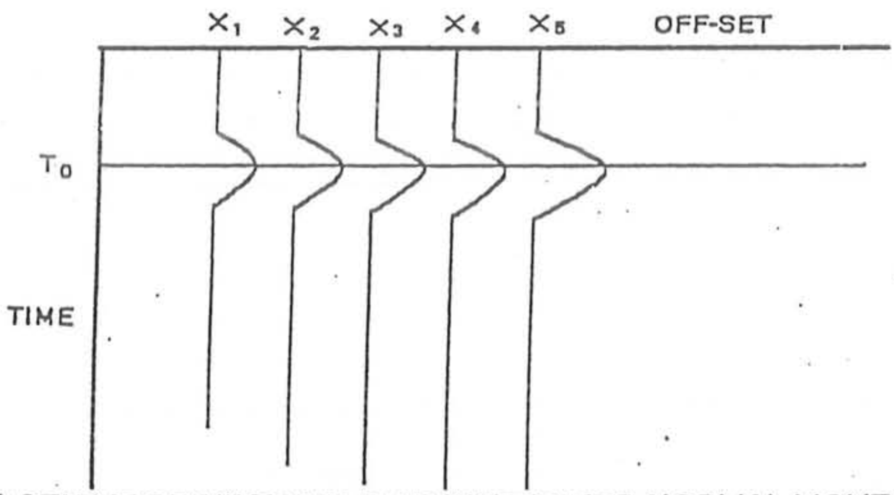
(A) REPLACING THE WEATHERED ZONE VELOCITY (V_0) WITH BEDROCK VELOCITY (V_1)
(B) REDUCING SOURCE AND RECIEVER POINTS TO THE SAME HORIZONTAL DATUM

STATIC CORRECTION

Figure 4·1



(A) SEISMOGRAM TRACES NOT ADJUSTED.



(B) SEISMOGRAM TRACES ADJUSTED FOR NORMAL MOVEOUT

DYNAMIC CORRECTION

Figure 4.2

time is measured under each section. If the reflector is flat, the reflection will be located directly beneath the shot station, and the recorded station displays the event in its true position plotted in time rather in depth. However if the reflector is not flat, the reflection point lie directly beneath the shot station, and the true position of the event will differ form its apparent position. (Zia 1989)

5.7 FILTERING:

A filter is a system, which discriminates against some of its input. Seismic data always contain some signal information, which we want to preserve. Everything else is called a noise, and we want to remove or reduce it. A filter is designed to preserve signals and to attenuate noise. (Zia 1989)

Digital Filtering:

In waveforms of the geophysical interest, the signal is almost invariably superimposed on unwanted noise. In favourable circumstances the signal / noise ratio (SNR) is high, so that the signal is readily identified and extracted for subsequent analysis. Often the SNR is low and special processing is necessary to enhance the information content of the waveforms. Digital filtering is widely employed in geophysical data processing to improve SNR or otherwise improve the signal characteristics.

A very wide range of digital filters is in routine in geophysical, and especially seismic data processing. The two main types of digital filters are

A) Frequency Filters
B) Inverse (Deconvolution) filters

A) Frequency Filters:

Frequency filters discriminate against selected frequency components of an input waveform. Any coherent or incoherent noise event whose dominant frequency is different from that of reflected arrivals may be suppressed by frequency filtering. These are of the following types

Low-Pass Filter:

To trap the high frequencies.

High-Pass Filter:

To trap the low frequencies.

Band-Pass Filter:

It eliminates both high and low frequencies and passes a specific band or range of intermediate frequencies.

Notch-Filter:

It attenuate a narrow frequency band.

B) Inverse (Deconvolution) Filters:

Many components of seismic noise lie with in the frequency spectrum of a reflected pulse and therefore cannot be removed by frequency filtering.

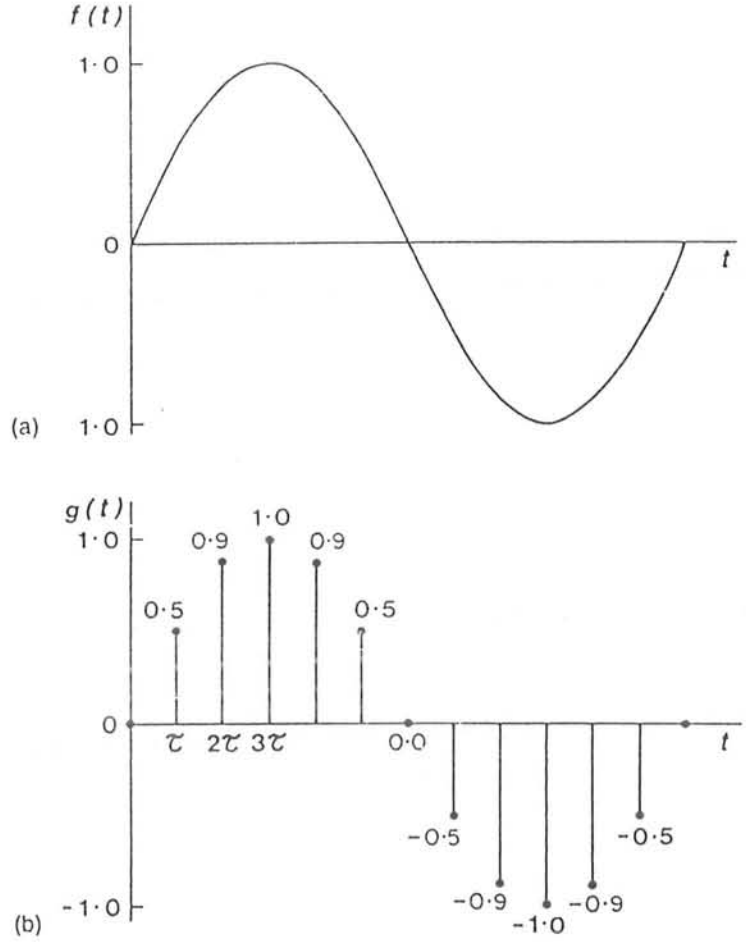


Fig. 2.1 (a) Analogue representation of a sinusoidal function. (b) Digital representation of the same function.

Inverse filters discriminate against noise and improve signal character using criteria other than simply frequency.
These are of the following types

Derverberation Filter:

To remove ringing associated with multiple reflections in a water layer.

Deghosting:

To remove the short-path multiple associated with energy traveling upwards from the source and reflected back from the base of the weathered layer or the surface.

Whitening:

To equalize the amplitude of all frequencies components with in the recorded frequency band.

Wiener Filter:

It converts the known input signal in to an out put signal that comes closest.

(Kearey & Brooks 1991)

FLOW-CHART OF THE PRINCIPAL PROCESSING SEQUENCE

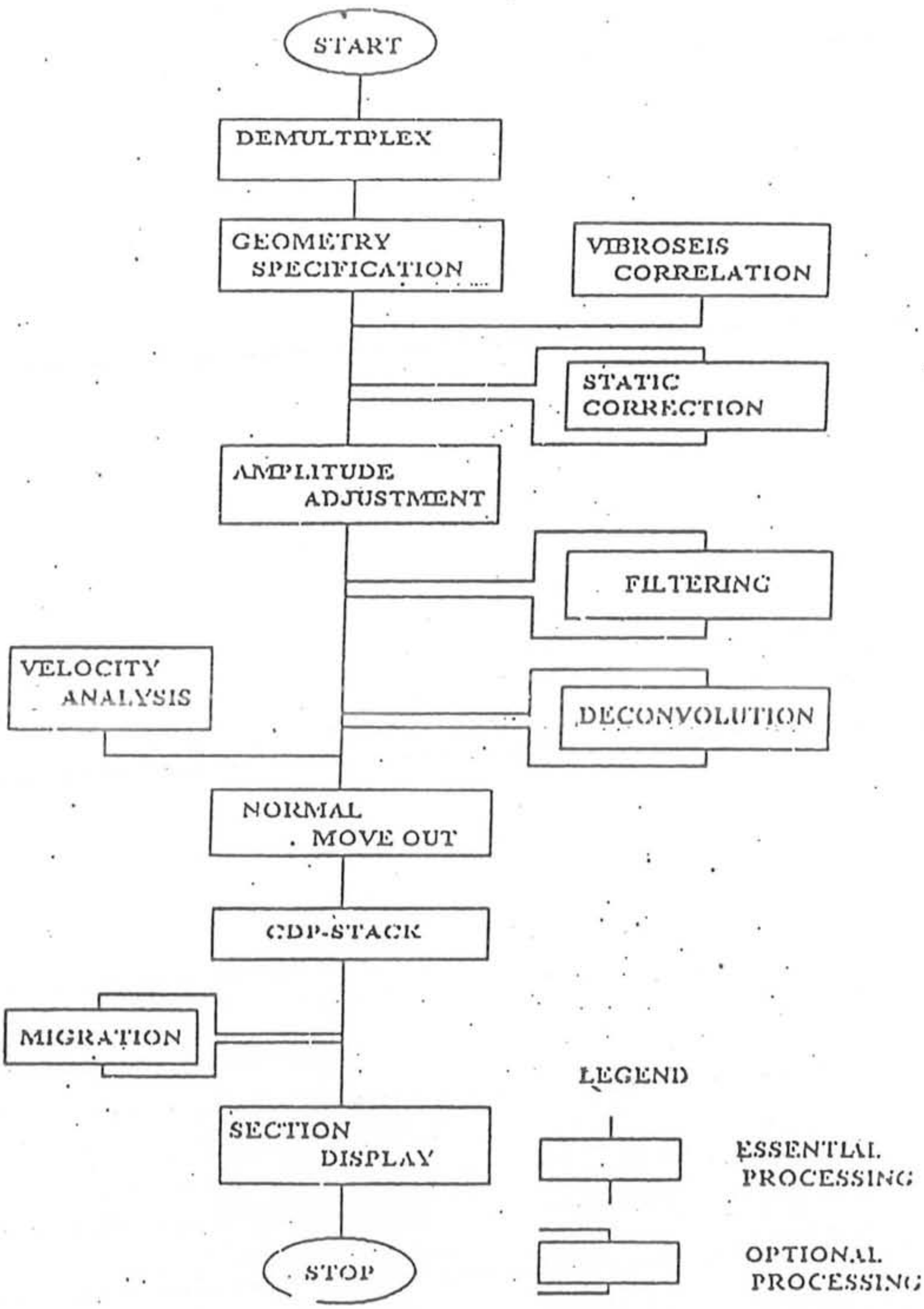


Figure 4. Flow chart of the principal processing sequence

(Al-Sadi, 1980)

Seismic velocities

6.1 Introductions:

It is a well-known fact that velocity, as a seismic parameter, plays a principal role in almost the whole range of activities involved in a seismic prospecting. The accuracy of the data reduction, prospecting and interpretation of seismic data depends mainly on the correctness of the velocity measurements. Erroneous velocity estimation can lead to a drastically distorted geological picture. For this reason, the question of velocity accuracy always demands serious attentation.

Since in seismic prospecting, we require velocity values as a function of depth, all velocity determination methods aim at computing velocity depth or time function. (Al-Sadi 1980)

Our concern here is the measurement of the actual velocities in or near the plane of the seismic profile. These velocities can be measured directly in Boreholes, or they can be estimated from the data. The spreads now used in recording by common-depth point techniques are generally so long (up to 3mi) that analytical methods are considerably more accurate than they were when the shorter spreads used for single-coverage shooting were common.

In many areas, seismic velocity data can also be used to identify lithology in discrete formations with in the geologic section.

(Robinson & Coruh 1988)

The seismic velocities may be used to establish the following

- True Depth.
- Migration Of Seismic Data.
- Stacking Of Seismic Data.
- Possible Lithology Estimation.
- Possible Porosity Estimation.

6.2 TYPES OF SEISMIC VELOCITIES:

The following types are referred to most frequently in the geophysical literature.

(Robinson & Coruh 1988)

a) AVERAGE VELOCITY:

This is simply the depth Z of a reflecting surface below a datum divided by the observed one-way reflection time t from the datum to the surface so that

$$Vav = Z / t$$

If Z represents the sum of thickness of layers Z1,Z2, Z3,..........,Zn, the average velocity is defined as

Vav = (Z1 + Z2 + Z3 + ... +Zn)

b) INTERVAL VELOCITY:

If two reflectors at depths Z1 and Z2 give reflections having respective one-way times of t1 and t2, then the interval velocity Vint between Z1 and Z2 is defined simply as

$(Z2 - Z1) / (t2 - t1)$.

c) INSTANTANEOUS VELOCITY:

If the velocity varies continuously with depth, its value at a particular depth Z is obtained from the formula for interval velocity by contracting the interval Z2 – Z1 until it becomes an infinitesimally thin layer having a thickness dz. The interval velocity computed by the formula above becomes the derivative of Z with respect to t, and we designate it as the instantaneous velocity V(inst), defined as

$$V\,(inst) = dz / dt$$

d) ROOT-MEAN SQUARE VELOCITY:

If the section consists of the horizontal layers with respective interval velocities of V1 , V2 , V3, ..., Vn and one-way interval travel times t1, t2, t3,............, tn, the root-mean-square (rms) velocity is obtained from the relation

$$V_{n,\,RMS}=\sqrt{(\Sigma V^2_i t_i / \Sigma t_i)} \qquad i=1, 2, 3\ldots n.$$

t =Two way travel time at distance X
V=Interval velocity
RMS velocity is always greater than the average velocity

e) STACKING VELOCITY:

The distance time relationship determined from analysis of normal moveout (NMO) measures from common depth point gathers of seismic data. The stacking velocity is used to correct the arrival times of events in the traces for there varying offsets prior to summing or stacking the traces to improve the signal to noise ratio of the data.

It is the velocity obtained from the application of normal moveout (NMO) correction to common depth point (CDP) gathers. It is based on the relation:

$$T=\sqrt{T_o^{\,2}+X^2/V^2_{st}}$$

Where,

V_{st} = Stacking velocity
X = Horizontal distance between source and receiver
T_o = Two way travel time at zero offset
T = Two way travel time at distance X

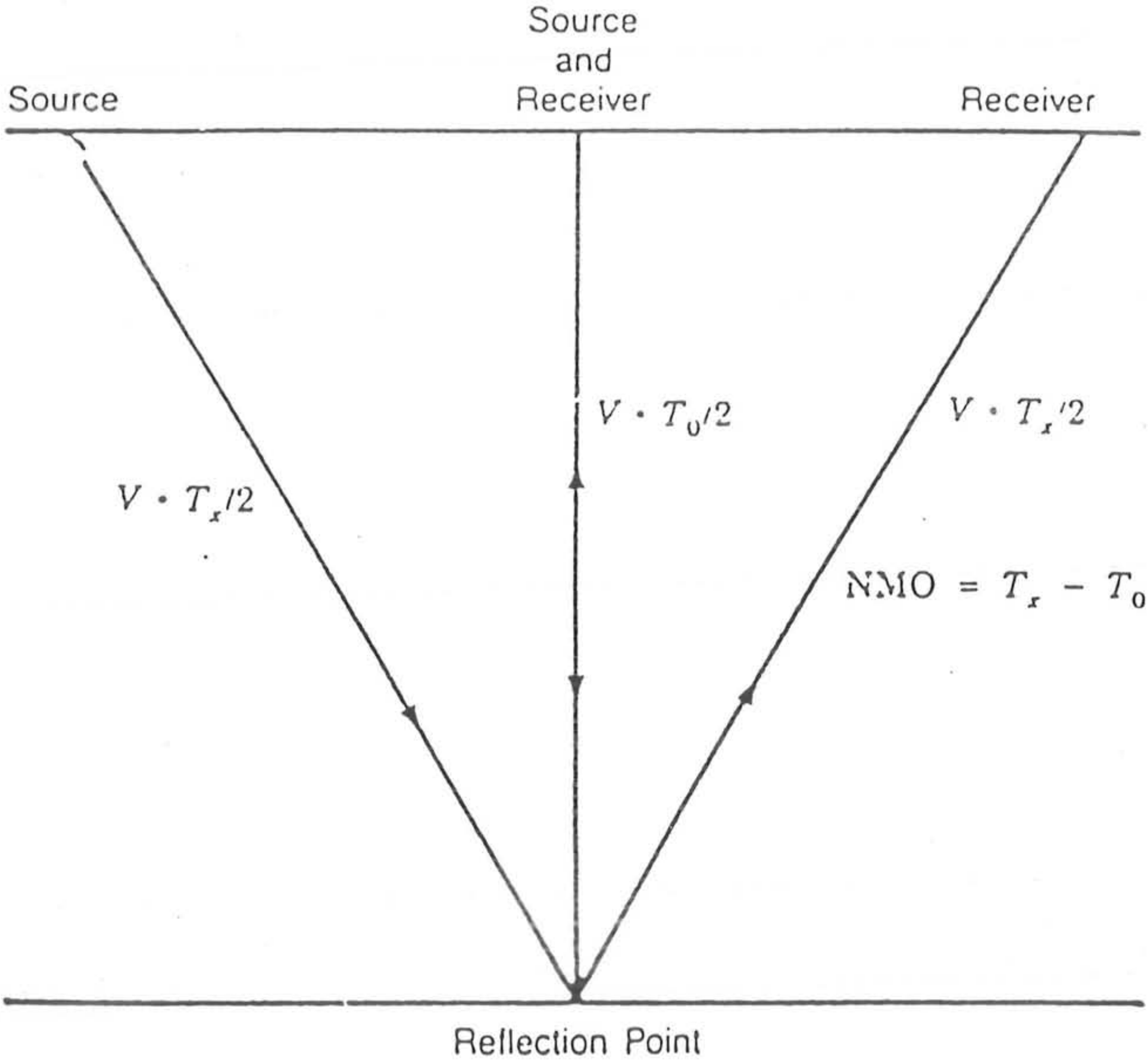


Fig. 4.22 Normal Moveout.

6.3 Factors Effecting Seismic Velocities

1. **DENSITY:**

The velocity is inversely proportional to the square root of density, but it is common observation that velocity appears to increase with increase in density. The reason is that compaction (increase) in density reduces porosity and increases elasticity in such a way that it offset the effect introduced by density increase.

2. **POROSITY:**

Porosity appears to be the dominant variable in determining the velocity in sedimentary rocks. Effect of porosity decreases the elasticity, that's why the velocity of porous material is considerably small.

An empirical time average equation is often used to relate the velocity "V" and porosity "$\varnothing$"

$$1/V = \varnothing / V_f + 1 - \varnothing / V_m$$

Where

$\varnothing$ = Average Velocity

Vf = Velocity of fluid contained in pores

Vm = Velocity of the matrix material

3. **DEPTH OF BURIAL:**

As a result elasticity increases and porosity decreases that in turns makes a corresponding increase in the velocity. An empirical formula for velocity in terms of depth of burial 'Z' and the formation resistivity *'R'* is,

$$\textbf{Velocity} = 2*10^3(ZR)^{1/6}$$

4. AGE OF THE ROCK:

An older rock might be expected to have a higher velocity, having been subjected for a longer time to pressure, cementation and other factors they might increase its velocity.

5. TEMPERATURE:

Seismic velocities decrease slightly with increase in temperature.

6. NATURE OF INTERSTITIAL FLUIDS:

Sand, containing water in pore spaces has higher seismic velocity than that containing oil and gas.

6.4 SIGNIFICANCE OF VELOCITY ANALYSIS:

We know that normal move out is defined as

$$NMO = T_x - T_0$$

Where

T_0 = Vertical two- way time.

T_x = Slant 2-way travel time.

Before reflection can be related to reflector depths, the non-vertical component of travel time must be removed. Root mean-square velocity (Vrms) and stacking velocity (Vnmo) are types of velocity that can be used to correct for normal moveout. Root-men-square velocity is determined from borehole measurements and stacking velocity is determined from analysis of seismic data.

(Zia 1989)

6.5 VELOCITY DETERMINATION:

The analytical processed and measuring techniques of velocity are listed below, (Zia 1989).

VELOCITY SURVEY IN WELLS:

Velocity surveys in well can be done in two ways:

1. SONIC LOGING:

Sonic log (also called the acoustic transit time logs or continuous velocity logs) measures the travel time in rocks adjacent to the Borehole, over intervals of about one foot. They are used for several geological and geophysical applications, including the determination of interval velocities over one-foot intervals through out the depth range of the log. These values are approximately equal to instantaneous velocities.

A sonic-log sonde consists of a cylinder about twenty feet long containing a sound source near each end and two pairs of detectors near the center. Each detector pair is separated by about one foot. As the sonde is raised slowly through the bore-hole, the sound sources are fired alternately, and successive pairs of the transit times, (t1-t3) and (t4-t2), are averaged to reduce effects of irregular side-walls and sonde tilt. The resulting log shows transit times in microseconds per foot.

An integrated sonic log shows the running sum of transit times in the boreholes. It is usually displayed as a sequence of spikes along the edge of the log at depth intervals corresponding to either one-millisecond or ten-millisecond time intervals.

Sonic logs can measure rock velocities only in uncased boreholes. Usually at least surface casing has been set before a sonic log is run, so the logged interval does not extend upward to the surface or elevation datum.

2. WEL GEOPHONE:

Well velocity surveys are made by using a seismic energy source (dynamite, vibroseis, air gun, etc) at or near the surface with in about 1000 feet of a deep borehole and recording the initial shock wave with a special down hole geophone. Well geophone, which is waterproof and can be clamped to the side of the well, is lowered to different positions where it is used to detect wave from small explosions on the land surface close to well. The velocity *"V"* is found from the difference in arrival times $\Delta t = t_2 - t_1$ over an interval of two geophone positions.

$$\Delta z = z_1 - z_2$$
$$V = \Delta z / \Delta t$$

3. T2- X2 METHOD:

This method is based on the equation

$$T^2 = X^2 / V^2\ rms + T_O^2$$

Where we plot T^2 as a function of X^2, we get a straight line whose slope is $1/V^2$ rms whose intercept is T_0^2 from, which we determine, the corresponding depth.

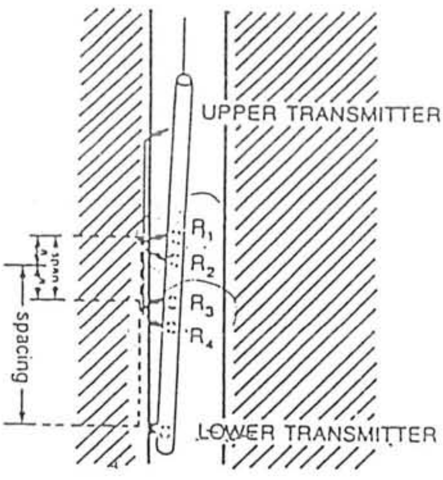


Fig. 4.23 Sonic Log Sonde

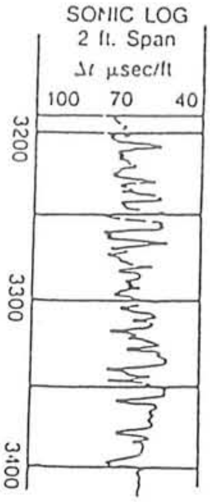


Fig. 4.24 Sonic log

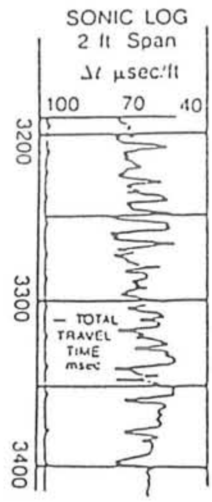


Fig. 4.25 Intergrated Sonic Log

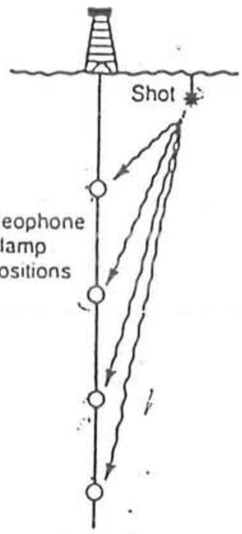


Fig. 4.26 Well Velocity Survey

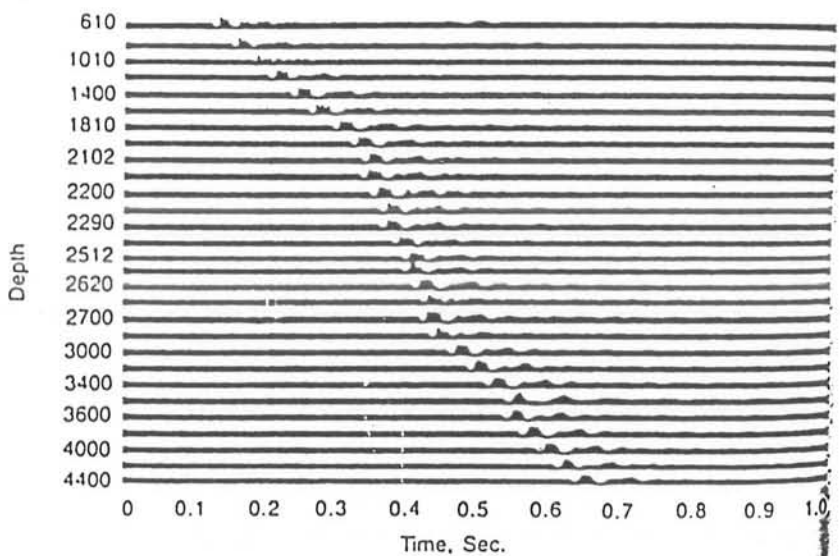


Fig. 4.27 Well Velocity Survey Downhole Recording

6.6 Compressional and Shear Velocities in Rocks:

MATERIAL	Compressional Velocity		Shear Velocity	
Source	m/s	ft/s	m/s	ft/s
Granite	5520-5640	17,200	2870-3040	10,000
Granodiorite	4780	15,800	3100	10,200
Diorite	5780	19,100	3060	10,100
Gabroo	6450	21,300	3420	11,200
Basalt	6400	21,100	3200	10,500
Sand Stone	1400-4300	14,200		
Lime Stone	1700-6060	13,900	2880	9500
Clay	1100-2500	3630		
Loose Sand	1800	5940	500	1650

INTERPRETATION

7.1 Introduction:

The word interpretation has been given many different meanings by geophysicists who deal directly with seismic sections and by the geologists and geophysicists who coordinate the geologic information with the seismic information. To some it is virtually equivalent to data processing and is tied inextricably to computer software.

Different procedures are adopted for the interpretation of 2-D and 3-D seismic data. The result of 2-D surveys are presented to the seismic interpretation as Non-Migrated and Migrated seismic sections, form which the geological information is extracted by suitable analysis of the pattern of reflection events. Interpretations are co-related from line to line and the reflection times of picked events are compared directly at profile intersection. There are two main approaches to the interpretation of seismic sections.

a) Structural Analysis
b) Stratigraphical analysis

Both structural and stratigraphical analyses are greatly assisted by "Seismic Modeling" in which the theoretical seismograms are constructed for layered models in order to derive insight in to the physical significance of reflection events contained in seismic sections.

In the interpretation of 3-D survey data, the interpreter has direct access at a computer station to all the reflection data contained with in the seismic data volume, and is able to select various types of data for color display.

7.2 Structural Analysis:

The main application of the structural analysis of seismic sections in the search for structural traps containing hydrocarbons. Interpretation usually takes place against a background of continuing exploration activity and an associated increase in the amount of information related to the subsurface geology. Reflection events of interest are usually "color-coded" initially and labeled as e.g. "Red-Reflector", "Blue-reflector", until there geological significance is established. Whereas an initial interpretation of reflections displayed on seismic sections may lack geological control, at some point the geological nature of the reflectors is likely to become established by tracing reflection events back either to outcrop or to an existing borehole for stratigraphic control.

Most structural interpretation is carried out in units of two-way reflection time rather than depth, and time structure maps are constructed to display the geometry of selected reflection events by means of contours of equal reflection time. Structural contour maps can be produced from time structure maps by conversion of reflection times in to depths using appropriate velocity information. Time structure maps obliviously bear a close similarity to structural contour maps but are subject to distortion associated with lateral or vertical changes of velocity in the subsurface interval overlying the reflector.

7.3 Stratigraphical Analysis:

Seismic stratigraphic involves the subdivision of seismic sections in to sequences of reflections that are interpretated as the seismic expression of genetically related sedimentary sequences. Having subdivided a seismic section into its constituent sequences, each sequence may be analyzed in terms of the internal deposition of reflection events and their character, to obtain insight into the depositional environments responsible for the sequence and in to the range of lithofaces that may be represented within it. This use of reflection geometry and character to interpret sedimentary facies is known as "Seismic facies Analysis".

Different types of reflection configuration are diagnostic of different sedimentary sequences. On a regional scale, for example, parallel reflections characterize some shallow water shelf environments. While the oblique cross-bedded shows the deeper water environment. The ability to identify particular sedimentary environments and predict lithofacies from analysis of seismic section can be of great value to exploration programmers, which provide a pointer to the location of potential source, reservoir and seal rocks.

This method also facilitates for the identification of the major proghraditional sedimentary sequences, which offer the main potential for "Hydrocarbon" generation and accumulation. Stratigraphical analysis therefore greatly enhances the chances of successfully locating hydrocarbon traps in sedimentary basin environments. Hydrocarbon accumulation are some times revealed directly on true-amplitude seismic sections by localized zones of anomalous strong reflections known as "Bright Spots". These high amplitude reflection events are attributable to the large reflection coefficients at the top and bottom of gas zones, with in a hydrocarbon reservoir. In the absence of "Bright Spots", fluid interfaces may nevertheless be directly recognizable reflection events discordant to the local geological dip.

7.4 Seismic Time Section:

Time section is actually the reproduction of reflectors marked on the given processed seismic section. The time of each reflector is read from the seismic section and then plotted against the shot points to draw a time section.(Figure7.4)

7.5 Iso-Velocity Contour Map:

In the given seismic section. RMS, Dix Average and Dix Interval velocities at different shot points have been provided Dix Average Velocities vary from 2100 to4400 m /sec for 2000 mili Seconds data and have been taken into account to construct a velocity contour map. Seismic velocity contour map helps to understand subsurface structures. The average velocities were calculated at the CDP's 149,183,208,233,253,283, and 308 directly from the interval velocities with the help of Dix Formula. (Table:7.1)

A considerable changes in the average velocity with time exists vertically and it is related to the fact that average velocity change with the physical change, and thus compaction and lithological change cause increase in velocity. ((Figure 7.1)

Equally spaced contours in the average velocity contour map represent the constant velocity gradient, while the widely spaced counters show the low velocity gradient.

With in a formation widening and closing of contour spacing show changes due to change in porosity and nature of interstitial fluids. The closely spaced contours show the very high gradient of velocity change, the contours can be observed to become close in the lower part. Thus it can be easily concluded that the average velocity increases with depth and the velocity gradient increases in the deeper strata. By observing the seismic section, it may be concluded that sharp gradient of velocity change results from more compaction.

7.6 Depth section:

The depth of each horizon can be calculated by their respective time and velocity with the help of the following relation

DEPTH = (Two way time x Velocity /2)

$$D = (T \times V) / 2$$

Where

T = Two way vertical time in seconds.

V = Dix Average Velocity in m /Sec.

First of all a horizon is selected from seismic section and then reflection time at the top of the horizon is read at suitable interval of shot points and then used to calculate the depth. This calculated depth is then plotted against the S.P's to get the depth section.

7.7 Methods Applied for the Preparation Of Depth Section:

An accurate measurement of seismic velocities is an important step in seismic data processing. Three different methods have been applied for the calculation of the depth for different horizons

1) Depth Section by taking Mean Of All Average Velocities.
2) Depth Section by Dix Average velocity.
3) Depth Section by Dix Constant average velocity method.

1) Depth Section by taking Mean Of All Average Velocities:

Plotting the average velocities at there different times, draw the mean average lines (Figure: 7.3). An average line is then drawn statically, by taking arithmetic mean of the average velocities at different SP at continuous time intervals (Table: 7.3), which represents the general trend of the plotted average velocity lines. The depth of each horizon can be estimated by putting these velocities and their respective time in the depth formula. Then plotting the depth of horizon under their SPs generates a depth section (Figure: 7.4). The observed reflectors of this depth section are given.

REFLECTOR - R1:

This reflector starts at depth 256 m at SP #160 and ends at depth 348 m at SP # 270. Minimum depth is 141m at SP # 235 and maximum depth is 348 m at SP # 270. Table (7.4a).

REFLECTOR –2:

This reflector starts at depth 456 m at SP# 160 and ends at 471 m at SP# 270. Minimum depth is 256 m at SP # 235 and maximum depth is 483 m at SP# 255. Table (7.4b).

REFLECTOR-3:

This reflector starts at depth 907 m at SP # 160 and ends at depth 832 m at SP # 270. Minimum depth is 550 m at SP # 235 and maximum depth is 907 m at SP# 160. Table (7.4C).

7.8 Structural Analysis:

It is based on the reflector geometry on the basis of reflector times. Most of structural interpretation is carried out in units of two ways reflection time rather than depth, and time structure maps are constructed to display the geometry of selected reflection events by means of equal reflection time.

From the "Depth Section" (figure: 7.4), it is clear that reflector R1 and reflector R2 are not horizontal. These may represent that the depositional environmental is uniform but due to strong tectonic forces the area is highly deformed.

7.9 Stratigraphic Analysis:

The stratigraphic interpretation of the seismic time section is done keeping in view the constructed depth section and the geology of the area. Sedimentary rocks are present in the area. GAJ formation of Miocene may be present between between reflector R2 and R3. Chinji formation and Nagri formation of late Miocene and early Pliocene age are also present above Gaj formation between R2 and R3. Chingi formation of Pliocene age may be present above R2. Nari formation of Oligocene age may be present below R3. Lateral and vertical variations of velocity may be due to structural variations and changes in physical properties of subsurface material.

The following sequence of formation is determined on the basis of reflector depth and geology of the area.

Late Miocene to Pleistocene age rocks are present above reflector R3.

Reflector R3 marks the base Miocene Rock that is Probably unconformity.

Below R3 rocks of Oligocene, Eocene and Paleocene ages are present.

TABLE FOR THE VALUES OF V (int) AND V (avg) FOR

SP#149

Time	V (Rms)	V (int)	V (Avg)
0	1900	1900	1900
450	2100	2100	2100
620	2600	3602.85	2512.07
650	2900	6519.97	2697.05
760	3300	5054.16	3038.21
900	3500	4430.89	3254.84
1500	3900	4432.83	3726.03
3000	4500	5028.91	4377.47
3300	4500	4500	4388.60

SP#183

Time	V (Rms)	V (int)	V (Avg)
0	1900	1900	1900
430	2100	2100	2100
580	2600	3673.78	2507.01
620	2900	5686.38	2712.13
750	3300	4766.30	3068.18
900	3500	4364.63	3284.25
1500	3900	4432.83	3743.68
3000	4500	5028.91	4386.26
3300	4500	4500	4396.60

SP#208

Time	V (Rms)	V (int)	V (Avg)
0	1000	1000	1000
450	2100	2100	2100
580	2600	3859.35	2494.33
630	2900	5248.80	2712.93
720	3300	5315.07	3038.19
830	3500	4599.11	3245.05
1500	3900	4344.75	3736.24
3000	4500	5028.91	4382.57
3300	4500	4500	4393.24

SP#233

Time	V (Rms)	V (int)	V (Avg)
0	1900	1900	1900
420	2100	2100	2100
520	2600	4077.99	2614.99
710	3300	4710.96	3175.88
800	3500	4793.62	3357.87
1500	3900	4311.94	3803.10
3000	4500	5028.91	4416.00
3300	4500	4500	4423.63

SP#253

Time	V (Rms)	V (int)	V (Avg)
0	1900	1900	1900
500	2100	2100	2100
610	2600	4176.34	2474.42
710	3300	6006.91	2971.95
790	3500	4931.53	3170.38
1500	3900	4301.57	3705.81
3000	4500	5028.91	4367.36
3300	4500	4500	4379.41

SP#283

Time	V (Rms)	V (int)	V (Avg)
0	1900	1900	1900
500	2100	2100	2100
670	2600	3697.53	2505.34
820	3300	5416.39	3037.84
920	3500	4837.56	3233.46
1500	3900	4461.52	3708.31
3000	4500	5028.91	4368.61
3300	4500	4500	4380.55

SP#308

Time	V (Rms)	V (int)	V (Avg)
0	1800	1800	1800
280	1900	1900	1900
500	2100	2329.84	2089.13
680	2600	3645.24	2501.04
800	3300	5856.05	3004.29
920	3500	4616.99	3214.64
1500	3900	4461.52	3696.76
3000	4500	5028.91	4362.83
3300	4500	4500	4375.30

Iso Velocity Contour Map Data

V (asum)	SP#149	SP#183	SP#208	SP#233	SP#253	SP#283	SP#308
2100	450	430	450	420	500	500	504.04
2500	617.02	578.37	581.31	497.12	616.3	668.57	679.71
2700	650.71	617.22	626.99	536.89	665.6	722.05	734.08
3000	750.44	733.33	710.94	670.68	716.7	809.78	798.85
3300	912.48	904.31	844.05	786.21	822.29	938.92	944.42
3700	1489.52	1482.49	1485.45	1459.32	1497.64	1496.63	1501.31
4300	2946.9	2941	2943.47	2921.19	2953.72	2952.87	2956.78
4400	3308.57	3302.55	3305.07	3282.37	3315.51	3314.65	3318.62

Table: 7.1

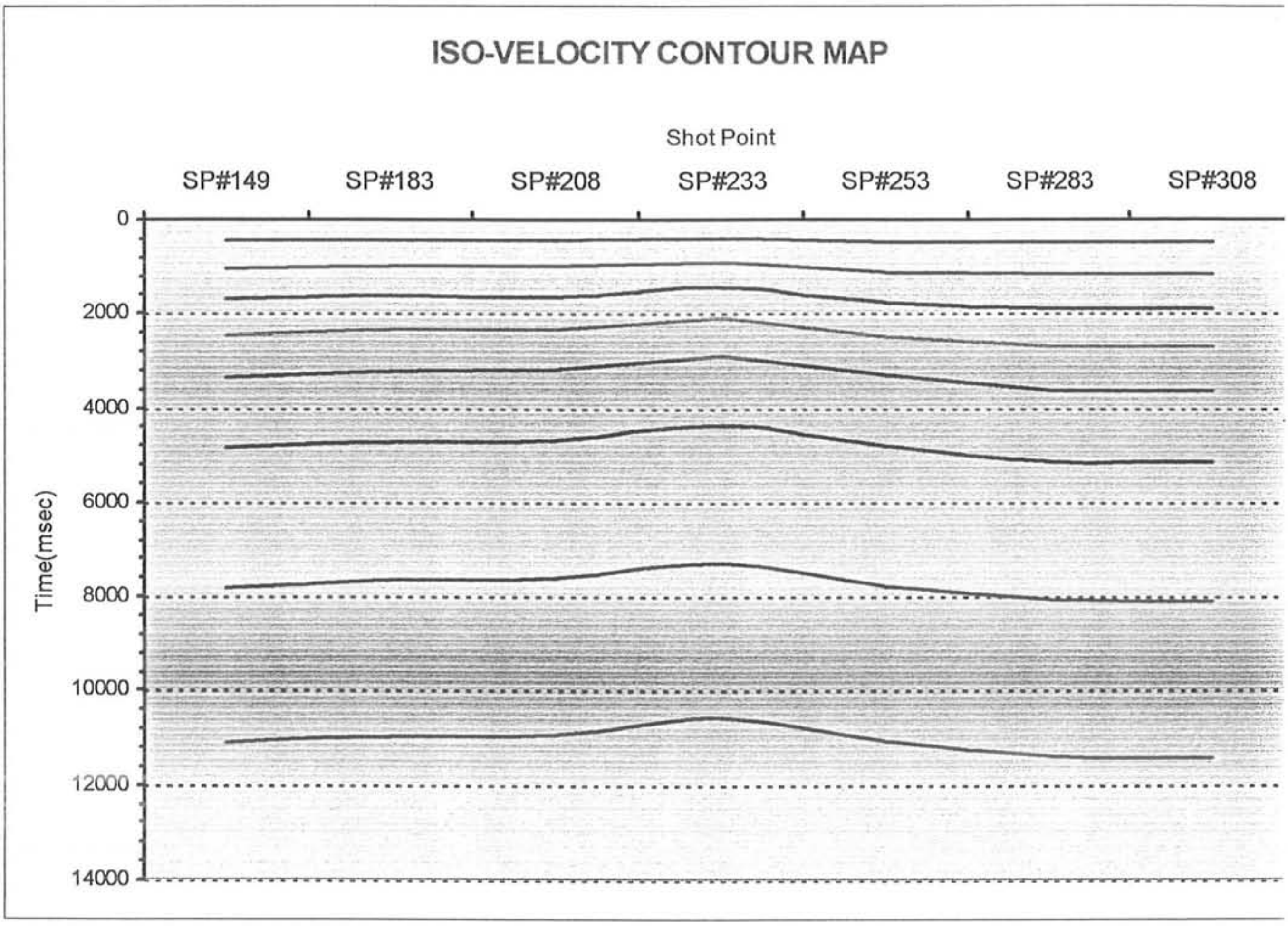

ISO-VELOCITY CONTOUR MAP
Shot Point
SP#149
SP#183
SP#208
SP#233
SP#253
SP#283
SP#308
Time(msec)
0
2000
4000
6000
8000
10000
12000
14000

Figure:7.1

Average Velocity Data of Seismic Section Windows

Time(ms)	SP#149	SP#183	SP#208	SP#233	SP#253	SP#283	SP#308
0	1900	1900	1000	1900	1900	1900	1800
500	2021	2290	2252	2512	2100	2100	2089
600	2264	2610	2582	2850	2406	2338	2317
700	2852	2931	2966	3148	2922	2612	2585
800	3100	3140	3189	3358	3178	2967	3004
900	3255	3284	3519	3421	3253	3194	3179
1500	3726	3744	3736	3803	3706	3708	3697
3000	4377	4386	4383	4416	4367	4369	4363
3300	4389	4397	4393	4224	4379	4381	4375

Table: 7.2

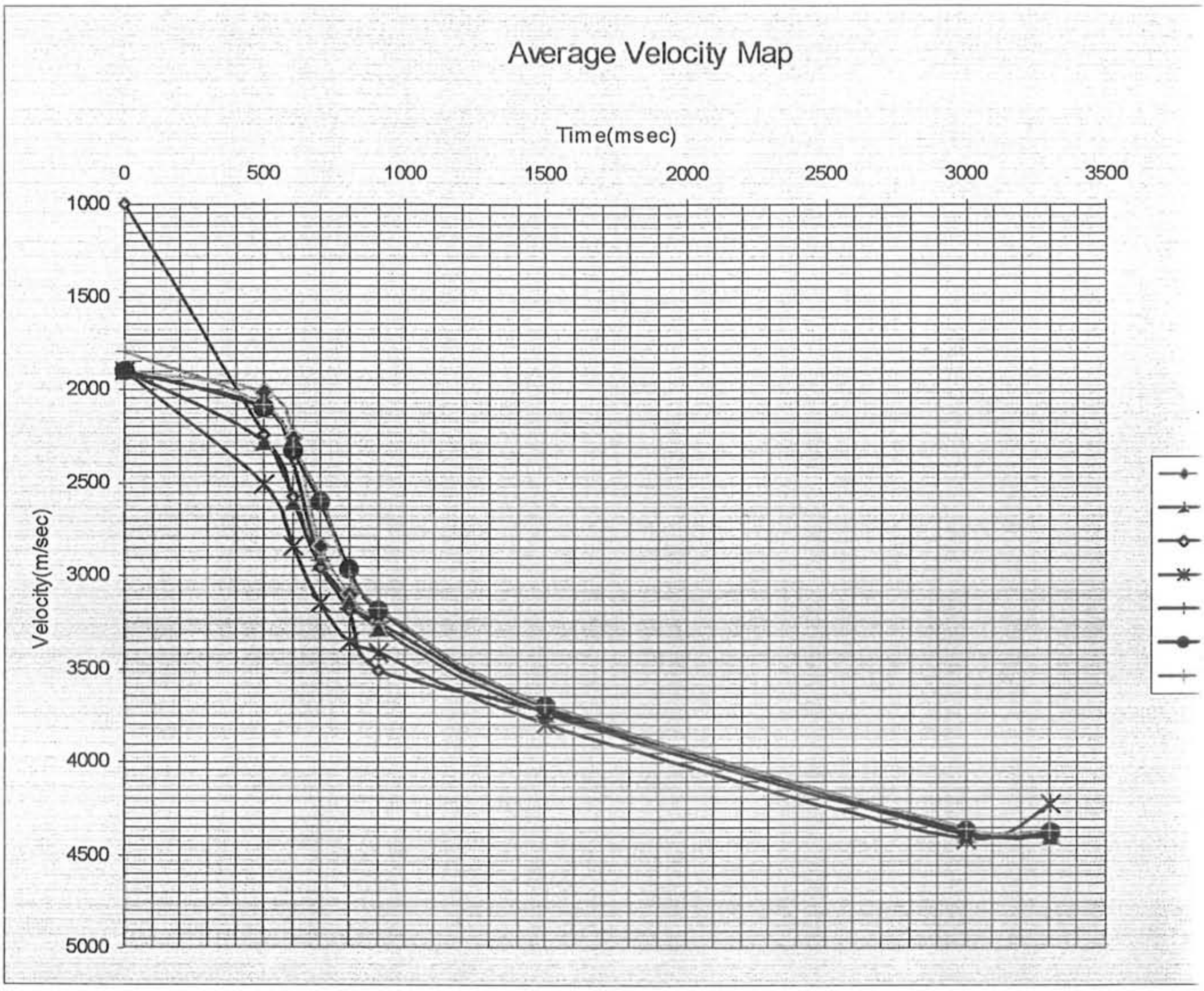

Average Velocity Map
Time(msec)
0
500
1000
1500
2000
2500
3000
3500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Velocity(m/sec)

Figure: 7.2

Mean Average Velocity Data of Seismic Section Windows

Time (ms)	SP#149	SP#183	SP#208	SP#233	SP#253	SP#283	SP#308	Mean Avg.velocity
0	1900	1900	1000	1900	1900	1900	1800	1757.143
500	2021	2290	2252	2512	2100	2100	2089	2194.857
600	2264	2610	2582	2850	2406	2338	2317	2481
700	2852	2931	2966	3148	2922	2612	2585	2859.429
800	3100	3140	3189	3358	3178	2967	3004	3133.714
900	3255	3284	3519	3421	3253	3194	3179	3300.714
1500	3726	3744	3736	3803	3706	3708	3697	3731.429
3000	4377	4386	4383	4416	4367	4369	4363	4380.143
3300	4389	4397	4393	4224	4379	4381	4375	4362.571

Table: 7.3

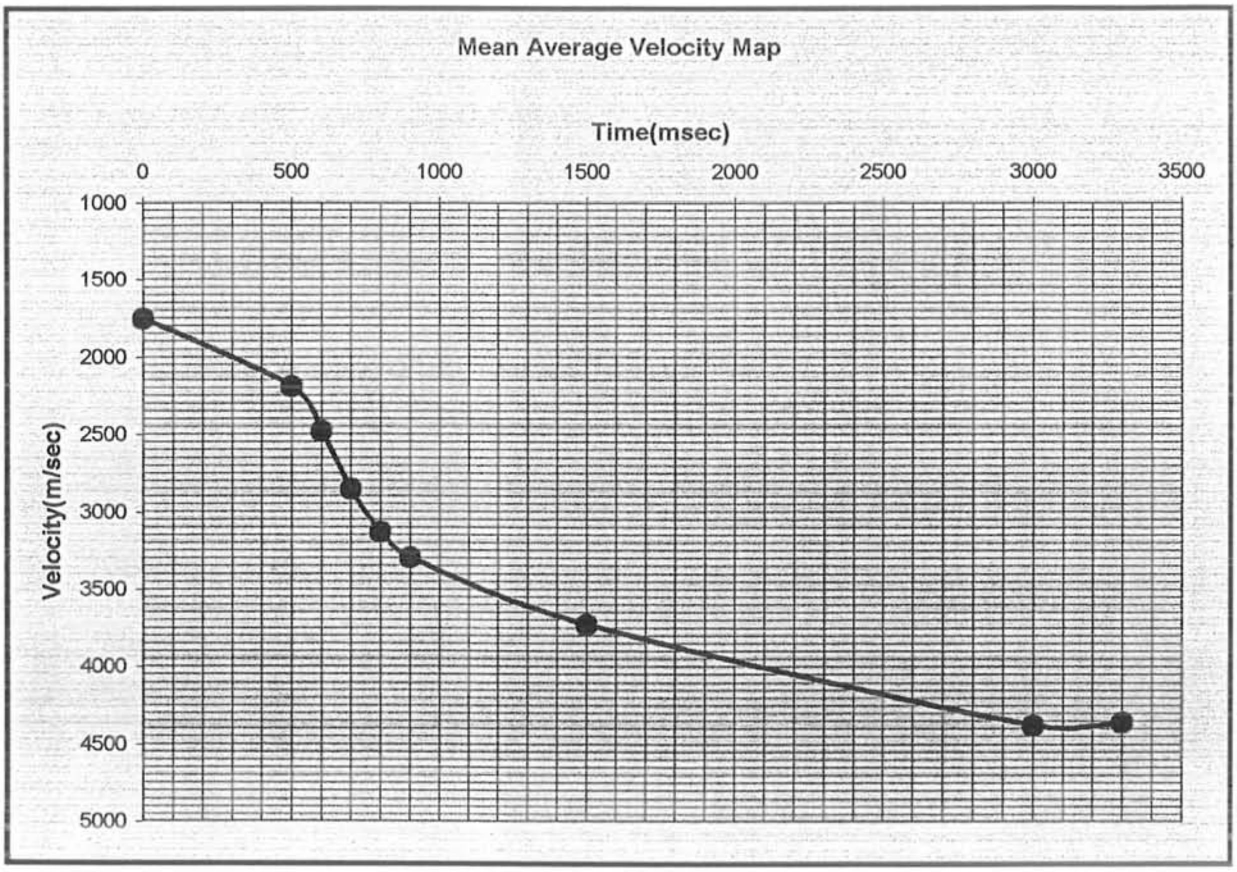

Mean Average Velocity Map
Time(msec)
0
500
1000
1500
2000
2500
3000
3500
Velocity(m/sec)
1000
1500
2000
2500
3000
3500
4000
4500
5000

Figure:7.3

Time Section

Shot Point	Reflector # R1	Reflector # R2	Reflector # R3
160	0.26	0.43	0.66
165	0.24	0.40	0.65
170	0.2	0.36	0.64
175	0.19	0.35	0.64
180	0.22	0.40	0.61
185	0.23	0.41	0.63
190	0.23	0.41	0.63
195	0.25	0.42	0.64
200	0.25	0.42	0.63
205	0.23	0.40	0.62
210	0.22	0.39	0.62
215	0.21	0.36	0.61
220	0.18	0.34	0.60
225	0.17	0.30	0.57
230	0.16	0.30	0.54
235	0.15	0.26	0.50
240	0.20	0.30	0.51
245	0.24	0.37	0.55
250	0.28	0.41	0.60
255	0.29	0.45	0.62
260	0.29	0.45	0.63
265	0.32	0.45	0.64
270	0.34	0.44	0.64

Table: 7.3b

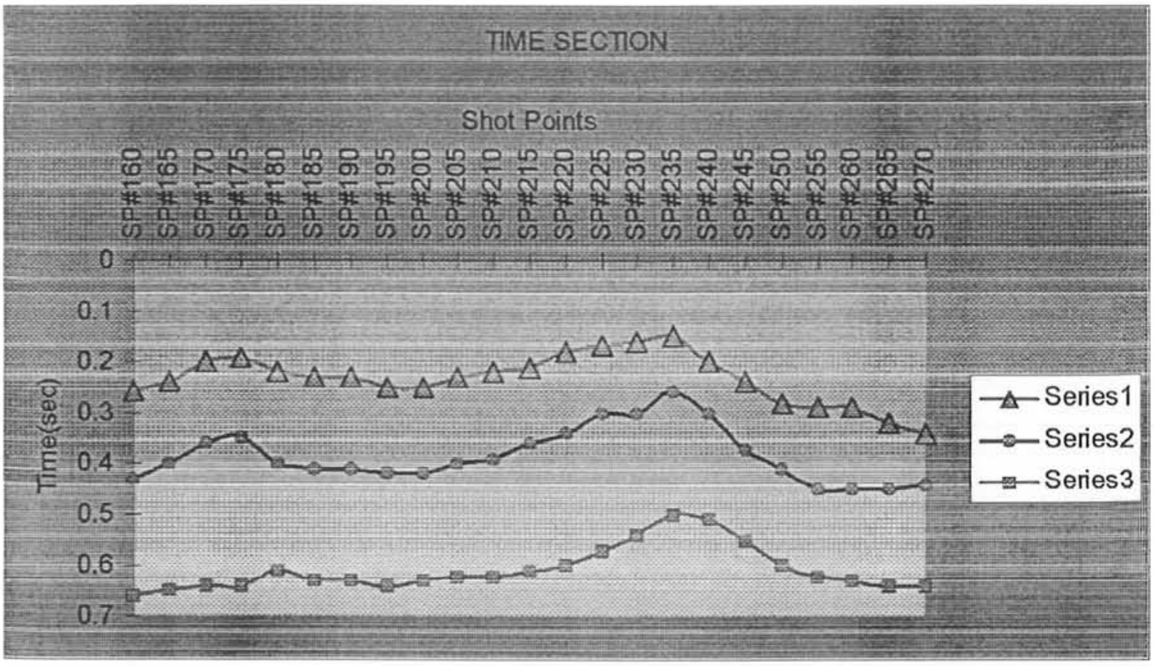

TIME SECTION
Shot Points
SP#160
SP#165
SP#170
SP#175
SP#180
SP#185
SP#190
SP#195
SP#200
SP#205
SP#210
SP#215
SP#220
SP#225
SP#230
SP#235
SP#240
SP#245
SP#250
SP#255
SP#260
SP#265
SP#270
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time(sec)
Series1
Series2
Series3

Fig: 73 b

REFLECTORS W.R.T. MEAN AVERAGE VELOCITY

REFLECTOR #1 (R1)

SP#	Time (msec)	Vavg (m/sec)	Depth (m)
160	260	1970	256.1
165	240	1950	234
170	200	1925	192.5
175	190	1890	179.55
180	220	1935	212.85
185	230	1940	223.1
190	230	1940	223.1
195	250	1960	245
200	250	1960	245
205	230	1940	223.1
210	220	1935	212.85
215	210	1925	202.125
220	180	1905	171.45
225	170	1900	161.5
230	160	1895	151.6
235	150	1880	141
240	200	1925	192.5
245	240	1950	234
250	280	2000	280
255	290	2005	290.725
260	290	2005	290.725
265	320	2025	324
270	340	2050	348.5

Table: 7.4a

REFLECTOR #2 (R2)

SP#	Time (msec)	Vavg (m/sec)	Depth (m)
160	430	2125	456.875
165	400	2100	420
170	360	2085	375.3
175	350	2050	358.75
180	400	2100	420
185	410	2110	432.55
190	410	2110	432.55
195	420	2118	444.78
200	420	2118	444.78
205	400	2100	420
210	390	2095	408.525
215	360	2056	370.08
220	340	2050	348.5
225	300	2004	300.6
230	300	2004	300.6
235	260	1970	256.1
240	300	2004	300.6
245	370	2065	382.025
250	410	2110	432.55
255	450	2150	483.75
260	450	2150	483.75
265	450	2150	483.75
270	440	2145	471.9

Table: 7.4b

REFLECTOR #3 (R3)

SP#	Time (msec)	Vavg (m/sec)	Depth
160	660	2750	907.5
165	650	2650	861.25
170	640	2600	832
175	640	2600	832
180	610	2535	773.175
185	630	2575	811.125
190	630	2575	811.125
195	640	2600	832
200	630	2575	811.125
205	620	2550	790.5
210	620	2550	790.5
215	610	2535	773.175
220	600	2500	750
225	570	2300	655.5
230	540	2250	607.5
235	500	2200	550
240	510	2205	562.275
245	550	2260	621.5
250	600	2500	750
255	620	2550	790.5
260	630	2575	811.125
265	640	2600	832
270	640	2600	832

Table :7.4c

Table for the calculation of depth section

SP#	Depth.R1	Depth.R2	Depth.R3	Fault 1	Fault 2	Fault 3
160	256.1	456.875	907.5	---	---	---
165	234	420	861.25	---	---	---
170	192.5	375.3	832	---	---	---
175	179.55	358.75	832	---	---	---
180	212.85	420	773.175	---	---	---
185	223.1	432.55	811.125	---	---	---
190	223.1	432.55	811.125	---	---	---
195	245	444.78	832	832	---	---
200	245	444.78	811.125	444.78	---	---
202	234	420	790.5	234	---	---
205	223.1	420	790.5	---	---	---
210	212.85	408.525	790.5	---	---	---
215	202.125	370.08	773.175	---	---	---
220	171.45	348.5	750	---	---	---
225	161.5	300.6	655.5	---	---	---
230	151.6	300.6	607.5	---	---	---
235	141	256.1	550	---	141	---
236	141	256.1	550	---	171.45	---
238	179.55	250	486	---	432.55	---
240	192.5	300.6	562.275	---	562.275	---
243	202.215	358.75	607.5	---	---	202.125
244	202.125	370.08	575	---	---	212.85
245	234	382.025	621.5	---	---	420
247	250	408.525	655.5	---	---	562.275
250	280	432.55	750	---	---	886.25
255	290.75	483.75	790.5	---	---	---
260	290.75	483.75	811.125	---	---	---
265	324	483.75	832	---	---	---
270	348.5	471.9	832	---	---	---

Table: 7.4d

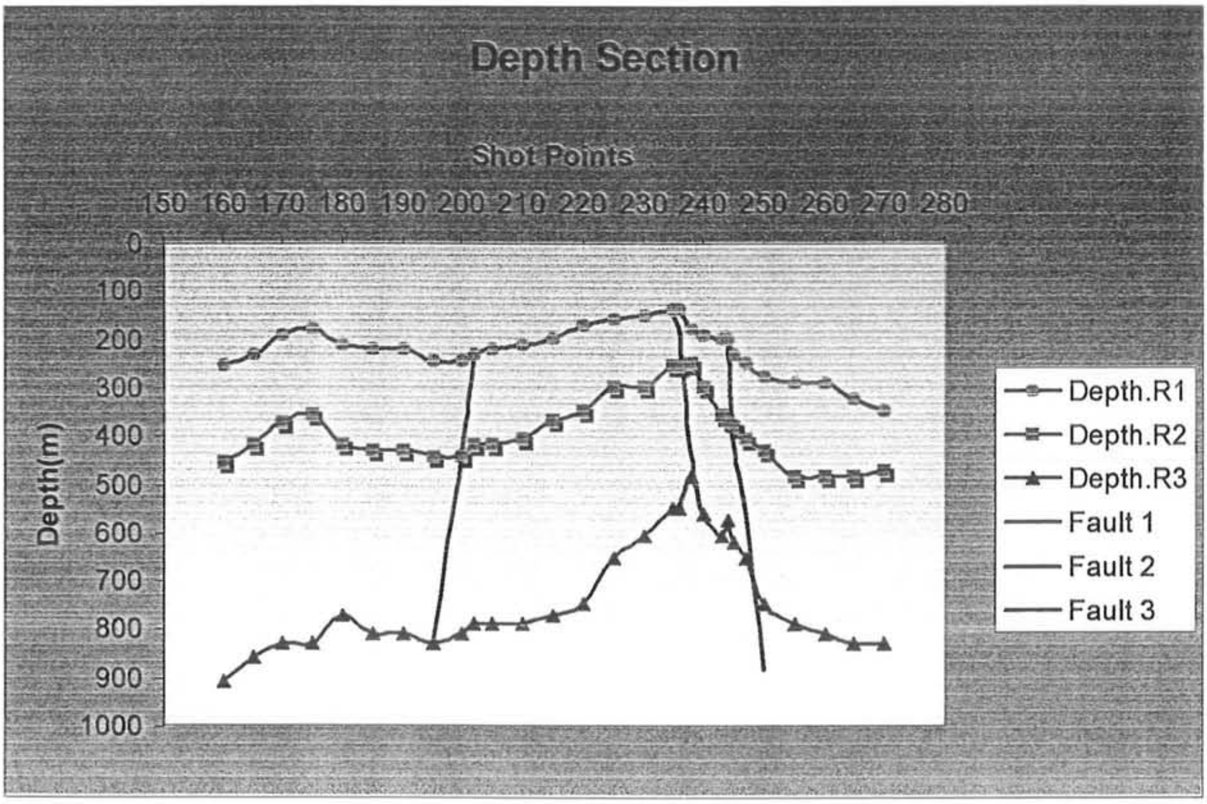

Depth Section
Shot Points
150 160 170 180 190 200 210 220 230 240 250 260 270 280
0
100
200
300
400
500
600
700
800
900
1000
Depth(m)
Depth.R1
Depth.R2
Depth.R3
Fault 1
Fault 2
Fault 3

Figure: 7.4

REFERENCES

1) Al-Sadi H.N. (1980), "Seismic Exploration Technique and Processing", Birkhauser Verlag, Boston, 215 P.
2) Kearey, P., Brooks M. (1991),"An Introduction to Geophysical Exploration".Blackwell Scintific Publications, Oxford 254 P.
3) Kazmi, A.H. & Jan, M.Q.(1977),"Geology and Tectonics of Pakistan". Exploration Publishers , Karachi, Pakistan, 133 P.
4) Dobrin M.B & Savit C.h., (1988)," Introduction to Geophysical Prospecting", (4th Edition), Mc, Graw-Hill Book Company, 867P.
5) Robinson E.S., Corugh C. (1988)," Basic Exploration Geophysics", John Wiley & Sons, inc New York, 562 P.
6) Nettleton.L.L (1940),"Geophysical Prospecting for Oil", Mc-Graw- Hill Book Company, INC. 444 P.
7) Zia (1988) ," Basic Seismic Processing Theory and Fundamentals", O.G.C.L.Pakistan