ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

FACULTY OF SCIENCE
DEPARTMENT OF EARTH SCIENCES

SURFACE WAVE INDUCED GROUND PARTICLES VIBRATION AT EASTERN AND WESTERN ETHIOPIAN PLATEAUS

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT FOR A MASTERS OF SCIENCES DEGREE IN APPLIED GEOPHYSICS

BY FISSEHA AYELE
Addis Ababa
EARTH SCIENCE DEPARTMENT
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Abstract

Blasting of explosives on or under the surface of the earth always induce seismic wave of all kinds that propagate in every direction away from the point of explosions. In the course of seismic propagation in ground medium, ground vibration will occur that may result distraction on man made structures unless appropriate seismic method of pre-Explosion ground vibration prediction are made to determine the size of explosive energy to be applied and relative distance of shot and man made structures are estimated.

In this research ground vibration prediction is made on the West and East Ethiopian plateau from surface wave recordings from two 900 kg and 1900 kg and 1100 Kg explosions made at Gohatsion and Gebre Guracha and Kula areas and peak ground vibration measurement made by Guralp 6TD seismic recorder at different points along EAGEAL profile 1.

As a result, the measured PPV at the western plateau is over determined by the oriard minimum prediction formula at large distances while at the Eastern plateau the observed value is greater than the prediction obtained from the Oriard maximum prediction formula.

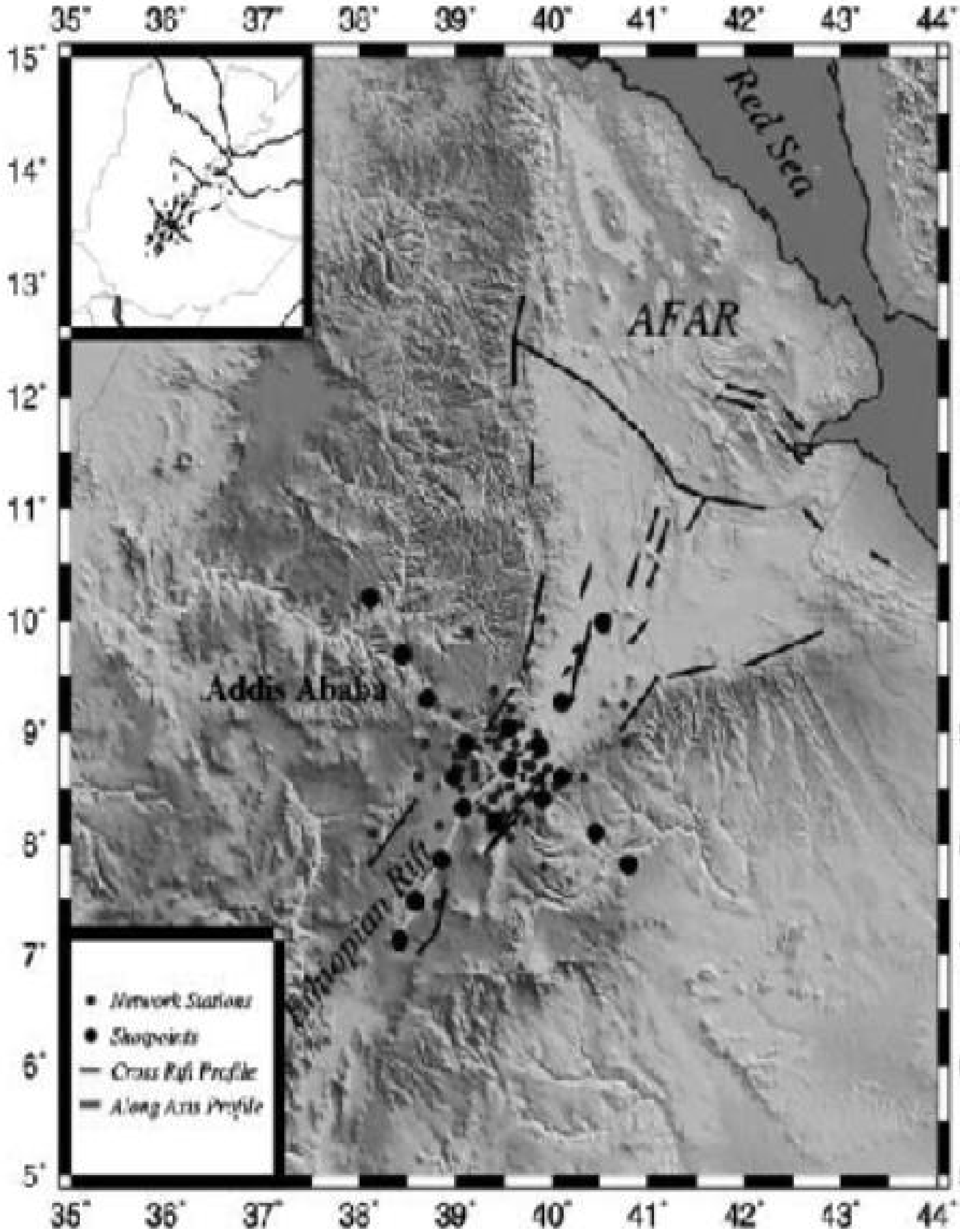

Red Sea
AFAR
Addis Ababa
Ethiopian Rift
Network Stations
Shotpoints
Cross Rift Profile
Along Axis Profile
35° 36° 37° 38° 39° 40° 41° 42° 43° 44°
15° 14° 13° 12° 11° 10° 9° 8° 7° 6° 5°

Fig. 1

1.2 REGIONAL GEOLOGY

As the Western Ethiopian plateau (WEP) is separated from main Ethiopian rift (MER) by sharp fault lines and its genesis and evolution is closely bounded to the East African rift system. MER is characterized by a series of major rift zones (Rosemdhal et.al 1986) having an extended existence ranging from Afar tipple Junction (as its extreme northern limitation) at Gulf of Aden – Red sea intersection to its extreme limit in The South at Ethio–Kenya boundary. The Ethiopian Rift is a part of East Africa Rift system. The main East African Rift system is elongating further to the south up to Zambezi – River basin in Mozambique with total North to South stretching of 3200 km.

The MER system is striking NNE from its southern extreme at (4^0 45^{11}) at lake Chamo (which is among Ethiopian Rift valley lakes) and continues so for 650km until it reaches AYELU volcano (at 9^0 , 45^{11}) and change its orientation from NNW with out any discontinuity. (mohr 1967 , wolde 1989).

The Genesis of North East Africa started about 30 million years ago due to letothermic forces induced from stationery and upper mantle originated very high thermal post that made the upper mantil execute series of up lifts. As result of some mantilla induced activates, three radial up lifts had developed. These three radial up lifts are identified as the RED SEA RIFT SYSTEM (RSR) the GULF OF ADEN RIFT SYSTEM(GER) and the most NORTH AFRICAN system. Among these three systems, the last one i.e NAR system is relatively in active while RSR and GER systems are extremely active to be the diverging boundary of the Arabian pensula from north East-Africa. These three rift systems form about $120\ ^0$ triple junction at AFAR Depression and made that point become a unique site of shallow tectonically active crust (Plumer 1998) and with several surface high thermal manifestations and Active Volcanism s.

The East African rift system has four major subs – parts which are the Lake Turkana, Lake Chew Bahir , the Main Ethiopian Rift (MER) and the Afar Triple Junction Depression. The fact that East African Rift system is very young and active rift system and its being an origin of oceanic ridge system. This made it to be characterized by various active volcanisms, weak and strong earth quakes (EAGLE 2004). Unlike the West African rift complexes which is relatively older, and non – oceanic ridge system (Mc Cannel, 1967) the EAR system is in a process of changing Geological picture of the African content.

The natural development and its distinguishing tectonics is forwarded to be in various manner including power tension (Di Palola 1972 , Woldegebriel et at 1990 Ebinger et el)), translational (Boccalettlet et at 1992) and oblique (Bonini et at 1997). The nature of active tectonics at Afar of MER is not limited to the tripped junction but also extended to the south being manifested by the occurrence of ten major volcanic centers as well as some major earth quake distributions. Recent scientific studies have confirmed that specific point just south of Ankober (south shewa) on the Western rift margin experienced intensive seismic disturbance(E. Daly, A Ayele, EAGLE 2004) and the region may serve as accommodation zone where the north ward propagations MER links with southern red sea lifts.

The main Ethiopian rift separates the Western and the Eastern plateaus and is much believed to be widening in its cross over distance as it becoming ocean meet and the place of new geologic scenario of the planate. As several scientific predication are confirming the MAR (and mainly at MER) will develop to be the splitting apart of the two African plate and the genesis of new ocean along the strike like of the Ethiopian dome.

The Ethiopian Western plateau is confined between the MER and the Sudan plain and rising up in altitude between the two and West ward declining nature to wards the prominent escarpment over looking the West Ethiopian low land and the Sudan plain. Its highest pick is found at its northern part at Ras-Dashan which a volcanic mountain is rising up to 4550 m above sea level. It is covered with 1000m basaltic lava flow and with ignimbrite inter-bedded beds under massive rhiyolites and intervening tuff and basalt (Di-paola 1972, 1973 Merla et.al 1975).

Most other parts of West Ethiopian plateau (WEP) are characterized by successive lithologici units with an older age of 250 million years and Archaean creation with less folded and metamorphosed younger varieties and it is classified in to three major categories (Paul A, mojr 1971) according to there age and kind.

The Pre-Cambrian orogenic mountain ranges formed at the early times Geologic history ware believed to denudated resulting nearly penuplnated land because the Arab Ethiopian massive was a stable land mass. Even if some local occurrences of Paleozoic **stratus** are occurring at some places (mohor 1971). The above denudalation was regionally true. The most distinguishable lithologic units of late time are edaga glacials and enticho sand stones which are believed to be records of the paleozic era. The existence of unconformity is between Adegrat sand stone and under lying clasties is not greater significant. The Paleozoic time clasties and the Mesozoic Adgrat sand stones are with barely possible differentiation at most parts of the plateau.

In Mesozoic time the horn of Africa including WEP had been exposed to the transgression of the sea. At this time the previously existing gondwana land was over passed by large scale massive transgression and its sinking epeorogery happened to be in Triassic with its climax being during early upper Jurassic. It was thus later than the end of Mesozoic that the rising of the entire Horn of Africa was re-attained and become above the oceanic level (Vkazmin AA 1972).

The transgression of the sea is believed to be executed from South – East to North - West direction because the transgressive facies vary from upper Triassic age in Ogaden (SE) to lower even middle Jurassic in Tigray (NW). The Adegrat sand stone formed during that geological time is presently found all over the country with fairly constant thickness and small scale variations are observed with irregularities in basement complex peneplaneation. In most central parts of Ethiopia, the Adegrat sand stone is found with average thickmess of 500m while at some places it is as thick as 1000m while at others it is few meters.

The other rock unit abundant through out the Western plateau is the Antalo limes stone. It is observed to be lying over the basement complex in northern and central Ethiopia and every time under lain by the Adigrat sand stone. The Antalo lime stone is characterized by many lithological lime stone varieties which include layers of marland silt. The thickness of this widely spread lime stone is about 500m in most places while at other it may not be seen at all.

The other important lithologic manifeastation is volcanic – origin basalts of the lower cretaceous time transgression (tuff sand lava flows) the ambardam formation (Abate et at 1969) . The main geological event of that time was a new transgression of the sea beginning in the Aptian which was also a time of wide spread marine transgression of the whole Middle East.

The upper sand stone resulting from this is irregularly distributed and some isolated out crops exist with thickness up to 150m (mohor 1971).

Apart from lime stone and sand stones , some volcanic origin rock units are abundant in Western plateau of these varieties the Ashangi basalts (Eocene paleocne) are clearly out cropling at the north central parts of the Ethiopian plateau (Zanettin Visentin 1975). In addition, basalts and ignimbrites of the trap series from Eocena- late Mcocene are found in Western and Eastern (Ethiopian Somalia) plateaus. (paola 1972). At some places un weathed lava flows of the trap series covering the Mesozoic sediments are visible. The trap series is mostly of basaltic lava flows with subordinately associated ignimbrite units sandwiched between lavas. The trap series is formed by fissure eruptions of ages between Eocene-oligocen and over lain by thick accumulations of basaltic lava erupted from shield volcanoes. (mohor 1962 ,1972). The name Trap series is usually applied to compact basalt (Kazmin 1972). The thickeast sections of this group occur near to the main rift escarpment.

1.3 About Study:

The West Ethiopian plateau is the most densely in habited part of the country where different Socio-Economic activities are taking place among this activities , constructions of different infrastructures buildings, dams as well as excavations of rock as quarry activates are some . Such activities need the use of explosives. In the course of using explosives for different geo-technical and construction and purposes Seismic energy will be induced to the ground and can result damage to different man made strictures unless the size of explosives is predetermined based on the knowledge of ground particles vibration. This research is intended for the same.

1.4 Objectives

1. To make accurate prediction of surface wave induced ground vibration and Explore its variation with explosive size , distance as well as shot site.

2. To make practical validity test of Oriarld empirical prediction formula over the Western and the Eastern plateaus and deduce the reason why it is not working if found impractical.

1.5 Methodology

Surface wave recordings made by EAGEL project along EAGEL profile I and on the Western and Eastern plateau will be analyzed and interpreted acceding to the detailed description to discussed in the data acquisition part of this thesis.

CHAPTER II

THE FUNDAMENTAL PRINCIPLES AND THEORY OF SEISMIC WAVES

2.1 Introduction

Seismic Explorations are primarily founded on the observation of the propagation of mechanical waves in rock medium. By creating seismic disturbance at a known point on or under the surface of the earth, the propagated wave will be picked and recorded by special instruments designed for the purpose, so that the observed arrival of waves at other places will be analyzed and interoperated according to lows and principles of seismic theories.

In most ordinary cases, seismic waves behave similar to other mechanical elastic waves and seismic wave propagation in earth-medium as well as some physical parameters of the medium are used to describe elastic nature of rocks. This valid approach is used in the predictions and interpretations seismic wave propagation while in some other very complicated cases theories exciding the perfect elasticity of earth medium are also applied.

Seismic wave generation and its propagation is due to transfer of impulsive Energy from the source to the rock medium then the migration from a point to the other in the medium characterized by the applicant on transit-stress imbalance between points. Just like other mechanical waves the energy transport is executed by the action of unbalanced force action on the particles of the rock medium. This will make the particles to be in motion in the direction of acting for companies resulting of particle displacement. The displaced particles will retain there equilibrium position if the net acting force is released with out exciding the elastic limit of the rock medium.

During temporary displacement of particles of the medium, dislocation occur in such away that the expansion in one direction is co-occurring with contraction in others the net deforming force is removed, the medium of the original shape and size or re-attaining of original location of the particle is referred as elasticity.

Thus packets of seismic energy produced at a specific point will be transported in every direction away from the source. The rate of energy transport is strongly determined on density and elastic properties of the rock medium through which it is propagation. The propagation of such wave will be variable in accordance to venation of elastic properties and densities and this will make it possible to use seismic waves for study of the rock medium through which they are migrating.

2.2 SEISMIC WAVE THEORY

Seismic waves are mechanical waves propagating through elastic rock medium. Due to this seismic waves are treated in similar ways as other elastic waves. Elastic waves are coherent with an action of net force that creates temporary dislocation of particles of the medium. The dislocation of particles of the medium intern produces a change in shape and size of the particular volume enveloping the particles.

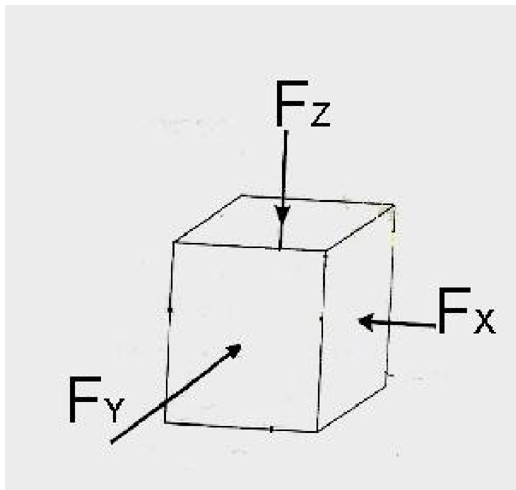
This change in the shape as well as the size of the theoretically taken isolated part of the medium is a dependent function of the magnitude and the direction of the active net force as well as on the cross sectional area upon which it is acting.

The theoretical formulation describing seismic propagation is founded on the following physical concepts.

1. STRESS

STRESS is defined as the ratio of net force acting on a cross-sectional area (A) which is normal to the net force.
In most real condition, the effect of the active force varies from one point to the other in medium. This stress varies in accordance to the variation of the force.

For the purpose of theoretical modeling let's assume that our isolated infinitesimal representative of the medium be three dimensional rectangular prism shaped enveloping a point inside it and centered we also assume that a force F acts on it. Introducing it in to a Cartesian coordinate system as shown below, we can easy observe that the net force F has components F_1 F_2 and F_3 acting parallel to the X, Y and Z axis's respectively.



Each force is acting on across sectional area perpendicular to it then we will have three independent stress related to the three components of the acting force.

Since stress is defined as the ratio of the active force to the cross-sectional area perpendicular to it

$$\text{STRESS (T)} = \frac{\text{Force Acting}}{\text{Perpendicular Area}}, \quad , \quad T = \frac{F}{\text{Apr.}} \qquad ....2.2.1$$

Such kinds of stress can be defined as normal stresses because the acting forces are effective on cross sectional area normal to them.

In situations where the force is not perpendicular to the element but act with some angle to the surface it can be solved as perpendicular and parallel Components in that case we have two kinds of stresses i.e normal stress and shear stress. We can then disenable the stresses T_{xx} T_{yy} T_{zz} as normal stresses and T_{xy}, T_{xz} , T_{yx}, T_{yz}, T_{zx} T_{zz} as shear stress.

Mathematically the above shear and normal stress are expressed as Follows

$$T_{xx} = \frac{F_x}{d_y d_z} \qquad T_{xy} = \frac{F_x}{dxdz} \qquad T_{yz} = \frac{F_z}{dxdy}$$

$$T_{yx} \quad \frac{F_y}{dydz} \qquad \frac{F_y}{dxdz} \qquad \frac{F_y}{dxdy}$$

$$T_{yy} \quad \frac{F_z}{dydz} \qquad \frac{F_z}{dxdz} \qquad \frac{F_z}{dxdy}$$

This leads to the concussion that the total stress T has a components and it can be described as tensor. Stress tensor is 2nd rank Tensor that can be described as

$$T = \begin{matrix} T_{xx} & T_{xy} & T_{xz} \\ T_{yx} & T_{yy} & T_{yz} \\ T_{zx} & T_{zy} & T_{zz} \end{matrix} \qquad \text{………… 2.2.2}$$

For the stress tensor described as above the diagonal elements Txx, Tyy and Tzz are normal stresses while other elements (off-diagonal elements are shear strains.

2. STRAIN

The Net force acting on an infinitesimal body of the medium resulted with normal and shear stresses. Due to these stresses particles of the body will be displaced from there original position to a new location and remain in the acquired new location until the action of the force or the stressing is removed. The infinitesimal body of volume V will then attain a new volume V^1 ($V^1= dx^1 dy^1 dz^1$) where. If an initially cantered practical is displaced from its original location by displacement vector u,v , and w in x, y, z, direction respectively. Then this dislocation or the resulting change in shape and size is described by strain.

Strain (e) is defined as the deformation of a body in a vicinity of a given point at which a reference practical is initially situated the dislocation of the particle to a new position is described by making position from original orientation. The first one is described by spatial gradient of the displacement vector (measuring elongation) called normal strain while the spatial gradient of angle (measuring internal angular elongation) is called shear strain.

Hence the strain can be described by the partial derivative of u, v and w. with respect to x, y, z,

i.e $e_{xx} = \frac{\partial u}{\partial x}$ $e_{xy} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$ $e_{xz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}$

$e_{yx} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$ $e_{yy} = \frac{\partial v}{\partial y}$ $e_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial x}$

$e = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}$ $e_{xy} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}$ $e_{zz} = \frac{\partial w}{\partial z}$

Thus the full description of the strain will have 9 components and described as a 2nd rank tensor.

$$E = \begin{matrix} e_{xx} & e_{xy} & e_{xz} \\ e_{yx} & e_{yy} & e_{yz} \\ \mathbf{e_{zx}} & \mathbf{e_{xy}} & \underline{\mathbf{e_{zz}}}. \end{matrix}$$

Mathematical analysis has confirmed that Actual deforming strain is characterized by six combinations of derivations since some Shan strains are found being paired and equal i.e

$$\mathbf{e_{xy}} = \mathbf{e}_{yx}\ ,\ \mathbf{e_{yz}} = \mathbf{e_{zy}} \quad \mathbf{e_{yz}} = \mathbf{e_{zy}}$$

The rest three quantities

$$O_x = \frac{\partial w}{\partial Y} - \frac{\partial v}{\partial x} \qquad O_y = \frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \qquad O_z = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Represent angular displacing (or rotation) along the three axis x, y, z, and are not strains.

3. Hooks Low

Strain is always associated to acting stresses since dislocation (deformation) is always came to happen as a net force is acting on a given area. Such change in sized & shape due to acting force is described by hook's low. The size and shape change (described by the strain and the action of the force per unit area (stress) are related by hook's low as follows.

Hooks Low states that a strain resulting on a body is proportional the stress that produce it. This relation is mathematically described as follows

$$T_{ke} = C_{ij\,ke} \; S_{ij} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2.3.1$$

Where Cijke is a proportional constant (or Elastic constant) and in rock mechanics it's is referred us stiffens

Because both strain and stress are symmetric tensors

$$C_{ijke} = C_{jike} = C_{ij\,lk}$$

The proportional constant Cijke vary from rock kind to rock kind describing its physical property.

According to Hook's low stress and strain are linearly dependent to Each other and the body behaves elastically until the years point is achieved. Below the yield point, on relaxation of stress, the body reverts to its pre-stress shape and size. At the stress beyond the yield point the body behaves in a plastic or in a ductile manner and permanent deformation results to the extent of fracturing.

Hooks low also confirm that stress & strain components at a particular point (and time) are dependent on the material's nature and each strain is a linear function of all independent component of the stress and vise versa.

In most practical cases hooks low leads to very complicated expressions as finalization but for, so tropic medium (medium with out a change of properties in direction) it can be expressed as follows. (TALE FORD 1971)

$$T_{ij} = \lambda (\mathbf{e_{11}} + \mathbf{e_{22}} + \mathbf{e_{33}}) + 2\mu\, e_{ii} \qquad \ldots\ldots\ldots\ldots 2.3.2$$

$$Tij = \mu\, \mathbf{eij}$$

Where λ and μ are lamme's constant and μ is measuring resistance to shear strain and named as rigidity constant or shear constant

4. ELASTIC CONSTANTS

For perfect description of the nature of seismic wave propagation, it will be important to express the stress-strain dependently in terms of some physical parameters that describe the Elastic properties of the rock medium. These very vital elastic parameters of seismic medium are YOUNG'S MODULU'S (E) Poisons ratio (δ) SHEAR MODULUDS (K) and rigidity shear modulus.

4 1. YOUNG MODULUS (E)

The Young's Modulus (E) is defined as the ratio of active stress to longitudinal elongation of the medium for one dimensional case

$$E = \frac{T_{11}}{e_{11}} \qquad \text{.............................2.4.1.}$$

In the three dimensional case of the dimension parallel to the normal stress increases in length which the other two dimensions contract in size.

4-2. POISSON'S RATIO (σ)

Poisson's ratio is the the ratio of traverse strain to longitudinal strain

$$\sigma = \frac{e_{yy}}{e_{xx}} = \frac{ezz}{exx} \qquad \text{.......................... 2.4.2.}$$

Poisons ratio is the measure of the relative deformation of body in two perpendicular directions the minus sign is introduce to make poison's ratio…

4-3. BULK MODULUS (K)

Bulk Modulus id defined as volume stress to volume strain

$$K = \frac{\text{Volume stress}}{\text{Volume strain}} \qquad \text{.................2.4.3}$$

4-4 SHEAR (RIGIDTTY) MODULUS (μ)

It is defined as the ratio between shear stress to shear strain

$$\mu = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{T_{12}}{e_{12}} = \frac{T_{13}}{e_{13}} = \frac{T_{23}}{e_{23}} \qquad \text{.................2.4.4}$$

4-5. AXIAL MODULUS (U)

Axial modulus is defined as longitudinal stress to longitudinal strain

$$U = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} = \frac{\frac{\triangle F}{A}}{\frac{\triangle L}{L}} = \frac{T_{11}}{e_{11}} \qquad \ldots\ldots 2.5.1$$

By substituting the above definition in Hook's low the following Expressions describing the relations between E , , K and the two LEMMA'S constants , e can be Found and stated here below

$$E = \frac{\mu (3x+ 2e}{\lambda+\mu} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.5.1$$

$$\upsilon = \frac{\mathbf{x}}{2(\lambda +\mu)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.5.3$$

$$K = \frac{3\lambda+ 2\mu\, \mathbf{x}}{3} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.5.4$$

$$X = \frac{2\boldsymbol{\delta}}{(1+ \sigma) (1- 2\sigma)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 2.5.5$$

By elimination of different pairs among the above Equations, various relations expressing one of the five in terms of the other two can be derived.

4.6 WAVE EQUATION

When impulsive seismic wave acting on a medium is not in Equilibrium, the Elastic body will start to under go deformation. Because the net force acting the medium will make particles of the medium change there position as the body is experiencing a change in shape and size in a definite infinitesimal time interval. The action of the force creating the motion of particles with in the body and this proves that energy is transported from one point to the other which is described by equation of motion

To derive an equation that describe the propagation of seismic wave in earth medium we will take a hypothetical road shaped medium with sides u,v and w, density ρ, young modulus E and rigidity medium if there is a net force F acting on the system, then the assumed rod shaped medium will not be in the state of Stress Equilibrium as described below.

Considering the change of position along the direction of the F, the rod medium will change its length from u to du and its sides from v to v + dv and w + dw

The Stresses in the front and rare faces are

$$T_{xx} + T_{yx} + T_{yz}\ , \qquad T_{xx} + \frac{\partial T_{xx}}{\partial x}dx\ , \qquad T_{yx} + \frac{\partial T_{yx}}{\partial x}dx\ , \qquad T_{zx} + \frac{\partial Tzx}{\partial x}dx$$

The net stress of the system will then be

$$T_{net} = T_{xx} + T_{yx} + T_{yz} - \left(T_{xx} + \frac{\partial T_{xx}}{\partial x}dx + Tyx + \frac{\partial Tyx}{\partial x}dx + Tzx\ \frac{\partial Tzx}{\partial x}dx \right)$$

$$T_{net} = \left(\partial T_{xx}\,dx + \partial T_{yx}\,dx + \partial T_{zx}\,dx \right)$$

$\partial x \qquad \partial y \qquad \partial z$

From definition of stress

$$F_{net} = T_{net}\,dA \,. \qquad \text{and } d_A = dxdy$$

$$= \left(\frac{\partial T_{x}}{\partial x} dx + \frac{\partial T_{yx}}{\partial y} dx + \frac{\partial T_{zx}}{\partial z} \right) dx\,dy\,dz$$

$$F_n = \left(\frac{\partial T_{yx}}{\partial x} + \frac{\partial T_{yy}}{\partial y} + \frac{\partial T_{yx}}{\partial x} \right) dv$$

From newto's 2nd low of motion

$$F_n = m \frac{\partial^2 U}{\partial t^2}$$

$$F_n = \rho dv \frac{\partial^2 u}{\partial t} = \left(\frac{\partial Txx}{\partial x} + \frac{\partial Tyx}{\partial y} = \frac{\partial Tzx}{\partial z} \right) dv$$

$$\rho \frac{\partial^2 u}{\partial t^2} = \frac{\partial Txx}{\partial x} + \frac{\partial Tyx}{\partial y} \quad \frac{\partial Tzx}{\partial z}$$

$$\frac{\partial^2 u}{\partial t^2} = \frac{\partial Txx}{\partial x}$$

Taking the one dimensional case (i.e when dv = dw = o).the above Equation reduces to

$$\frac{\partial^2 u}{\partial t^2} = \frac{\partial Txx}{\partial x}$$

But $T_{xx} = E \frac{du}{dx}$

Thus $\rho \frac{\partial^2 u}{\partial t^2} = \frac{\partial}{\partial x}\left(E \frac{du}{dx}\right) = \frac{E \partial^2 u}{\partial x^2}$

$$\left(\frac{\partial^2 u}{\partial t^2}\right) = \left(\frac{E}{\rho} \frac{\partial u}{\partial x^2}\right.$$

This is one dimensional wave Equation describing the motion of a wave with propagation velocity

$$V = \underline{E/}\ \rho$$

From this Equation we can generalize that the velocity of this kind of particular wave is dependent of the density of propagation medium and the elastic parameter –

And for the three dimensional case the wave Equation is

$$\rho \frac{\partial^2 u}{\partial t^2} = (\lambda + \mu) \frac{\partial^2 \theta}{\partial x^2} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right.$$

$$\frac{\rho \partial^2 u}{\partial t^2} = (\lambda + \mu) \frac{\partial^2 \theta}{\partial x^2} + N \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right) u$$

Introducing the Laplace operator in place of terms under the right side bracket

$$\frac{\partial^2 u}{\partial t^2} = (\lambda + \mu) \frac{\partial^2 \theta}{\partial t^2} + \frac{\nabla^2 u}{\partial x^2} \qquad \text{……..} \quad 2.6.1$$

Similarly the wave Equation in v and w direction are

$$\frac{\partial^2 V}{\partial t^2} = (\lambda + \mu)\ \frac{\partial^2 \theta}{\partial y^2} + \mu\ \nabla^2 v \qquad \text{………. 2.6.2}$$

and $$\rho\,\frac{\partial^2 V}{\partial t^2} = (\lambda + \mu)\ \frac{\partial^2 \theta}{\partial y^2} + \mu\,\nabla^2 w \qquad \text{.. …. 2.6.3}$$

Summing up the above three Equations will give us

$$\rho\,\frac{\partial^2 \theta}{\partial t^2} = (\lambda + 2\mu)\ \nabla^2 \theta \qquad \text{……2.6.4}$$

$$\frac{\partial^2 \theta}{\partial t^2} = \underline{(\lambda + 2\mu)}\ \nabla^2 \theta \qquad \text{………2.6.5}$$

To find the velocity of the shearing wave

$$\lambda + \frac{\partial^2}{\partial x^2} = \left\{ \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial x}\right) + \frac{\partial^2}{\partial y^2}\left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right) + \left(\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}\right) \right\}$$

$$\rho\ \frac{\partial^2}{\partial t^2} = \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial x}\right) + \left\{ \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right) + \left(\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}\right) \right\}$$

Substituting corresponding shear stress in place of relation Expressed by the x,y and z partial derivatives of dimensions u,v,w in the above Equation gives

$$\mu \nabla^2 (s_{12} + s_{13}\ s_{23}) = \rho \frac{\partial^2}{\partial t^2} (s_{12} + s_{13} + s_{23})$$

but $s_{12} + s_{13} + s_{23}$ gives the total shear strain tobe

$$\mu \nabla^2 s_{sh} = \rho \frac{\partial^2 S_{sh}}{\partial t^2} \qquad \ldots\ldots 2.6.6$$

$$\frac{\mu}{\rho} \nabla^2 s_{sh} = \frac{\partial^2 S_{sh}}{\partial t^2}$$

Hence the share wave velocity $V_s{}^2 = \frac{\mu}{\rho}$

Then the propagation velocities of the p- wave and s- wave are

$$Vp^2 = \frac{E}{\rho} \qquad\qquad V_s{}^2 = \frac{\mu}{\rho}$$

Which show that the velocity of p wave depend on density and young modules of the rock medium while shear wave depend on rigidity modulus.

4.7 CLASSIFICATION OF SEISMIC WAVES

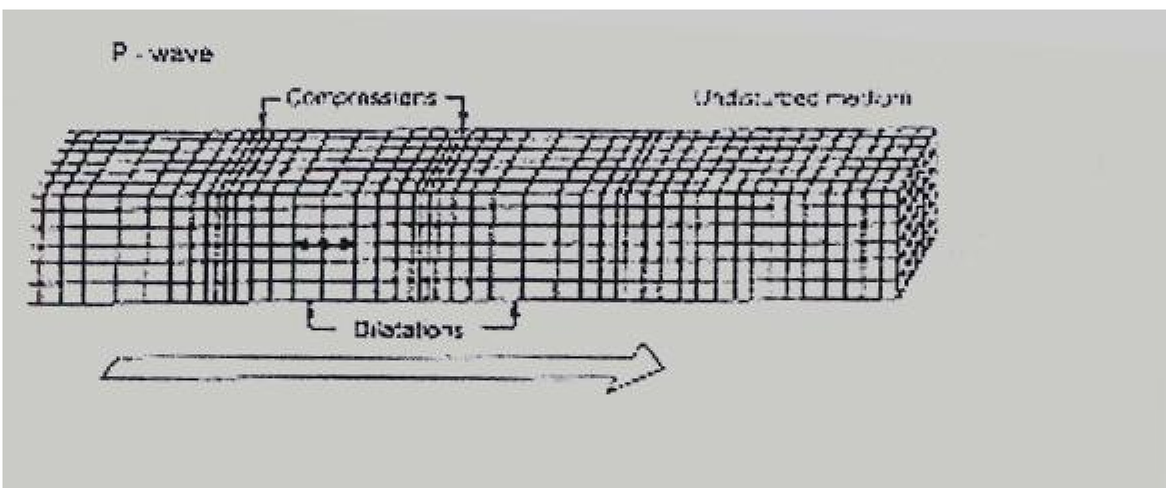
Seismic waves propagating in Earth crystal medium are composed of tiny packets of Elastic Strain Energy that migrate out – ward from the source. During the out ward transport of seismic strain Energy elastic properties and density of the rock medium make the primarily influence as the speed of migrating Energy packets. The propagation nature of seismic waves are not only controlled by medium Elastic parameters but also on through the bulk of the rock medium while other energy packages are confined to specific then bands propagating between the interface of the rock medium. Based on this difference in energy package transporting seismic waves are classified as follows.

I. Body waves

Body waves are seismic waves that propagate through balk of the medium. Body waves are either longitudinal (or p- wave) waves or transversal (s – waves).

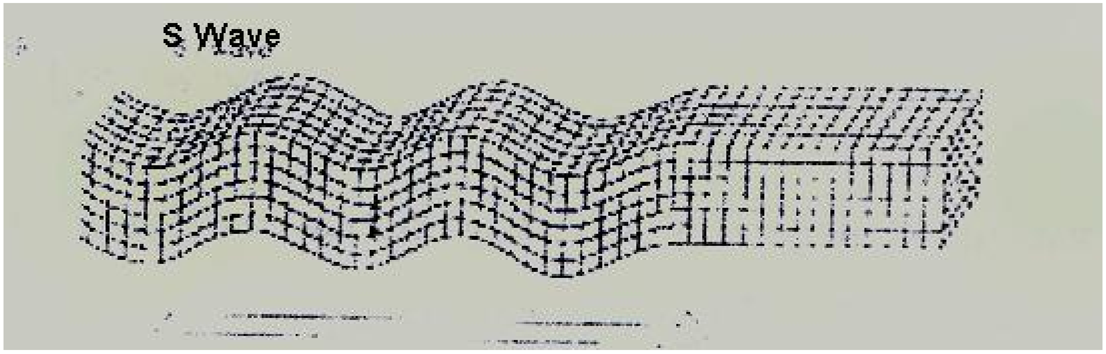
A- P-waves (longitudinal waves)

P-waves are body wave that carry seismic energy from a point to other in rock medium by oscillation of particles medium about a fixed point in the direction of wave propagation (F16) these waves make seismic energy transport by compress ional and dilatation strain.



B. S- waves (Transversal waves)

The propagation and energy transport made by these waves by motion of particles oscillating right angle to the propagation direction and by shear strain (Fig   B).



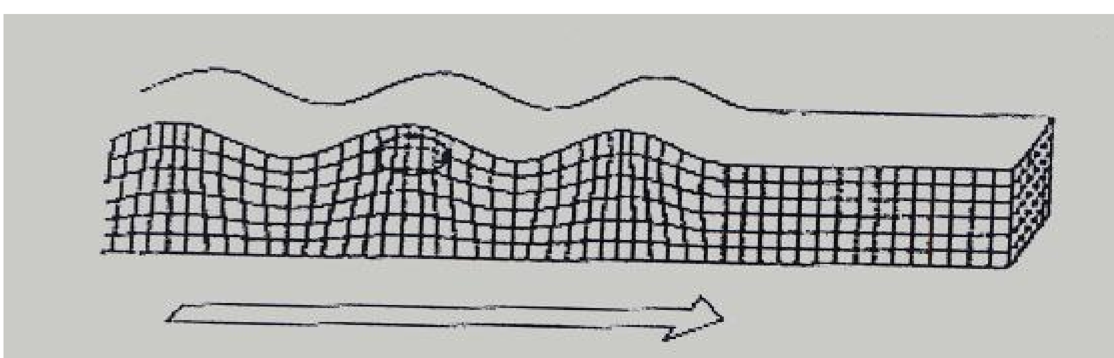
One distinguishing property of the propagation of body waves is the fact that the propagation velocity waves is independent to the wave frequency but determined by Elastic modulus and density of the rock medium through which they migrate

II **Surface waves**

These waves are characterized by there propagation along free surface of solid elastic rock medium. Surface migrates with lower velocity comp aired to body waves. Surface waves do not penetrate deep in to subsurface formations. Surface waves are either Raleigh waves or love waves.

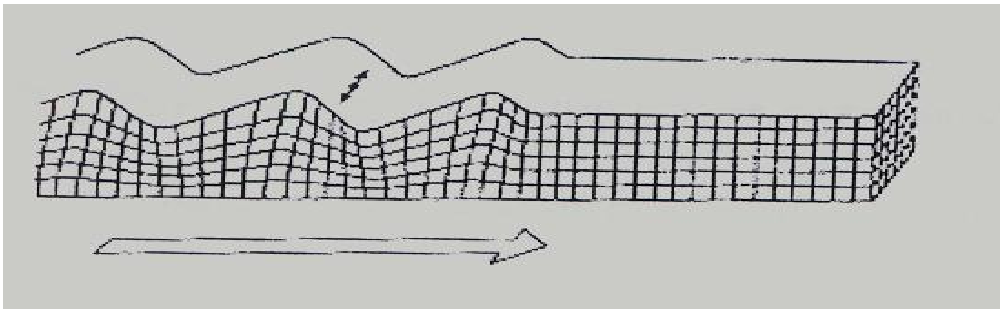
A) **Raleigh waves**

These waves are characterized by motion of particles of the medium in a retro grade elliptical path and in vertical plane with respect to the surface as shear are involved. Raleigh waves are limited to propagate through solid rock media but not in liquids.



B) **Love waves**

Love waves are surface wave that propagate being carried by particles motion right angle to the propagation direction and parallel to the surface. ., They are transversal waves occur only at multiple rock formation in which lower S- wave velocity over lies a layer with a higher S- wave velocity love waves are polarized shear waves.



Surface wave propagation is frequency selective i.e. there wave from changes during propagation because different frequency Compounds have different propagation velocity. Due to this dispersion of the wave occur. And thus it can yield the velocity structure of the medium in which the propagation occurred

C) **Guided waves**

Guided waves are characterized by there propagation Confined in thin layers. Its propagation depends up on the wave length (λ), the thickness of the then layer conjoining them as well as elastic properties and density of the rock medium .

4.8 PROPAGATION OF SEISMIC WAVES EARTH MEDIUM

Seismic energy package introduced in Earth medium propagate away in every direction from the source. In addition to the elastic parameters and density of the medium its propagation is affected by the energy distribution that results the loss of amplitude of the wave as it propagate further and further from the source. This occurs in three main ways.

1. Geometric Spreading (Spherical divergence)

The Seismic energy induced at a particular point will propagate in every direction with spherical wave front. The total energy at the instant of seismic energy release will be distributed over all spherical wave front which is getting larger and large as the wave propagates out ward. If the radius (distance of the wave front from the source at a particular is r then density (Energy per unit area) will be

$$\frac{dE}{dA_1} == \frac{E}{4\pi r^2}$$

After some interval time the wave front reaches a distance R (R>r) away

$$\frac{dE}{dA_2} = \frac{E}{4\pi R^2}$$

But

$$- \quad \frac{dE}{dA_1} \quad \frac{dE}{dA_2}$$

The Energy density decreases by $1/r^2$. The amplitude which is proportional the squire root of the energy thus vary proportional to the livers of r.

2. Intrinsic attenuation

As the Seismic energy is carried away from the source it will create motion of particles of the medium. During such interaction particles moving against each other and there Exist function between them that change some of the seismic energy to heat. To this absorption of seismic energy is called intrinsic attention. Intrinsic attention decreases exponentially with distance it travels.

Attenuation also varies the medium of propagation and characterized by the attenuation coefficient a. combining the spherical divergence term 1/r and absorption term e^{-ar}, the reduction of amplitude with distance is given by

$$A = \frac{A_o r_o \ \mathbf{exp} \ (-\alpha (r - r_o))}{r}$$

Where A and Ao are amplitudes at distance r and ro from the source and a is attenuation coffient .

The attenuation coffient is related to velocity of seismic wave v and their frequency f by

$$\alpha = \frac{\pi f}{Qv} \quad \text{and} \quad Q^{-1} = 2 \alpha \lambda$$

Where Q is Quality or slowness factor. And Q^{-1} is called Specific disputation factor.

The attenuation coefficient is an indication of physic nature of rocks for example for sand stones with porosity ¢ present and clay constant C,

$$= 0.03154 + 0.241C - 0.132 \frac{db}{cm}$$

And $Q = 179C - 0.0843$

The attenuation coefficient α is a measure of the fractional loose of energy per unit distance and $\frac{2\pi}{Q}$ is fractional loose per wave length.

Scattering

Scattering of seismic waves occur due to reflection refraction and diffraction of de seismic waves.

4.9 LAWS AND PRINCIPLES GOVERNING SEISMIC PROPAGATION

1. Huygens principle

Huygens principle states that every point on the wave front can be considered as a secondary source of spherical seismic wave propagating out ward.

The new wave front is the envelope of theses waves after given time internal. Because the propagation direction of the wave is right angle to the wave front it is practically possible to represent seismic waves by a ray directed perpendicular to the wave front.

2. Fermat's principle

It states that seismic wave fronts will propagate in a rock medium along the path which takes the list amount of travel time.

If we consider tow layers in which seismic wave propagate with different speed.

$$\frac{\text{Sin I}}{V_1} = \frac{\text{Sin R}}{v_2} \quad \text{or} \quad \frac{\text{Sin I}}{\text{SinR}} = \frac{V1}{v_2}$$

Where I = Angle of incidence and V_1 and V_2 are Velocities of
R - Angle Refraction Layer 1 and 2

The above equation is called snell's low and it is possible to define seismic parameter (p) as follows.

$$P = \frac{\text{Sin I}}{V}$$

The Seismic parameter (p) has the following nature

1. The Seismic ray parameter (p) is constant for entire path.
2. It a ray in entering from a layer of lesser velocity to higher velocity the ray will be deflected to wards to horizontal
3. If the ray enter from a layer of higher velocity to a layer of lower velocity it will be deflected to wards vertical
4. The ray keeps its original path is P = O

From the above generalization it is confirmed that we can conclude that if the velocity of the wave increases with depth, it is deflected up wards and can be defected and recorded by the receiver. But if the velocity decreases with depth the wave deflect to wards to vertical and thus it can not be defected at the surface.

As the Seismic wave propagates through rock medium, it causes the vibration of particles of the medium. Based on this we will have two kinds of velocities related to the waves. These are seismic propagation velocity (which is associated the rate of propagation of the wave away from the source) and particles velocity (which is the velocity with which particles of the medium are oscillating).

The velocity of particles of the medium is not uniform through out the passage of the wave through the medium but will attain its maximum value (peach particle velocity at a particular time.

Energy density (Intensity)

The energy of particles in motion due to passage of seismic wave is important parameter in seismology. For most practical seismic analysis it is the energy density (Energy in a vicinity of a point of observation) but not the total energy of the wave.

Suppose we have a spherical harmonic wave the radial displacement r. given by

$$U = A \text{ coos } (w \ t + \varphi).$$

Where ¢ is phase angel and arranges from – A to A. since the displacement is time dependent the medium velocity is given by

$$\grave{U} = \frac{\partial u}{\partial t} = \frac{\partial}{\partial t} (A \cos (w t + \varphi))$$

The kinetic energy d ▲L contained in infinitesimal column d v is

$$\partial L = \tfrac{1}{2} (\rho \partial \nu) \upsilon^2$$

$$\frac{\partial L}{\partial \upsilon} = \tfrac{1}{2} \rho \grave{U}^2 = \tfrac{1}{2} \rho w^2 A^2 \text{ Sin}^2 (w t + \varphi)$$

This Equation vary from o to $\rho w^2 \frac{A^2}{2}$

The wave also posse's potential Energy due to its elastic strains and the total energy of the system will be to the same even if the energy transforms from one form toe the other. The total energy is Equal to maximum kinetic energy or the maximum potential energy because one will be maximum when the other is minimum hence the total energy E of the harmonic wave

$$E = \tfrac{1}{2} \rho w^2 A = 2\pi^2 \rho \nu^2 A$$

Then the energy density is proportional to A,ρ and ν^2 . Then we can define intensity (I) as follows.

Seismic Intensity

Seismic intensity is an amount of Energy which flows through a unit normal to the direction of wave propagation.

$$I = EV$$

For harmonic wave

$$I = \frac{1}{2} \rho v\, w^2 A$$

3. For a wave propagating out ward from r to R from the source

$$I_o A_o = AI .$$

Or $$\frac{I}{Io} = \frac{r_o}{r}^2 = , \frac{E}{Eo}$$

This is spherical divergence.

And change of seismic intensity to absorption will be

$$I = I_o \mathbf{e}^{-\alpha r}$$

Seismic wave energy in multiple medium

When seismic wave propagating in a rock medium came at an interface of another rock medium with deferent elastic parameter, the seismic Energy will be partially transmitted and partially reflected.

The proportion of energy reflected or transmitted are referred or transmission and reflection coefficients and are described by Zoeppritz Equation as follows.

Reflection coefficient (R)

$$R = \frac{A_1}{A_0} = \frac{(z_2 - z_1)}{(z_2 + z_1)}$$

Transmission Coefficient (T)

$$T = \frac{A_2}{A0} = \frac{.\ 2z}{(Z+Z)}$$

Reflected energy ER = $(z_2 - z_1)^2 / (z_2 + z_1)^2 = \frac{\frac{1}{2} a_1 \rho_1 w^2 A_1^2}{\frac{1}{2} a1 \rho 1 w^2 A_0}$

Transmitted Energy (E_T)

$$E_T = 4Z_1 Z_2 / (Z_2 + Z_1)^2 = \frac{\frac{1}{2} a_2 \rho_2 w2 A_2^2}{\frac{1}{2} a \rho_1 w^2 A_0^2}$$

When Z_1 Z_2 are a acoustic impede us of first and second layers respectively A_0 A_1 A_2 are relative amplitudes of incident, reflected and transmitted waves and Er E_T are reflected and transmitted energies.

CHAPTER III

3.1 Sources and measurement of seismic waves

Seismic Exploration is based on observation made on seismic waves propagating in rock formation. The most usual method used in seismic studies is executed by using controlled seismic sources which man produce in the course of his daily activates or purpose fully done for specific seismic works.

Different kinds of instruments or methods are possible to include seismic energy at known point on or under the surface so that the seismic waves produced at a known location and time are recorded at various other points away from the source the record at this point be will analyzed and interpreted . The method by which seismic energy is induced to rock formation is selected based on some practical requirements related to the particular study, and safety conditions. The aim of using any seismic source is to produce a large enough signal in to the ground to ensure sufficient depth of penetration and high enough resolution to image the sub surface formations. There are several methods of inducing seismic disturbance in rock formations that will be selected in accordance to study requirements and environments. The following table summarizes major kinds of seismic sources

	On Land	**On Water**
	Sledge hammer	
	Drop weight	
Impact	Accelerated weight	Sparker
	Dynamite	Air Gun
Impulsive	Detonating cord	Gas Gun
	Air / Shot Gun	Sleeve Gun
	Bore whole sparker	water Gun
	Vibroseis	Bomber
Vibrator	Vibrator plate	Multiples

Among the above sources explosives are selected for explorations that are involved in long distance and greater depth study.

Because relatively larger amount of explosive energy is obtained the introduced wave can be fulfilling exploration requirements. In land seismic studies the use of single shot can provide enough energy to the ground with sufficient frequency band width for rapid coverage of survey lines.

Blasting operation of explosives is physically interpreted as an introduction of transit force on to a rock medium so that seismic waves are produced. The energy used by exploding are obtained by chemical activities of contents of the explosive, by introducing an small activation energy's chemical decomposition can be started and will produce extreme heat and excess gasses that will apply very great pressure on the hosting rock medium. The introduced energy will make particles of the medium become agitated together with the propagating seismic disturbance. Fragmentization of the rock at the near by territory of the explosion point will occur because the rupturing action of the explosive pressure (or force) excided the elastic limit of the medium.

Different chemical composition and related activation mechanisms are available for seismic and other blasting. Among others, Ammonium – and Ammonium Nitrate gelatin with Detonating cords and Rock Ammonite with blasting caps are widely used. These chemical compositions are preferred because they can be detonated by very high temperature.

For seismic explorations and geotechnical purposes (Exploitation rocks at quarries, construction purposes) the blasting of explosive will be made in bore holes made by drilling using machines. The drilling of exploding holes is made to the required depth so that the exploding material and detonating cord (or elastic blasting caps) are put in to it.

In most seismic exploration works enveloping the use of explosives, it is necessary for the shot to be acoustically coupled to the ground which can be achieved by blasting in water filled holes. For very shallow work, detonator caps can be used as source. For exploration works it is beast to use “Zero-delay” seismic detonated vicious other types as used in quarry blasting have a definite delay.

I explosive energy used as source of wave for seismic works, it may be needed to have larger energy so that the wave can be detected and measured by measuring device at distance.. This can be achieved by adding the amount of chemical explosive to be blasted with serious concern with accurate ground velocity prediction. Accurate ground particle prediction yield very vital information used in determination shot size so that the needed signal to noise ratio at large distance will be at hand with out creating risk to man made structures at near by distance.

To avoid explosion induced dangers on man made structures, it is needed to make ground vibration predications when ever blasting are made for exploration and geotechnical purposes. In the course of making such ground vibration predication, it is required to make approximation of the peak particle velocity for places where man made structures are found.

Since the ground vibration due to explosions depend on the amount of explosive energy introduced (weight of chemical explosive), the Elastic nature of the propagation medium and the distance between the shot point and the specific point for which ground vibration is to be estimated, it would be vital to consider a method that relates size of shot and the distance from shot point. For the mentioned theoretical computation of ground vibration and peak ground velocity determination of ground the scaling of distance are used.

3.1.1 Scaled distance (SD)

Scaled distance is a scaling factor that relates similar blast effects from various charge weights or the same explosive but at various distance.

In the use of scaled distance, the distance of a specific point for which peak ground velocity is to be determined (or distance to structure) will be divided by fractional power of the weight of the explosive maternal. There are two scaling factors applied for the same purpose.

Square root scaling

Square root scaling is the general formula used in general blasting situations where the charge is consider linear and it is based on the realities small size of explosives are high frequency and smaller displacement generators.

Square root scaling formula is

$$SD = \frac{\text{Distance of structure}}{(\text{Explosive weight})^{1/2}}$$

Cube Root Scaling

Cube root scaling is used for explosive shots at very near distance to man made structures or when the charge is considered as a point charge or very great amount of explosive energy (as nuclear explosions) is used. Cube root scaling is mostly recommended for construction blasting.

Cube root scaled distance formula states that scaled distance (SD) is Equal to the ratio of the distance of the point of pick ground velocity prediction to the cube root of shout weight.

$$\text{Cube root scaled distance} = \frac{\text{Distance from shot point}}{(\text{Explosion weight})^{1/3}}$$

3.1.2 Ground Vibration Predication

Ground vibration predication is theoretical method of finding the peak ground velocity (maximum Amplitude of expected particles velocity) that can be induced by energetic explosions near the surface

There are two methods of Ground vibration predication

1. Using Regression Analysis
2. Ground vibration predication formula

1. Regression Analysis

Regression Analysis is the process of estimating peak ground velocity statistically from explosive weight, delay and scaled distance from the point of explosion to the observation.

Regression Analysis is based on plotting of data of scaled distance against Amplitude on bi-log (log - log) scale by doing so a leaner relation will be obtained since pack ground velocity is decreasing with scaled distance. From the plotted data the peak ground velocity (PPV) can be found as follows.

PV = K x (SD)   where   K is scaling factor

SD is scaled distance

And   S is Slope

The intervals of confidence can be determined from the standard deviation of the data which are based on weight of explosive / delay that can be detonated at certain distance.

In practical blasting an interval of 95% confidence is taken as maximum (beast analysis) and (30 – 35) % for minimum.

2. Ground vibration predication formula (Hendron Oriards formula)

a) Oriard formula for PPV.

$$PPV = K \times (P / \sqrt{w})^{-1.6}$$

Where PPV is particle ground velocity
SD scaled distance
K Confinement factor

The confinement factor have lower bounds = 20 upper bound =242 Average 150 and highly confined 605.

$$V_{m}in = 20.(\text{ offset }/\sqrt{\text{ charge wt}})^{-1/.54}$$

$$V_{max} = 184 \times \{\text{offset/charge Wt})^{-1./54}$$

b) Herndon's Formula

Henderson Formula use cube root scaling.

$$PPV = k \times [D/(w)^{1/3}]^{-1.6.}$$

Henderson formula is applied for very near man made structure explosion or when the amount of Explosive energy is extremely high.

3.1.3 Measurement of seismic wave

Seismic wave from explosive sources encompasses a wide spectrum covering from lower (0.0to 2 Hz) to higher frequencies (10-10 HZ) waves whose Energy is distributed our the area spherical wave front that will make the enclosed energy become vary with the increase the square of the distance it travel and the amplitude falls off inversely with the distance .

Waves that propagated to our point of interest need sensing devices that detect and record the arriving wave. Geophones are seismic signal sensors that are used on substrate some kind normally on the ground surface or down holes. For seismic studies that need wave detection under water, special geophones called hydrophones are used.

Geophones convert the arriving seismic Energy (mechanical wave) to measurable Electrical signals. Fig Shows construction of most widely used Geophones.

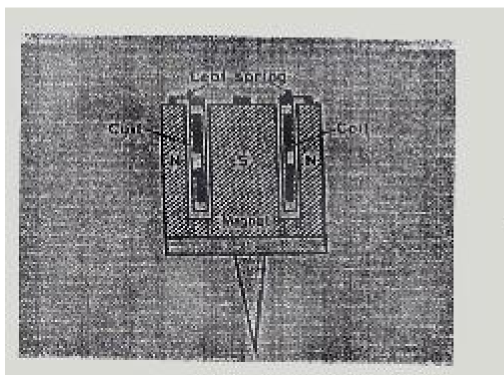


Figure 3.1

A leaf spring suspended cylindrical coil is placed permanent magnet created magnetic field and fixed to its casing. The coil which is suspended from a spring create resonant frequency dependent oscillatory system which is also dependent on mass and stiffness of the spring . As the geophones which is implemented in to the ground (with a spike attached to the base of the casing to ensure good ground coupling) moue in harmony to the vibration of the ground current will be induced and amplified so that it cone be recorded by the appropriate amplifying and recording unit.

Thus Geophones respond to the rate of movement of ground particle velocity) but not the displacement.

The maximum sensitivity of any geophone occurs when the coil; axis is parallel to the direction of maximum ground movement.

Some Special kinds of Geophones are designed to detect and measure the acceleration of particles of the ground These devices are called accelerograms . The out put of accelerograms describe the acceleration but not the velocity.

In controlled source seismic studies Geophones will be placed in pre determined places along straight line and away from the source so that the Explosive induced Energy at the shot point will be detected and recorded by devices dispersed at distance from the source.

CHAPTER 4

SURFCE WAVE INDUCED GRUOND PARTICEL VIBRATION PRIDICTION AT WESERN AND EASTERN ETHIOPIAN PLETEUES

4.1 Introduction

The EAGLE project (Ethiopian Afar Geo-Scientific Liothospheric Experiment) was an international multidisciplinary study of the Ethiopian Rift in particular the translational process from continental to oceanic rifting along the Ethiopian rift at the horn Africa. The EAGLE group of international scientists organized from Leiceaster, Leeds and Royal Hollow of UK Stanford, Texas at El Paso from USA and from Geology and Geophysics department of A.A.U, Ethiopian Geological Surveys, and Petroleum operation department of Ethiopia under the coordination of Science and Technology Commission of the F. Republic of Ethiopia.

The prime scientific objective of the EAGLE was to determine at what stage and in what way the processes controlling magma supply come to dominate over lithosphere faulting as continental rifting proceeds to sea floor spreading. As an integrated part of the study, series of Seismic, Magneto Telluric, Petrologic and Gravity experiments ware done.

The controlled source seismic study includes three profiles (Fig 4.1). The first profile (EAGEL profile I) is across the Ethiopian rift in the vicinity of Nazret Extended to the north and south to the Blue Nile and to Ginir (Bale region) respectively. EAGEL profile 2 extended along the rift from its southern extreme at Awassa to Gewane in the north. EAGEL profile 3 is to provide 3-D topographic image the sub surface beneath the new volcanic segment of Bosettiy in the vicinity of Nazret.

The total numbers of 19 shots are fired over 450 X 450km^2 area. The kind of Explosives used are powergel 6+ which can be detonated up to 50 m depth. Each Explosive unit has a weight of 12.5 kg and packed in polythene container. Premix Boosters are used to boost the charge to ensure no fail in shot.

The EAGLE shots Exploded in drilled holes and under water. Quarry blasts are also applied for purposes.

The two under water (lake) shots done by EAGLE were at Lake Shala and Lake Aarenguade and intended to ensure larger seismic energy that can be recorded at large distance.

The two varieties of seismic recorders used by EAGEL are the Gurlap systems (3T, 4DT, 6DT) and Reftex Texan's. Raftex Texans are single channel, 4.5 HZ vertical Geophone having a power system of 8 days life time. Guralp 6TD single channel, broad band instruments with 12V Battery, solar panel and GPS receiver.

The data recording of both kinds of recorders are transferred to a computer system before the active life time of the power unit is over and that the data will be permanently preserved.

The transferred data stacked by the computer is then used for each specific seismic study being processed in accordance to appropriate methodology.

4.2 Data Processing

In this study surface wave recordings by Gurlap6TD's are utilized being processed in the following way.

1. Surface wave recordings from the three shots at Gohatsion, Gebre Guracha and Kula will be independently stacked by selecting only Guralp6TD's (fig. 4.2.1, 4.2.2, 4.3.3) and traces are examined one by one.
2. A single surface wave trace will be truncated by approximating its distance from the shot and then applying the following formula.

$$\text{Time} = \frac{\text{Approximated distance}}{\text{Velocity of surface wave}}$$

After approximating the arrival time of surface wave at each 6 TD position, the trace will be truncated with time interval.

- The wave will be further processed so that accurate amplitude will be read relative to zero value.
- Noise coexisting associated the required trace will be filtered by band pass filter using appropriate time window
- Removal of instrumental respond was will follow according to manufacturer's specification for the particular device.
- The Trace which had passed through all the above processes with further be changed from qualitative form (Traces or graphical form) to quantitative (number) describing parameters. From this final quantitative description values of the required parameters are tabled. (Table 2, 3 and 4)...

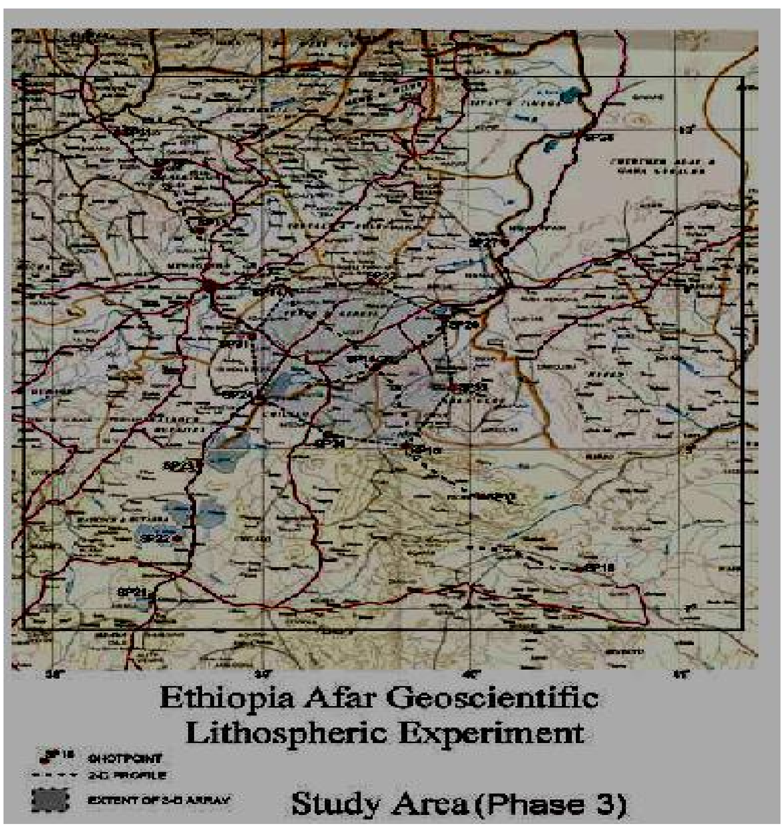


Fig. 4.1.

4.3 Data

Shot	Shot point	East	North	Zone	Elevation	Borehole depths	Shot weight (KG)
Goha Tsion	Sp11	421589	1103530	37p	2505	50m	900
Gebere Guracha	SP12	442579	1078803	2570	2570	50m	1900
Kula	SP16	575823	886441	2502	2502	50m	1100

Table 4.3.1: Shot location, Elevation and Shot size

No	Geop .No	Easting	Northing	Elevation	Offset in km	Recorded Amplitude nm/s	Scaled distance Km /(kg)^2	Velocity amp cm/ Sc
1	1034	446617.9	1076276.4	2673	4.77	1.04x105	0.1094	0.1094
2	1042	4483338.6	1070937.3	2565	9.76	4.47x104	0.2239	0.00447
3	1046	51026.3	1000834.2	2525	12.24	1.19x104	0.2808	0.00119
4	1054	454408.2	1062671.4	2669	20.01	3.93x103	0.4591	0.000393
5	1058	4556391	1058846.9	2525	23.86	1.31x104	0.5474	0.00131
6	1062	454080.7	1055340.9	2450	26.1	1.6x103	0.5988	0.000131
7	1069	461070.2	104330.4.4	2385	32.3	6.09x102	0.9185	0.00011973
8	1081	461070.2	1043304.4	2385	40.04	6.09x102	0.7410	0.0000609
9	1081	462918.6	10387005	2426	44.9	5.76x10	1.0300	0.0000576
10	1085	463794.0	1035198	2454	48.5	8.08x102	1.1127	0.0000198
11	1089	463794.0	1032144.3	2602	52.3	1.98x103	1.3168	0.0000126
12	1097	470172.1	1028505.4	2578	57.4	1.26x103	.3512	0.0000733
13	1097	472625.6	1028101.0	2578	68.90	7.33x102	1.3512	0.00000636
14	1101	475965. 2	1025951.0	62.5	62.5	6.36x102	1.4338	0.00000106
15	1105	478648.6	1023343.0	66.2	6.36x102	1.5187	1.5187	0.00000 898
16	1110	483573.0	1022862.9	69.4	69.4	8.98x102	1.5921	0.00000898
17	1120	4919441	1014703.4	80.9	80.9	3.14x102	1.8560	0.0000314

Table 4.3.2 Gebreguracha Shot

No.	Geophone	Location		Elevation	offset distance in km	Velocity Amplitude Nm/s	Scaled distance Km /(kg)^{2}	Amplitude cm/s
		Easting	Northing					
1	1001	420999.3	1103578.3	2530	0.58	1.587x10^{7}	0.01933	1.587
2	1004	422867.6	1100870.1	2562	2.93	9.4147x10^{5}	0.09833	0.09147
3	1011	427754.0	1095391.	2592	10.21	3.7372x10^{5}	0.3403	0.37372
4	1014				13.4	3.7553x10^{5}	0.4467	0.07266
5	1018	432129.0	1089261.9	2588	17.74	7.266 x 10^{5}	0.5913`	0.07266
6	1023	434605.0	1084830.6	2560	22.79	8.873x10^{3}	0.7596	0.000873
7	1026	435914.0	1083230.1	2572	24.88	6.198 X10^{3}	0.0006198	000006198
8	1030				29.74	2.62x10^{3}	0.99133	0.000262
9	1037	446617.9	1076216.4	2673	37.01	1.875x10^{3}	1.3367	0.0001875
10	1042	448338.6	1070937.3	2565	42.18	1.654x10^{4}	1.47270.	0.0001654
11	1046	1070937.3	1076216.4	2525	44.18	1.969x10^{3}	0.99133	0.0001969
12	1054	454408.2	1070937.3	2669	52.42	6.556x10^{2}	1.23367	0.0006556
13	1062	452918.6	10000834.2	2450	58.14	1.441x10^{3}	1.406	0.0001441
14	1081	462918.6	1062671.4	2426	76.8	6.88x10^{3}	1.4727	0.000688
15	1085	463794.0	1055340.9	2454	80.3	1.06x10^{3}	1.4727	0.000106
16	1089	1032144.3	1038700.5	2602	84.2	1.95x10^{3}	1.4733	0.00195
17	1094	470172.1	102855.4	2578	89.4	2.06x10^{3}	1.938	0.000206
18	1094	472625.6	1028101.0	2578	91.1	14.01x10^{3}	2066	0.0001401
19	1101	475965.2	1025951	2614	94.8	1.51x10^{3}	3.16	.000151
20	1110	483573	102286629	3262	101.8	1.92x10^{3}	3.3933	0.000192
21	1120	49194401	101470304	264	113.4	1.25x103	3.78	0.0000121

Table 4.3.3.: Gohatsion Shote

Geophone No	Offset dis	Amp Rm/s	Scaled distance	Amplitude in cm/sa
1315	4.9	$2.67 X 10^4$	0.14774	0.00267
1320	7.7	$2.32 X 10^4$	0.2321	0.00232
1324	11.8	$1.03 X 10^4$	0.3557	0.00103
1329	16.9	$5.2 X 10^3$	0.5095	0.00052
1333	20.9	$3.65 X 10^3$	0.4794	0.000365
1337	24.8	$3.5 X 10^3$	0.747	0.00035
1340	27.8	$2.2 X 10^3$	0.8382	0.000202
1344	32.1	$1.45 X 10^3$	0.96785	0.000145
1346	35.1	$2.34 X 10^3$	1.058	0.000234
1351	38.1	$1.75 X 10^3$	1.487	0.000175
1356	43.1	$1.14 X 10^3$	1.299	0.000114
1360	48.1	$1.24 X 10^3$	1.450	0.000124
1366	53.0	$1.77 X 10^3$	1.59	0.000177
1370	57.3	$1.8 X 10^3$	1.72	0.00018
1373	60.2	$9.4 X 10^2$	1.8150	0.000094
1377	64.2	$1.4 X 10^3$	1.9357	0.00014

Table 4.3.4: The Kula shot

4.4. Data Analysis

a) Shot Distance is scaled according to square root scaling formula

$$SD = Distance / (Weight)^{1/2}$$

B) Amplitude of the PPV value is converted from nm/s to cm/s

The result is given by the following three graphs.

C) Scaled distance and amplitude of the PPV are plotted on double logarithmic scale and compared with Oriard maximum and minimum prediction formula plotted on the same graph.

4.5: RESULT:

Based on the data obtained from measurement and distance scaled according to Oriard square root scaling formula is plotted on long scale as shown by fig. 4.5.1, 4.5.2 and 4.5.3

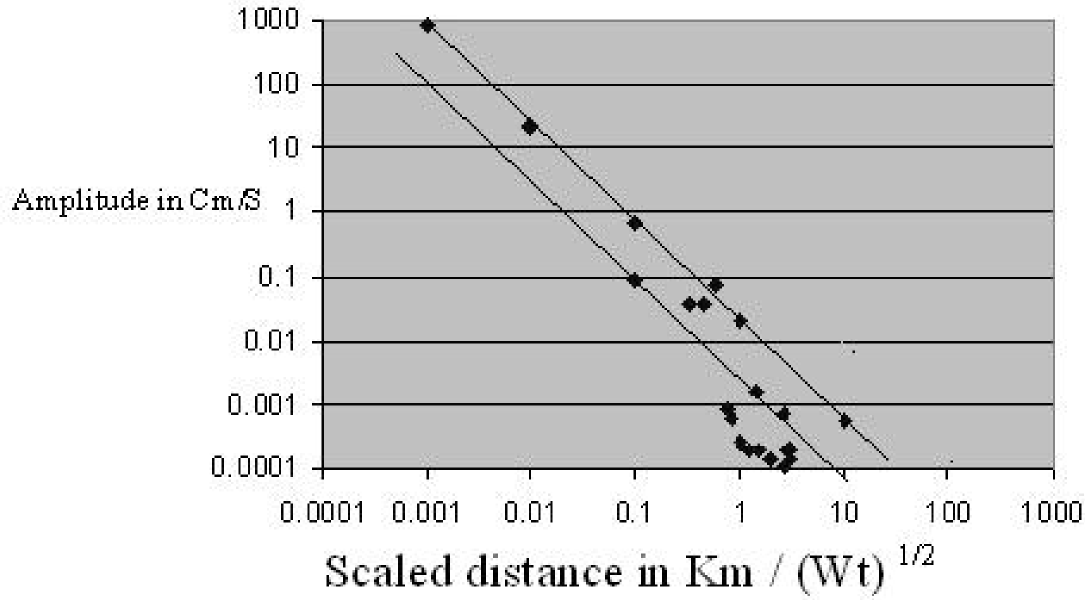


Fig. 4.5.1 For Gohatsion Shot

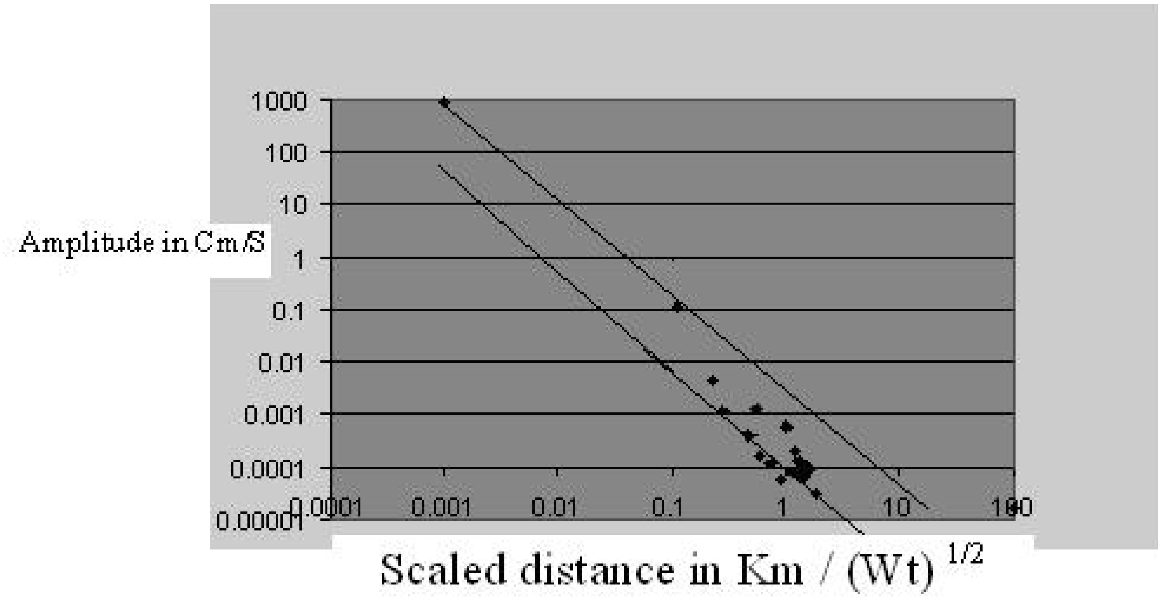


Fig. 4.5.2 : Gebreguracha Shot

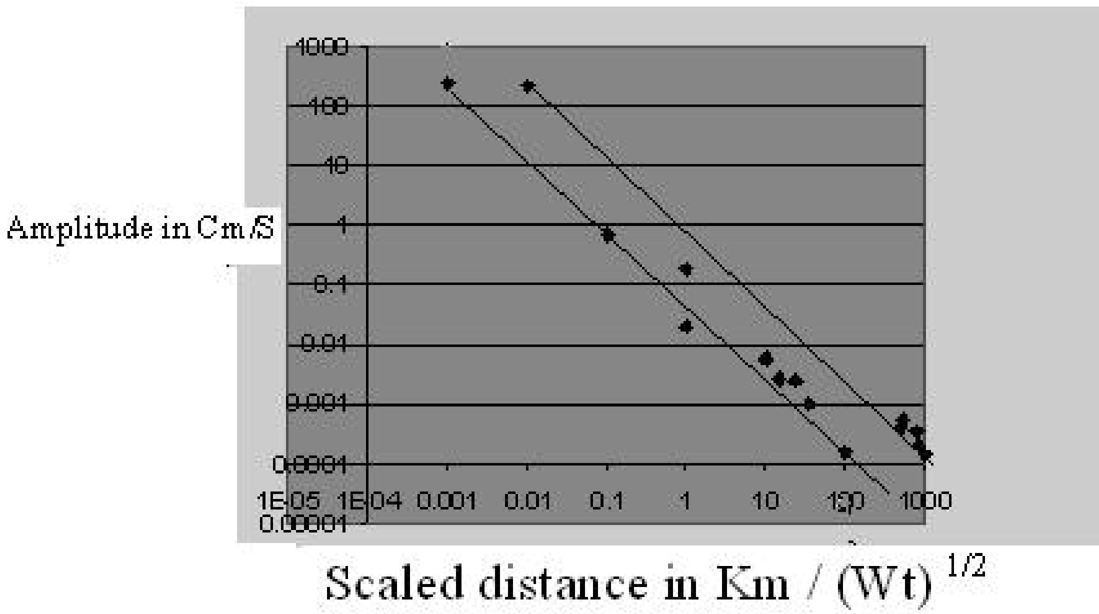


Fig. 4.5.3. The Kula Shot

4.6 DISCUSSION

The above plots show some difference with Oriard prediction because Oriard considered a homogeneous ground model while the two plateaus are not homogenous.

4.7 CONCLUSION AND RECOMMENDATION

As shown by the three plots, the measured ground particles vibration at Eastern and Western plateaus have confirmed that,

1) For the Western plateau, 900kg Gohatsion shot the distribution of measured PPV values are over determined by the Oriard minimum PPV prediction formula. The same is true for 1900kg Gebere Guracha shot.

2) Concerning the 1100kg Kula shot at the Eastern plateau some measured PPV values at larger distances are found to be greater than the maximum PPV predication made by maximum Oriard formula.

The above plots from Guralp 6TD measurements are very much similar to the previously made Raftex Texan measured results by Andrees (Stanford University) shown by his graph 4.7.1.

The Oriard maximum prediction formula has under predicted the PPV values at the Eastern plateau. Thus it is recommended that it shall not be used to determine the PPV value at the Eastern plateau.

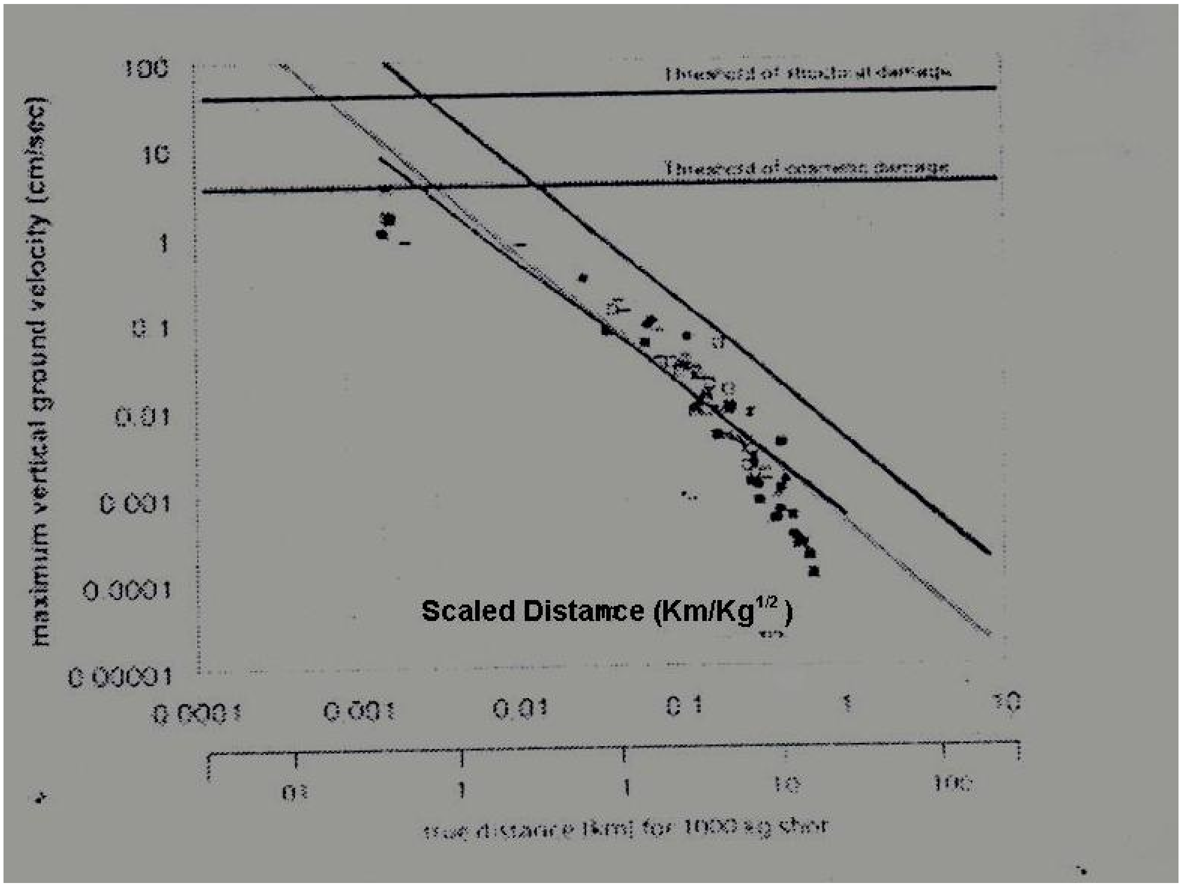


Fig 4.7.1 Andrees graph for wet solid rook

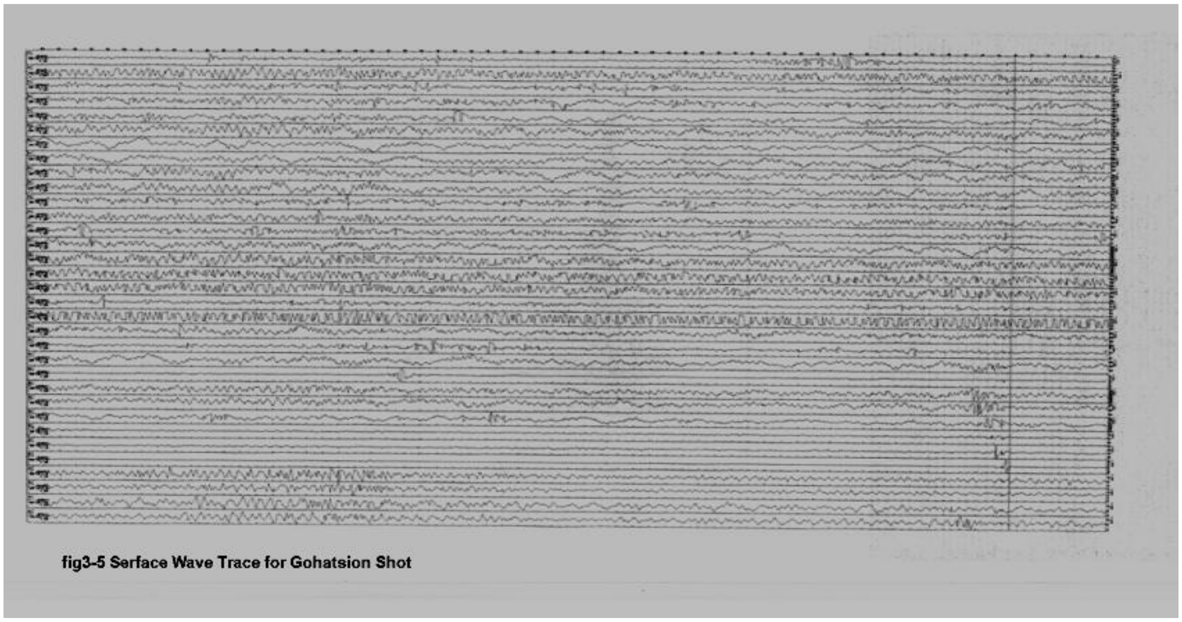
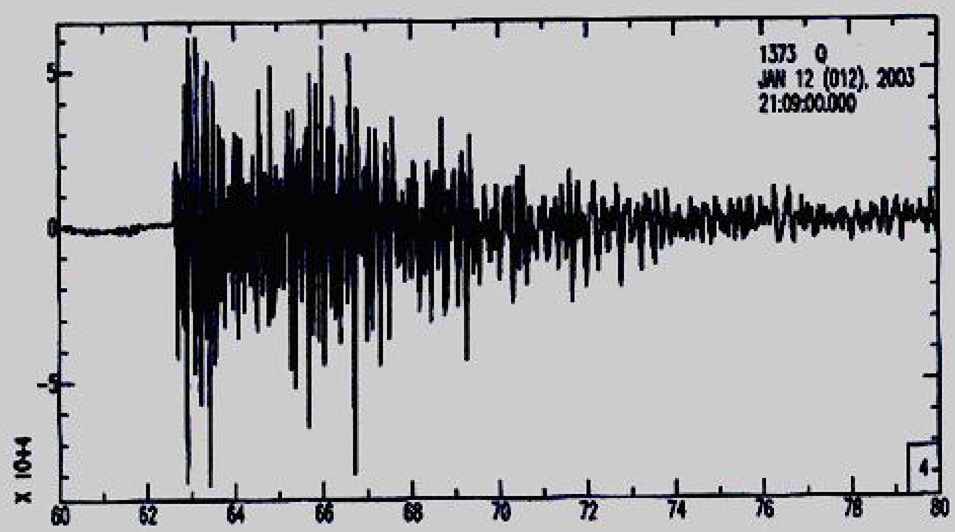
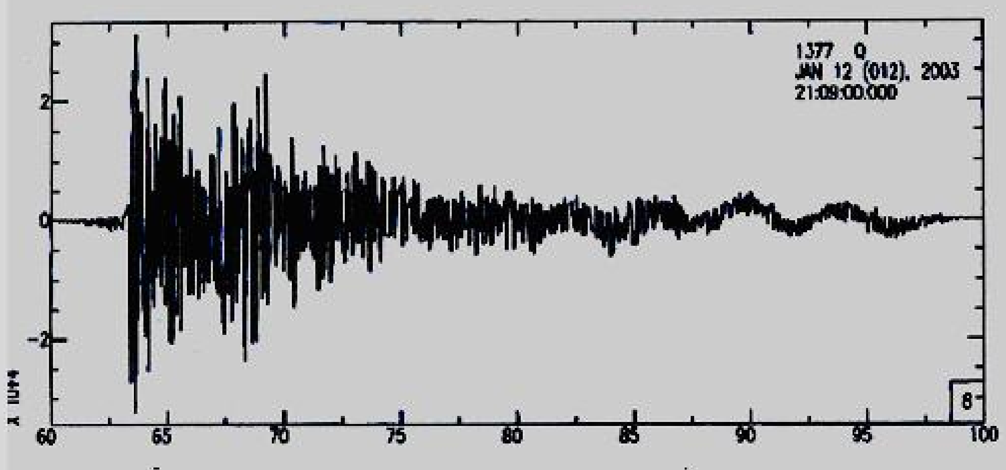


Fig: 4.2.1 Start Guralap 6TD’s traces of Gohatsion shot



Trace 1373

Fig: 4.2.2



Trace 1377

Traces for Kula Shot

Fig: 4.2.3