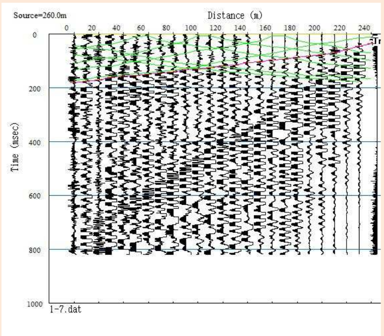
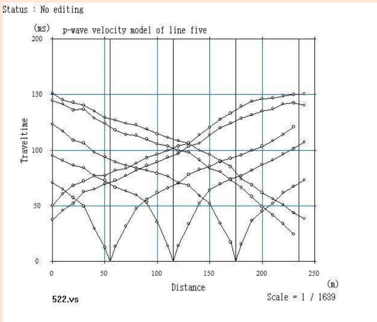
ADDIS ABABA UNIVERSITY

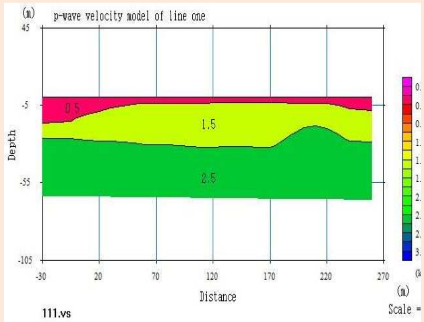
SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF EARTH SCIENCE

SEISMIC AND MAGNETIC STUDIES TO CHARACTERIZE THE FOUNDATION LAYER OF THE FUTURE KALEHIWOT UNIVERSITY SITE, DEBREZEIT AREA







A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSc) IN GEOPHYSICS

BY:

LINGEREW NEBERE

June, 2014

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Seismic and magnetic studies to characterize the foundation layer of the future Kalehiwot University site, Debrezeit area

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Declaration

I, the undersigned, hereby declare that this thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for the thesis have been duly acknowledged.

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This thesis has been submitted for examination with our approval as university advisor.

Name: Dr. Tilahun Mammo

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Name: Dr. Mulugeta Alene

Signature: ___________________

Abstract

Ground geophysical study was conducted at the future Kalehiwot university site, Kuriftu, Debre zeit, Ethiopia, using an integrated approach of seismic refraction and magnetic survey techniques in order to image the near subsurface in terms of main geological and geophysical properties covering the study area for construction purpose.

Kuriftu is located in the south end of Northern Main Ethiopia Rift (NMER), more specifically northeast of Debrezeit town. The main objective of the study has been to characterize the foundation layer of the future Kalehiwot University site with seismic refraction and magnetic methods. Seismic refraction method is based on the first arrival time information of seismic waves propagating through the subsurface, whereas magnetic method is based on the magnetic susceptibility contrast of the geology. Data enhancement techniques such as analytic signal and upward continuation were used to filter the magnetic data and clearly image the area anomaly.

Seismograph, geophones, as well as proton precision magnetometer was the instruments used in seismic refraction and magnetic survey respectively. The seismic refraction data were processed using SeisImager software, facilitates construction of time-distance plots and velocity model. The travel time curves were inverted using tomographic inversion techniques and reveal the velocity model of the area. Likewise the magnetic data was processed using Geosoft (oasis montage) software and different anomaly map and magnetic model was produced.

From the result of the velocity and magnetic models, the foundation layer was characterized. The area of study is covered by soil deposits with maximum thickness of 10 m.Volcanic origin phreatomagmatic materials underlie the soil deposit. This volcanic material originated from the interaction of hot magma with the ground water and it is located about 5-10m depth. The seismic velocity of this material is 1.5Km/s. The bedrock of the area is located about depth of 20-30 m; it is slightly weathered pyroclastic rock type. The seismic velocity of this layer is 2.5Km/s, reveals that it is relatively hard rock type. The rest of the lithologies underlie are welded pyroclastic and basalt.

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First of all, I would like to praise God, for being with me from the very beginning of my carrier up to the end.

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Acronym

CGMW	Commission for the Geological Map of the World
CMER	Central Main Ethiopian Rift
DZVL	Debre Zeit Volcanotectonic Lineament
GPS	Global Positioning System
IGRF	International Geomagnetic Reference Field
MER	Main Ethiopian Rift
MSc	Master of Science
NMER	Northern Main Ethiopian Rift
RMS	Root Mean Square
RTE	Reduction to the Equator
RTP	Reduction to the Pole
SMER	South Main Ethiopian Rift
2D-FFT	Two Dimensional Fast Fourier Transforms
YTVL	Yerer Tullu Wellel Volcanotectonic Lineament

CHAPTER ONE

INTRODUCTION

1. Background

To construct an effective and long last building, it is necessary to know the foundation layer and structure. Nowadays to solve the house demand of the people several companies and private individuals engage in infrastructural developments, such as roads, communications, building constructions etc. However, most of the service providers use the traditional geotechnical techniques, such as soil borings and rock coring only at the specific location of the predefined site to determine the quality of the earth materials.

In the case of construction problem, the adverse effects have been poor building constructions which ultimately lead to gradual or sudden collapse of such structures. The stability of a structure depends upon the stability of the supporting earth materials. The overall objective of a site investigation for construction design is to determine the geological profile and the properties of the various strata (Deng, 2000). The geological sequence can be established by sinking boreholes from which soil and rock samples are retrieved for identification and testing. But in this research geophysical methods were used as to characterize the subsurface geology by determining the physical property of the subsurface materials.

Knowing physical properties of geo-materials are the very important parameters for building construction. Physical properties of earth materials reveal the strength and weakness of the area geology. The best technique to know physical properties of the earth materials within a short period of time over a wide area are geophysical techniques. Geophysical investigations of the interior of the earth involve taking measurements at or near the earth's surface that is 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 (Reynolds, 1997).

Before the erection of any civil engineering structures such as bridges, dams, tunnels and building constructions it is important to analysis horizontal and vertical lithologic extents, depth to competent rock, bedrock quality by geophysical methods (Alemayehu Ayele, 2012), such as electrical tomography, seismic refraction and magnetic method. Seismic refraction and magnetic survey are among the most used methods in engineering application to delineate subsurface structures. Those geophysical methods are depends on the acoustic impedance and magnetic susceptibility contrast of the subsurface materials. Different types and strengths of rocks transmit energy at different velocities and have different magnetic susceptibility.

1.1. Description of the study area

1.1.1. Location of the study area

The area proposed for the geophysical work is found in central Ethiopia, Ada'a Woreda, 47.9 kilometers southeast of Addis Ababa, in the northeast end of Debrezeit town and it is accessed by about 8km asphalted road from northeast of Addis Ababa-Mojo main road (Fig. 1). It is one of the famous recreational centers and easily accessible area of the country. The town, Debre Zeit, is located in the east Shewa zone of the Oromiya region; its geographical coordinates are 8° 45' 0" north, 38° 59' 0" east and has an elevation of 1,875-1,920 meters, which forms in part of the Main Ethiopian Rift (MER).

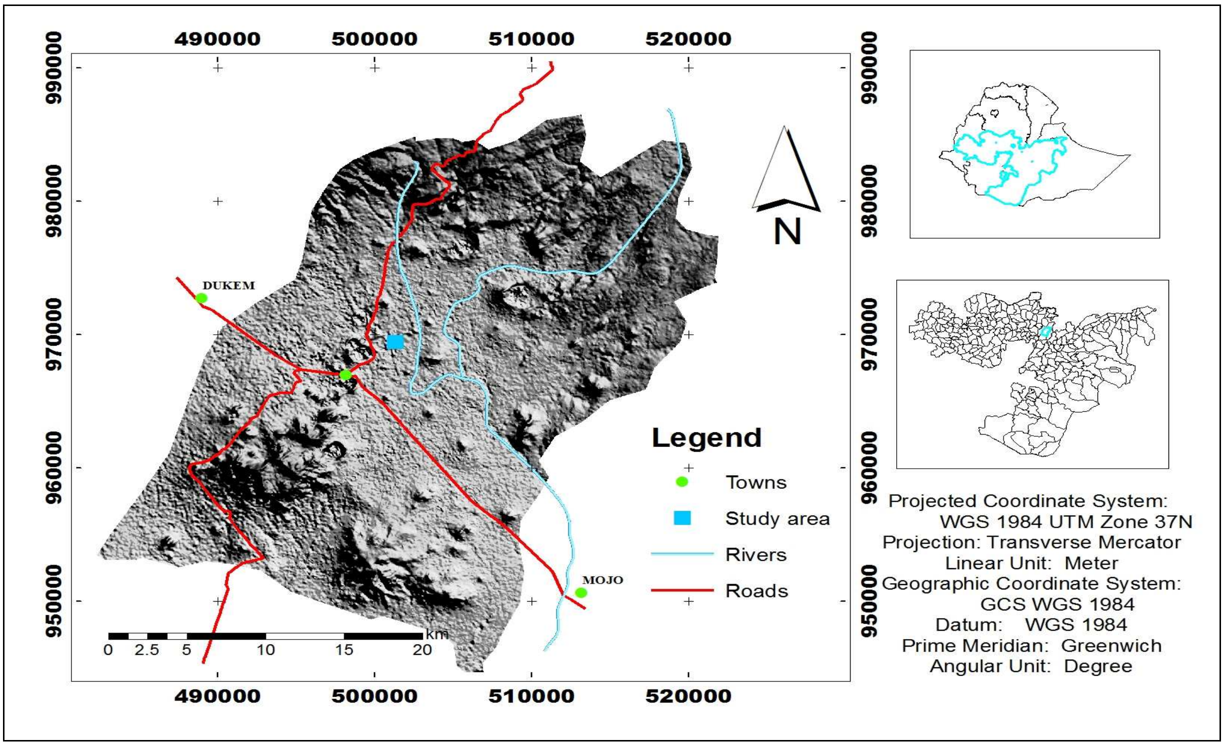

Figure 1. Location map of the study area.

1.1.2. Topography

The flat topography of Debre zeit as shown from the location map (Fig. 1) is disturbed by the Bade Gebabe volcano that exists in the southeast end, central volcano unit (Yerer) located north end of the Woreda and several lakes that exist in the central part of the area. The area, Kuriftu, on which different building construction is going to be constructed is a flat topography land bounded by a small relief on the Southwestern, western and northwestern side. The Kuriftu Lake is located in the northeast of the site. The south and southeast of the site is bounded by a land with gentle slope. Figure 2 shows the partial view of the construction site topography.

Figure 2. Partial view of the construction site topography.

1.2. Statement of the problem

The area of study is located in the south end of Northern Main Ethiopia Rift (NMER), more specifically outside (northeast) of Debre zeit town, Kuriftu which is located in the central Ethiopia. The area is situated in the highly active tectonic area of the NMER, near the boundary of the NMER and Central Main Ethiopian Rift (CMER) where the Main Ethiopian Rift intersects the E-W trend of the Yerer Tullu Wolel volcanotectonic lineament. As a result of location of the site within the MER, there is a probable existence of active faults, failure surface, underground cavity and lateral variation of geological formation. Any design needs knowledge of the detail subsurface conditions. In such area traditional geotechnical techniques, such as soil borings and rock coring only at the specific location, does not provide a good information, and cannot be used reliably to interpret the surrounding conditions at sits with probably highly inhomogeneous subsurface.

Thus the above problems can be resolved with the help of well-established geophysical methods, which can reveal better characteristics of physical properties of detail subsurface over the whole area by conducting a number of investigations on the site. As a result, investigations of subsurface material properties using geophysical methods are taken along closely spaced measurements to provide the actual detail in a cost effectively manner.

The various geophysical methods rely on different physical properties. Therefore it is important that the appropriate technique be used for a given type of application. In this study for the application of subsurface geology characterization, geophysical methods such as seismic refraction and magnetic methods are implemented. Thus used as to identify week zone of the area, variation in strength of structures either laterally or vertically, quality of the competent rock and depth of the bedrock. The above two geophysical methods use physical properties of acoustic impedance and magnetic susceptibility of the earth materials respectively.

1.3. Objectives

1.3.1. General objective

The main objective of this thesis is to characterize the foundation layer of the future Kalhiwot university site using seismic refraction and magnetic methods.

1.3.2. Specific objective

To fulfill the research, specific objectives are the following:

- To acquire seismic and magnetic data of the construction site
- To determine depth of the bedrock

- To determine bedrock surface structure of the site
- To characterize the rock quality of the site
- To determine/ map weak zones that may affect the quality of rocks

1.4. Methodologies

In order to effectively and systematically accomplish the above objectives, the following approaches and methodologies have been adopted:

- Literature review and collection of relevant materials/data that include available published and unpublished works, geological maps, aerial photos, software's etc.
- The research work involved six day fieldworks. The approach was accomplished using measured seismic refraction data and magnetic survey data to determine and characterize the subsurface geology and to map weak zone of the site. The basis of using variation in arrival time and variation in magnetic susceptibility is that depend on the variation in geology of the area.
- The acquired magnetic data from the survey is reduced using base station reading by Microsoft excel software. The effect of diurnal variation had been corrected in order to remain with the magnetic variation which is significant for processing. The travel time curve, seismic velocity model, magnetic anomaly map, and model was produced using SeisImager, and Geosoft (oasis montaj) mapping software for qualitative and quantitative interpretation of the data, i.e. to map variation of susceptibility and velocity contrast, depth and structure of the underlying rock.
- The generalized flow chart of the methodological approach deployed for this investigation is described in Figure 3.

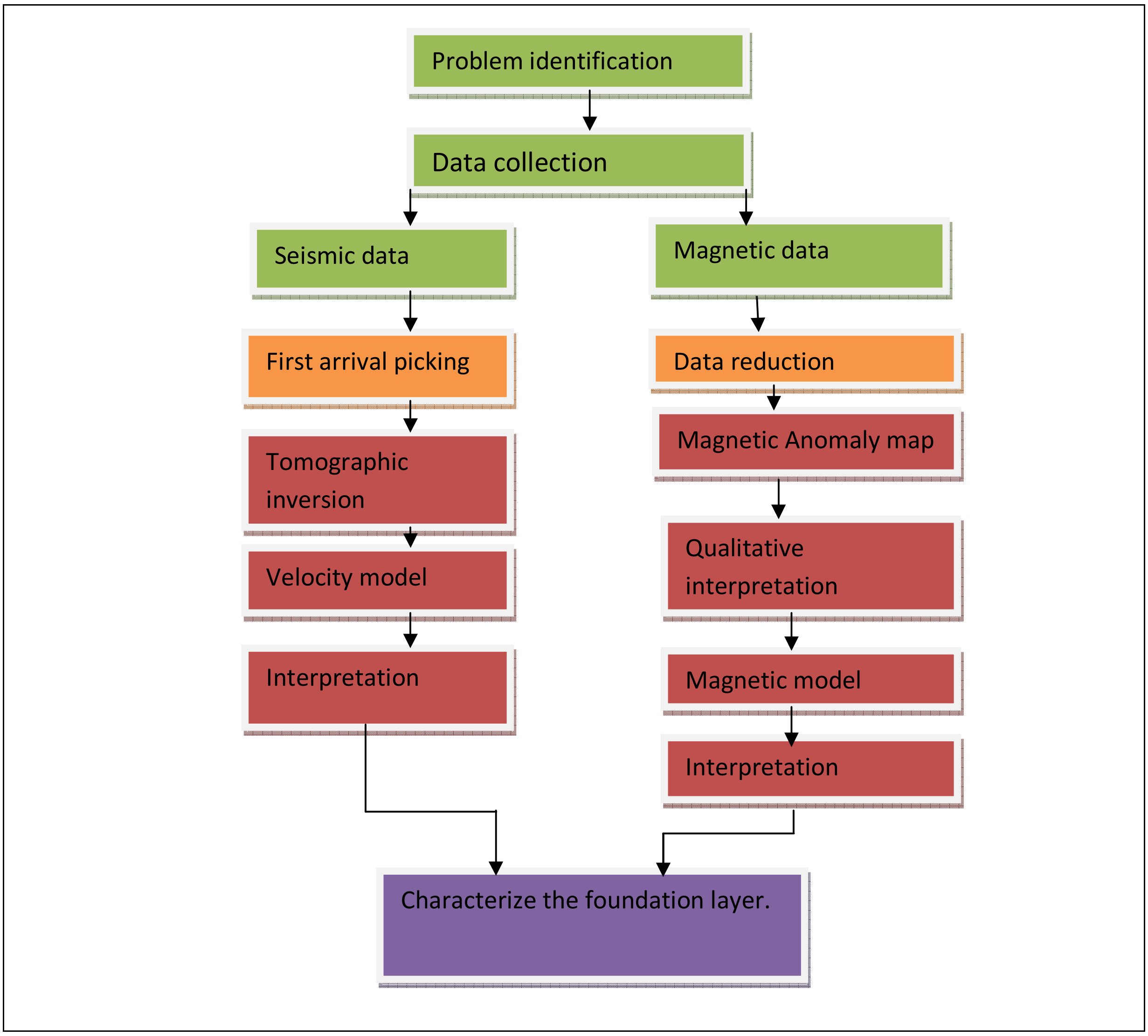

Figure 3. Flow chart of the methodologies applied for the investigation.

1.5. Layout of the thesis

This thesis contains six chapters. The first chapter explains the general introduction of the study, methodology and instrumentation applied. The second chapter is all about geology and seismicity of the study area and its surroundings. Chapter three covers the theoretical background employed in this study. Chapter four describes the data acquisition, data processing, and presentation of the geophysical methods. Chapter five covers results and interpretations of geophysical methods. The last chapter contains conclusions of the research work.

CHAPTER TWO

GEOLOGY AND SEISMICITY OF THE STUDY AREA

2.1. Regional geology

Because the study area is part of the MER, the regional geology and geological history of the study area is an integral part of the evolution and development of the Ethiopian Rift system. The MER system is characterized by a series of formation of normal faults from Tertiary to Quaternary era. It is a key region as it comprises a series of rift segments linking the Kenya rift to the Red sea-Gulf of Aden rifts at the Afar triple junction.

Following uplift of the Horn of Africa, immense quantities of lavas, the Trap series, extruded from fissures and eruption centers (Mohr, 1961).The Trap Series lavas, the earliest and most extensive groups of volcanic rocks erupted from fissures during the early and middle Tertiary (Kazmin,1975 and Solomon Tadesse et al.,2003), which are mostly made up of basaltic lava flows (with some acidic flows in the upper parts), cover large areas of Mesozoic sediments and in some places; they rest directly on the Basement complex. Such uplifts, together with the extrusion of thick and extensive Trappean lava, account for the formation of the present highland region of Ethiopia.

Rifting started during late Miocene time; extensional deformation is still active as testified by the intense seismic activity (Tsegaye Abebe et al., 2005).The Ethiopian rift is the northernmost extension of the great east African rift that extends from north eastern Ethiopia to Mozambique in south Africa, with a length of more than 4000km (Solomon Tadesse et al.,2003). It dissects the Ethiopian dome, which is made of Precambrian crystalline basement, Mesozoic marine and continental sediments and Tertiary- Quaternary volcanic rocks

The MER has traditionally been divided into three sectors based on surface geology and geomorphology, the NMER, Central Main Ethiopian Rift (CMER), and Southern Main Ethiopian Rift (SMER) sectors (Keranen and Klemperer, 2008). The study area, Debrezeit is located south end of the NMER. Active deformation within the NMER is consisting of rift volcanoes, basaltic fissures, and young fault belts, with a north-northeast trend oblique to the overall rift trend.

The MER intersects the E-W traverse structure, the Yerer-Tullu Wellel volcanotectonic lineament-YTVL, that produced the smoothing of the morphological expression of the rift margin and the onset of a secondary rift axis associated with the most recent volcanic activity in Debrezeit area since upper Miocene. This area represents the transition zone between the Ethiopian plateaus and the MER. As Keranen and Klemperer (2008) explained the YTVL is a trend of volcanoes and fracture systems trending roughly east-west, intersecting the MER at the NMER–CMER boundary.

2.2. Regional structures and tectonics

Principally four regional structures exist near the study area. The first one is faults associated with the MER, parallel and sub-parallel to the NE–SW trending rift axis. The rift floor is affected by several faults that form smaller horst and graben structures. The Debre zeit volcanotectonic lineament (DZVL) is the second structure parallel to the main rift axis at the margin. The third one is the Wonji fault where it has a NNE-SSW trending narrow zone of active deformation made up of high angle en-echelon normal faults which occurs at the eastern border of the Main Ethiopian Rift in the Asela-Ziway area (Bonini et al., 2005). Most of the recent (Quaternary) volcanic activity in the MER is closely associated with the Wonji faults, as suggested by alignments of Caldera structures, Cinder cones, Volcanic fissures (Keranen and Klemperer, 2008). In the NMER, there are four major Wonji fault belt segments (Gedemsa, Boseti, Kone and Fantale-Dofen). The YTVL is another main structure of the area, having E-W trending almost perpendicular to the Main Rift axis.

The East African Rift (EAR) system is most typically developed in the section as the MER, which extends from Lake Chamo, in the south, to Afar in the north. It is one of the largest structural features of the earth’s crust. From early Tertiary until the end of Eocene the region had been under intense vertical uplift producing the Afro-Arabian dome. As a result the region has been trisected in to distinct crustal segments: the Arabian Segment, the Nubian (African) Segment and, the Somalian Segment.

The main zones of weaknesses are located along the Red Sea, Gulf of Aden and East African rift system. From early Tertiary onwards these zones of weaknesses have been under tensile stress accompanied by upwelling of the underlying asthenosphere causing boundaries to diverge and are moving apart from each other. This spreading is a tectonic deformation which as consequence made the region an active tectonic and volcanic zone. Decompression of the asthenosphere results in large volumes of magma generation. Further brittle extension of the crust results in down-faulting and formation of the graben (Omenda, 2005).

2.3. Geology of Debrezeit

The general smooth surface morphology of Debre zeit area is interrupted by the two central volcanoes, Yerer and Ziquala, which rise more than 1000m above the plain. As Mazzarini et al. (1999) explained the area around Debre zeit, is mainly covered by volcanic and sedimentary rocks. The sedimentary rocks consist of alluvial cover and lacustrine sequences. Volcanic activity in the area has given rise to the central composite volcanoes and monogenic apparatea as domes, spatter cones and maars.

The lithology of the area is grouped into three units.

2.3.1. Bishoftu volcanic unit

This unit forms a NNE trending belt outcropping mainly in the central flat areas of Debre zeit. It consists of volcanic spatter and cinder cones with associated tabular basaltic lavas flows and phreatomagmatic deposits. The basalt is vesicular and coarse grained with olivine phenocysts. The phreatomagmatic deposits are mainly consisting of surges and highly fragmented deposits associated with maars and tuff ring.

2.3.2. Bede Gebabe volcano unit

It is a circular volcanic complex outcropped southwest of the study area with maximum elevation of 400m above the surrounding plane. It forms a morphology dominated by the occurrence of several coalescent caldera structures. Spatter cones and basaltic lava flows belonging to younger Bishoftu Volcanics are present in the central part of the volcanic complex. Lacustrine deposits rest above Bede Gebabe volcano unit all over its marginal portion.

2.3.3. Lacustrine deposit

This unit occurs in the Ada’a plain and lakes region. The lacustrine beds are fine grained deposits, generally brown-yellowish, thinly stratified and often contained volcanic matrix;

thickness of the beds ranges from 5 to 8m. In these successions volcanic layers are frequent and become predominant and coarse grained near by the maars.

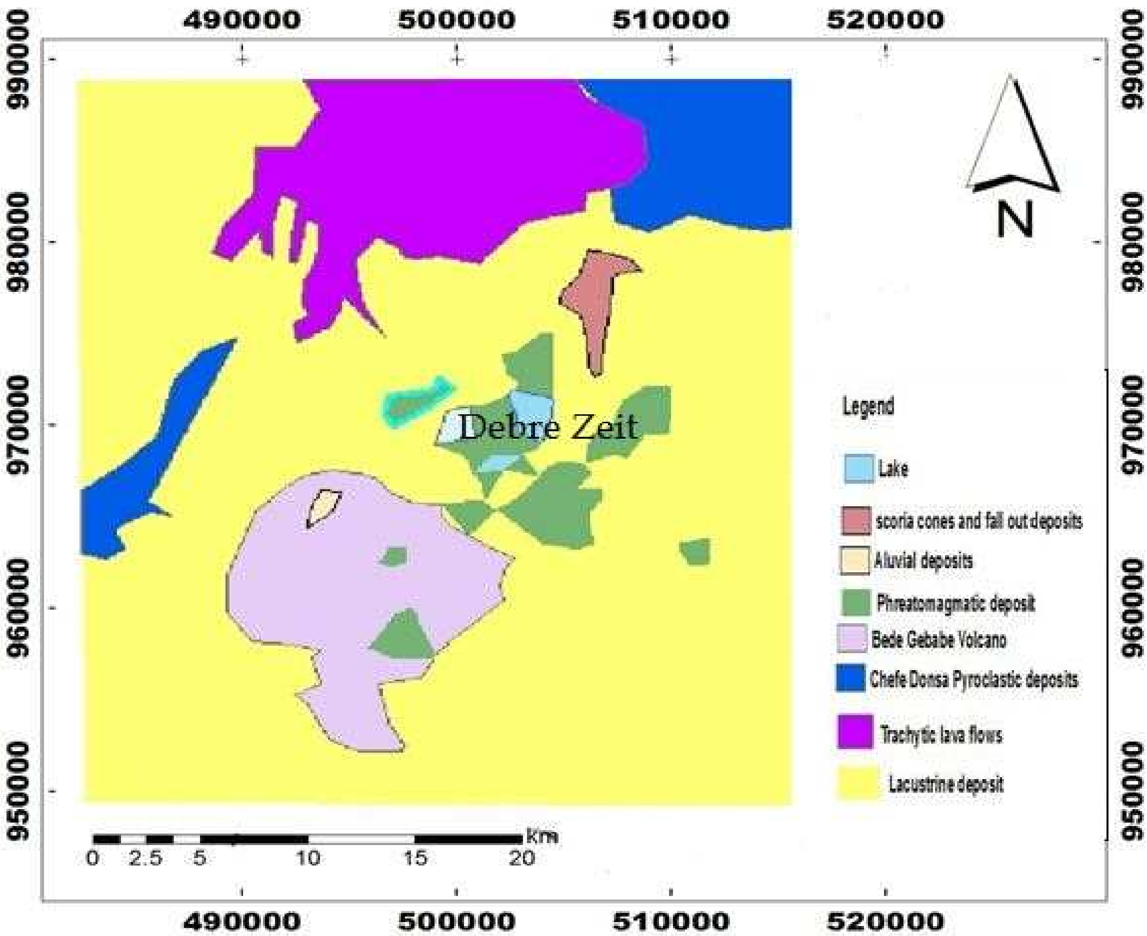

Figure 4. Geological map of the Debre Zeit area (Tsegaye Abebe et. al., 1999).

2.4. Seismicity of the study area

The Main Ethiopian Rift is a seismically and volcanically active portion of the East African Rift System (EARS) trending NE across the Ethiopian plateau (Keranen and Klemperer, 2008). The study area is located in the Main Ethiopia Rift. In addition to the existence of this seismically active rift, the Quaternary-recent tectonically active lineament of DZVL, parallel to the trend of the MER and Miocene-recent YTVL, which is almost perpendicular to the main rift are another considerable seismically active lineament at the east and south of the study area respectively.

Therefore because of this lineament and the Main Rift, the study area is in seismically active region. In addition, due to the lacustrine and alluvial deposits, have an ability to amplify the amplitude of the seismic waves. Because of these reasons even small magnitude of earthquake might damage the building structures easily. Structures in many earthquake prone countries are now being designed more safely from information obtained from seismic zonation maps.

Based on the seismicity and the knowledge of the geology and tectonics the region can be broadly divided into three seismic source zones (Fig. 5). These are the Afar Depression, the Escarpment and the Ethiopian Rift System. Each zone is, therefore distinguished by its own specific tectonic, geologic and seismic characteristics (Tilahun Mammo, 2005).

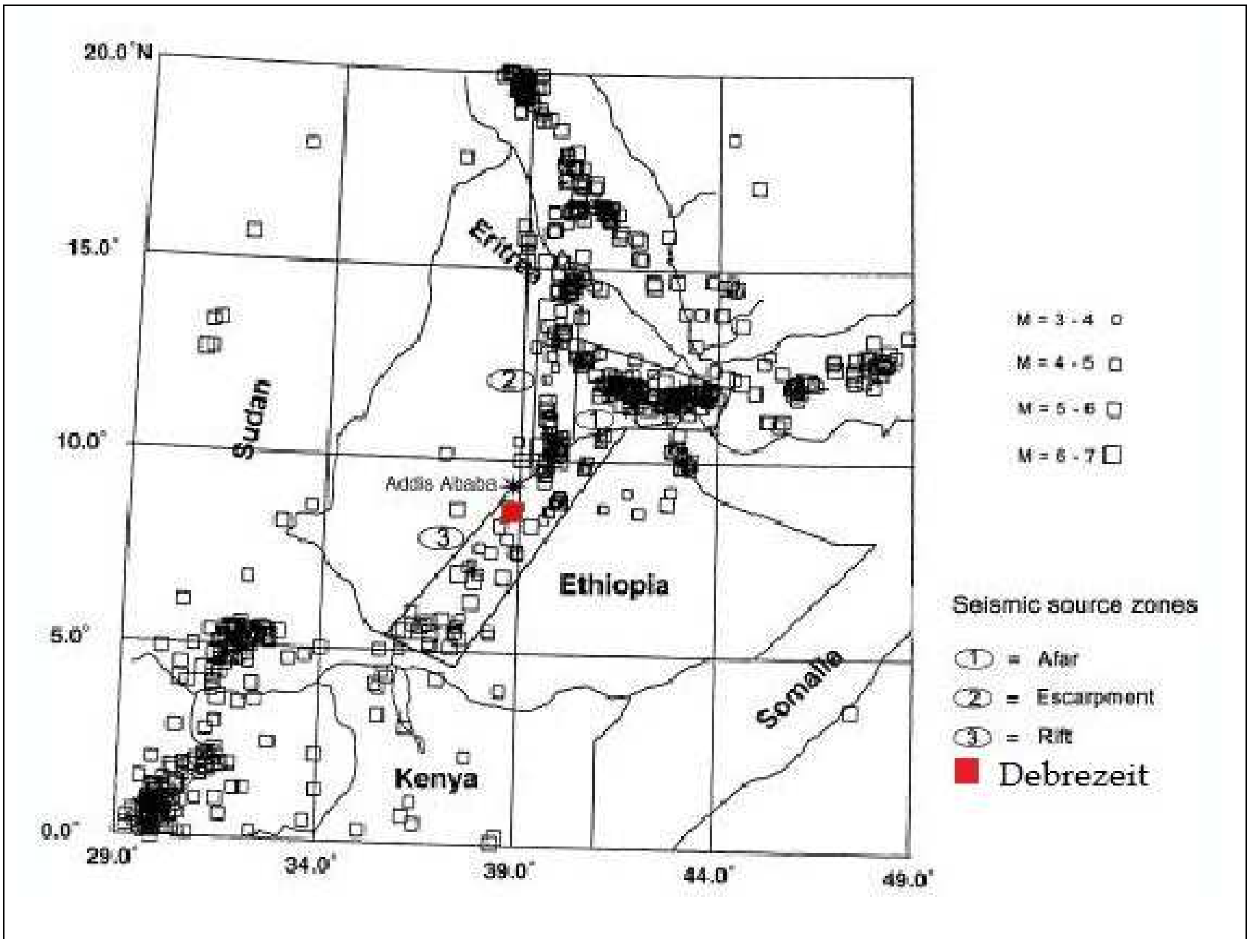

Figure 5. Seismicity of the Region with the Seismic Source Zones (Tilahun Mammo, 2005).

As shown from the above Figure (Fig. 5) the study area is located in the Main Rift. This shows that the study area and its surrounding are in seismically active area. Therefore, considering the lacustrine and alluvial deposit, which is able to magnify the amplitude of earthquakes in the site and its vicinity to seismically active area of the rift, the design should incorporate all necessary conditions to withstand any seismic hazard.

CHAPTER THREE

THEORETICAL BACKGROUND OF METHODS OF INVESTIGATION

3.1 Introduction

In this study, the main objective has been to characterize the foundation layer of the future Kalehiwot university site by determining the physical property of the subsurface material using geophysical methods. Geophysical methods study parts of the earth hidden from direct view by measuring their physical properties with appropriate instruments, usually on the surface. Geophysical methods such as seismic refraction, electrical and electromagnetic methods are used as the primary methods for engineering site investigation. However, in this research seismic refraction and magnetic methods has been used. Even though magnetic method is secondary method of engineering sit investigation, it has a power to see the anomaly of the week zone clearly additional to seismic refraction and it can map the anomaly of deep situated.

3.2 Seismic methods

The seismic method utilizes the propagation of waves through the earth and is the most commonly conducted geophysical survey for engineering investigation. According to Aigbogun and Egbai, (2012, as sited in Telford, 1974) the seismic method is by far the most important geophysical technique in terms of cost effectiveness, high accuracy, high resolution and great penetration of which the method is capable. Reflection and refraction are the most commonly used seismic techniques. But in this research seismic refraction method has been used as the primary engineering site investigation to measure the depth to bedrock, to determine structure of the bedrock and to identify week zone of the area in connection with the construction of buildings. These techniques provide detailed information about subsurface layering and rock geotechnical properties using seismic waves.

3.2.1 Seismic waves

A seismic wave is acoustic energy transmitted by vibration of rock particles. Seismic waves are often referred to as elastic waves because they cause deformation of the material in which they propagate (John, 1986). Elastic waves, leaving the rock mass unchanged by their passage, but close to a seismic source the rock may be shattered and permanently distorted **(**Milsom**,** 2003**).**

From the point of view of the spatial concentration of energy, waves can be divided into body waves and surface waves. Body waves can propagate into the interior of the corresponding medium, whereas surface waves are concentrated along the surface of the medium.

Body waves

These are elastic waves that propagate through the earth's interior. In refraction prospecting, body waves are the source of information used to image the earth's interior. It follows from the theory of elasticity that there are two principal of elastic body waves. The two wave types are called longitudinal and transverse waves (John, 1986), used for seismic refraction tomography (Kesarwani et. al., 2012).

Longitudinal waves

Longitudinal waves are also called **P** waves (primary waves), because they represent the first waves appearing on seismograms. These waves involve the compression and rarefaction of the material as the wave passes through it, but not rotation. According to (Salvador, 1999) every particle of the medium, through which the longitudinal wave is passing, vibrates about its equilibrium position in the direction in which the wave is traveling. Regarding this research longitudinal waves are the primary source of information by picking the first arrival time.

Transverse waves

Transverse waves are also called shear, rotational waves. In seismology, they are also called S waves (secondary waves). The particle motion is perpendicular to the direction in which the wave is traveling (Salvador, 1999).These waves involve shearing and rotation of the material as the wave passes through it, but no volume change.

The propagation velocities of the two wave types through a rock mass depends upon the rocks bulk modulus (k), shear modulus (μ) and the density (ρ) (John, 1986). Bulk modulus is incompressibility of the medium, meaning that if bulk modulus is very large, then the material is very stiff, it does not compress very much even under large pressure. Whereas shear modulus describes how difficult it is to deform the material under an applied shearing force.

The relationship between the compressional wave velocity $\mathbf{v_p}$ and the elastic parameters are;

$$vp = \sqrt{\frac{k+\frac{4\mu}{3}}{\rho}} \tag{3.1}$$

And between the shear wave propagation velocity $\mathbf{v_s}$ and the elastic constants;

$$vs = \sqrt{\frac{\mu}{\rho}} \tag{3.2}$$

Both longitudinal and transverse elastic waves can propagate in solid media. However, only longitudinal waves can propagate in liquids and gases; transverse waves cannot propagate in these media because $\mu=0$ and, consequently, $\mathbf{V_s}=0$. Any change in rock or soil property that causes ρ,μ or k to change will cause seismic wave speed to change. As Salvador (1999) explained, Elastic body waves are reflected and transmitted at the discontinuities of elastic parameters. Variations in seismic velocities offer the potential of being able to map many different subsurface features.

Changes in lithology, cementation, compaction, fluid content etc will result change in seismic velocity and cause refraction and reflection at the boundary of elastic parameters. This research is interested in using refraction of seismic waves at the boundary of the discontinuity and delineates the structural feature of the subsurface by closed view of the first arrival time of longitudinal wave.

3.2.2. Refraction seismic method

The seismic refraction method uses the seismic energy that returns to the surface of the earth after traveling along ray paths through the ground, to locate refractors that separate layers of different seismic velocity (Alhassan, 2010), therefore the primary application of seismic refraction techniques are for determining the depth to bedrock and bedrock structure(Kesarwani et al, 2012). It is based on the times of arrival of the seismic energy generated by a source recorded at a variety of distance. Later- arriving complications in the recorded ground motion are discarded. Thus, the data set derived from seismic refraction consists of times versus distances.

These are inverted and then interpreted in terms of the depths to subsurface interfaces and the speeds at which motion travels through the subsurface within each layer. These speeds are controlled by a set of physical constants, called elastic parameters that describe the material Aigbogun and Egbai, (2012), so that because of the dependence of seismic velocities on the elasticity and density of the material of the subsurface layer through which it is passing seismic refraction surveys also give a measure of material strengths and consequently it acts as an aid in assessing rock strength and rock quality (Kesarwani et al, 2012).

3.2.3. General principle of refraction method

The underlying principle behind seismic refraction technique is the measurement of travel times of the seismic waves refracted at the interface between the subsurface layers of different velocities. Seismic refraction investigates the subsurface by generating arrival time and offset distance information to determine the path and velocity of the elastic disturbance in the ground. The seismic energy generated by a seismic source ('shot') located on the surface radiates outward from the shot point spreading in all direction (Kesarwani et. al., 2012), it may either travel directly through upper layer (direct arrivals), or it may travel down to and then laterally along the high velocity layers (refracted arrivals) before bouncing up and coming back to the surface (Fig.6).

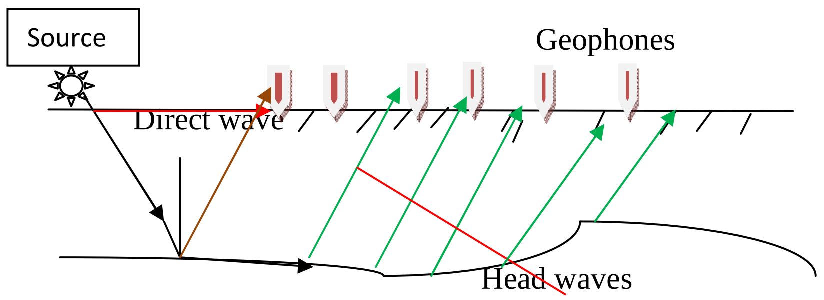

Figure 6. Seismic refraction geometry.

The disturbance is created by shot, hammer, weight drop, or some other comparable method for putting impulsive energy into the ground. Detectors laid out at regular intervals measure the first arrival of the energy and its time.

Refraction seismic is based on the following principles of physics;

- Fermat's principle
- Snell's law
- Huygens's principle

Fermat's principle states that seismic waves travel between two points (Fig.7) along paths requiring the least time.

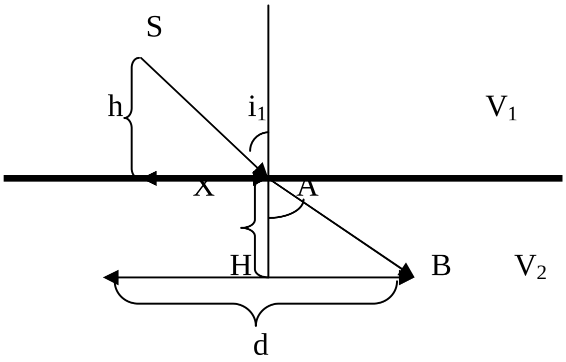

Figure 7. Seismic ray path.

Now

$$T = t_1 + t_2$$

But

$$t_1 = \frac{SA}{V1} = \frac{X}{V1 sini_1} \quad \text{and} \quad t_2 = \frac{AB}{V2} = \frac{d-X}{V2 sini_2}$$

Therefore,

$$T = \frac{X}{V1 sini_1} + \frac{d-X}{V2 sini_2} \text{ where } sini_1 = \frac{X}{\sqrt{X^2+h^2}} \quad and\ sini_2 = \frac{d-X}{\sqrt{(d-X)^2+H^2}}$$

$$T = \frac{\sqrt{X^2+h^2}}{V_1} + \frac{\sqrt{(d-X)^2+H^2}}{V_2}$$

Now, using minimizing criteria $\frac{dT}{dx} = 0$; gives

$$\boxed{\frac{\sin i_1}{v_1} = \frac{sini_2}{V_2}} \quad \text{Snell's law} \qquad (3.3)$$

Snell's law shows that rays get closer to the vertical if going into a slower layer. Therefore refraction does not work if the deeper layer is slower than the shallower, implies there is no critical angle if the velocity of the deeper layer is less than the upper layer. Huygens recalls that rays are not real; they are just an easy way to understand and quantify waves. Wave fronts are what are really happening. When any particle oscillates it is a tiny source of waves, so every point on a wave front acts as a small source that generates waves (Telford et al., 1990).

Critical refraction

The seismic refraction method is based on the principle that when a seismic wave /p- and/or s-waves/ impinges upon a boundary across which there is a contrast in velocity, then the direction of travel of that wave changes on entry into the new medium. The amount of change of direction is governed by the contrast in seismic velocity across the boundary according to Snell's law (Reynolds, 1997**).**

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2} \qquad (3.4)$$

The necessary condition for waves to be critically refracted is that the velocity of seismic waves in the lower medium should be higher than in the upper medium (Sander, 1978). Critically refracted waves travel along the interface with the velocity of the lower medium. While doing so, they initiate vibrations-seismic waves- in the upper medium that eventually reach the surface, where they can be detected by geophones.

The conventional seismic refraction technique works best when it is applied to geological situations where there are essentially flat laying strata, with seismic velocities which increase successively with depth (John, 1986). That is, even though refraction occurs in the normal manner, the refracted pulse from a layer may not reach the surface as a first arrival and will thus be obscured in the disturbance created by the first arriving signal. These conditions occur when a refracting layer is relatively thin and its velocity is not significantly greater than that of the overlaying medium. In refraction surveying such problem is resolved by clearly picking the first arrival time of longitudinal wave and by introducing geophysical model based on the given data.

3.2.4. Geophysical Inversion

Geophysical inversion is a method which finds a model that gives a response that is similar to the actual measured values. The model is an idealized mathematical representation of a section of the earth and it has a set of model parameters of physical quantities which required are to be estimated from the observed data. The model response is the synthetic data that can be calculated from the mathematical relationships defining the model for a given set of parameters. All inversion methods essentially try to determine a model for the subsurface whose response agrees with the measured data subject to certain restrictions. All inversion methods essentially try to find model for the subsurface whose response agrees with measured data. In this study (refraction survey) the model is done by software called SeisImager/2D, it is a powerful refraction package. It offers three separate inversion techniques: the time term method, the reciprocal method, and tomography. Tomography is a best method which can map the details of earth's structure, when the geology is very complex based on the first arrival time of p wave and is the inversion method applied to this study, which is the best inversion method to see the earth in slices.

Tomography

In this research the ultimate goal of seismic surveying is seeing the subsurface of the earth as sectional view. Doing so, the way of seismic imaging methods all require an accurate parameter estimation process. So that in processing seismic data the earth internal parameters of velocity and density play a critical role.

The word tomography is defined by many authors (Jones, 2010; Padina, 2006), origins in the two Greek words tomos, meaning section, and graphy, which translates as drawing. The basic idea of tomography in all of its uses is to obtain a cross-section of an object which will then be used to infer various facts regarding the particular objects internal structure.

The tomography method relies implicitly on the general principles of inverse theory. Inverse theory provides a mathematical framework to construct a suitable image (model) of some physical quantity based on a set of measured data (Yordkayhun, 2008). To find the best earth model when observation data are given is called an inverse problem on the other hand, to determine what kind of signal a given geophysical model would give is referred to as a forward problem.

According to Yordkayhun (2011) a suitable image (model) of physical properties is constructed based on a set of measured data through a mathematical framework providing by the inverse theory. If we represent some property of the subsurface (example velocity) by a set of model parameters m, then a set of data (example travel time) d can be predicted for a given source-receiver array by line integration through the model. The relationship between data and model parameters forms the basis of any tomographic model;

$$d = Gm \tag{3.5}$$

where d-vector of the observation

G- Kernel matrix that relates the model to the observation

m- Model parameter

The inversion process involves computing the model m. A solution is often found by using a least squares approach. However, the problem should be constrained or regularized in some way to control the inverse solution to be stable. The first step in tomography processing is picking the first arrival travel times since they served as the input parameters for the inversion procedure.

3.3. Magnetic method

3.3.1. Introduction

Magnetic method is a passive geophysical method (use the natural field of the earth) involves the measurement of the earth’s magnetic field intensity to investigate subsurface geology on the basis of anomalies in the earth’s magnetic field resulting from the magnetic properties of the underlying rocks (Kearey et. al., 2002). The magnetic method of prospecting has a great deal in common with the gravitational method. Both make use of potential fields. Both seek anomalies caused by changes in physical properties of subsurface rocks (Dobrin and Savit, 1988). It has a broad range of applications, from small scale engineering or archaeological surveys to detect buried metallic objects, to large scale surveys carried out to investigate regional geological structures (Kearey et. al., 2002).

3.3.2. Principles and elementary theory

The principle underlying the operation of the Magnetic Method is based on the fact that when a ferrous material is placed within the Earth's magnetic field, it develops an induced magnetic field. The induced field is superimposed on the Earth's field at that location creating a magnetic anomaly. Detection depends on the amount of magnetic material present and its distance from the sensor. The anomalies are normally presented as profiles or as contour maps. Magnetism is based on the physical property of the materials and the magnetic properties of materials are expressed by the physical quantities. The force **F** exists between magnetic poles of strength ρ_1 and ρ_2 separated by a distance r, are given by Coulomb’s law.

$$F = \frac{\rho_1 \, \rho_2}{\mu r^2} \tag{3.6}$$

where μ- is magnetic permeability

P_1 and P_2 - are the strengths of the two magnetic monopoles, and

R- is the distance between the two poles.

The direction of the force is depending on the polarity of the poles.

The strength of the magnetic field existing at a point in space, as a result of a pole strength P_1 located at a distance r from it. The magnetic field strength H is defined as the force per unit pole.

$$H = \frac{F}{\rho_2} = \frac{\rho_1}{\mu r^2} \tag{3.7}$$

The poles of a magnet exist in pairs and they referred as dipoles.

3.3.3. Magnetic Susceptibility

Magnetic susceptibility is a measure of the ease with which particular rock are magnetized when subjected to a magnetic field. The ease of magnetization is ultimately related to the concentration and composition (size, shape and mineralogy) of magnetizable material contained within the sample. The intensity of magnetization, I, is related to the strength of the inducing magnetic field, H, through a constant of proportionality, k, known as the magnetic susceptibility, which is a measure of how susceptible a material is to becoming magnetized.

$$k = \frac{I}{H} \tag{3.8}$$

The magnetic susceptibility is a unit less constant that is determined by the physical properties of the magnetic material. It can take on either positive or negative values. Positive values imply that the induced magnetic field, I, is in the same direction as the inducing field, H. Negative values imply that the induced magnetic field is in the opposite direction as the inducing field.

In magnetic prospecting the susceptibility is the fundamental material property whose spatial distribution are attempting to determine. In this sense, magnetic susceptibility is analogous to density in gravity surveying.

3.3.4. The earth's magnetic field

Earth's magnetic field depends on earths internal properties and so has provided a wealth of information on the interior of the planet. The earth's magnetic field is a vector quantity that is far from being constant either in magnitude or in direction and varies spatially over the surface of the earth as well as in time. The magnetic field of the earth (Arewa and Kolawole, 2012), sampled at any point on its surface is made up of two main parts, the external and internal components.

$$B_T = B_{ext} + B_{int} \tag{3.9}$$

where B_T- total magnetic field

B_{ext}- external magnetic field

B_{int}- internal magnetic field

The external magnetic field accounts for 1% of the earth's field. It is caused by solar activities involving emission of ultraviolet radiation and streams of electrons which, in turn, create electric currents through ionization of particles in the upper atmosphere (Telford et al., 1990). It is very variable, and has an 11-year periodicity which corresponds to sunspot activity. There is a diurnal periodicity of up to 30ϒ, which varies with latitude and season because of the effect of the sun on the ionosphere. There is a monthly variation of up to 2ϒ which is the effect the sun on the ionosphere. Any variation in the number or velocity of such ionized particles causes a change in the magnetic field at the surface of the earth.

As Arewa and Kolawole (2012) explained the internal components are subdivided into two parts, the first one is regional component caused by deep-seated and distant magnetic sources. The origin of the earth's field is known to be 99% internal and to be generated by convection in the liquid outer core, which drives electric currents. It cannot be due to rocks because it must be deep, and rocks lose their magnetization above the Curie temperature. The Curie temperature for magnetite is 578^0c, whereas the temperature of the core is probably approximately $5,000^0$c. As CGMW (2007) explained the core field is not static and undergoes both special and temporal variation. For example, the magnetic poles are constantly in a state of motion.

The second one is residual component due to magnetic in-homogeneities of the earth crust and other magnetic sources near the earth surface (Arewa and Kolawole, 2012). It is carried by the crust and the upper part of the earth's mantle. The magnetic field of a rock depends on its mineral content and the main magnetic mineral in the crust, the magnetite (Fe_3O_4), loses its magnetic properties at 580^0c (CGMW, 2007). The field varies on all special scales and is often referred to as the anomaly field. Knowledge of the crustal magnetic field is often very valuable as a geophysical exploration tool for determining the local geology.

The earth's crust carries both induced and remanent magnetizations that depend not only on the chemical composition and the crystal conformation of subsurface rocks, but also on the earth's core field history. The magnetic property of a rock and its ability to retain remanent magnetism basically depends on grain size, pressure, and temperature. A coarse-grain structure is poor carrier of remnant magnetization in comparison to a fine-grained rock.

3.3.5. The geomagnetic elements and their characteristics

At every point along the earth's surface, a magnetic needle free to orient itself in any direction around a pivot at its center will assume a position in space determined by the direction of the earth's magnetic field **F** at that point (Dobrin and Savit, 1988).

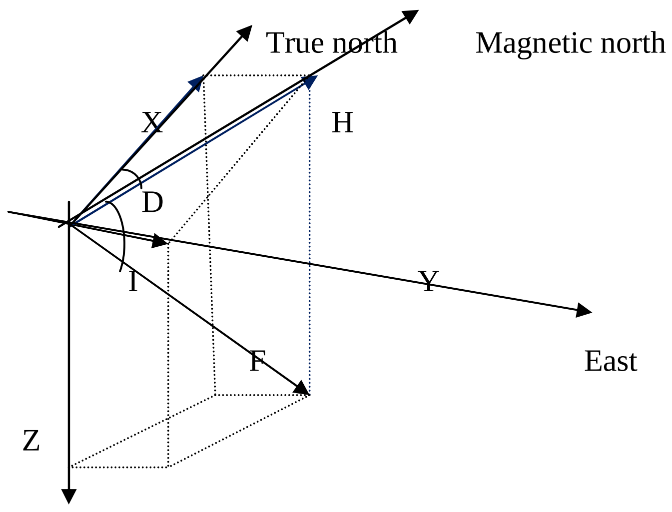

Figure 8. Elements of the Earth's Magnetic Field (Z: Vertical component H: Horizontal component).

The geomagnetic field vector, **B**, is described by the orthogonal components **X** (north intensity), Y (easterly intensity), and Z (vertical intensity, positive downwards); total intensity F; horizontal intensity H; inclination (or dip) I (the angle between the horizontal plane and the field vector, measured positive downwards); and declination (or magnetic variation) D (the horizontal angle between true north and the field vector, measured positive eastwards) (Macmillan, 2006). Declination, inclination, and total intensity can be computed from the orthogonal components using the following equations:

$$D = \tan^{-1}\frac{Y}{X}$$

$$I = \tan^{-1}\frac{Z}{H} \qquad (3.10)$$

$$F = \sqrt{H^2 + Z^2}$$

where H is given by $H = \sqrt{X^2 + Y^2}$

3.3.6. Temporal variation of earth's magnetic field

The geomagnetic field has its main source in the fluid outer core of earth. Near the surface of the planet it is observed to vary in space and in time on a huge range of scales. As Macmillan,

(2006) explained these variations result from processes in regions ranging from the deep interior of the earth, the crust, ionosphere, magnetosphere, all the way to the sun. Depending upon the frequency, duration and intensity of these fluctuations, they are given different names.

I. Diurnal variation

Diurnal variations arise from the rotation of the earth with respect to the sun. The 'solar wind' of charged particles emanating from the sun, even under normal or 'quiet sun' conditions, tends to distort the outer regions of the earth's magnetic field. The daily rotation of the earth within this sun-referenced distortion leads to ionospheric currents on the ‘day‘ side of the planet and a consequential daily cycle of variation in H that usually has an amplitude of less than about 50 nT. The main variation occurs towards local midday when peaks are observed in mid-latitudes and troughs near the magnetic equator. Surveys have to be planned so as to allow for corrections to be made for diurnal (and other) variations. However, they are not predictive and are usually not a problem when conducting magnetic surveys.

II. Magnetic storms

Occasionally, magnetic activity in the ionosphere will abruptly increase. The occurrence of such storms correlates with enhanced sunspot activity. The magnetic field observed during such times is highly irregular and unpredictable, having amplitudes as large as 1000ϒ. Exploration magnetic surveys should not be conducted during times of magnetic storms. This is simply because it is difficult to correct for magnetic storms in the acquired data.

III. Secular variations

These are long term (changes in the field that occur over years) variations in the main magnetic field that are most probably caused by fluid motion in the earth’s outer core (due to slow movement of eddy currents in Earth‘s core). Since these variations occur slowly with respect to the time of completion of a typical exploration magnetic survey, secular variations will not complicate data reduction efforts of the acquired field data.

3.3.7. The International Geomagnetic Reference Field (IGRF)

The IGRF is published by a working group of the International Association of Geomagnetism and Aeronomy (IAGA) on a five-yearly basis. A mathematical model is advanced which best fits all actual observational data from geomagnetic observatories, satellites and other approved sources for a given epoch. From the point of view of exploration geophysics, undoubtedly the greatest advantage of the IGRF is the uniformity it offers in magnetic survey practice since the IGRF is freely available and universally accepted.

The geomagnetic field intensity can be expected to have local variations of several hundred nT imposed upon it by the effects of the magnetization of the crustal geology. The IGRF removal involves the subtraction of about 99% of the measured value; hence, the IGRF needs to be defined with precision if the remainder is to retain accuracy.

3.3.8. Nature of magnetic field with geology

The aim of a magnetic survey is to investigate subsurface geology on the basis of the anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks (Kearey et. al., 2002). The character of a magnetic anomaly is often indicating the type of rock producing the anomaly.

Magnetic prospecting looks variations in magnetic field of the earth that are caused by changes in the subsurface geologic structure or by differences in the magnetic properties of near surface rocks (Mariita, 2007). As Komolafe (2010) stated association of geological formations with magnetic minerals makes it possible for mapping with magnetic field data. Lithology controls magnetic properties through mineralogy, and sharp variations in rock properties generally concedes with lithologic contacts. In general, the magnetic susceptibility of rocks is extremely variable depending on the type of rock and the environment it is in. The magnetic field of a rock depends on its mineral content and the main magnetic mineral in the crust, the magnetite (Fe_3o_4), loses its magnetic properties at 580^0c (CGMW, 2007). Mariita (2007) explained Sedimentary rocks generally have a very small magnetic susceptibility compared with igneous or metamorphic rocks, which tend to have much higher magnetite (a common magnetic mineral) content. Existence of faults and fractures in the geologic units creates magnetic variations and can cause anomaly in magnetic measurements (Komolafe, 2010).

3.3.9. Magnetic data reduction

All magnetic data sets contain elements of noise and will require some form of corrections to the raw data to remove all contributions to the observed magnetic fields other than those caused by the subsurface magnetic sources. To produce the magnetic anomaly of an observation point or the magnetic anomaly map of a survey region, the observed total field B_T as collected by a magnetometer has to be corrected for the effect of diurnal variation and for the effects of special variations of the dipole field.

Survey data at any given location can be corrected by subtracting the diurnal corrections δ_D and the IGRF corrections B_D. the objective of making IGRF correction is that we need the measured field to reflect the effect of subsurface local anomaly sources, i.e. the magnetic field due to other deeper sources should be removed. The part of the magnetic field that remains after subtracting the diurnal correction and the geomagnetic correction is known as the anomalous magnetic field ΔB. that is

$$\Delta B = B_T - \delta_D - B_D \tag{3.11}$$

3.3.10. Data Enhancement Techniques

Enhancements of magnetic field data are processing operations designed to preferentially emphasize the expression of a selected magnetization at the expense of others. Fourier transforms are particularly useful in the transformation from the frequency domain to the wave number domain and also for the calculation of derivatives (Telford et. al., 1990). Conversely, some enhancement operations distort the data, and care must be taken to ensure that enhanced data is not used inappropriately. Some of the data enhancement techniques are;

1. **Vertical continuation of the field**

The amplitude of a magnetic field above a source varies with elevation as an exponential function of wavelength. This relationship can be readily exploited with FFT filters to recompute the field at a higher elevation (upward continuation) or lower elevation (downward continuation). A potential field measured on a given observation plane at a constant height can be recalculated as though the observations were made on a different plane, either at higher or lower elevation. This means that upward continuation smooth out high-frequency anomalies relative to low-frequency anomalies. The process can be useful for suppressing the effects of shallow anomalies when detail on deeper anomalies is required. Downward continuation on the other hand sharpens the effects of shallow anomalies (enhances high frequencies) by bringing them closer to the plane of observation (Telford et. al., 1990).

$$B(x,y,-h) = \frac{h}{2} \iint \frac{B(x,y,0)\partial x \partial y}{\left\{(x-x')+(y-y')+h^2\right\}^{\frac{1}{2}}} \tag{3.12}$$

where B(x,y,-h)- Total field at the point p(x',y',-h) above the surface of which B(x,y,0) is known.

h- is the elevation above the surface.

2. Analytic signal

Analytical signal of total magnetic intensity has much lower sensitivity to the inclination of the geomagnetic field than the original total magnetic intensity data, and provides a means to analyze low latitude magnetic fields without the concerns of the Reduction to the Pole (RTP) operator (Ansari and Alamdar, 2009). Analytical signal is a popular gradient enhancement, which is related to magnetic fields by the derivatives. The analytic signal or total gradient is formed through the combination of the horizontal and vertical gradients of the magnetic anomaly. It has a form over causative body that depends on the locations of the body (horizontal coordinate and depth) but not on its magnetization direction. This quantity is defined as a complex function that its real component is horizontal gradient and its imaginary component is vertical gradient (Salem and Ravat, 2006). The amplitude of the analytic signal can be derived from the three orthogonal gradient of the total magnetic field using the expression:

$$|A(x,y,z)| = \sqrt{\left(\left(\frac{\partial B}{\partial x}\right)^2 + \left(\frac{\partial B}{\partial y}\right)^2 + \left(\frac{\partial B}{\partial z}\right)^2\right)} \tag{3.13}$$

where A(x,y,z) is the amplitude of the analytical signal at (x,y,z), and

B is the observed magnetic anomaly at (x,y,z).

While this function is not a measurable parameter, it is extremely interesting in the context of interpretation, as it is completely independent of the direction of magnetization and the direction of the Earth's field. This means that all bodies with the same geometry have the same analytic signal. Analytic signal maps and images are useful as a type of reduction to the pole, as they are not subject to the instability that occurs in transformations of magnetic fields from low magnetic latitudes. They also define source positions regardless of any remnant magnetization in the sources.

CHAPTER FOUR

DATA ACQUISITION AND PROCESSING

4.1. Introduction

For this study seismic and magnetic data were collected in order to achieve the main objectives of the research. In general seismic refraction survey was conducted to image out the subsurface geological structures and strength of the bedrock by carefully examining the first arrival refracted waves for the purpose of building construction. Similarly magnetic survey was conducted to investigate the subsurface geology on the basis of the anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks (kearey et al, 2002). In applied geophysics the anomalous magnetizations might be associated with local mineralization that is potentially of commercial interest, or they could be due to subsurface structures.

The data were acquired and analyzed using different software's to get the relevant information for the subsurface condition. The detailed data collection, processing and procedure of the present study are given below.

4.2. Data acquisition of seismic refraction survey

The seismic refraction survey for the study area was conducted for six days. The survey was carried out using 24 channels Mc SEIS-sx model 1125A refraction system seismograph produced by OYO Company. The geophones were laid down at regular interval on the ground. It was connected to the spread cable (a cable which connected the geophones to the seismograph (Fig.9)). After the geophones being connected, the spread cable was connected to the seismograph. The total of nine 230 m spread length with each geophone space of 10 m apart was surveyed. Five of the survey lines were aligned in the NW-SE direction almost perpendicular to the main rift axis, where as the other four spread was ENE-WSW direction as shown in Figure 10.

The seismic energy was induced by striking a metal plate on the ground with 12kg sledgehammer. The sledgehammer was connected to the seismograph using the trigger cable to arm the seismograph as the impact is done. Shots were started at -30m from geophone number one along each of the nine lines, for a total of seven shots along each line. At each geophone and source location coordinate and elevation data were recorded using GPS.

Figure 9. Field setup of seismic survey photo.

4.3. Data acquisition of magnetic survey

The ground magnetic survey for the study area was carried out using Proton Precession Magnetometer. GPS was used to record position location and timings of series of discrete magnetic reading measurements. The magnetic survey in the area was completed along twelve lines extending WSW-ENE and NW-SE. Lengths of these lines ranged from 180 to 340 m, while the magnetic reading, time and GPS coordinates of the measuring stations were recorded at every 15 m station interval and at around 30 m profile spacing randomly to cover the study area.

The total magnetic data collected during the field survey was 214 data points. The lines were nominated profile 1, 2, 3…, and 12 (Fig. 11). At the field survey three magnetic readings were taken for a specific station and then average of this readings were used for the processing and interpretation purpose. The distribution of magnetic data in the study area is shown in Figure 11. The magnetic data were collected for two days. A base station was established at the center of the survey area away from magnetic noises like buildings and green houses established at the east and south end of the site. Readings at the base station were taken every 2 hours of the first day and for the second day it was taken immediately after the end of the total survey to correct the diurnal variation of the Earth's magnetic field.

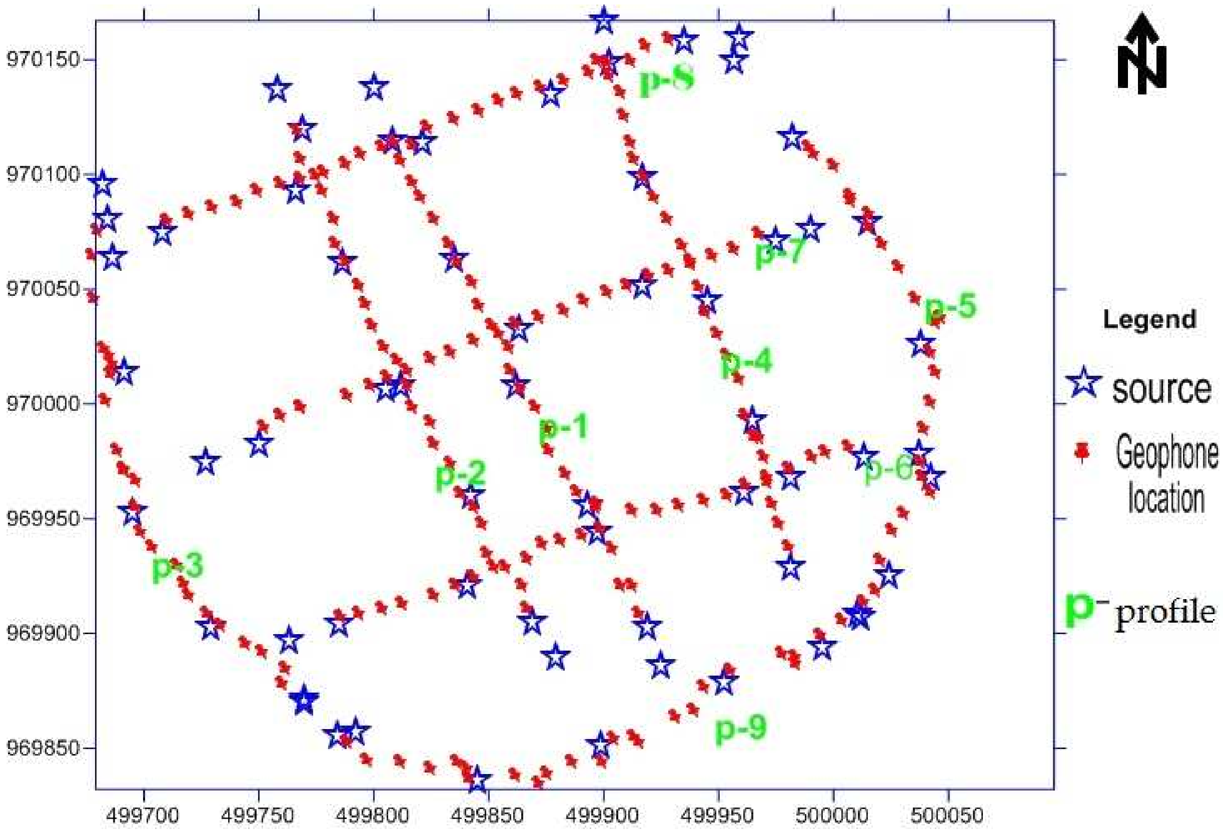

Figure 10. Locations of seismic sources and profile lines.

4.4. Seismic refraction field data processing

After the field portion of the seismic refraction was completed, the next step was to begin processing the data collected. The first step in this process was to determine the first arrival times, which was accomplished using SeisImager's first arrival picking module PickWin95. The data for each of the nine refraction survey lines were imported into SeisImager's PickWin95 module where first arrival times were determined manually through visual inspection from the records; see a typical example of Figure 12. This was done for the nine survey lines and for each of the seven source locations.

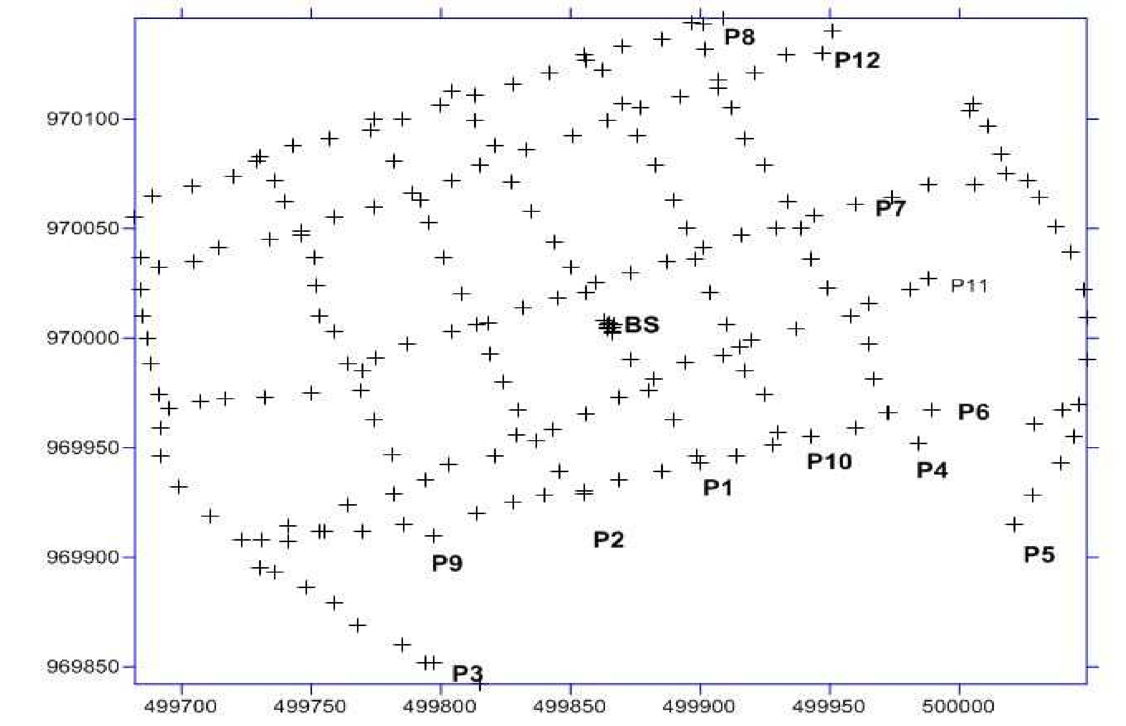

Figure 11. Magnetic survey data points.

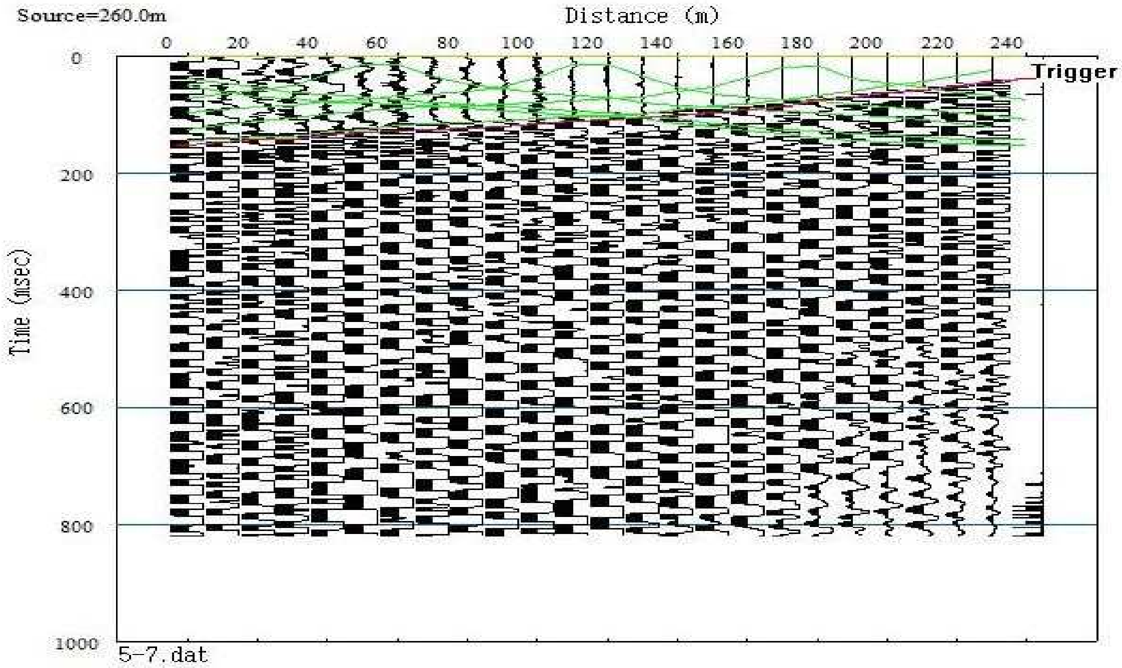

Figure 12. An example of selected first arrival times of profile five.

After the first arrivals were determined, PlotRefa, the interpretation module of SeisImager, was used to generate travel time curves and velocity models of each line. Typical travel time curves generated by PlotRefa for line eight are shown in Figure 13. This travel time curve contains the first arrival times for each of the seven shot locations along a given refraction spread. The seismic velocity model was produced using first arrival p-wave, travel time tomography. Travel times were inverted for each line as follows. First, an initial velocity model was generated by inserting a velocity ranging 0.3-3.5 km/s and setting total of 15 layers with the top of the bottom layer at a depth of 20 m. This velocity parameter was taken from velocity line of the travel time versus distance graph (Fig. 16). The inversion was performed, and results in smooth boundaries between regions with different velocity labels. Rays were traced (Fig.17) to the model and the Root Mean Square (RMS) error was checked.

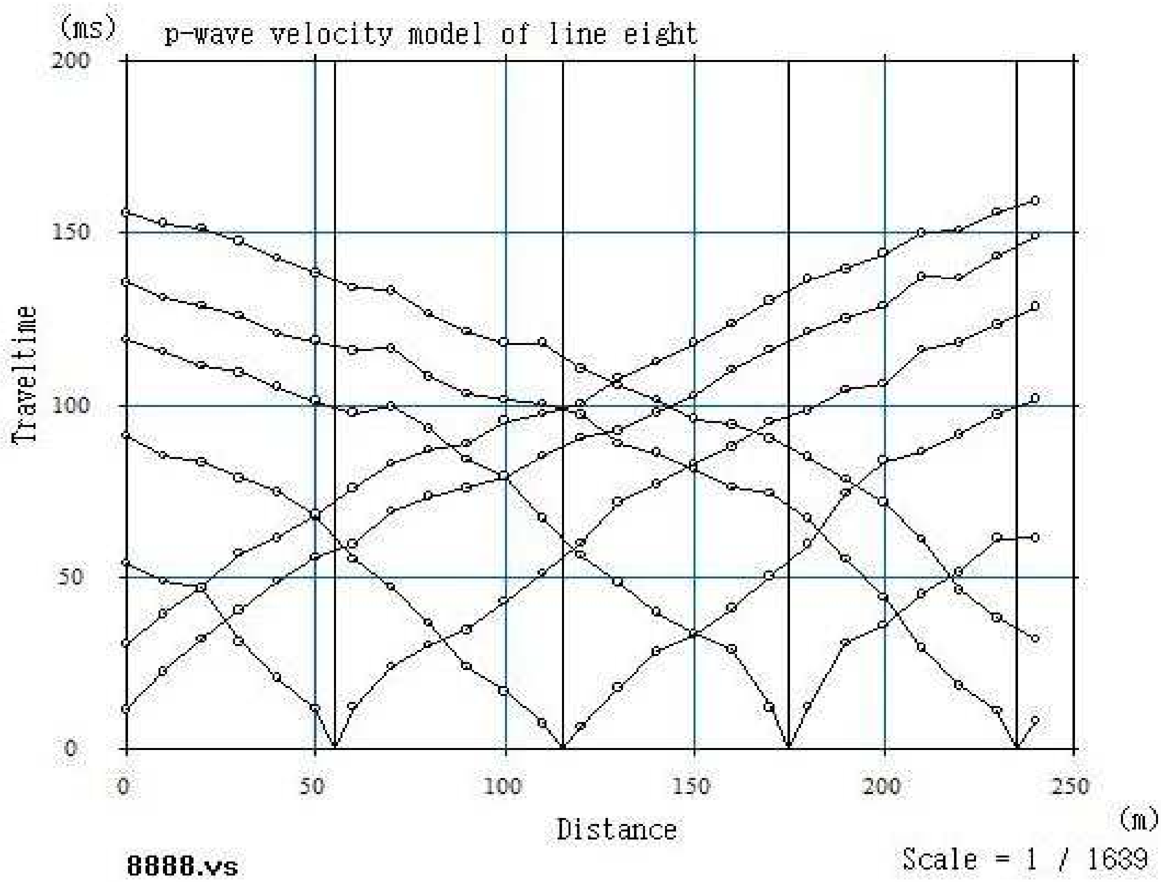

Figure 13. Travel time-distance graph of spread eight.

Ten iterations of tomographic inversion were conducted in order to minimize the RMS error. The minimum the RMS error shows that the calculated and observed travel time curve matched. A typical agreement between calculated and observed travel time is shown in Figure 18. Finally the model was inverted to layered model.

4.5. Magnetic data processing

To create magnetic anomaly maps, first temporal changes in the earth's field during the period of the survey must be considered. Microsoft excel 2007 was used to correct the raw magnetic data by removing the diurnal variations through close examination of the data using the base station readings taken during the survey. The main software used for the processing and enhancement of the magnetic data were Geosoft (oasis montaj).

Additionally the magnetic data required geomagnetic correction, which is a technique that removes the effect of geomagnetic references field from the survey data. The most accurate method of geomagnetic correction is the use of the IGRF value (Kearey et al., 2002). But the survey area was very small, so that in this research a trend analysis technique was used, where a regional field is approximated by a linear trend. Therefore, the correction was made for the study area obtained from Oasis Montaj of version 6.4.2.

The processing of magnetic data for this research involved the application of enhancement technique and removal of the regional field. The *MagMap extension* in Geosoft, which offers a number of utilities for processing of magnetic data, was used for processing and filters. Because it is known that high susceptible geologic formation is correlated with high frequency magnetic responses, so that upward continuation, for separation of this high frequency magnetic response to the regional magnetic response and Analytic Signal was applied to the magnetic data in order to enhance high frequencies and define body edges. All the enhancement techniques were performed with the Geosoft (Oasis montaj 6.4.2). Finally the residual anomaly, obtained by subtracting the upward continued grid from the observed data grid, was used to produce anomaly map and models using Oasis Montaj. The Two Dimensional Fast Fourier Transforms (2D-FFT) filter used included upward continuation and Analytic Signal. The observed data grid map is shown in Figure 14.

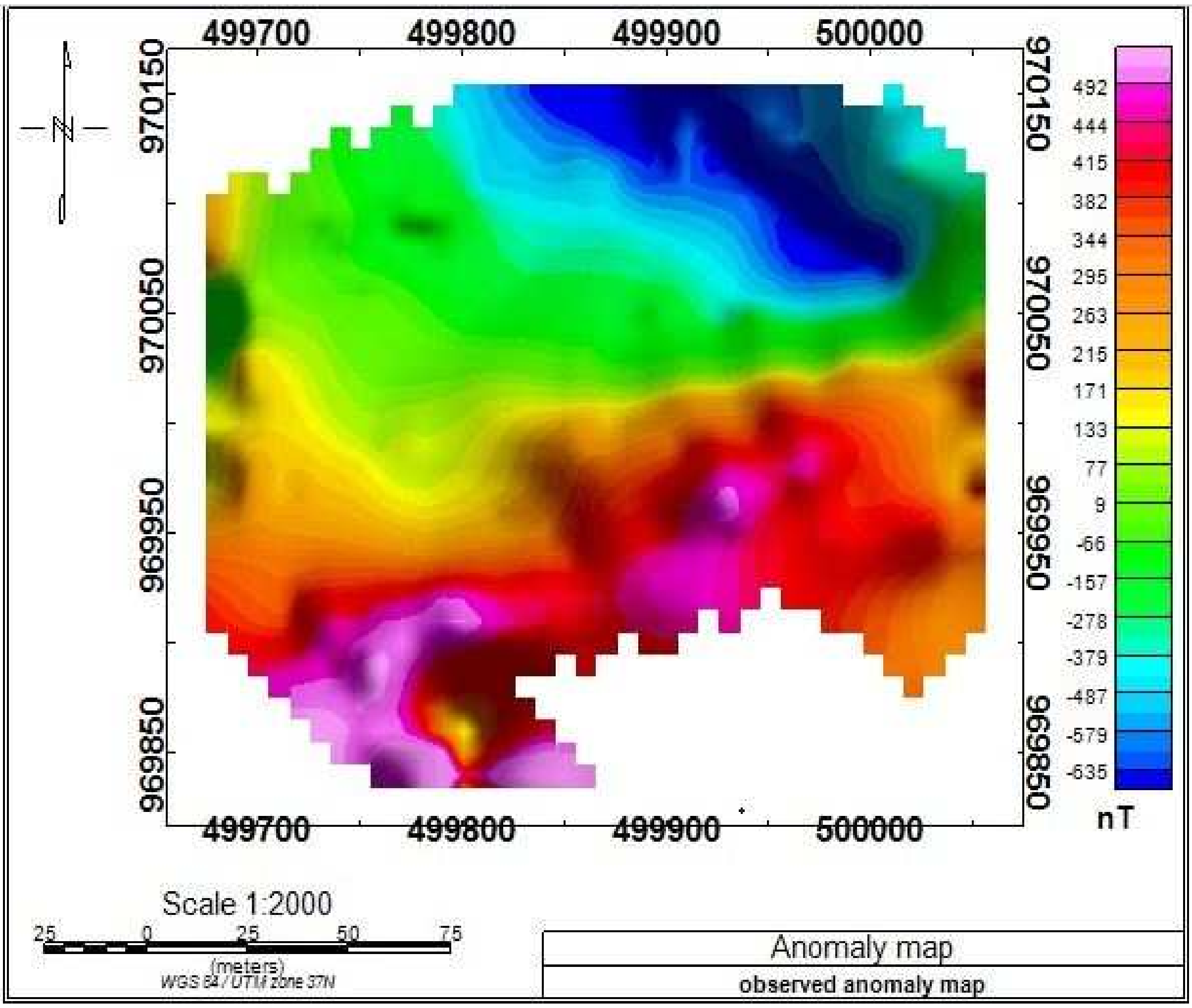

Figure 14. Observed data grid map.

CHAPTER FIVE

RESULTS AND INTERPRETATION

5.1. Introduction

The result from the magnetic and seismic refraction datasets are presented and discussed in this chapter. Interpretation of these data was carried out to identify the individual lithologies and delineate bedrock quality and structures.

5.1. Results and interpretation of seismic refraction data

The seismic refraction data processed using SeisImager/2D software. Pickwin95 module of seisimager/2D software was used to determine the first arrival time. These data were then input into plotrefa module to create the p-wave velocities model, using tomography modeling algorithms. The model produced using the above software was interpreted according to the area geology and the parameters determined from the model.

Because of low data quality of the seismic refraction line of two, three and seven, first arrival picking of p-wave travel times was very difficult. Therefore the three lines were not considered in the processing and interpretation part.

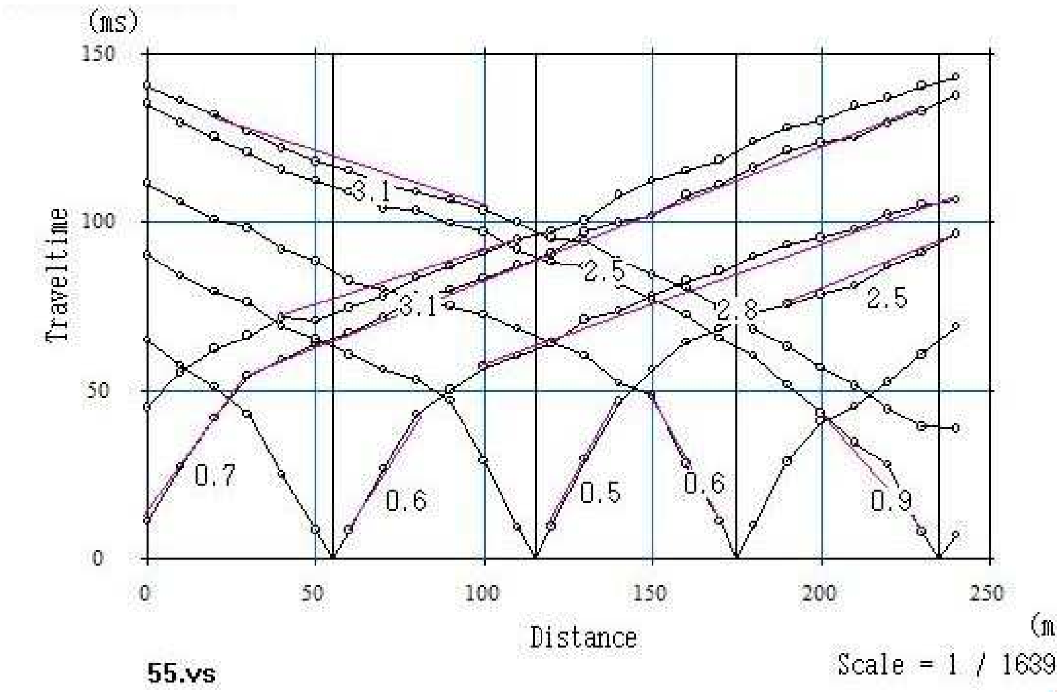

Figure 15. View of velocity line graph of line five.

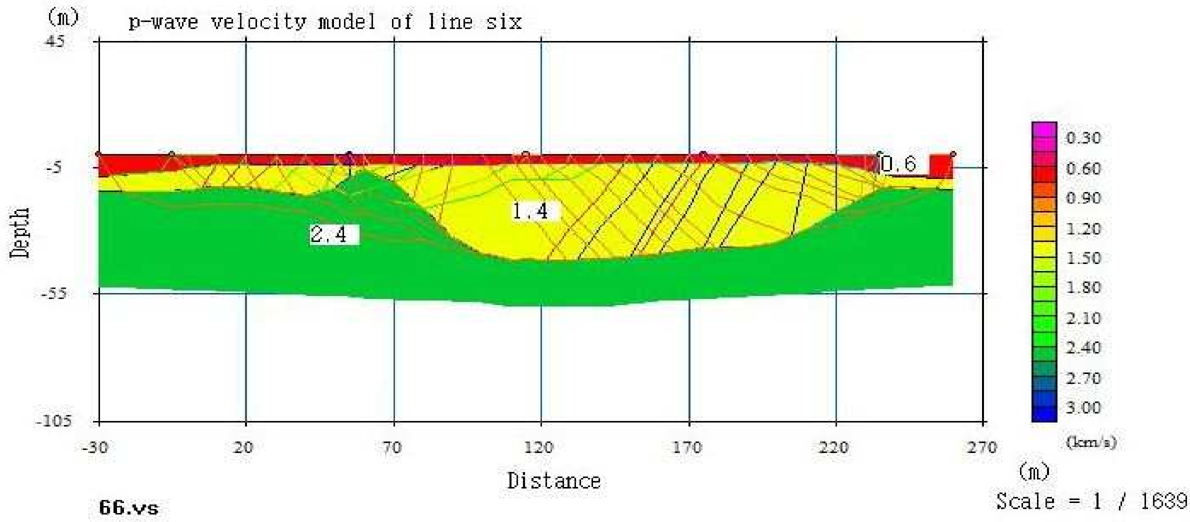

Figure 16. Ray tracing model of line six.

5.1.1. Velocity model of line one

The seismic refraction model for line one is presented as Figure 18. Total spread length of line one is 230 m. The model presents seismic velocities between 0.5 km/s and 2.5 km/s. It shows slower velocity (0.5km/s) for the top layer that is about 5 m thick at the center of the model and about 9 m at both ends of the model. The velocity indicates that the top layer consists of soil deposits. This velocity gradually increases with depth. The second layer is located at depth of about 5 m and 9 m at the center and both ends of the model respectively. From local geology and the velocity of the second layer, it is phreatomagmatic deposits. From local geology the third layer is unwelded pyroclastic rock, with a faster velocity of 2.5 km/s. It is slightly weathered rock and it will be regarded as the bedrock of the site. The velocity of the model shows that the third layer is relatively strong rock type. It is located about 20- 30 m depth. The topography of this layer is somewhat irregular as shown in the right side of the model.

5.1.2. Velocity model of line four

The seismic refraction line four is parallel to line one, laying in NW- SE direction. The velocity model is shown in Figure 19. The thickness of the top layer increases towards the right of the model and exactly 5 m near the left end of the model. From local geology the second layer is

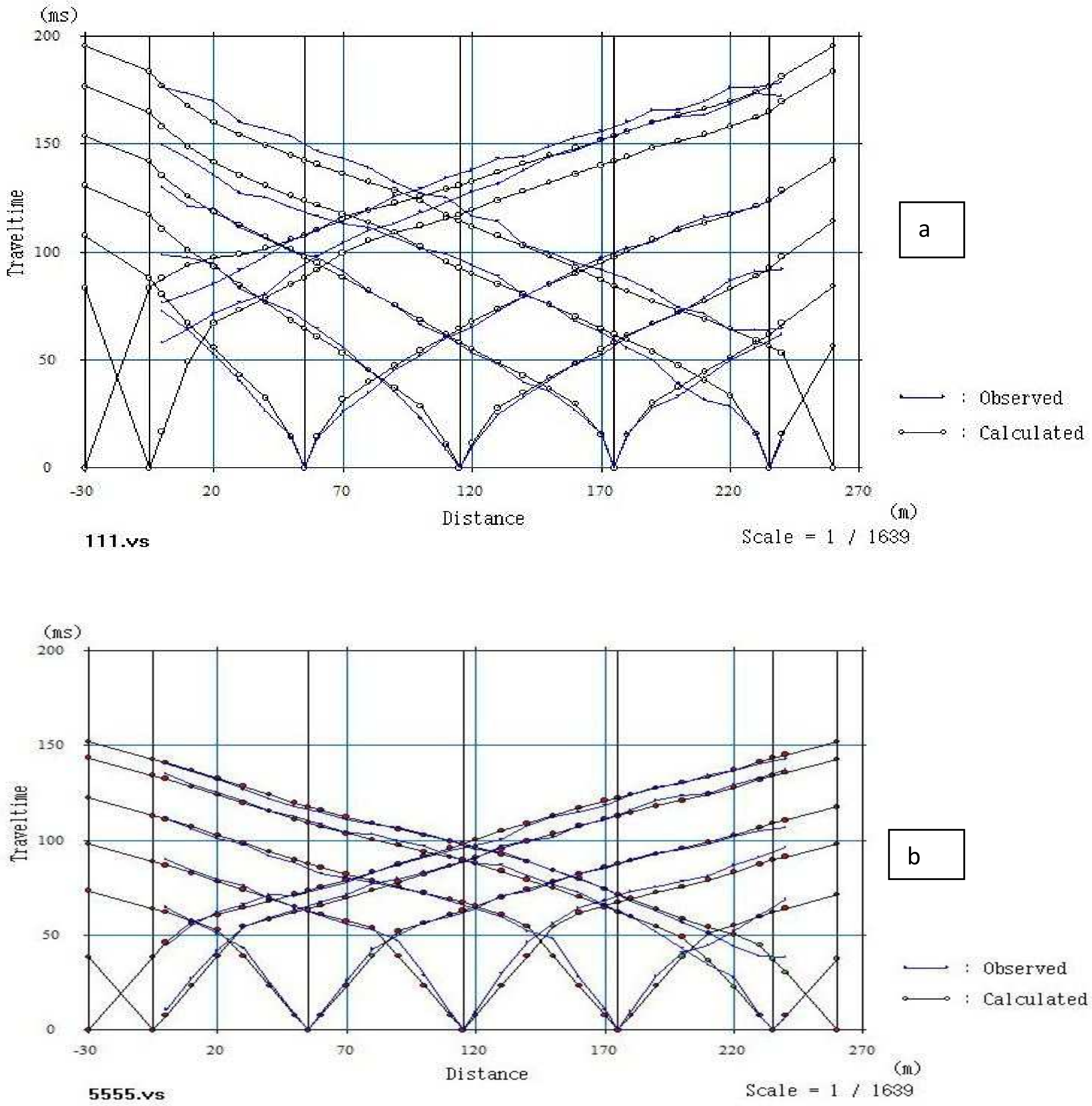

Figure 17. Typical agreement between observed and calculated travel time of line one (a) and line five (b).

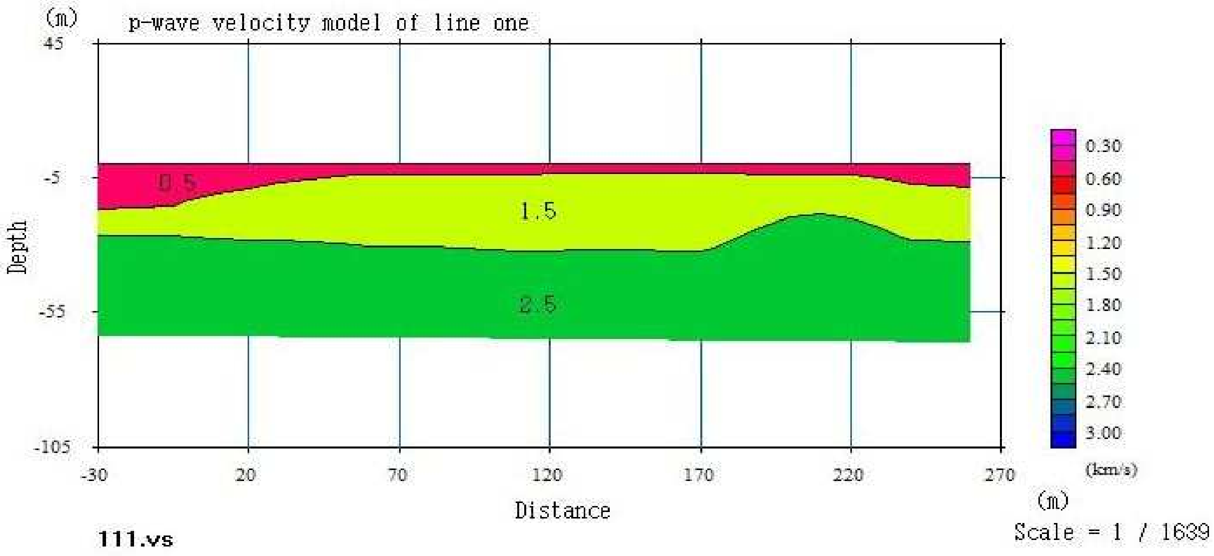

Figure 18. Velocity model of line one.

Phreatomagmatic deposits with seismic velocity of 1.5 km/s. The depth of this layer is exactly 5 m near the left end of the model and increase to the right of the model to10 m. The seismic velocity increases with depth, suggesting that the compaction and lithology of the area varies

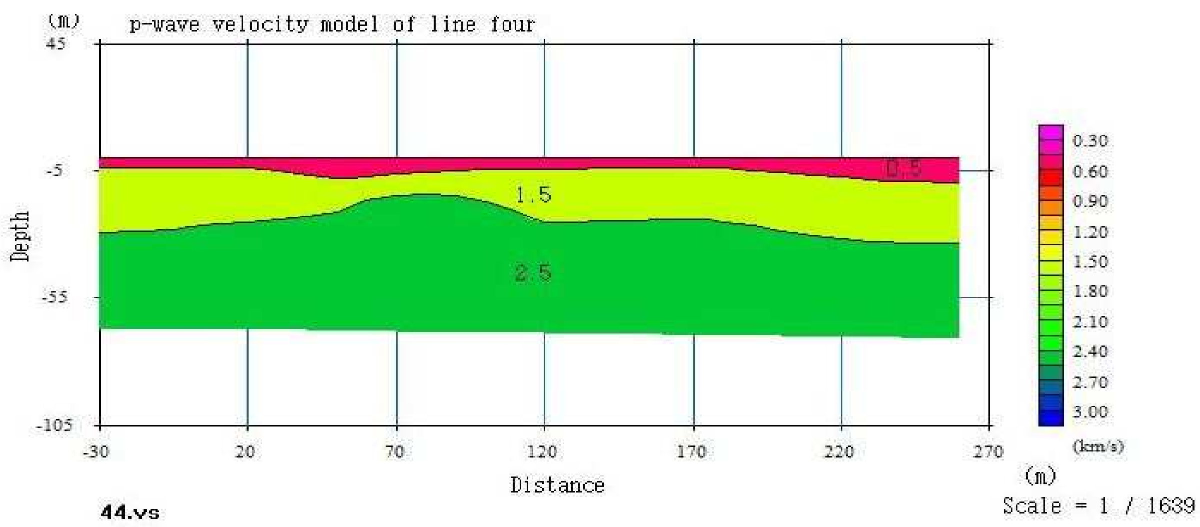

Figure 19. Velocity model of line four.

with depth. Unwelded pyroclastic rocks are mapped below this layer with velocity of 2.5 km/s. It is located about 20-30 m depth. This layer is regarded as the bedrock of the area, it has almost regular topography.

5.1.3. Velocity model of line five

The seismic refraction line five is also parallel to line one, laying in NW- SE direction. As shown from the model (Fig. 20) the thickness of the top layer is about 6 m with seismic velocity of 0.5 km/s, indicating soil deposits. The seismic velocity of the second layer is 1.4 km/s. From the local geology and seismic velocity, the second layer is phreatomagmatic deposits. The depth of this layer is 6 m. it has regular topography. The velocity of the third layer is 2.2 km/s, thus associated with the local geology, this layer is unwelded pyroclastic deposits. This layer is regarded as the bedrock of the area. It is located about 15-26m depth.

Figure 20. Velocity model of line five.

5.1.4. Velocity model of line six

Seismic velocity model of line six is shown in Figure 21. Seismic refraction line six is perpendicular to line one. It is laid along WNW-ESE direction; near the houses, south end of the survey area. The thickness of the top layer is range from 5-10 m. it is 5 m thick in the center of the model and about 10 m thick near both ends of the model. The seismic velocity (0.6 km/s) indicates it is soil deposits. The seismic velocity of the second layer is 1.4 km/s, and from local geology this layer is phreatomagmatic deposits, the depth of this layer is ranging from 5-10 m. The third layer of this model is unwelded pyroclastic rock with velocity of 2.4 km/s. It is located about 17-45 m depth and as the velocity indicates it is relatively hard rock type with irregular topography. This layer is regarded as the bedrock of the area.

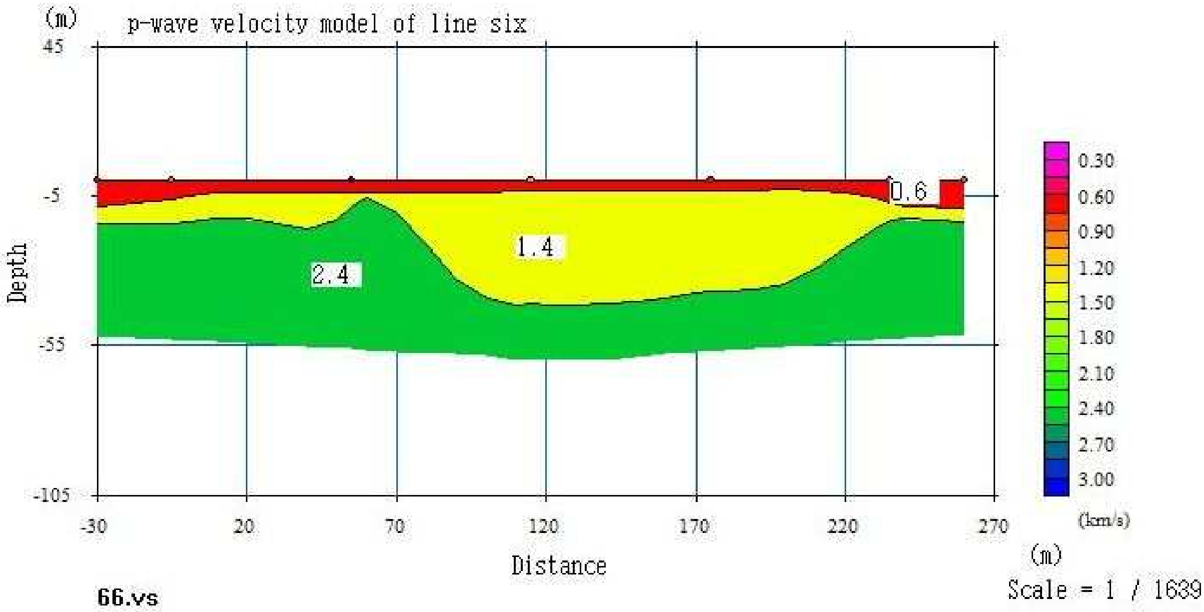

Figure 21. Velocity model of line six.

5.1.5. Velocity model of line eight

Seismic refraction line eight is parallel to line six, laid north end of the survey area. The model (Fig. 22) shows thickness of the top layer is 5 m thick, with velocity of 0.6 km/s indicating soil deposits. From local geology the second layer is phreatomagmatic deposits with seismic velocity of 1.5 km/s, this layer is located about 5-8 m depth with regular topography. The seismic velocity increases with depth, suggesting that the compaction and lithology of the area varies with depth. Unwelded pyroclastic rock is mapped below this layer with velocity of 2.4 km/s. the velocity of this layer indicates that it is strong rock type. This layer has irregular topography and it regarded as the bedrock of the area, located at depth of about 12-28m.

5.1.6. Velocity model of line nine

The seismic refraction line nine is laid in the south most end of the survey area, which is almost parallel to line six. The model (Fig. 23) shows the thickness of the top layer is 5 m thick with seismic velocity of 0.6 km/s. From local geology the second layer is phreatomagmatic deposits

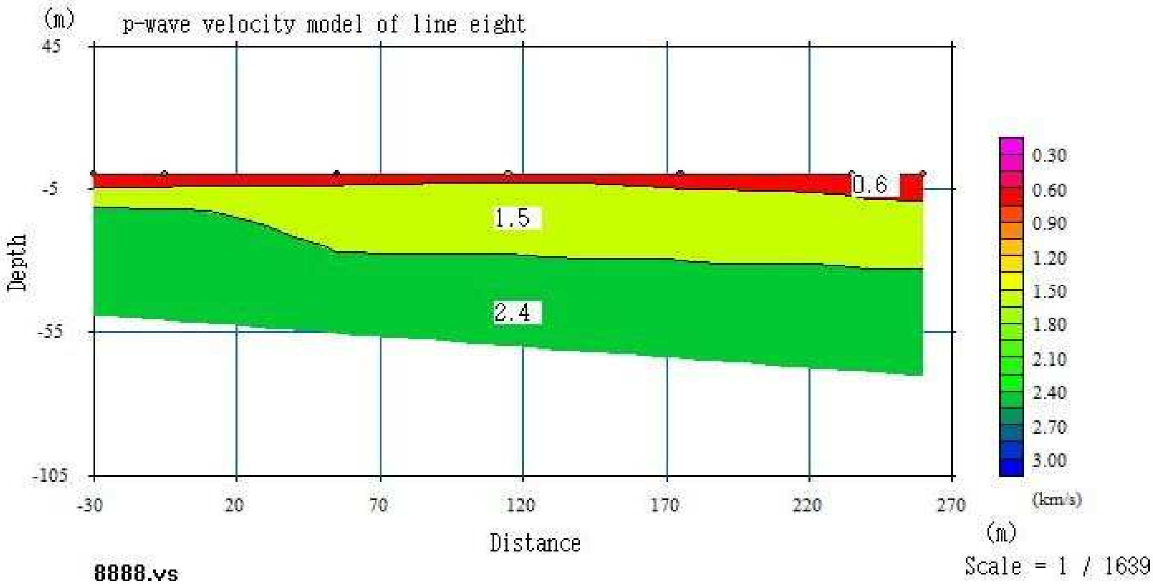

Figure 22 Velocity model of line eight

with seismic velocity of 1.3 km/s, this layer is located about 5 m depth with regular topography. The seismic velocity increases with depth, suggesting that the compaction and lithology of the area varies with depth. Unwelded pyroclastic rock is mapped below this layer with velocity of 2.4 km/s. the velocity of this layer indicates that it is strong rock type. This layer has irregular topography and it regarded as the bedrock of the area, located at depth of about 15-26m.

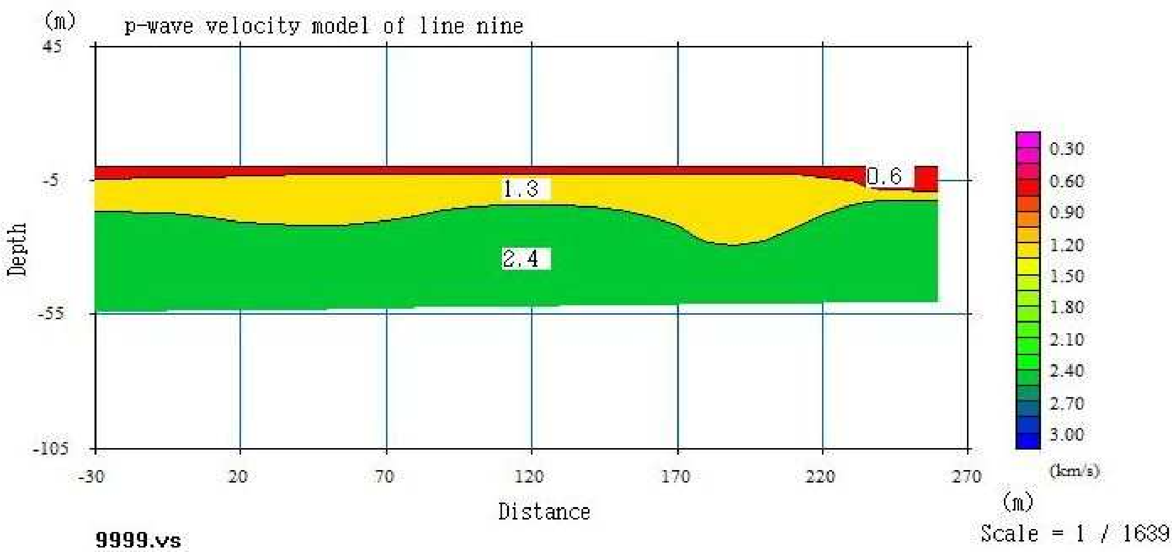

Figure 23. Velocity model of line nine.

5.2. Results and interpretation of magnetic data

According to Mariita, (2007), total magnetic anomalies are highly variable in shape and amplitude; they are almost always asymmetrical, sometimes appear complex even from simple sources, and usually show the combined effects of several sources. An infinite number of possible sources can produce a given anomaly, giving rise to the term ambiguity.

The 2D-FFT filters used included upward continuation and Analytic Signal.

5.2.1. Upward continuation

In this research upward continuation was used to separate a regional magnetic anomaly resulting from deep sources. The upward continued anomaly map was subtracted from the observed data map; as a result relatively the short wavelength anomaly response depending on the continued height was determined. The observed data grid map was upward continued to the height of 1Km, to get the anomaly map from 0 – 500 m depth. The map (Fig. 24) shows the residual map of the observed and upward continued map.

As shown from the anomaly map, the magnetic anomaly contrast is distributed in the study area. The magnetic response of the residual anomaly map is range from -362 nT to 265 nT. The magnetic response of the site is maximum at the northwest (region A), partially central and southeast part of the site, shows probably the existence of high magnetite content materials. However the north and northeast part of the site has low magnetic response. The intermediate magnetic response distributed at the southwest end of the study area and in between the high and low response of the site.

5.2.2. Analytic signal

Analytic signal (horizontal gradient if the real part is considered or total gradient if the 3-D is considered) maps help to reveal the anomaly texture and to highlight discontinuities. The strength/ amplitude of an analytic signal anomaly is proportional to the susceptibility of the causative body i.e., the greater the proportion of magnetic materials in the body the larger the analytic signal anomaly.

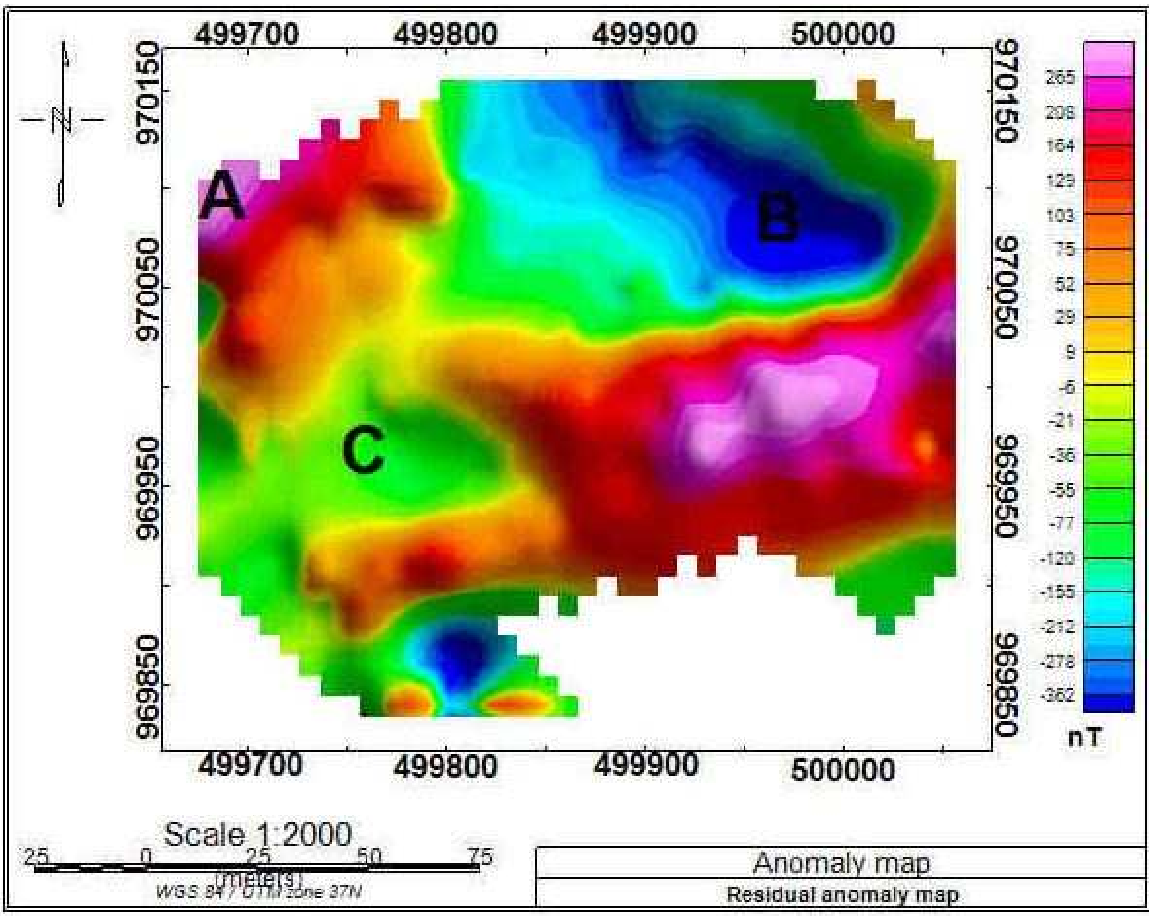

Figure 24. Residual anomaly map

The analytic signal map as shown from Figure 25, the anomalous body is distributed more or less in NE-SW direction. The map reveals that the south part (region C) has low analytic signal response, implies the region around and along ‘C’ has almost equal magnetic response as shown from the residual anomaly map of Figure 24 and is high in the middle of the site (region B), where the magnetic response gradient of the region is high as shown Figure 24, also high analytic signal is scattered in the northern part of the map. The analytic signal of region A and B is extended from North east to the south west of the study area. The intermediate, high and low response of the residual map of Figure 24 reveals intermediate analytic signal as shown mainly in the middle of the map (region A). Generally the analytic signal map highlights the edge of the anomaly of the study area.

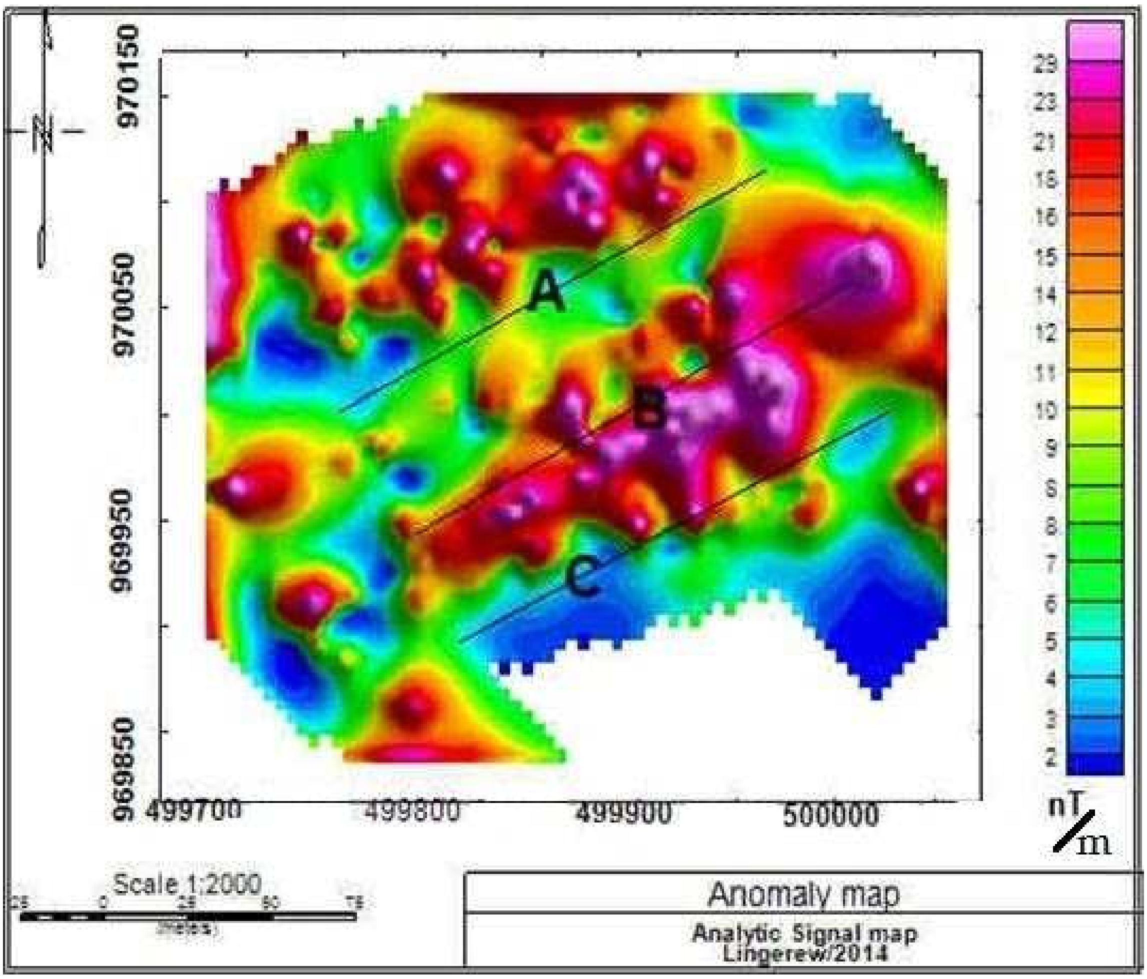

Figure 25. Analytic signal map of the site.

5.2.3. Magnetic model

Magnetic modeling was done using GM-SYS software which is the product of Geosoft. GM-SYS provides an easy- to - use interface for interactively creating and manipulating models to fit observed gravity and/or magnetic data. It is a program for calculating the potential field response from a geologic cross- section. The best fit of the calculated magnetic values were generated from the proposed model section with the respective observed values while adjusting systematically the size, shape, susceptibility and remanent magnetization of the sections. The modeled sections were prepared based on some prior information on the seismic velocity model and geological map of the study area. The model was produced from the residual anomaly map. All the model section presented in this research has depth of the lithologic unit up to 500 m, which is half of the depth response of upward continued anomaly map. In this study the magnetic profile line was twelve, but for the model section four profile lines has been presented.

Magnetic model of profile nine

The magnetic model section presented (Fig. 26), is a model located in the west side of the study area, along the NW-SE direction.

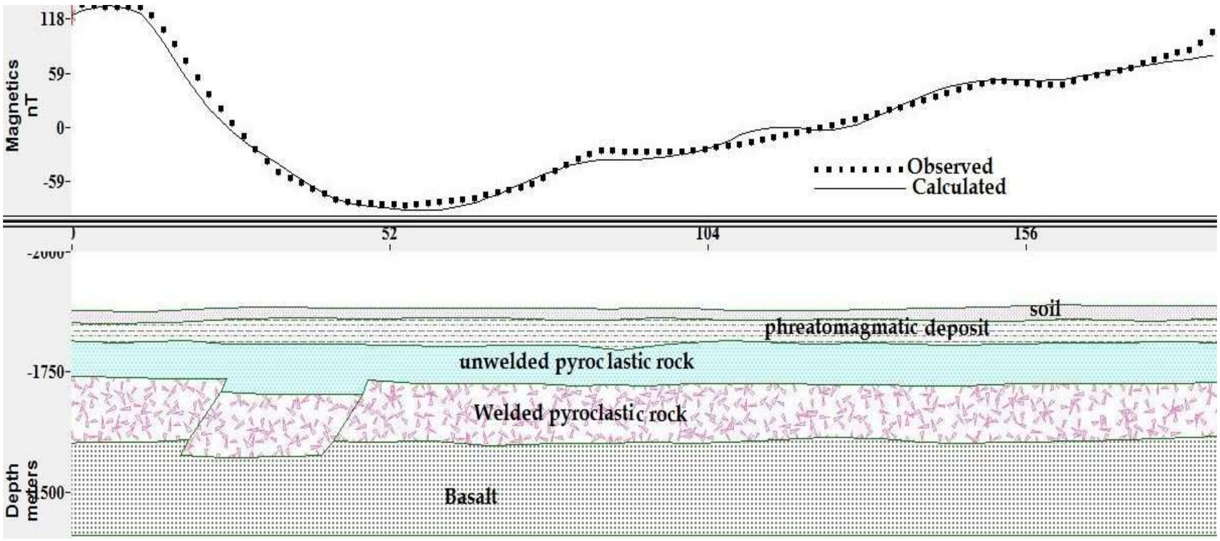

Figure 26. Magnetic model of profile nine.

It is shown from the model the top layer is covered by soil with maximum thickness of 15 m. It is approved from the area geology; the second layer is phreatomagmatic deposit. This layer is located at 15 m depth. The model has high magnetic response at the beginning and to the end of the model. About 45 m from the initial of the model, the response is minimum and it is due to the week zone of that area as shown from the model.

Magnetic model profile two

The model section of line two (Fig. 27) shows the top layer (soil deposit) has thickness of about 5-15 m from the ground surface. From the seismic model it is shown that this layer has average seismic velocity of 0.5 km/s. The second layer is covered by phreatomagmatic materials of Bishoftu volcanic group with seismic velocity of 1.5 km/s and it is located at depth of 5-15 m. This layer is relatively compacted and has almost regular topography. The third layer is pyroclastic rock type and it has seismic velocity of 2.5 km/s. It is regarded as the bedrock of the construction site. Maximum magnetic response from the beginning of the model reveals the effect of the high magnetic content of the lithologies.

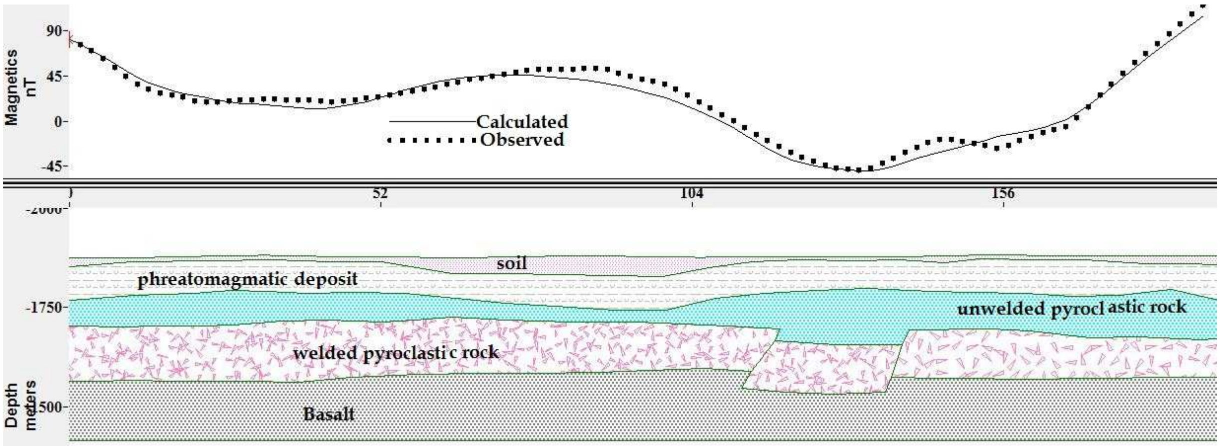

Figure 27. Magnetic model of profile two.

The response gradually decreases and becomes relatively minimum at 125 m from the initial point. It is may be due to the effect of the fault of the fourth layer. The pyroclastic rock overlay on the basalt rock as shown from the model contain week zones resulting low magnetic response. The fault is aligned in the trend of the rift axis.

Magnetic model of profile four

The top layer is covered by soil deposits and it has maximum thickness of 5 m with seismic velocity of 0.5 km/s. The second layer in this model is located at depth of about 5 m, having almost regular topography. The model (Fig.28) shows, to the left end of the model the magnetic response is high. About 120 m distance the magnetic response is minimum. It is related to the effect of the fault of the welded pyroclastic rock.

Magnetic model of profile five

From the model (Fig.29), the top layer (soil deposit) has maximum thickness of 5 m and from the seismic model it has seismic velocity of 0.5 km/s. Associated with the high content magnetic material of the lithologies the model has high response to the left side.

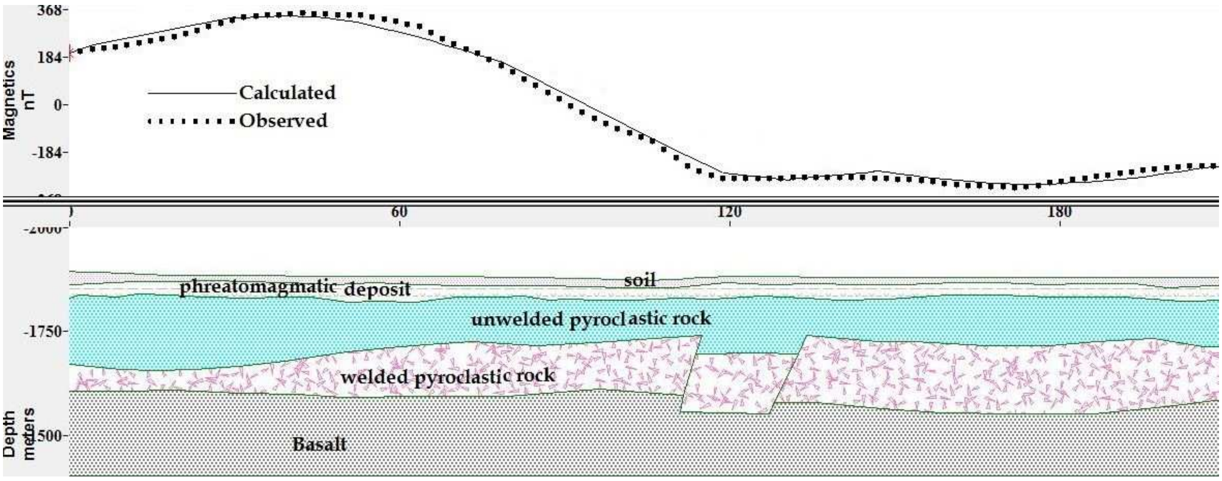

Figure 28. Magnetic model of profile four.

The magnetic response decreases towards the right of the model. About 150 m from the initial point of the model the magnetic response became minimum from the starting point. This is due to the effect of the fault as shown from the model.

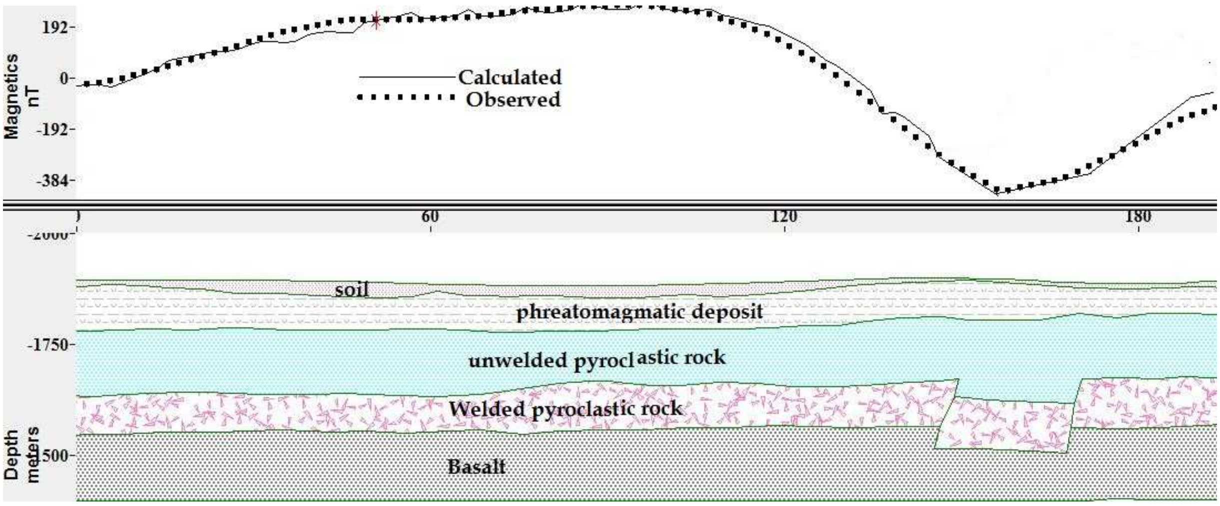

Figure 29. Magnetic model of profile five.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Integrated geophysical surveys employing the methods of seismic refraction and magnetic surveys were used at Kuriftu, the future university site to characterize the subsurface geology.

Seismic and magnetic data were acquired along nine and twelve traverses with seismograph and proton precession magnetometer instruments respectively. Ten meter geophone spacing and fifteen meter magnetic data point spacing were surveyed. The seismic data were acquired using hummer source and for each line seven shot arrangements were employed.

The seismic data were filtered using pickwin 95 and plotrefa module of SeisImager/2D software and magnetic data were corrected for high variation data, corrections for diurnal and regional field were made.

The results of the survey were presented in the form of velocity model, magnetic anomaly map (residual and analytic) as well as magnetic modeled profile plots. The velocity models were identifying the lithology of the site. The analytic signal anomaly map shows the texture of the anomaly distributed in the study area. The upward continued anomaly map enhance the low frequency response (regional geology response) of the survey area, however, the aim of the research was to now the magnetic response of the shallow subsurface geology (high frequency response). So that the difference of the original total intensity anomaly grid and the upward continued (up to 1000 m) anomaly grid was taken. As a result the anomaly map of up to 500 m depth produced.

From the results of the survey it was possible to conclude that the top layer of the site is covered by soil deposits. It has maximum thickness of 10 m, with seismic velocity of 0.5 Km/s. The second layer of the site is covered by the result of shallow explosive rock type of phreatomagmatic deposits. This layer is located at depth of ranging 5-10 m, with seismic velocity of 1.5 Km/s and it has almost regular topography. The bedrock (third layer- pyroclastic rock) of the site is found about 15-30 m depth, with seismic velocity of 2.5 Km/s. This reveals that it is relatively hard rock. This layer (the bedrock) is slightly weathered, results irregular topography.

This layer overlay on the welded pyroclastic rock type, low rock quality. The fourth layer of the construction site is week (low rock quality) zone of the area.

The interpretation of the two geophysical methods revels that the bedrock has relatively a good quality rock type of volcanic origin. Even though the seismic refraction has high resolution to characterize the lithology, it has small depth of investigation because the energy source that used for the survey was sledge hammer. As a result the velocity and magnetic models are not exactly matching the depth level and the topography of each lithology. Moreover the magnetic model response is due to the superimposed of all the lithologies from the surface to 500 m depth. But the velocity model shows very shallow depth.

6.2. Recommendations

Based on the present study the following recommendations are forwarded;

- ✓ The maximum effort was implemented to acquire noise free seismic data during the field survey. But it was difficult to processes the whole data and to get noise free data as expected. Therefore it is highly recommended to conduct another geophysical method, like electrical imaging, which has comparable resolution to seismic refraction, to validate the seismic velocity model.
- ✓ The scorcious basalt outcropping in the area may not have constant remanent magnetization. It is due to the temperature variation and biological effect losses its magnetization. As a result the total magnetic intensity in the area may not have the same response. These have an effect on the interpretation of the magnetic data. Therefore considering this to assure the validity of the magnetic data interpretation, it is highly recommended to conduct gravity survey.
- ✓ Kuriftu is situated in seismically active zone therefore designers should consider the seismic code and building code before designing the buildings.
- ✓ From the seismic and magnetic model the construction site has a good rock quality but the compactness of the first two layers are relatively less, but from the velocity model the compactness of the third layer is relatively high. Therefore this layer was considered as the bedrock of the site and it is located at depth of 20-30 m, therefore it is recommended to use deep foundation system (pile foundation system) to construct long lasting and high rising building.

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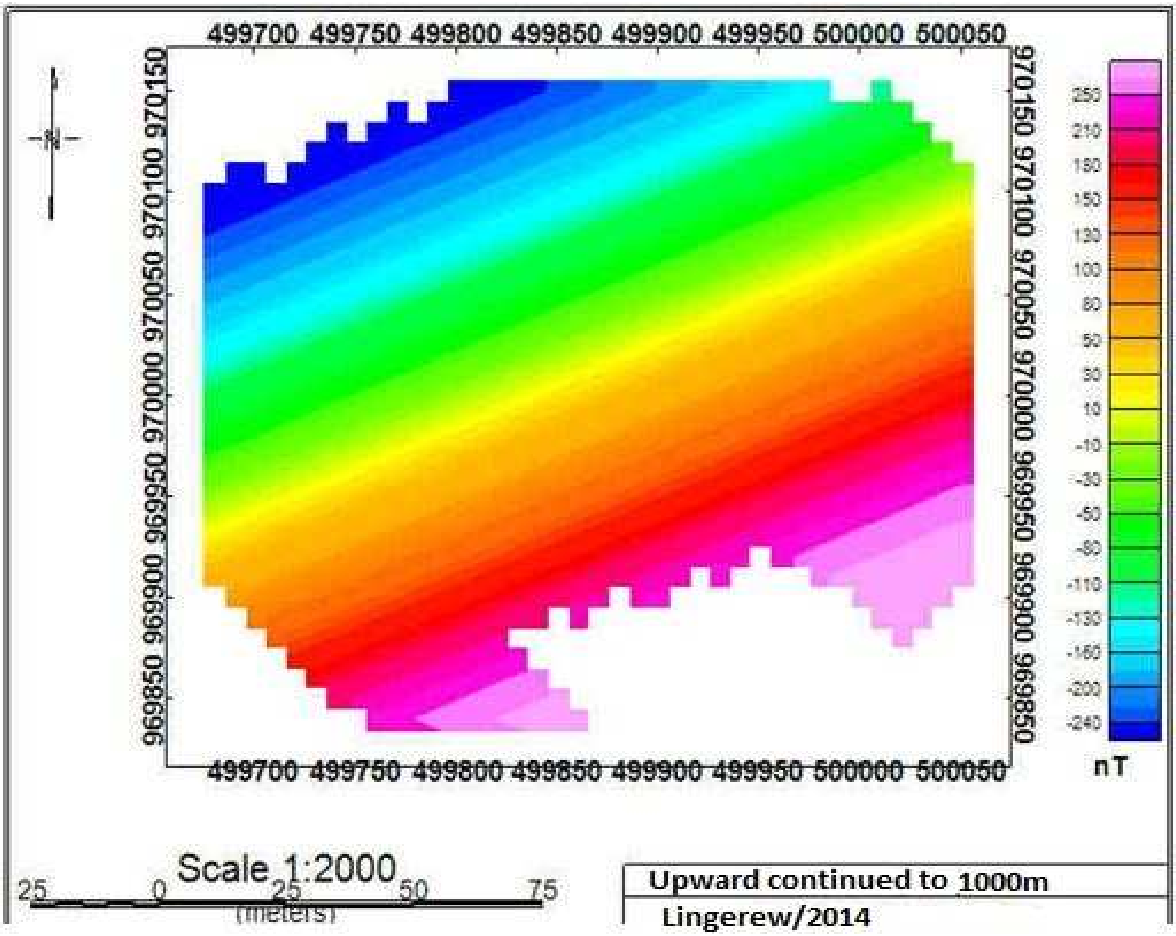
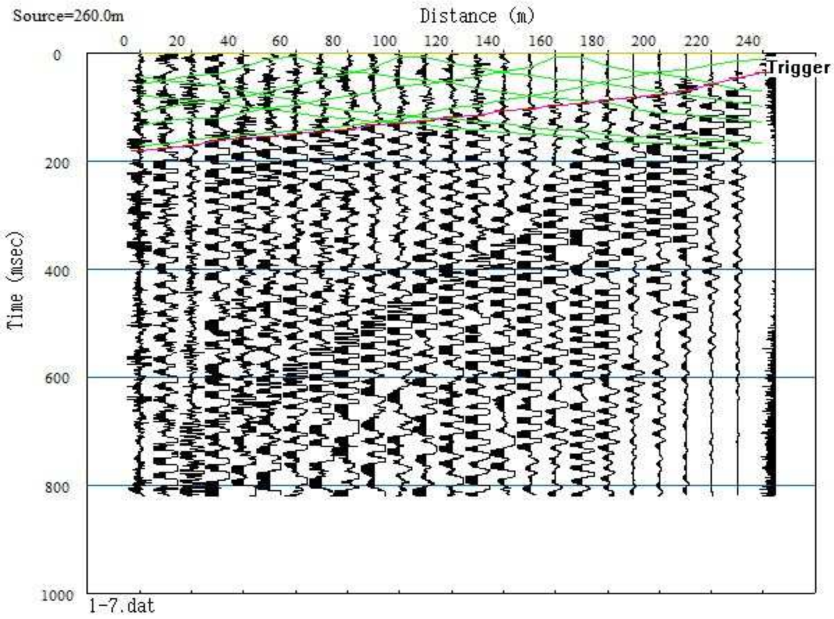
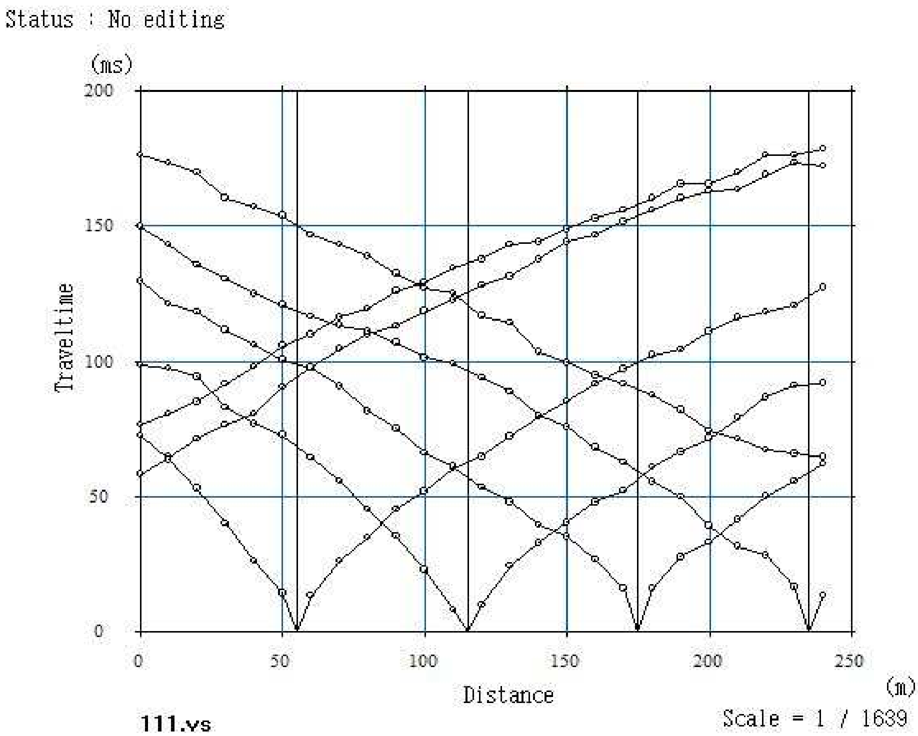
Appendix

Appendix 1 Upward continued to 1 km map

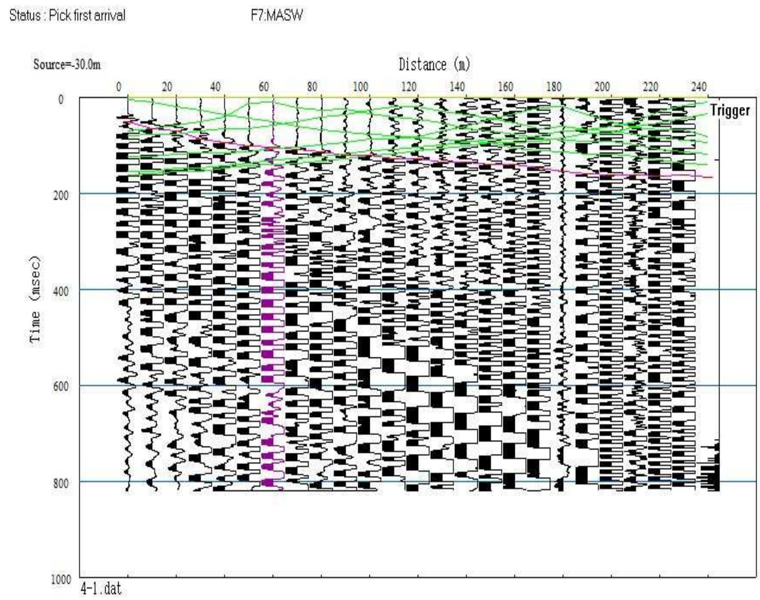


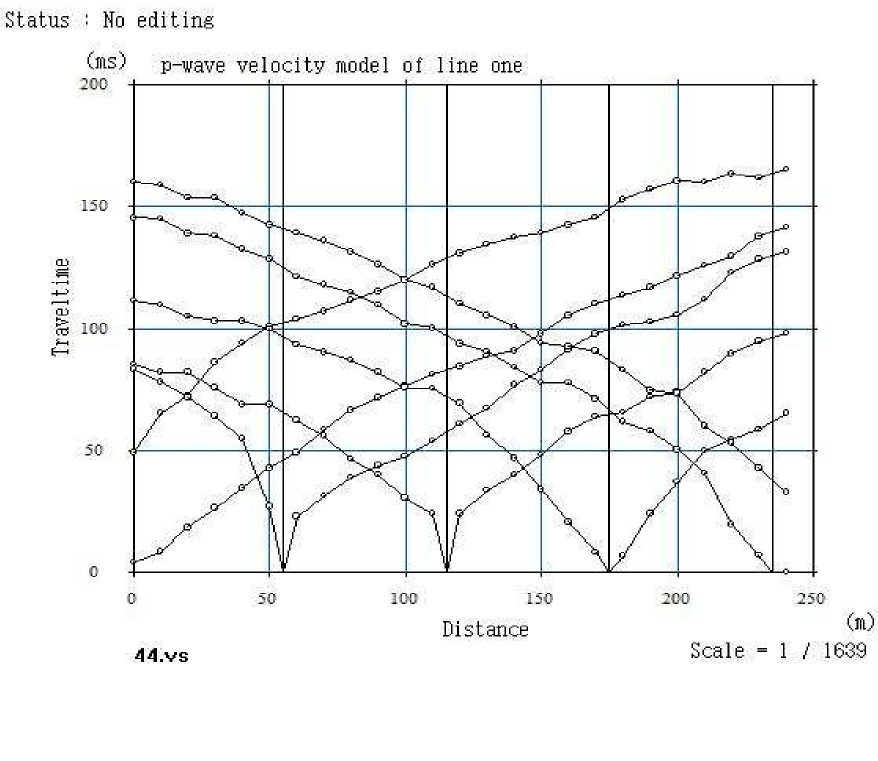
Appendix 2 Picked first arrival time and travel time versus distance curve of line one



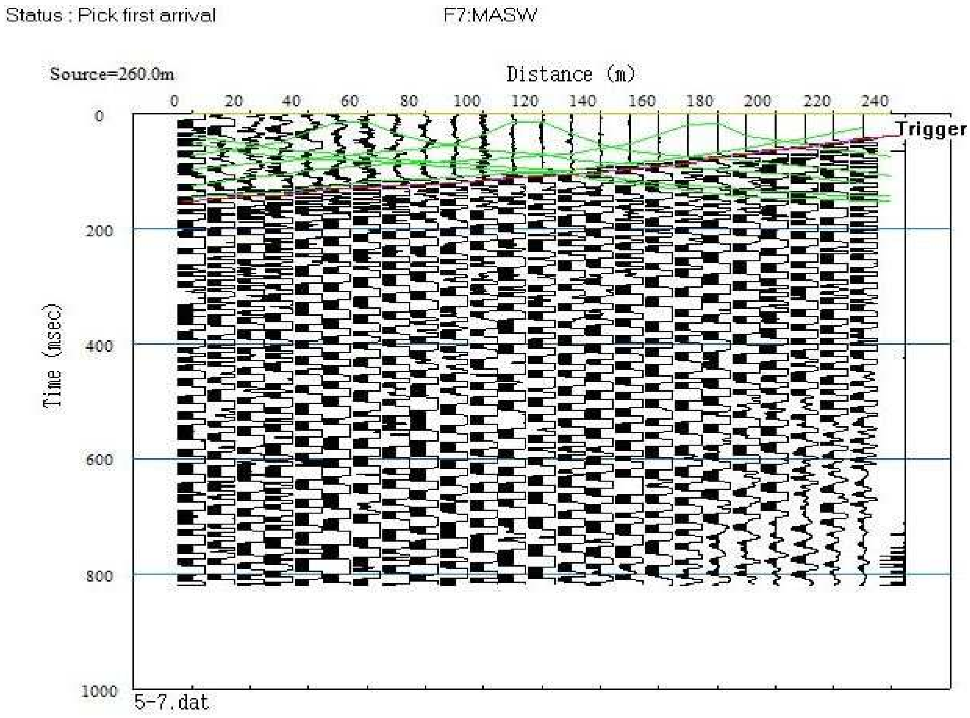


Appendix 3 Picked first arrival time and travel time versus distance curve of line four

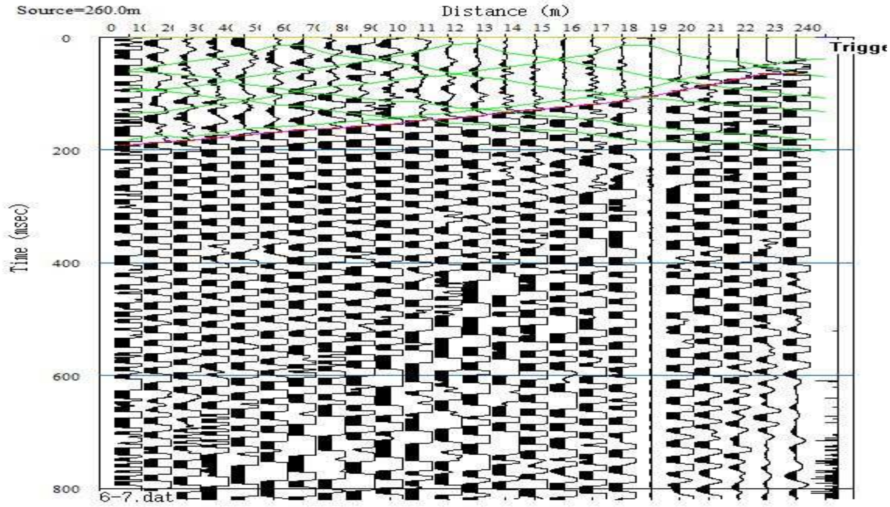


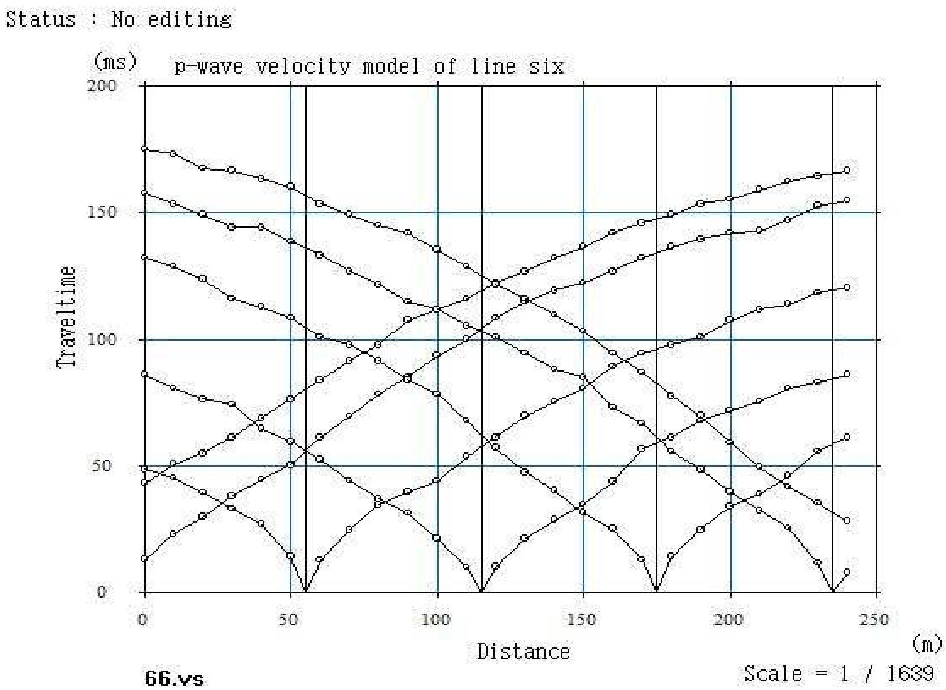


Appendix 4 Picked first arrival time curve of line five

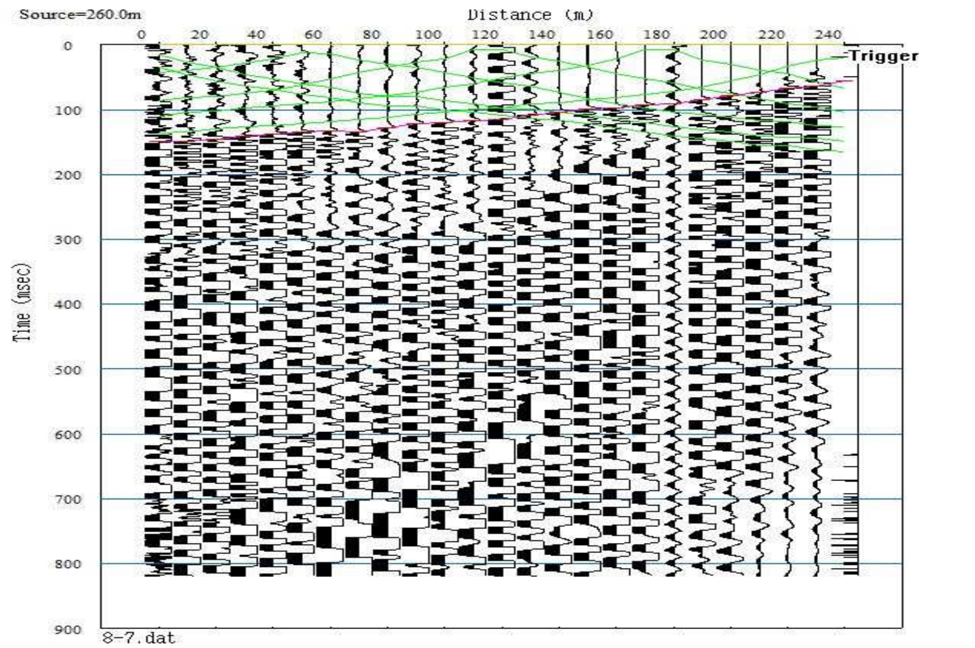


Appendix 5 Picked first arrival time and travel time versus distance curve of line six

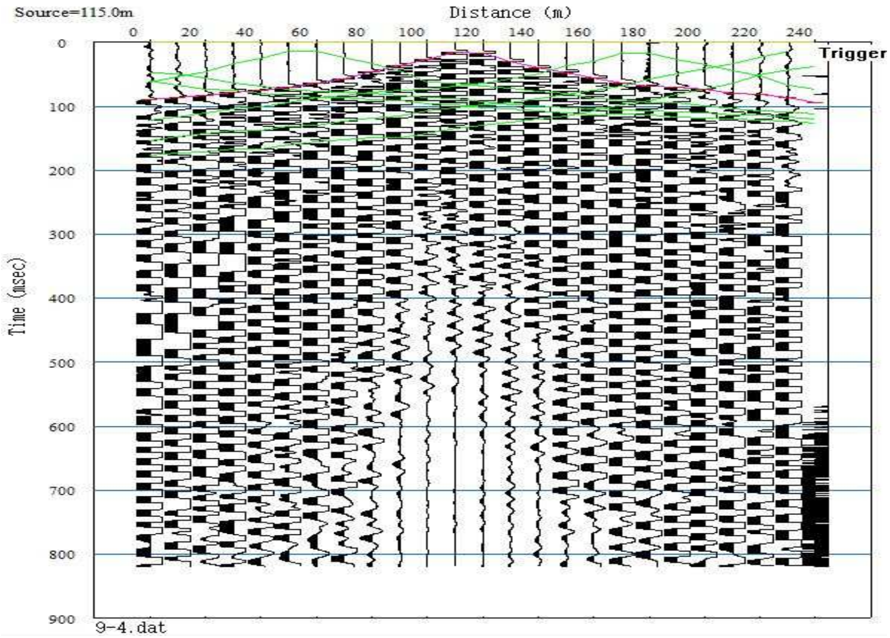




Appendix 6 Picked first arrival time curve of line eight



Appendix 7 Picked first arrival time and travel time versus distance curve of line nine



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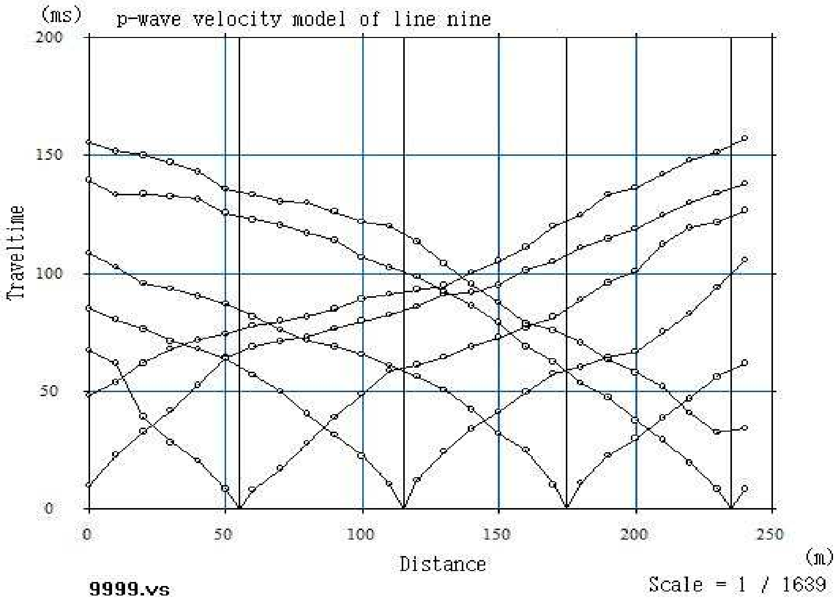

Appendix 8 Susceptibility of the lithology that used for magnetic modelling

Lithology	Susceptibility (SI units)
Soil	0.00001
Phreatomagmatic deposit	0.00501
Unwelded pyroclastic rock	0.008
Welded pyroclastic rock	0.00695
Basalt	0.03001