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The Application of Shallow Seismic Refraction Method to Study the Dynamics Properties of Soil in Atbara Area, Sudan

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Abstract

Atbara is located at the confluence of the river Atbara which descends from the Ethiopian highlands and the main Nile. This region witnessed in the last few decades development regarding buildings of many industrial activities specially regarding a lot of cement factories around the town. Shallow seismic refraction measurements are carried out in Atbara area to define subsurface layering and dynamics characteristics of soil. In this paper ABEM TERRA LOC MK6 system is used and a set of profiles with a 24 channel for vertical geophones was used to generate P-waves. The data were recorded on a seismograph and later downloaded to computer for analysis of the first-arrival times to the geophones from each shot position using recent software. Travel-time versus distance graphs were constructed, velocities and the depth to the layers were computed. The P-wave for the subsurface layer was determined and also the S-wave velocities in m/s was calculated based on the P-wave velocity. Interpolation map and histogram were constrcted for the wave velocity. Finally, it could be conclude that the shallow seismic refraction is one of the most important techniques that used to study the soil dynamics and mechanics properties of the subsurface layers.

Keywords

Shallow Seismic Refraction, P-wave Velocity, S-wave Velocity, Travel Time Dictanse Curve, Velocity Model, Interpolation Map

1. Introduction

The shallow seismic refraction techniques are mainly used for calculation of seismic velocities of soil and bedrock, mapping the bed rock topography, determination of lateral and depth variations and to display a detailed image of structural features in the subsurface.

Also, the seismic methods can be applied to delineate any mechanism for changing mechanic properties. Many text books and numerous journal articles present the details of seismic refraction theory [5, 8, 13, 14]. Various researchers have used the seismic refraction technique to determine the characteristics of the sites, such as [1-2, 4, 6, 7, 9, 10, 11-12].

The source of a coustic energy, detector for monitoring the transmission of energy through the layers and recording system are the basic materials for seismic field procedure in shallow seismic refraction method. The basis of seismic refraction theory is Snell's law, which illustrates the refraction of a sound or light ray a cross the boundary between layers of different characteristics. There are five types of waves in refraction seismology, which is direct, diving, reflected, head, refracted. In general, the velocities of the body and shear waves in the upper surface layers are usually much lower than those of deeper layers. Generally, there are three interpretation methods for refraction which is an intercept time method, delay time methods and ray tracing.

Generally, in P-waves the motion of the particles of the medium moves in the direction of wave travel, but in S-wave the particles are moving perpendicular to the wave travel. The time-distance curve (T-X) can be obtained from Time versus distance plot, the direct wave is displayed by interpolated line for arrival time data passing through the origin. The slope of this interpolated line is time over distance, or the inverse of velocity. The slope of the lines of the T-X plot is named slowness.

The main objectives of this research are to study the dynamic characteristics of soil using shallow seismic refraction.

The area lies in central northern Sudan in Nile river state where the surface is generally flat in the area south and north of Atbara river, where as the south western part of the study area is characterized by rigid features of sandstone plateau. Geologically the study area consists of basement rock and sediments. Figure 1 displays the study area.

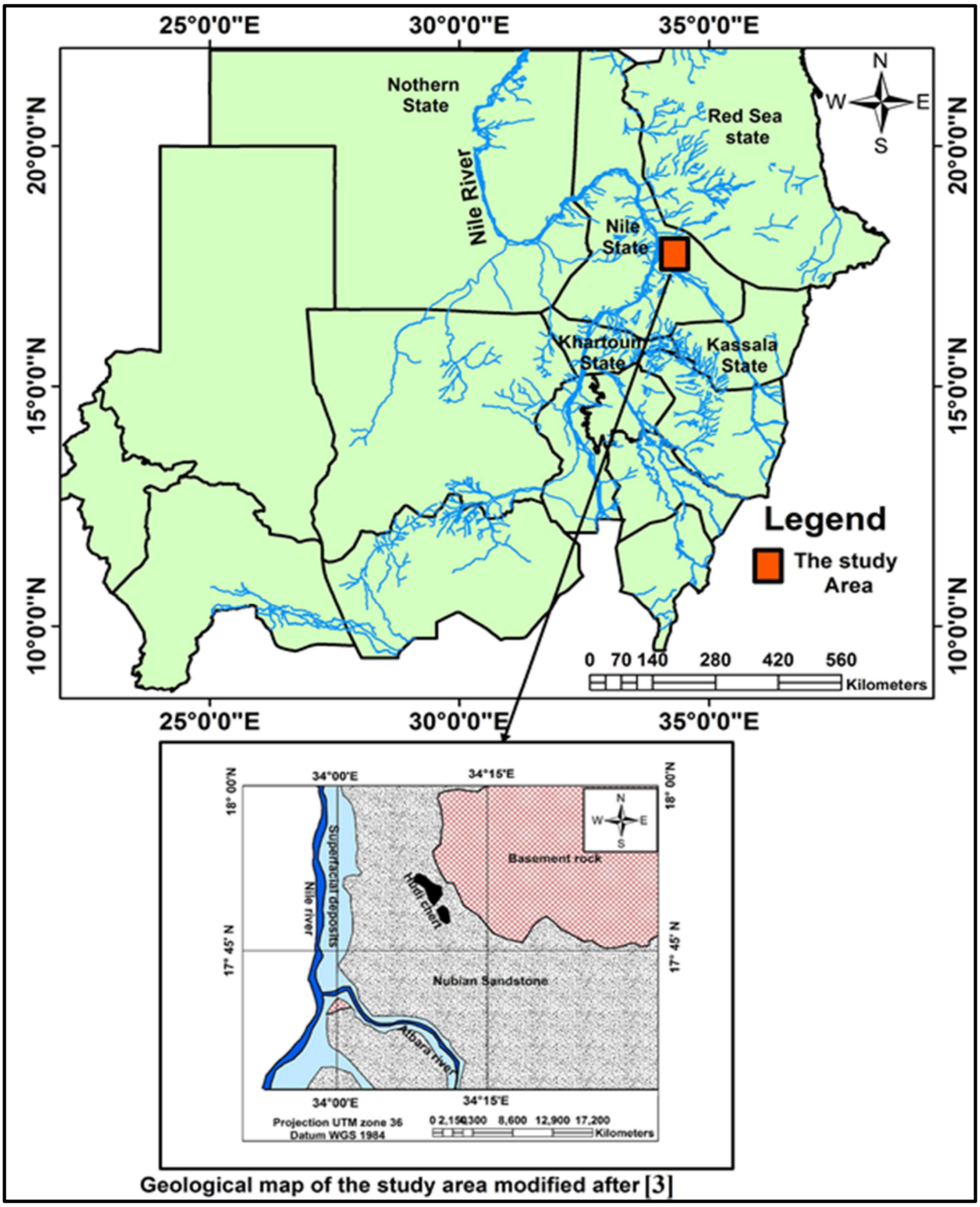

Figure 1. *The study area.*

2. Material and Method

Seismic refraction data were collected during July 2010 using ABEM TERRA LOC MK 6 inorder to gain a better understanding of layers depth and velocity and lateral extension. This study considers 12 seismic P-wave profiles directed east–west Figure 2. The spreads of P-wave refraction data were obtained using 24-channel Geometrics Geodes. Asledge hammer was used as an energy source, generally five shots were made for every single profile to generate P-waves but some times usedt here or four. Four to seven shots were stacked at each shot point to enhance the arrivals at distant geophones and to increase the signal to noise ratio at all of the geophones. The length of every seismic profile is 69 m and the geophone interval is 3 meters.

Data was analyzed using the software programs Pick Win 95 and Plotrefa from the SeisImager software package (OYOCorporation, 2004). These programs allow computing the subsurface layer velocities at every profile, thus modeling of depth, velocity were conducted using a time-term inversion method (OYO Corporation, 2004). A three-layer model was employed to represent the subsurface layer, and a thin layer of superficial deposits. Raw field data was imported into Pick Win 95 and the first arrivals of the P-waves were chosen. This was performed for each of the all shot points along the profiles. The first arrival data were imported into Plotrefa, and a plot of time versus distance (1/v) was generated. After the layer assignment, a time-term inversion model can be run. Velocity is calculated, and from the model depth is inferred. Models were created for all profiles. Due to the technical problems the records of S-wave was not clear, therefore, the below equation is used to calculate the S–wave velocity in the present study.

$$Vp=1.7Vs \text{ [15]}$$

Where Vp is P –wave velocity and Vs is S-wave velocity

The velocities of P wave at every layer were interpolated to determine the area of high and low velocity in the investigation area.

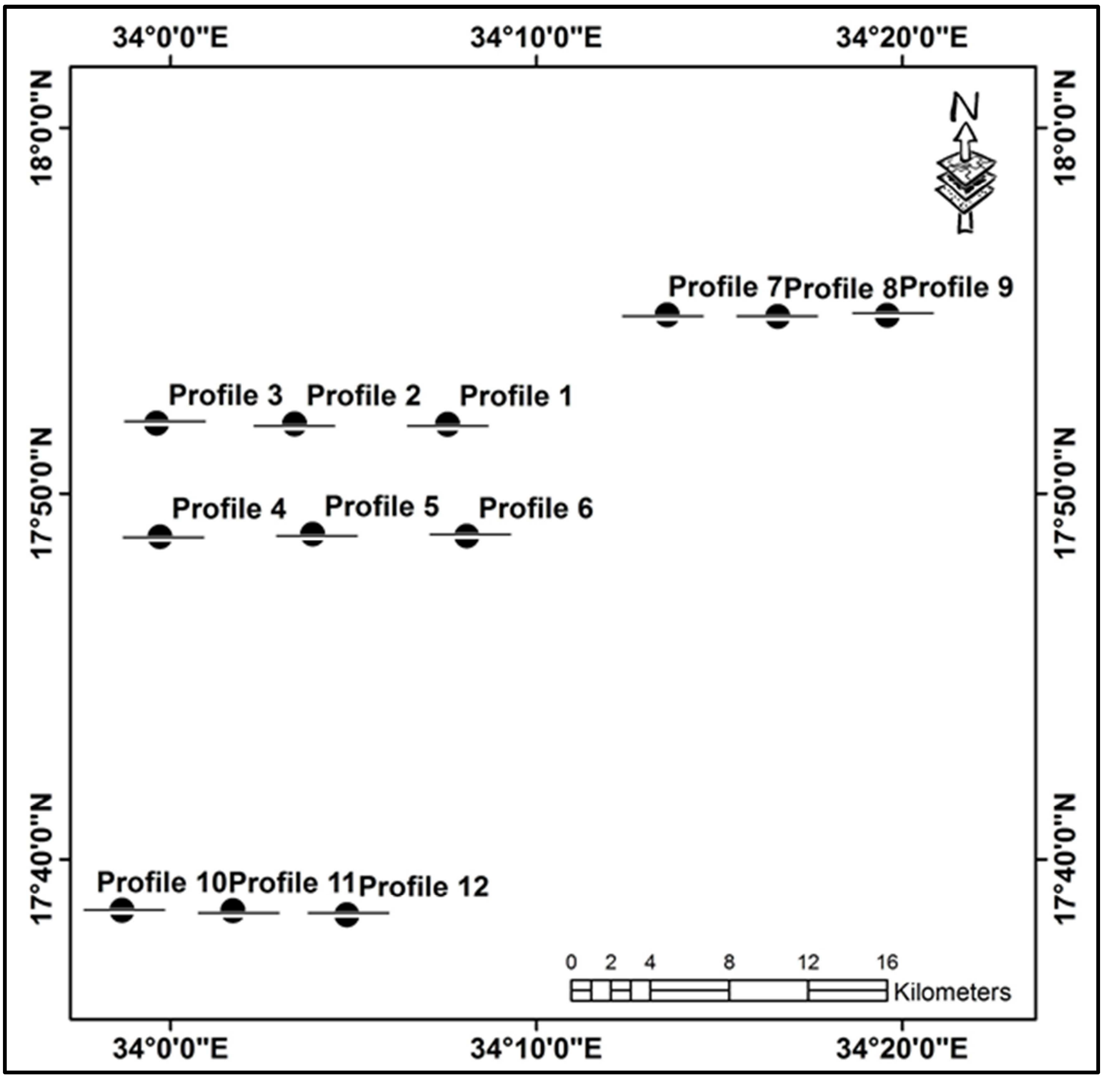

Figure 2. *Display the profiles location.*

3. Results

The travel time distance curve and depth velocity model were created for all profiles based on the first arrival time of P-wave. Figures 3 and 4 explains the example of travel time distance and velocity model of profile no 1 and 12.

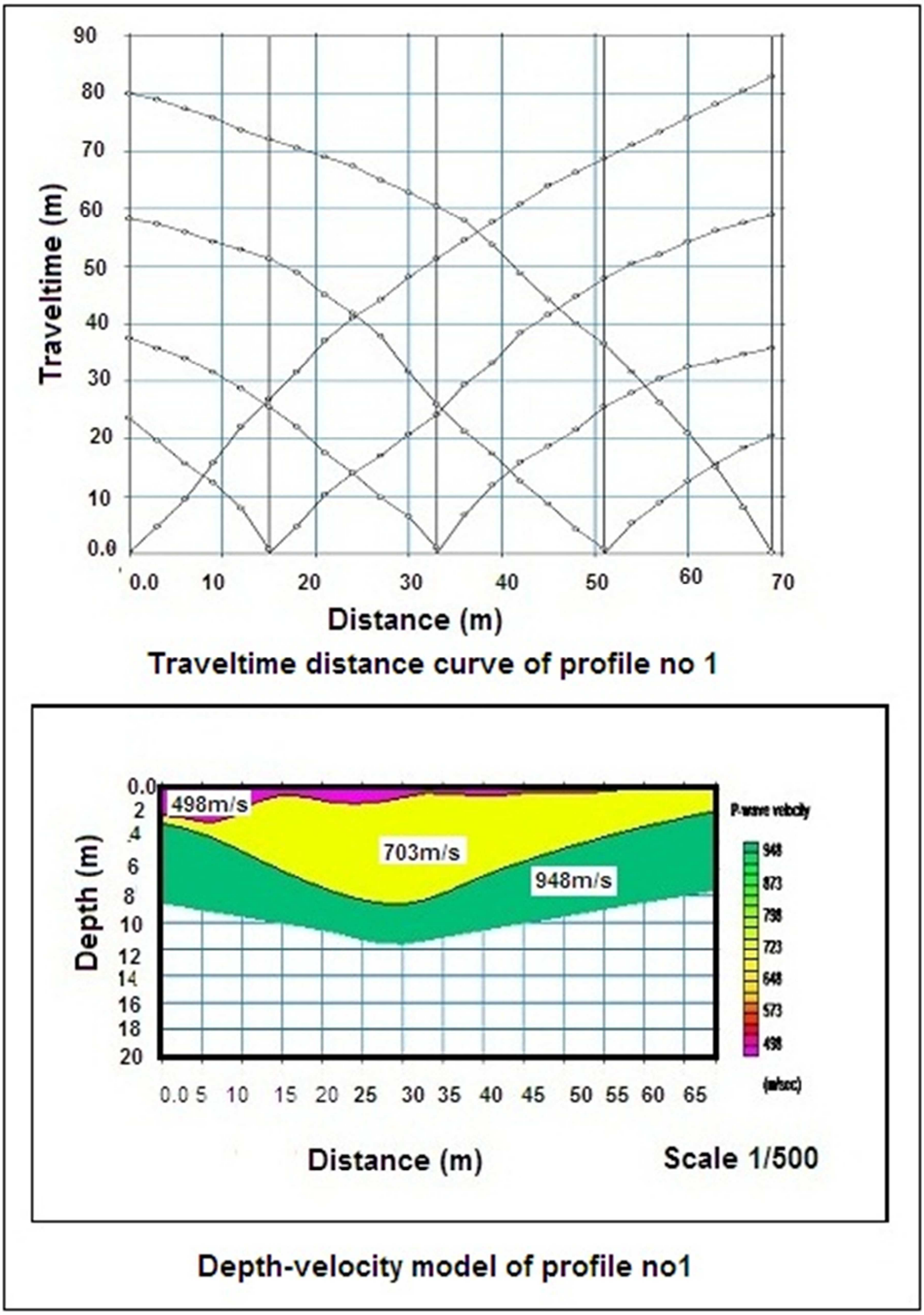

Figure 3. Example of time distance curve and depth velocity model.

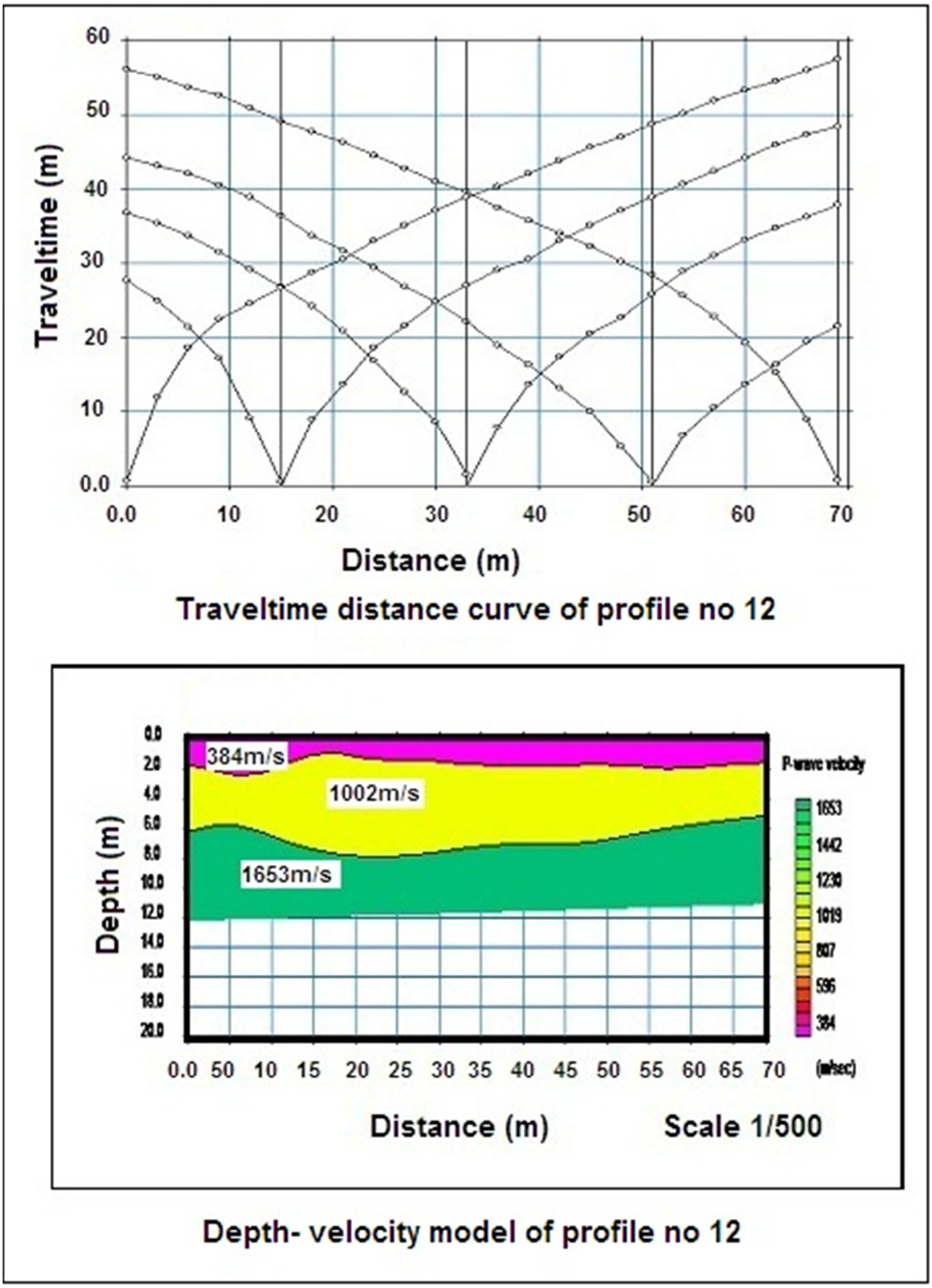

Figure 4. *Example of time distance curve and depth velocity model.*

The final results illustrated that the subsurface structures characterizing the shallow seismic profiles consist mainly of three layers. The P-wave velocities ranges of 248 m/s to 498m/s, 596 m/s-1005 m/s and 908 m/s-1896 m/s for the first, second and third layer, respectively.

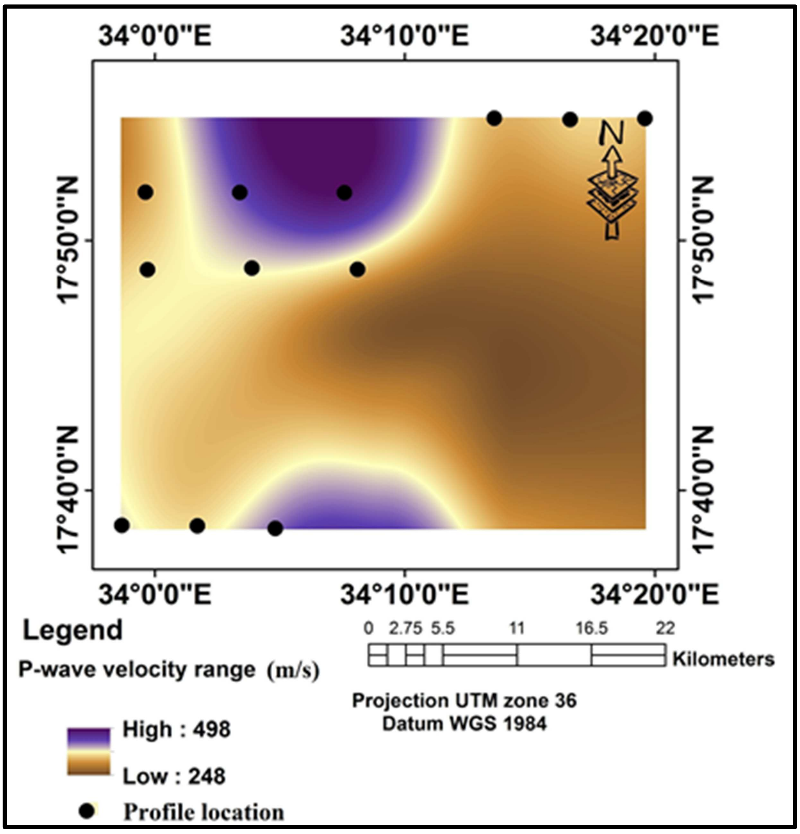

Figure 5. *Interpolation map of P –wave velocity for the first layer.*

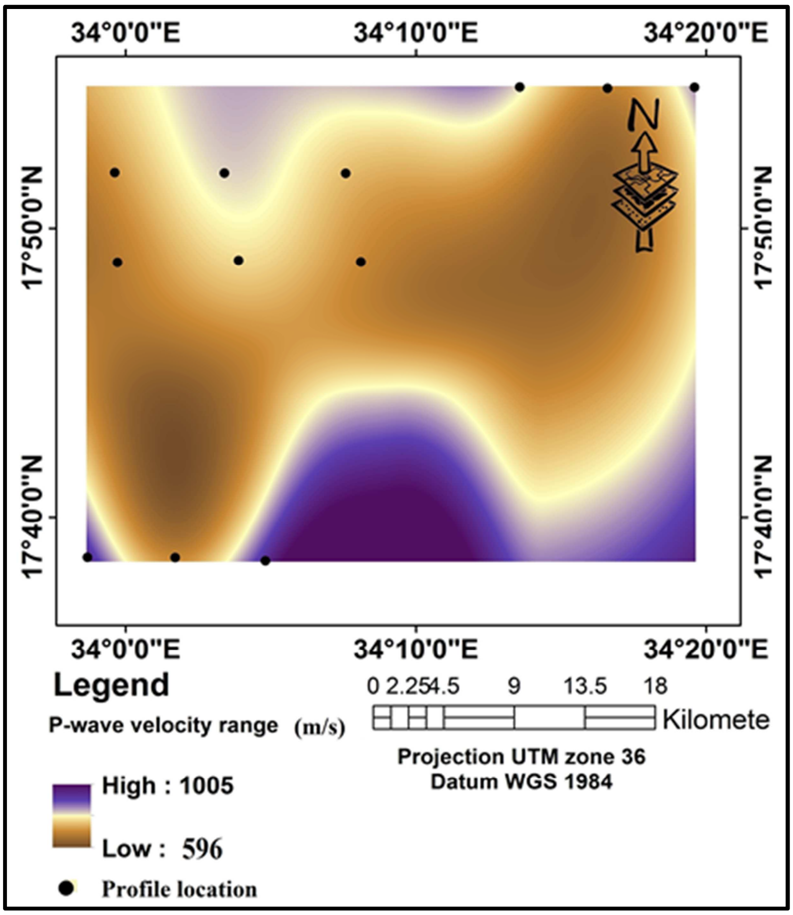

Figure 6. *Interpolation map of P –wave velocity for the second layer.*

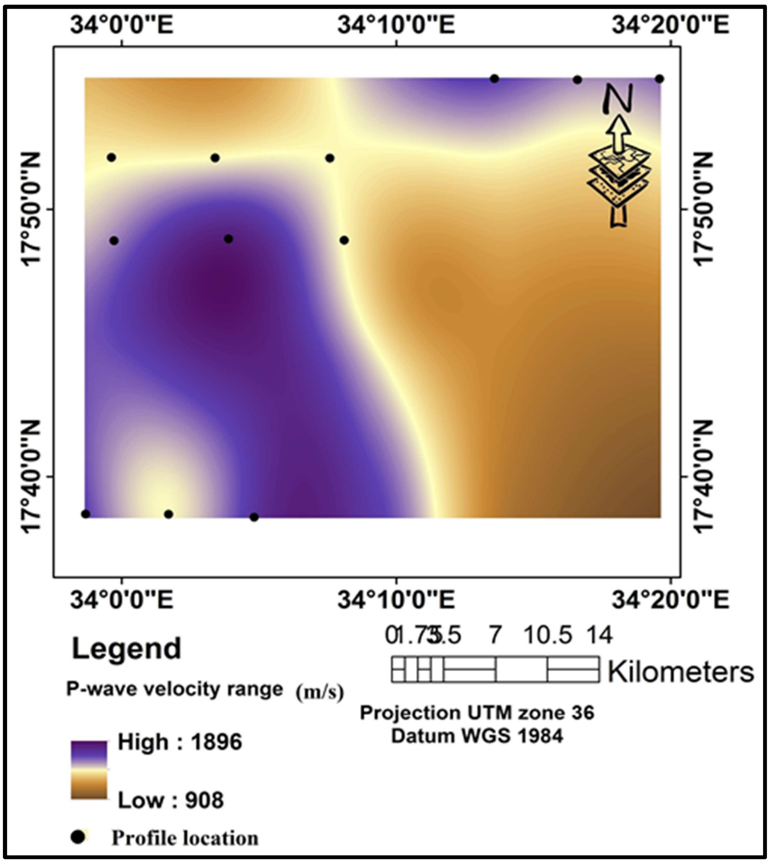

Figure 7. *Interpolation map of P –wave velocity for the third layer.*

Figure 5 shows that the dark violet color delineates high P–wave velocity which is located in the northern and southern part of the study area reach to 498 m/s but the dark brown color represents low P-wave velocity that located in the eastern part of the study area reach to 248 m/s and so Figure 6 illustrates that the dark violet color delineates high P–wave velocity which is located in the north and south part of the study area reach to 1005 m/s while the brown color represents low P wave velocity that located in the central, west and north eastern part of the study area reach to 596m/s. Lastly Figure 7 reveals that the violet color explains high P–wave velocity which is located in the central, south and north eastern part of the study area reach to 1896 m/s but the brown color represents low P wave velocity of the study area reach to 908 m/s.

The velocity of P –wave and S-wave of the subsurface layers were calculated as illustrated by histogram (Figure 8).

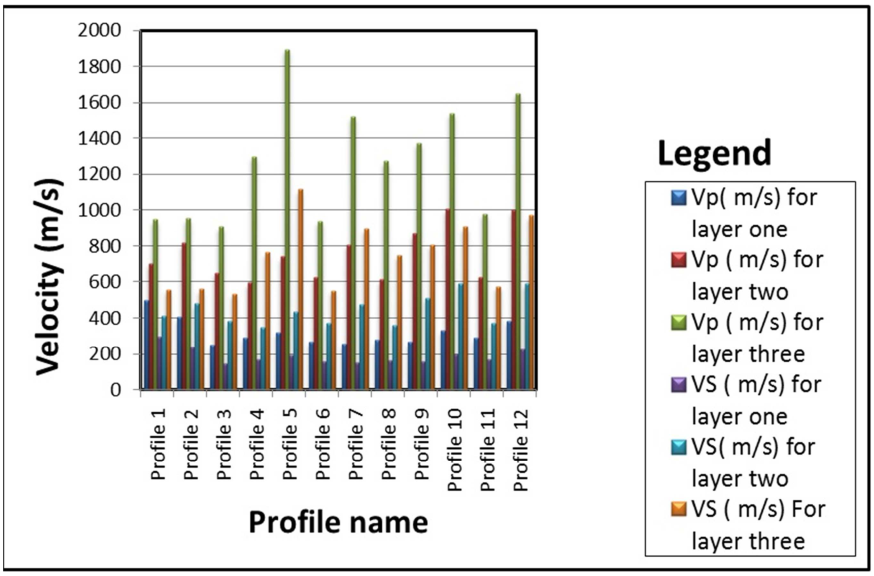

Figure 8. *Histogram displays the P & S wave velocities in m/s for subsurface layers.*

4. Conclusion

The shallow seismic refraction technique is considered as one of the most effective methods, which used in the present research for engineering purpose. The technique was mainly used for determining the velocity, the depth of the subsurface layers and the change in the lateral extension. The P-wave velocity for the top most layer is consistent and is found to be about 248 m/s to 498 m/s for 0.2 m to 3 m, in this range of velocity can be represented as the organic materials in the soil or superficial deposits. For engineering construction, this layer does not have sufficient bearing capacity for building and road foundation. The under lying soil of 0.7 m to 9 m shows alateral variation of 596 m/s to 1005 m/s for P-wave velocity. The lowest underlying layer shows alateral variation of 905 m/s to 1896 m/s of strong rock (or bedrock) layer. From the statistic rules the average of the P-wave velocity can be calculated, the average of P-wave velocity for the first, second and third layer is about 319 m/s, 754 m/s and 1274 m/s respectively. P-wave velocity was used to calculate S-wave velocity. More detailed study should be conduct in the future such as multi-channels Array of Surface Wave (MASW) technique either by using active source (e.g.sledgehammer) or passive source (e.g.microtremor) inorder to estimate the shear wave velocities at large depths.

Acknowledgements

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