# Characrerization of Arba Minch University General Hospital, Construction Site, Using Seismic Refraction Method in Arba Minch Town of Southern Ehiopia

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## Abstract

The seismic refraction method is one of geophysical technic which is frequently used to determine the characteristics of soils and rocks (Ugwu, 2008; Ayolabi *et al.*,2009). This geophysical method is based on measuring the arrival times of seismic waves refracted by the interfaces between layers of ground, characterized by different propagation speeds. The energy source is represented by an impact on the surface. The energy radiates from the “shot point,-travelling both directly in the uppermost layer (direct arrivals), and deep down and laterally along layers at a higher speed (refracted arrivals)-then returning to the surface, where it is measured through the spreading of geophones.


# 1. Introduction

## 1.1 Back ground of the study

The seismic refraction method is one of geophysical technic which is frequently used to determine the characteristics of soils and rocks (Ugwu, 2008; Ayolabi *et al.*,2009). This geophysical method is based on measuring the arrival times of seismic waves refracted by the interfaces between layers of ground, characterized by different propagation speeds. The energy source is represented by an impact on the surface. The energy radiates from the “shot point,-travelling both directly in the uppermost layer (direct arrivals), and deep down and laterally along layers at a higher speed (refracted arrivals)-then returning to the surface, where it is measured through the spreading of geophones.

The energy generated either travels directly through the upper layer or travel down through the various layers before returning to the surface. The energy is then detected on surface at a series of receivers called geophones at regular intervals (Anomohanran, 2012). After a certain distance from the shot point, known as the cross over distance, the refracted signal is observed as a first arrival signal at the geophones (arriving before the direct arrival). Both the p-and s-wave provide information about depth of interfaces and about engineering properties. The primary waves (compressional waves or P-waves) are commonly used to determine depth to interfaces and locating weakened zones in rocks. The secondary waves (shear waves, or S-waves) could be used to provide additional information on top of the P-wave prospection. Each of these wave types carries different information about the subsurface due to differences in their propagation. Therefore, registering and processing both of them gives more detailed image of subsurface. E.g. A ratio of their velocities ($v_p/v_s$) could be related to consolidation (or fracturing) of the rock which is an essential parameter in engineering geology.

In seismic refraction method, the signal from the shot points returns to the surface by refraction at subsurface interfaces and is recorded at distances much greater than the depth of investigation (Igboekwe and Ohaegbuchu, 2011). The method relies on the tendency of seismic velocities to increase with depth, which sometimes makes it insensitive to low velocity layers in the subsurface. Based on the analysis of the field data, the seismic surveyor draws a profile showing the thickness of the subsurface and a good estimate of what materials they consist of (Gabre et al., 2012). Seismic refraction survey uses the process of critical refraction to infer interface depths and layer velocities. The data are usually presented as cross sectional plots representing P-wave path, velocities and depths to various interfaces.

# 1.2 common applications of seismic refraction

Estimating rip ability prior to excavation, Mapping depth of bedrock/bedrock topography, mapping to the groundwater existence, calculation of elastic moduli/assessment of rock quality, mapping thickness of landslides and identification and mapping of faults

# 1.3 Statement of the problem

In Ethiopia, there is growth and transformation plan to group under medium economy country. Therefore, by using seismic refraction methods to identify subsurface lithology, structure and know the existence of groundwater for different purposes like engineering structures. The study area is near to the city; therefore the future master plan of Arba Minch town will reach up to the study area, so that the study area is detail investigated by using seismic refraction survey.

# 1.4 Limitation of seismic refraction.

The study area poses a several limitations to the geophysical field works. First of all, the heavy traffic on a nearby main road generates a considerable level of seismic noise which interferes with the seismic source and read the weak seismic signal for long source-receiver distances unreadable. Finally, the thick layer of unconsolidated sediments quickly attenuates the seismic signal which limits the depth reach.

# 1.5 Description of the study area

# 1.5.1 Location of the study area

The study area is located in the southern part of Ethiopia in southern nation and nationality. It is situated 12 km southwards from the Arba Minch town. Absolute location of the study area on the topographic map is shown as Fig. 1.2

# 1.5.2 Accessibility of the study area

The study area has main road (asphalt) goes to konso and many gravel roads (foot trails) which connect different part of the study area for the purpose of studying.

# 1.5.3 Climate and Vegetation cover of the study area

The study area is found in the main Ethiopian rift valley. This determines the climate condition of the area, it is hot and arid. And the temperature is hot both in summer and winter seasons. The mean annual temperature is 21.8˚c. Throughout the year little only a little a small amount of precipitation is present. The mean annual rainfalls range from 750mm-900mm, sources from (geological mapping agency). Due to this the study area is overgrown with dry resisting vegetation.

# 1.7 METHODOLOGY AND MATERIAL

## 1.7.1 Methodologies

In general, methodology of field work is dividied into three phases.

## 1.7.2. Beforefield work

This phase involves; Gather all the existing information useful to the investigation. Search for previous investigations in archives and database. Study topographical maps and plan course of the profiles, model a physical response of the target structures and design the field layout

## 1.7.3 During field work

In order to image a geological structure a geophysical investigation involving seismic refraction was carried out. The seismic refraction data were measured using a 24-channel Oyo McSeis seismograph. The seismic data were acquired along a 225 m long profile at the foot scarp of the East African Rift. The technique consisted of laying 24 geophones (one for each seismograph channel) along a profile and record arrival times of seismic waves. The seismic energy was produced by striking a 10kg sledgehammer into a steel plate.

The geophones were spaced 5 meters apart. This 24-geophone spread was then moved along a profile to cover the remaining part. Two geophones were overlaping to ensure continuity of data. The shoting point of the frist profiles were 2.5, 27.5, 52.5, 62.5, 87.5 and 112.5 m. The offset point was 5m behind the end of the profile. The sources for the second geophone spread were at x-coordinates 5, 55and 105 m. The offset points of the second profile were again placed 5m apart from the geophone spread. The sources for the third profile also 5m apart and spread at x-coordinates 2.5, 27.5 and 52.5m.

## 1.7.4 After field work

After the field work download the data from the seismograph and start the data processing. In this work the data were processed by the SeisImager software provided by the seismograph manufacturer. The goal of the data interpretation is to derive distribution of seismic velocities along the measured profile and to interpret it in geological terms. Finally, the result and conclusions were written using a personal computer and a microsoft office Word, a text processing software.

## 4. Data Acquisition, Processing And Interpritation

# 4.1 Seismic refraction methods

Seismic refraction survey is employed to determine the subsurface geological structures or weak zones, lithological successions and water zones. In order to know these hidden subsurface geological conditions, for example the source of a problem with building foundations precise and accurate data is needed implying careful data processing and collection. The field procedure, data acquisitions and data processing are summarized as follows.

## 4.2 Data Acquisition

The aim of this work was to get a seismic velocity model of the foot scarp of the East African Rift region, specifically around southern part of Arba Minch town. Consequently, the work is conducted to determine a thickness of sediments below the escarpment and to image the fault zone. The measured profile started at the footwall of the rift zone, crossed the trough below it and continued SE to sediment sequences. The course of the profile was measured using the Garmin handheld GPS receiver, inevitable measurement errors were minimized by averaging the measurements for several minutes on every measured point. The overall length of the profile was 235 m, the geophone spacing was 5 m. The sledgehammer was used as a source of wave. Data were acquired using the 24-channel Do Lang seismograph.

Offset shots were used to cover the edges of the profile. Totally 13 shot positions were used based on geological variation of the area. Sampling frequency of the records was 200 as to ensure precise readings of arrival times.

The field data are inserted into the computer software to pick the first arrival times. The recorded seismic waves by a distance vs time graph. The different wave types appears at each geophone at a particular distance with a particular time. For our survey a refracted p_wave is needed, which is the firest wave arriving at the geophones. This means the frist arival time at each geophone.The overlap between the two spreads is two geophones. The seismic wave was generated using a hammer with a metal plate. At each shot point the arrival times for each of the geophones were recorded.

## 4.3 Data processing

The data needed for further processing were arrival times and distances from the source point. Seismic refraction data processing was done using a Pick win and Plotrefa software. The first step for processing seismic refraction data is opening the pickwin software and then loading the seismc data (seismic traces).

After loading the data the p-waves (frist arrival times) or frist breaks are picked

The picked first arrival times are input for the second stage of the processing – the inversion of a traveltime curve. This was done via the Plotrefa software.

The traveltime curves were then checked for a reciprocal traveltimes, the error is reported in msec percent. Reciprocal errors lower than 5% are considered small enough to enter further porcessing. Otherwise it is necessary to correct the first breaks picks. This step is repeated starting from the frist profile, first shot point upto the last profile, the last shot point. .

When all the reciprocal errors are low enough it is possible to continue with a next step – the data inversion. The Plotrefa code alows for two different types of inversion – the time-term inversion, using a layered velocity model, and a tomography inversion based on the gradient velocity model. The type of the velocity model determines the application of particular individual approaches – a strictly layered geological media would, naturally, require a layered model approach. Nevertheless, a common geological media is usually a mix of both types – for example a soil layer overlying a weathered bedrock.

The first step in the Plotrefa software is to open the travel time data, select an apropriate inversion approach, include topography information and do the inversion. First insert the elevation data.

## 4.3.1 Tomography

The tomographical inversion in the Plotrefa code is based on the gradient model, which means that the seismic velocities changes throughout the model in a smooth manner. Subsurface is divided into small cells with constant values of seismic velocities. Then the rays are traced from sources to individual geophones. From the traced raypath and known velocities in individual cells a theoretical traveltime for every source-receiver pair is computed and compared with measured data. If the measured and theoretical data does not agree the velocity model is changed to better fit the data. The whole procedure (called an iteration) is repeated until a satisfactory fit of theoretical and measured travel times is obtained.

The first step in the tomography procedure is to generate an initial model. A dialog box is shown to enter several selectable parameters.

## 4.4 Data interpretation

This chapter includes interpretation of the seismic refraction data collected in the field and processed by authors of this thesis. Some top part of the study area covers by extremely low velocities ranges from 0.3-06 km/sec. This indicates that the upper part of the succession is a deposit of fluvial and colluviums (means deposited by transported mass movement) deposits depend up on the standard velocity of material which are highly disturbed. In another way, other second top part of the area is covered by high velocity materials relative with the first succession. Gradually increasing the velocity goes down the depth. This indicates that the degree of compaction is increase, the degree of weathering decrease down the depth and the composition of the material is change. In addition, the geological structures that observed on the surface didn't penetrate to depth greater than 7m. However, the seismic velocities below this layer increasing gradually from 0.9-3.0 km/sec. Hence, from the standard velocity of materials, the composition of this layer is sand. Generally, the data shows that there are no sound rocks up to 50m depth of the subsurface.

# 5. Results And Interpretation

## 5.1. Results and interpretation of seismic refraction data

The seismic refraction data processed using SeisImager/2D software. Pickwins95module 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 velocity 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.

## 5.1.1. Velocity model of line two

The sixth shot of line two, the recorded and display in seismograph is shown in Fig. 5.1. The figure shows data collected by 24 geophones. The deviation from geophone to other represented the distance between geophone to another. The first geophone is the first signals arrive to seismograph, and so on to last geophone is the last signals arrive to seismograph. Seismic refraction model for line two is presented as Fig. 5.3. Total spread length of line two is 120m. The model presents seismic velocity between 0.51km/s and 3.53km/s. It shows slower velocity (0.51km/s)

The picked first arrival times are input for the second stage of the processing – the inversion of a traveltime curve as Fig. 5.2. I received this figure from SeisImager by snipping tool. Then, after this done on seisimager saved to plotrefa file by save pick file. This was done via the Plotrefa software for velocity model of different layers with their thickness.

The Plotrefa code alows for two different types of inversion – the time-term inversion, using a layered velocity model, and a tomography inversion based on the gradient velocity model. The type of the velocity model determines the application of particular individual approaches – a strictly layered geological media would, naturally, require a layered model approach. Nevertheless, a common geological media is usually a mix of both types – for example a soil layer overlying a weathered bedrock.

The first step in the Plotrefa software is to open the travel time data, select an apropriate inversion approach, include topography information and do the inversion. First insert the elevation data. The topography of this layer is somewhat irregular as shown in the right side of the model (Fig. 5.3)

## 5.1.2. Velocity model of line three

Third shot, in third shot the signals are at variance in first shot signals. The seismic source at last geophone. The last geophone is the last reading signals and so on until geophone number one. The data that collected in seismograph export to plotrefa and the program make process on this data. The first processing on data, Set the display gain so the first breaks are clearly visible. Seismic refraction of velocity model for line three is presented as Fig. 5.6. Total spread length of line three is 110m. The model presents seismic velocity between 0.28km/s and 4.06km/s. It shows slower velocity (0.28km/s).

After the first arrivals were determined, plotrefa, the interpretation module of SeisImager was used to generate travel time curves and velocity model of each line. Typical travel time curves generated by plotrefa for line three are shown in Fig. 5.5. this travel time curve contains the first arrival times for each of the line three shot locations along a given refraction spread.

From 0-50m and 50m-110m distance, the thickness of layers are different. For the foundation of constructions the distance from 0-50m is important because of its shallow basement rock for construction foundation. The thickness of layers from 0-50m distance are; layer one is 2.5m thick, layer two is 1.5m thick and layer three is a very thick basement rock on (Fig. 5.6).

# 5.1.3. Velocity model of line five

The sixth shot of line five, the recorded and display in seismograph is shown in Fig. 5.7. The figure shows data collected by geophones. The deviation from geophone to other represented the distance between geophone to another. The geophones signal as stairway left direction. The first geophone is the first signals arrive to seismograph, and so on to last geophone is the last signals arrive to seismograph. Seismic refraction model for line five is presented as Fig. 5.9. Total spread length of line two is 120m. The model presents seismic velocity between 158m/s and 270m/s. It shows slower velocity (158m/s).

After the first arrivals were determined, plotrefa, the interpretation module of SeisImager was used to generate travel time curves and velocity model of each line.

Typical travel time curves generated by plotrefa for line five are shown in Fig. 5.8. This travel time curve contains the first arrival times for each of the line five shot locations along a given refraction spread

# 5.1.4. Velocity model of line seven

Seismicity model of line seven is shown in Fig. 5.12. Seismic refraction of line seven is perpendicular to line five. The thickness of the top layer is 2-6m and it is 1m thick at the left side of the model and 6m thick to the right side of model. The seismic velocity model of this line seven is between 300m/s and 1999m/s. it shows slower velocity in the layer arrivals is about 300m/s.

After the first arrivals were determined, plotrefa, the interpretation module of SeisImager was used to generate travel time curves and velocity model of each line. Typical travel time curves generated by plotrefa for line three are shown in Fig. 5.11. This travel time curve contains the first arrival times for each of the line three shot locations along a given refraction spread.

## 6. Conclusion And Recommendation

# 6.1 CONCLUSION

Seismic methods are applied primarily in order to determine the zones of different earth subsurface lithology. Seismic refraction method delineated the third layer as the most competent layer, having recorded higher values of velocity than the other layers. Geophysical (seismic refraction method) surveys are the basis for preparation of engineering geological profiles and velocity models separated in terms of the parameters of longitudinal wave velocity. The primary use of seismic refraction is for determining the depth and structure of bedrock. Seismic velocity depends on elasticity and density of the material through which energy passes; seismic refraction provides data on strength of materials and therefore can be used as a means of assessing rock quality. The technique has been successfully employed in establishing depth and strength of overburden rock and describing areas containing groundwater. Results of geophysical investigations should be included in the data obtained by geological mapping, which will in correlation with drilling results complete the picture of geological structure of terrain and facilitate categorization of materials and rocks for the purpose of developing the engineering structures and Hydrogeological profiles. The work yield three lithological seismic layers based on intercept time and generalized reciprocal methods of interpretation. The methods have yielded velocities of 0.51 km/s to for the upper layer, interpreted top layer with average thickness of 3m. The middle layer has average thickness of 25.5 m and velocity of 1 km/s.. Third layer's velocity is 2 km/s and 23m average vertical extension. Thickness of each the layer has increased from west to eastern direction of study area. According to velocity and lithology of third layer which could form bedrock for engineering structures identified.

## Declarations

Competing interests: The author declares there is no competing interest.

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# Figures

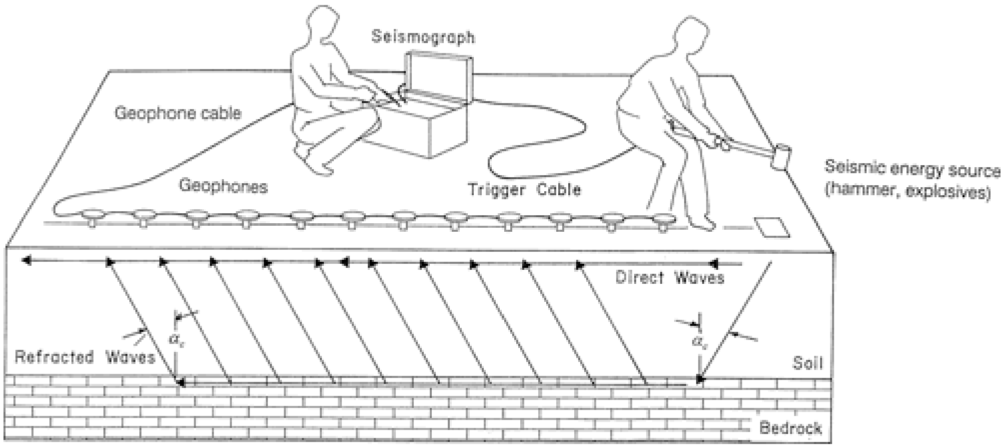


**Figure 1**

Fig 1.1 Seismic refraction survey arrangement of the instrument.

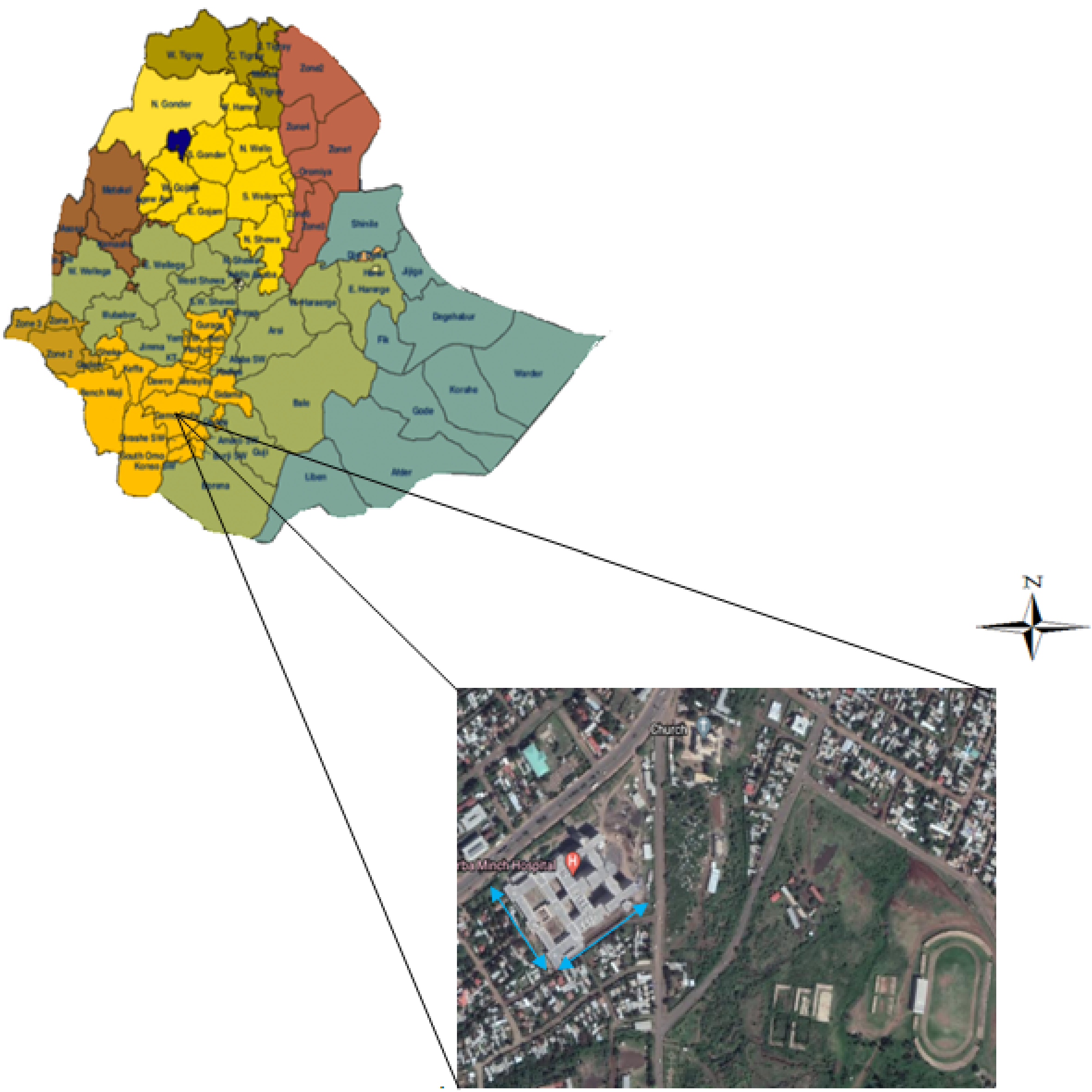


**Figure 2**

Figure 1.2 Location map study area

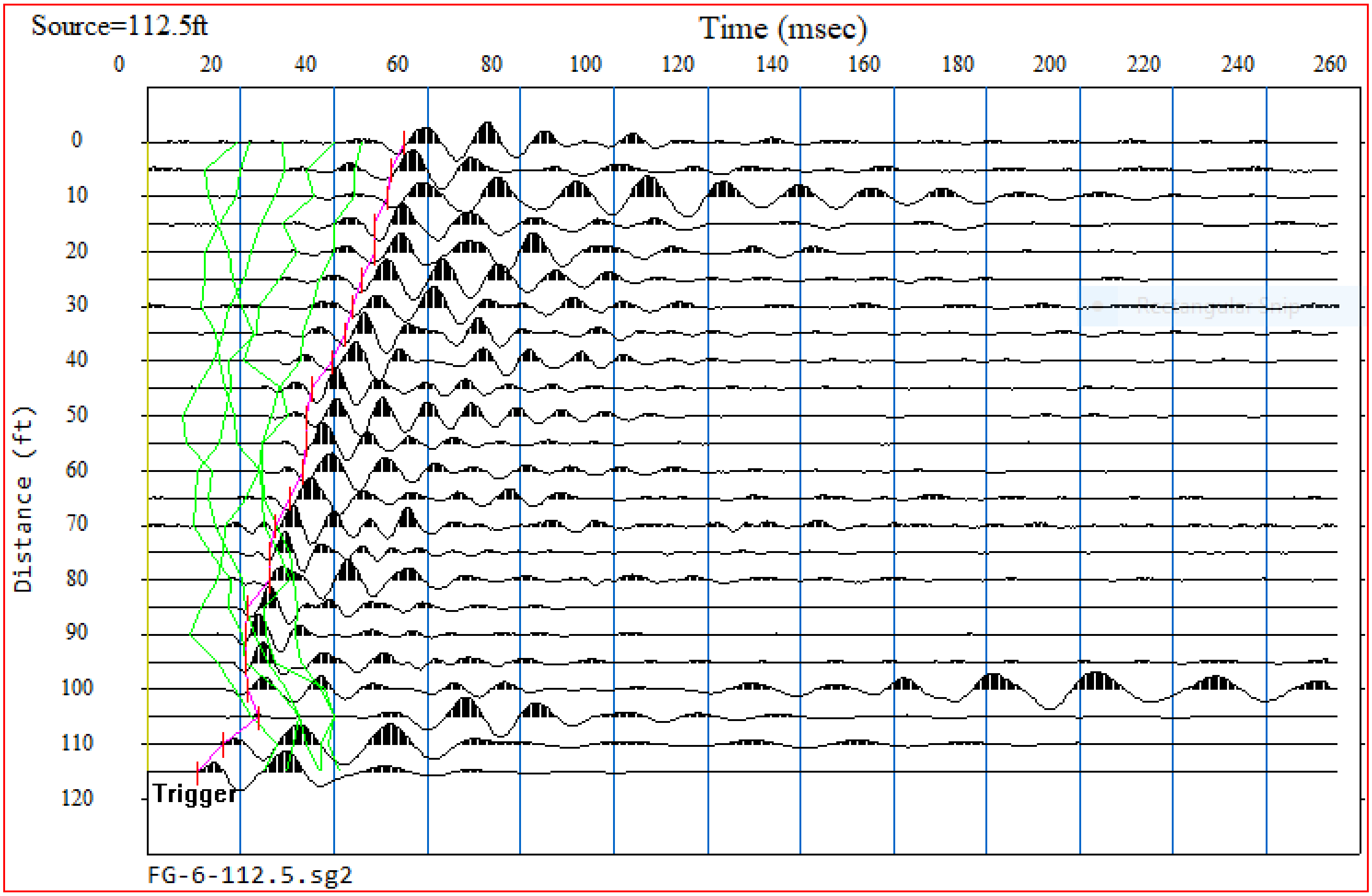


**Figure 3**

Figure 5.1 First arrival times of profile for line two

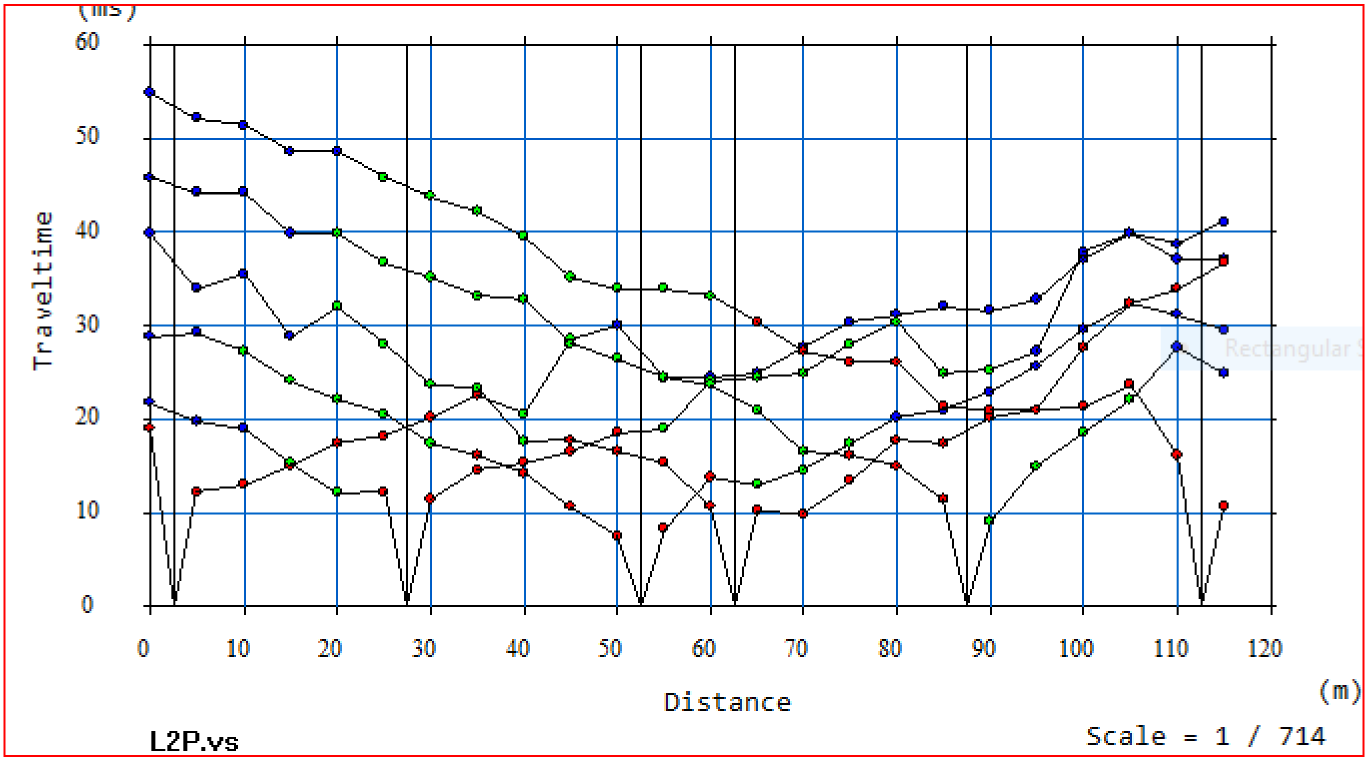


**Figure 4**

Figure 5.2 Travel time-distance graph of spread for line two

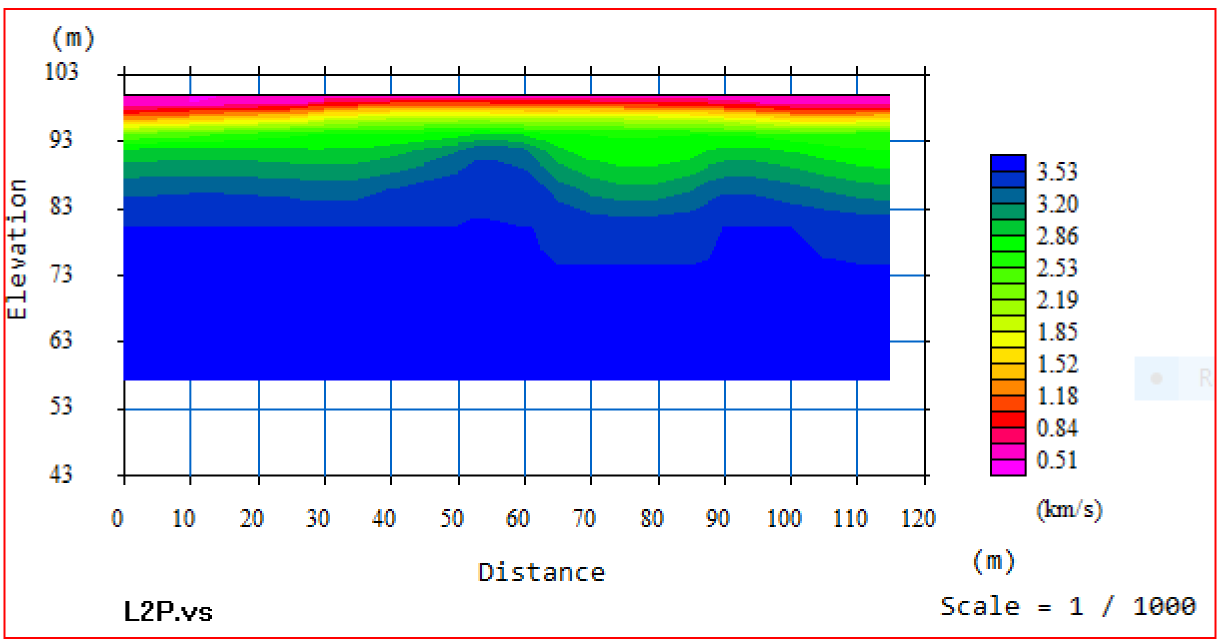


**Figure 5**

Figure 5.3 Velocity model of line two

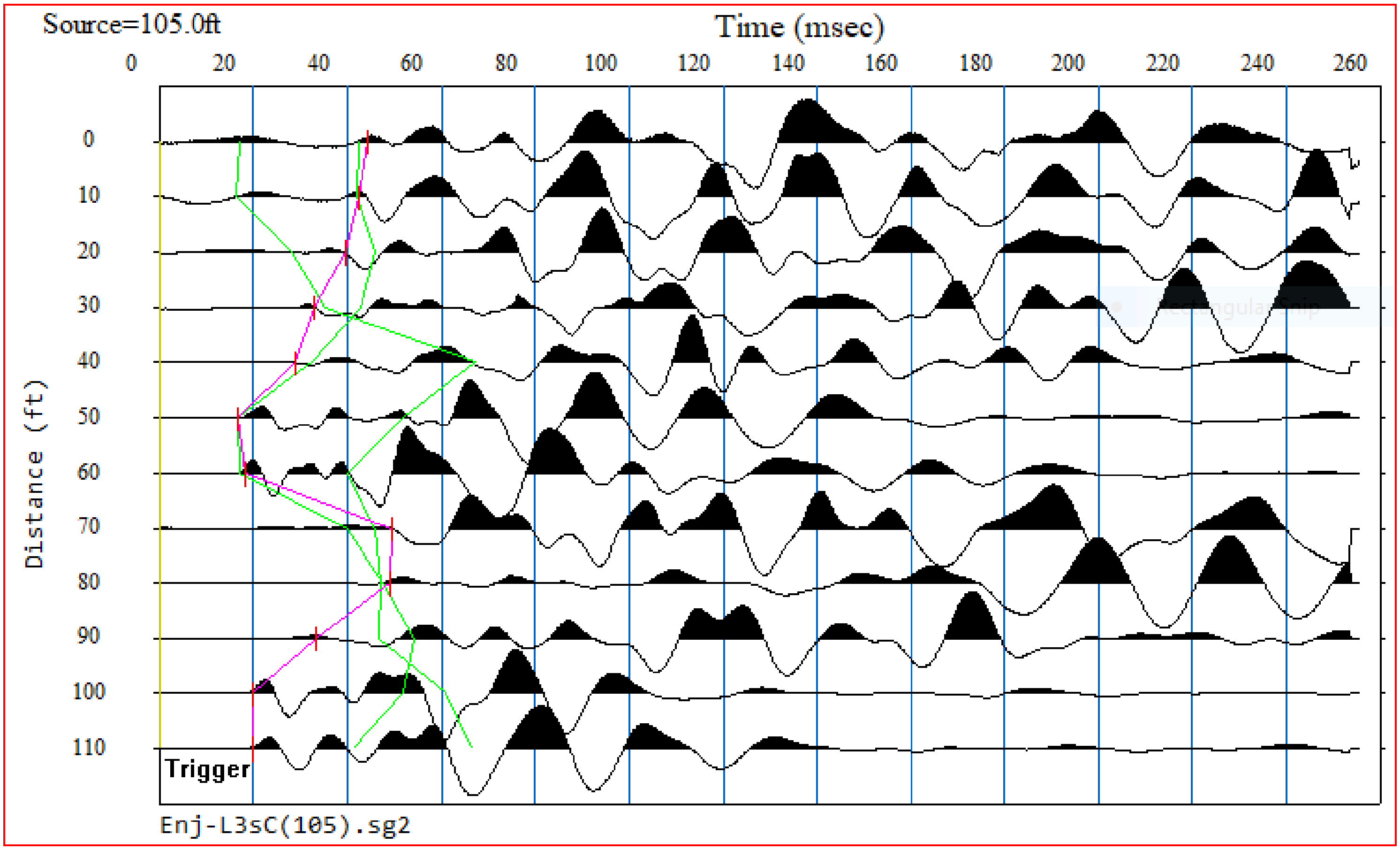


Figure 6

Figure 5.4 First arrival times of profile for line three

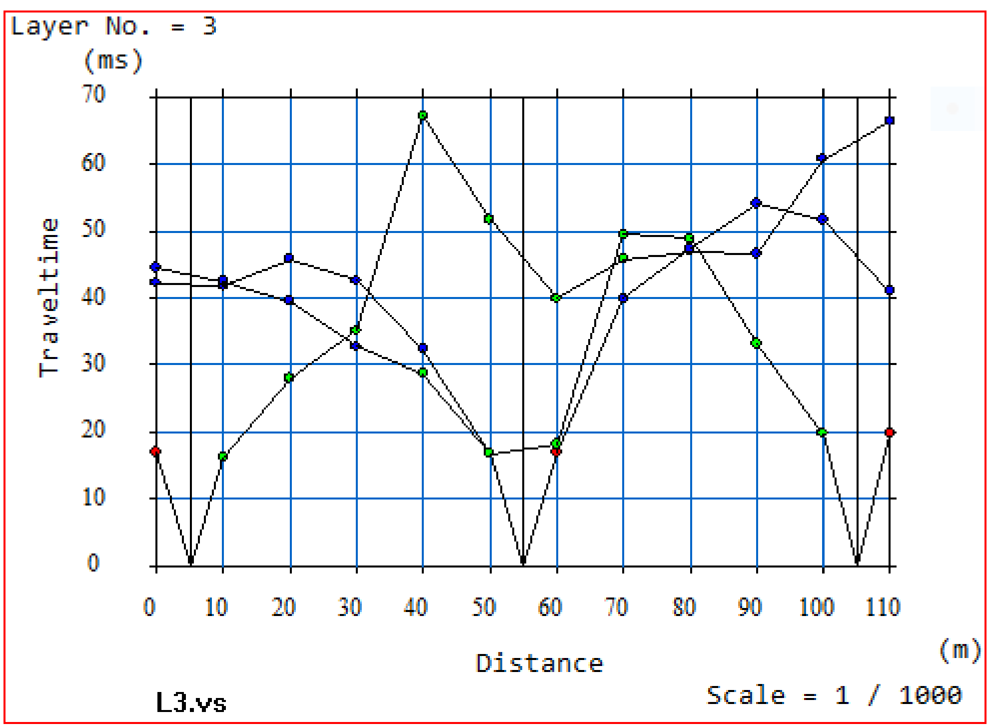


Figure 7

Figure 5.5 Travel time-distance graph of spread for line three

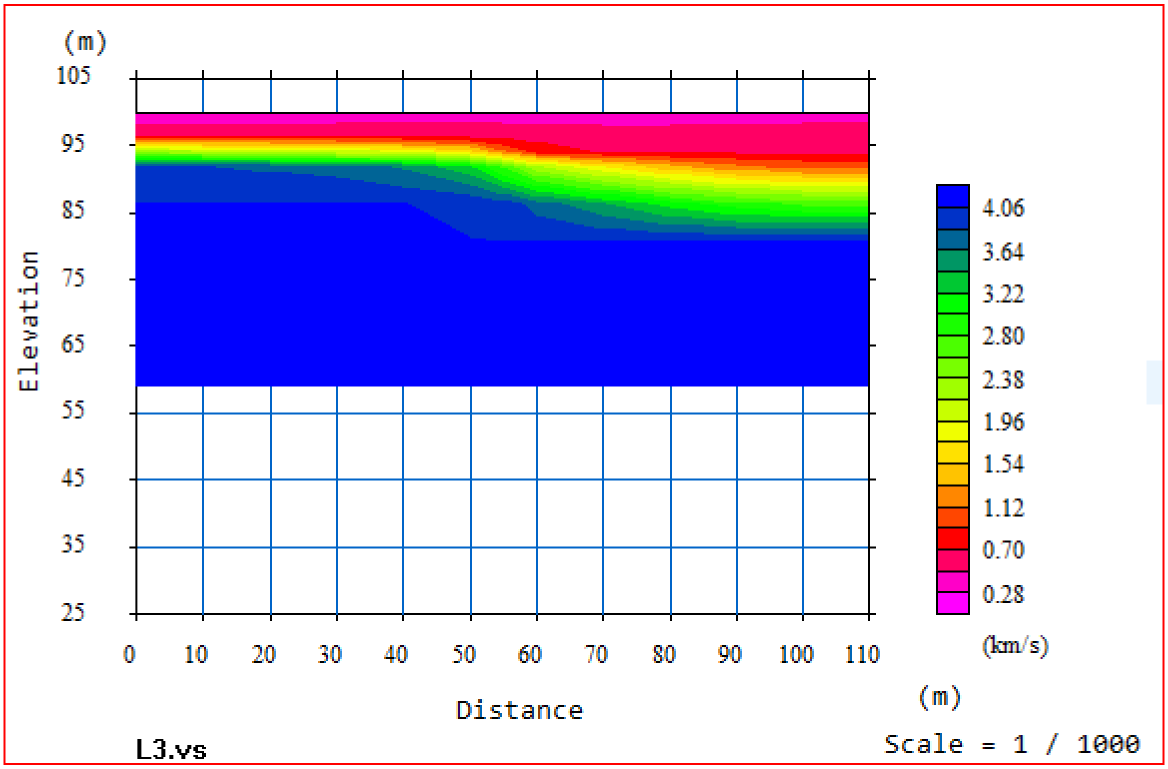


**Figure 8**

Figure 5.6 Velocity model of line three

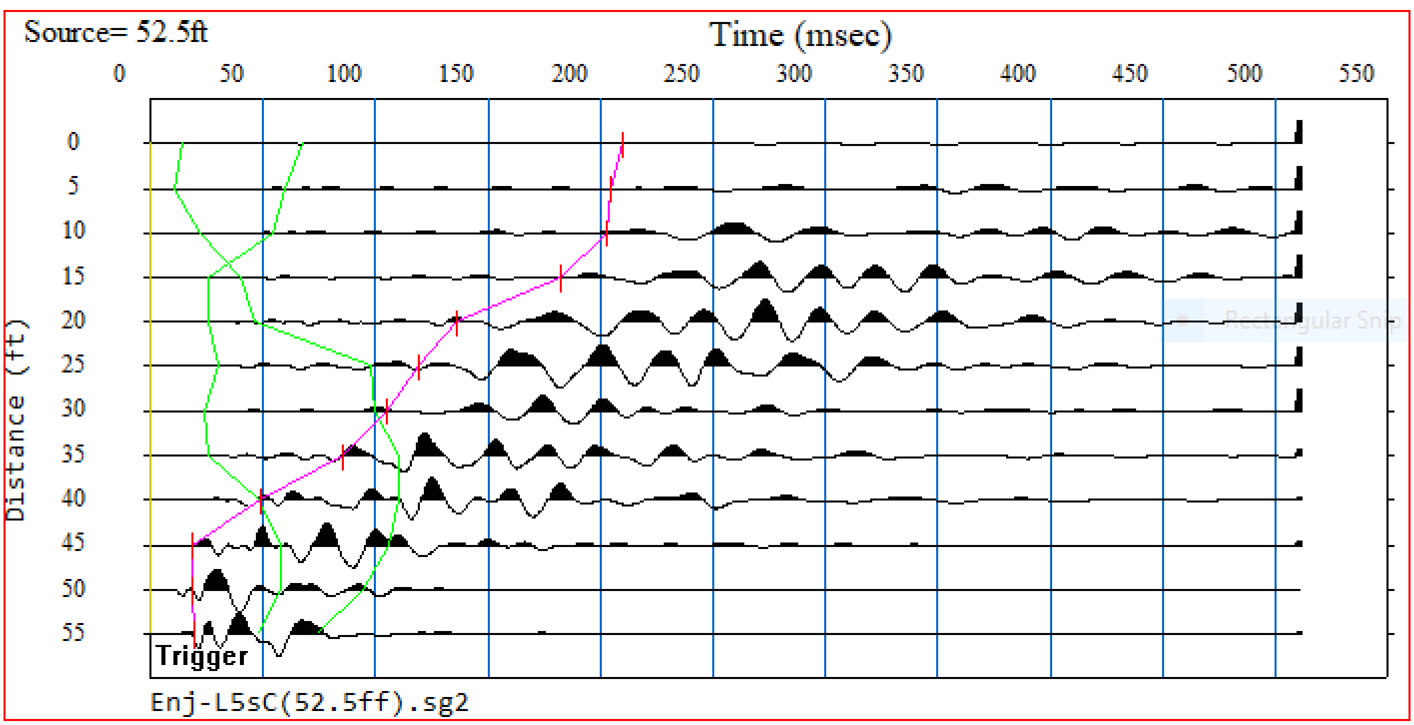


**Figure 9**

Figure 5.7 First arrival times of profile for line five

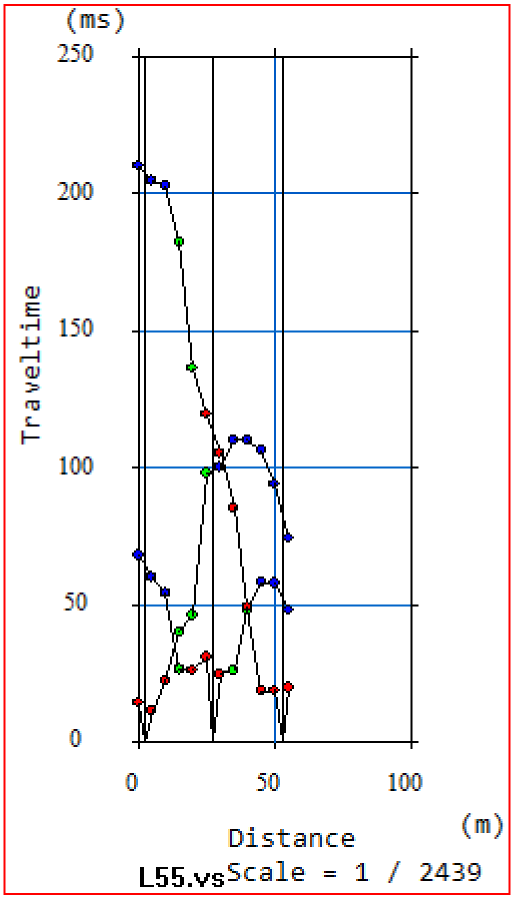


**Figure 10**

Figure 5.8 Travel time-distance graph of spread for line five

**Figure 11**

Figure 5.9 Velocity model of line five

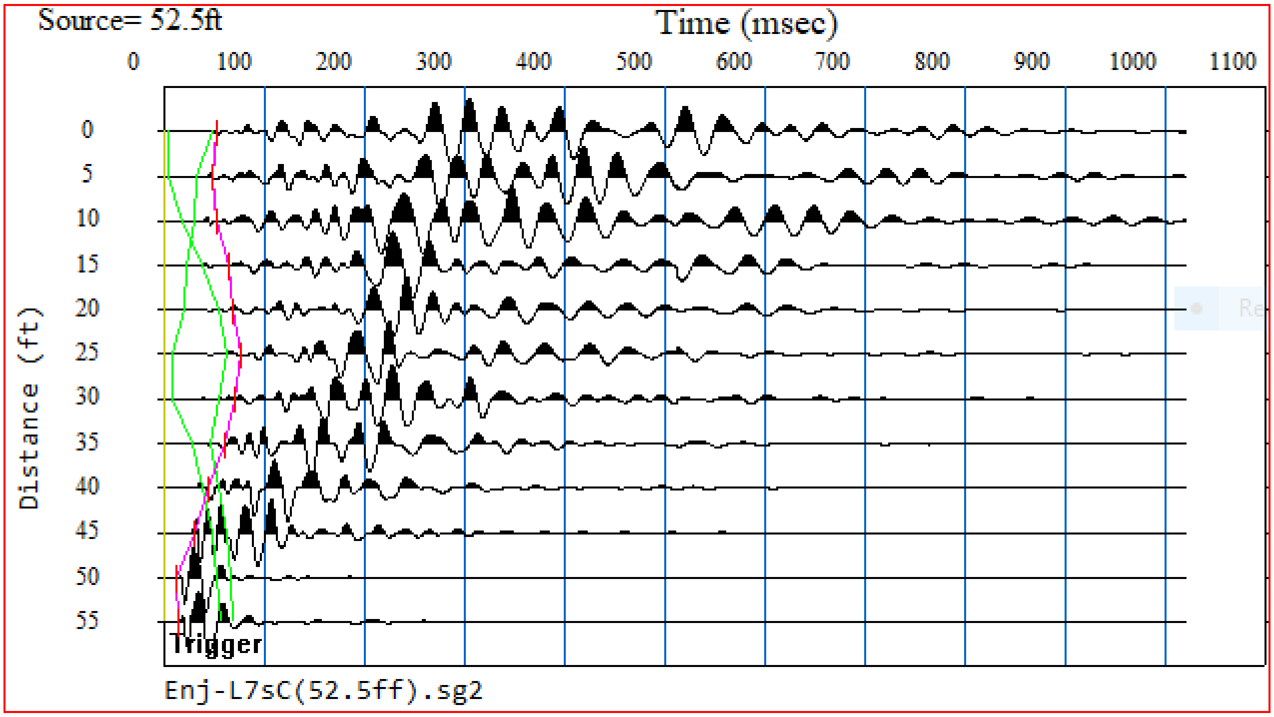


**Figure 12**

Figure 5.10 First arrival times of profile for line seven

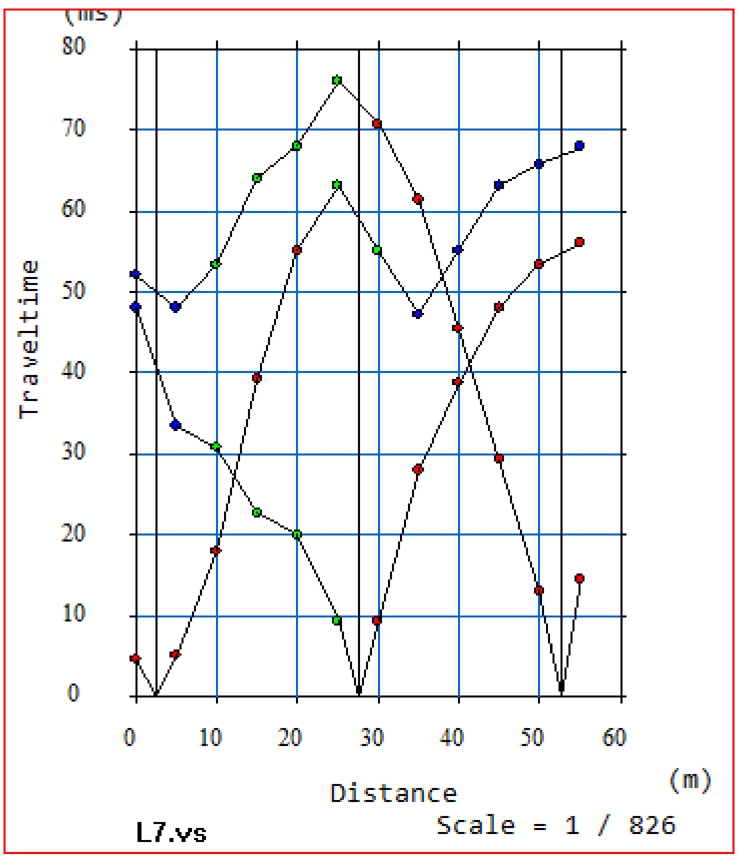


**Figure 13**

Figure 5.11 Travel time-distance graph of spread for line seven

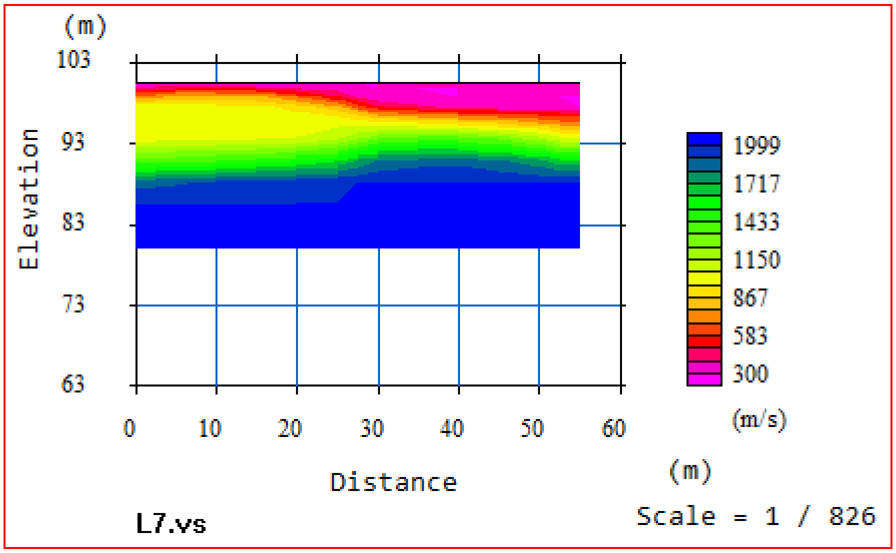


**Figure 14**

Figure 5.12 Velocity model of line seven