IOP Conference Series: Earth and Environmental Science

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# Application of Refraction Seismic Tomography Method Using Wavepath Eikonal Traveltime Inversion for Modelling the Subsurface

To cite this article: Hashina Nurul Nida *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **318** 012016

# Application of Refraction Seismic Tomography Method Using Wavepath Eikonal Traveltime Inversion for Modelling the Subsurface

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**Abstract**. Refraction seismic tomography is a geophysical method that is able to image shallow subsurface velocity variation. Common application of this method is for Civil Engineering include near-surface problem such as weathering zone and bedrock. In this study, refraction seismic tomography was using Wavepath Eikonal Traveltime (WET) inversion. This method is performed by software Rayfract$^{TM}$. The initial model is generated by Delta-t-V method and smoothing inversion. The Delta-t-V method obtain a 2D initial model, while the smoothing inversion obtain a 1D initial model. The forward modelling is done by finite-difference solution using Eikonal equation to obtain the ray tracing. Then WET inversion will obtain the subsurface model. The imaging result is able to show the thickness of weathering layer and the depth of the bedrock. The tomographic interpretation indicates the thickness of weathering layer is 2-10 meter, while the bedrock presence at depth 7-35 meter from the surface.

## 1. Introduction

Refraction seismic is a geophysical method that use for near-surface investigation such as imaging geological conditions in subsurface. This method is conducted in areas where the velocity of wave propagation increases at the deeper layer. Refraction seismic tomography is able to image shallow subsurface velocity variation as gradient. In this study, refraction seismic tomography is applied to determine the thickness of weathering layer and the depth of the bedrock.

The inversion we used in this study is based on Wavepath Eikonal Traveltime (WET) (Schuster dan Quintus-Bosz, 1993). The WET inversion inverting the velocities based on travel times computed by a finite-difference solution to the Eikonal equation (Qin et al., 1992). Seismic refraction tomography was performed by software Rayfract$^{TM}$ and the initial model is generated by Delta-t-V method and smoothing inversion.

## 2. Method

Refraction seismic data with total length of survey line is 1030 meter, divided into 5 spreads. Each spread consists of 24 geophones as receiver with a space of 10 meters, 7 shot points, and using a 20 kg Wooden hammer as a source. Figure 1 show the configuration shot point for each spread.

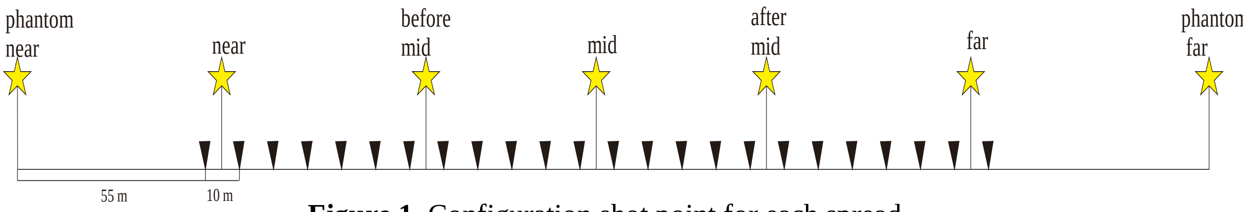


**Figure 1.** Configuration shot point for each spread

The study involves data processing and tomography interpretation. Figure 2. shows the data processing flowchart.

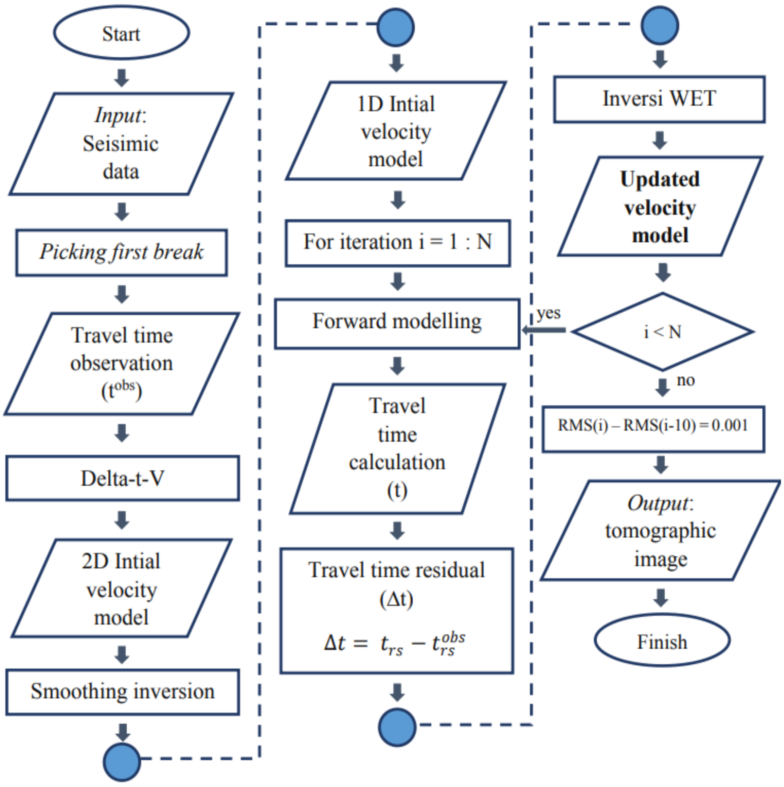


**Figure 2.** Data processing flowchart

Picking first break is done manually with regard to first arrival travel time, amplitude, characteristics, and trends of picking on each trace to obtain the first arrival travel time based on observation ($t_{rs}^{obs}$). The travel time observation is used as input to generate the initial model.

The 2D initial model was generated by using delta-t-V method (Rohdewald, 2010). Then the smoothing inversion generated 1D initial model based on 2D initial velocity model.

The WET inversion is applied to obtain the tomographic image. WET inversion is using Fresnel volume principle to describe the wave propagation. The travel time ($t_{rs}$) is calculated by finite-difference on Eikonal equation (Vidale, 1988) using existing initial velocity model. WET inversion is performed iteratively until the subsurface velocity model is generated by the value of RMS error in the particular iteration with the previous iteration less than 0.001 ms.

The initial model has been generated using delta-t-V method and smoothing inversion (Figure 3). The delta-t-v inversion result in Figure 3(a) shows that the velocity model is not evenly distributed on each layer, and has many artifacts. While the 1D initial model obtained using smoothing inversion in Figure 3(b) has a vertical velocity variation with smooth gradient.

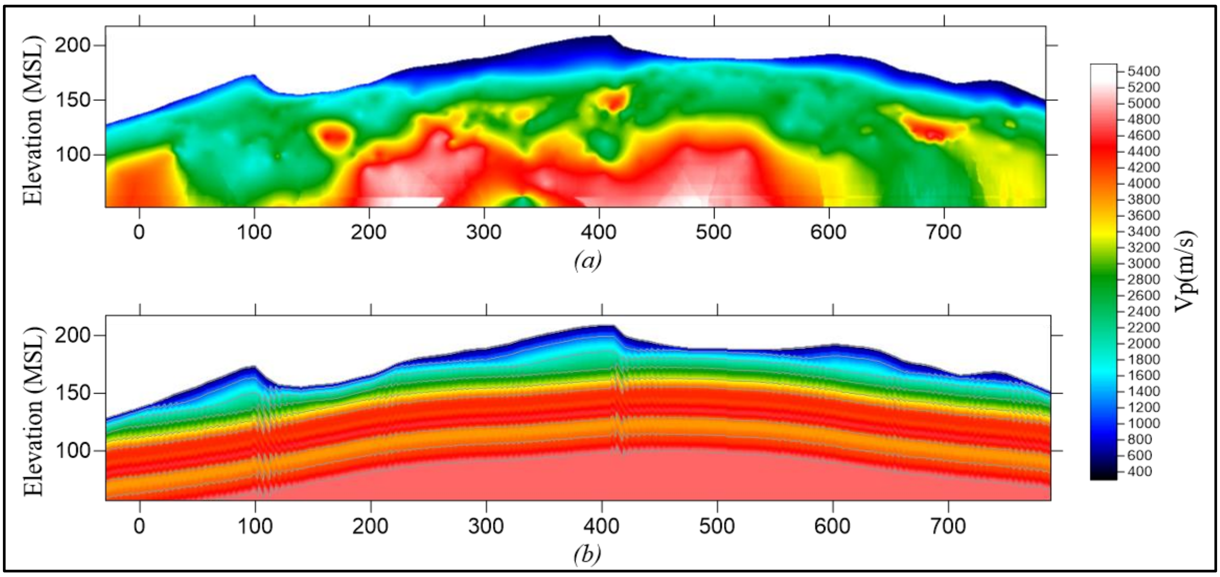


**Figure 3.** (a) 2D initial velocity model (b) 1D initial velocity model

The t-x (time-offset) curve which obtained by picking first break shows that the subsurface consist of three layers with different velocity (Figure 4). Based on the calculation of the t-x curve gradient, the velocity of first layer is between 500-1000 m/s, the second layer is between 1000-2200 m/s, and the third layer has a velocity greater than 2300 m/s. The first layer is made of soil, dry clay, and dry sand. The second and third layer consist of wet clay and wet sand, and there is sandstone in the third layer.

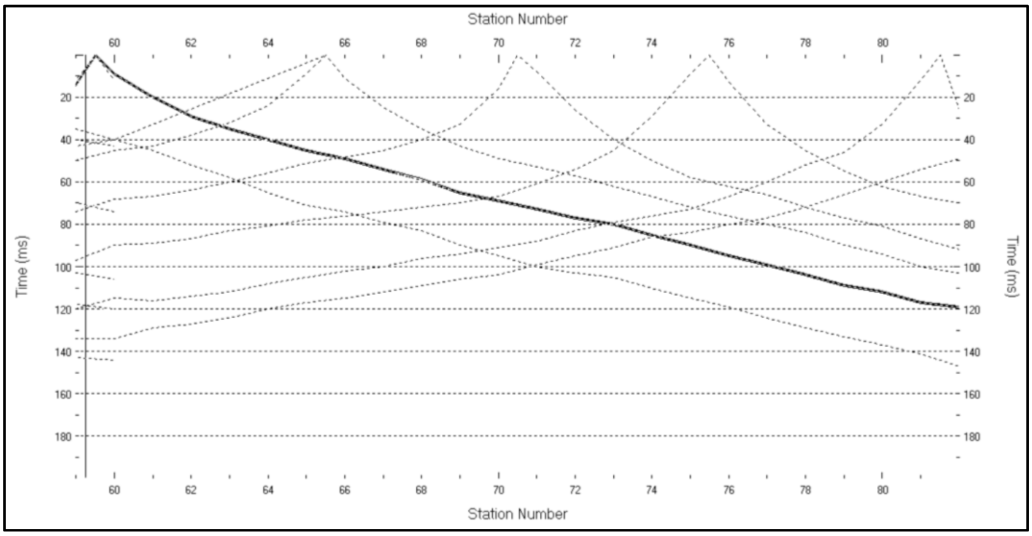


**Figure 4.** t-x curve spread 1

WET inversion result in Figure 5 shows the ray coverage and the tomographic image. The result is obtained by 70 WET iterations with RMS error value 3.26 ms. Ray coverage describe the ray paths model that pass below the surface. The more ray paths that pass through in the area the higher the resolution will be. From the model in Figure 5, it could be seen that at the deeper layer the lower resolution produced. The ray coverage helps to determine the layers. Areas with high ray coverage indicate good resolution. In contrast, areas with low ray coverage indicate poor resolution, resulting a subsurface image that is not necessarily appropriate with actual geological conditions. Based on this, low-resolution areas are analyzed by looking at the surrounding conditions which area has high ray coverage.

The tomographic interpretation in Figure 5 indicates that the blue layer is a weathering layer, green layer is intermediate layer, and the yellow to red layers are consolidated layer (bedrock). The black dashed line in Figure 5 is interpretation of boundaries layer. The tomography interpretation indicates the thickness of weathering layer is 2-10 meter, while the bedrock presence at the depth 7-35 meter from the surface, below the depth 150 MSL.

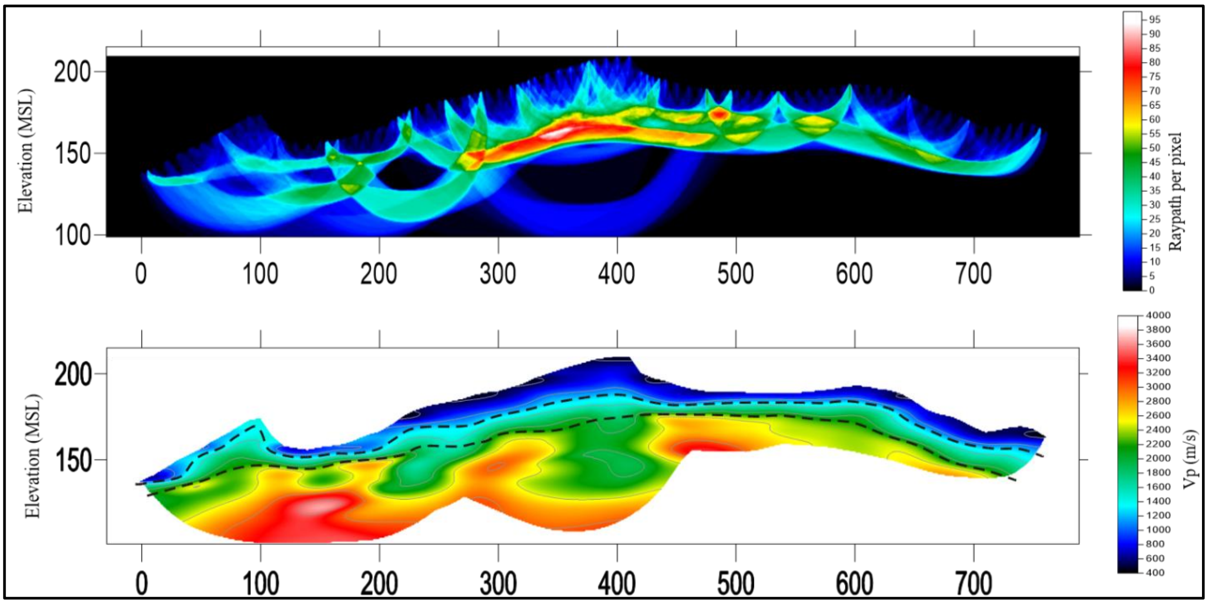


**Figure 5.** Tomographic interpretation after 70 WET iteration RMS error = 3.26 ms.

## 3. Conclusion

Refraction seismic tomography method is effective to obtain the subsurface information. Refraction seismic tomography using WET inversion is able to determine the thickness of weathering layer and the depth of the bedrock. The tomographic interpretation after 70 WET iterations with RMS error 3.26 ms indicate the thickness of weathering layer is 2-10 meter, while the bedrock presence at the depth 7-35 meter from the surface, below the depth 150 MSL. The maximum depth obtained using this method is 70 meter.

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