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Research Article

Application of Generalized Reciprocal Method on 2D Seismic Refraction Data in Mt. Manglayang, West Java

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Abstract.
The imaging of shallow subsurface structures, weathered rock thickness and velocity propagation distribution of the rocks can be identified by seismic refraction. This method is one of the geophysical exploration methods utilizing refracted wave once it reaches the boundary of subsurface layer. In this research we used the generalized reciprocal method (GRM) as one of the robust processing methods in analyzing subsurface data. This method was chosen due to its accuracy in interpreting shallow subsurface layer with highly undulating refractors by determining time velocity analysis, XY optimum distances, and time depth analysis, then, the expected depth values can be achieved. The acquisition of data for this research was conducted using 13 geophones with forward and reverse sources, the data were then picked to get travel time values and inverted to obtain real geological setting of the earth. The results were interpreted as 2 layers, the first layer had a velocity distribution of 499.289 m/s which was identified as a weathered layer with a thickness of about 4.74 meters, whereas the second layer was interpreted as clay rock with velocity distribution of 1270.433 m/s with the thickness reached up to 16 meters.

Keywords: generalized reciprocal method, 2D seismic refraction

1. INTRODUCTION

Manglayang Mountain is located in North Bandung Regency, West Java at an altitude of 1817-2000 masl, the height of this mountain peak was formed due to the lava flows that overflowed many times resulting from the eruption, so that deposits formed which resulted in the peak of the mountain getting higher. The research location is located at Batu Kuda camping ground which is on the Mount Manglayang climbing route at an altitude of about 1150-1300 meters above sea level. Geologically, the subsurface structure of Batu Kuda camping ground is composed of weathered rock. In determining the depth of the overburden layer and bedrock layer boundaries, seismic refraction can be used for this measurement with the Generalized Reciprocal Method (GRM) which is able to determine high undulation values at shallow depths. This method is the latest development of the delay time seismic data processing method. This research was conducted to determine the geological structure of the subsurface and the value of wave velocity propagation below the surface of this mountain. So that it can be interpreted the research results in the form of a seismic cross-section to determine the depth of the weathered rock structure which is expected to be useful for studies related to natural disaster mitigation such as landslides.

Figure 1: The location of research was in the slope of Manglayang mountain, regionally, this area is a volcanic deposit classified as older undegraded volcanic sediments, with lithology of breccia, lava, and tuff sand which are layered with relatively small slopes.

1.1. Seismic Refraction

Seismic refraction is a geophysical method that utilizes the propagation of waves below the earth's surface which are refracted when the waves reach the boundary layer [1]. In determining the value of the wave propagation velocity of each subsurface layer, Seismic Refraction only takes advantage of P wave, this is due to the P wave propagates faster than other waves [2]. In addition, the value of the seismic wave propagation velocity is influenced by the physical properties of the of the rock in every layer, which is called as the elasticity Parameter [3]. The velocity propagation of seismic waves has a great value when it passes the rocks with low elasticity and vice versa. The waves which can be recorded by the receivers above the earth's surface are only refracted seismic waves that propagate at the boundary between rock layers. This condition can occur if the angle of incidence is in a critical angle (i=r) or the angle of refraction is perpendicular to the normal line (r=90 so sin r=1) [3].

1.2. Generalized Reciprocal Method

Generalized Reciprocal Method (GRM) is a seismic data processing method which is able to map the subsurface structures with high levels of rock hardness and refractor undulation [4][5]. There are several analytical functions in the Generalized Reciprocal Method, one of them is the Time-Velocity analysis function which is mathematically expressed by the following equation.

$$t_V = \frac{t_{FY} - t_{RX} + t_{FR}}{2} t_V = \frac{t_{FY} - t_{RX} + t_{FR}}{2} \quad (1)$$

By $t_{AY}t_{AY}$ *(m/s)* is travel time of wave propagation from A to Y, $t_{BX}t_{BX}$*(m/s)* is travel time of wave propagation from B to X, and $t_{AB}t_{AB}$ *(m/s)* is defined as travel time from A to B [6] [7]. The following function definiens Time-Depth analysis which mathematically is expressed as

$$t_G = \frac{t_{FY} + t_{RX} - t_{FR} - \left(\frac{XY}{V1}\right)}{2} \quad (2)$$

While *XY* is a distance between geophone, *V1* is interpreted as wave velocity propagation values in medium 1 [8], and below equation can determine the depth value in the certain layer which is mathematically explicated as

$$(3) \quad h = \frac{t_{Gopt} V1V2}{\sqrt{V2^2 - V1^2}}$$

and *V2* is defined as velocity propagation in medium 2 and $t_G t_G$ optimum is taken from $t_G t_G$ value in the optimum values of XY [9].

2. RESEARCH METHOD

Data acquisition was conducted on April 27, 2018, at Batu Kuda camping ground, Manglayang mountain, while the process of GUI work and data processing were done in the range time between May-July 2018 at Geophysical Laboratory State Islamic University of Sunan Gunung Djati Bandung. This research used seismic refraction with Generalized Reciprocal Method (GRM) by using Vista 7 software for First Break Picking (FBP) to get travel time values and GRM2D GUI by using MATLAB® and SeisImager/2D software as comparison for data interpretation. Afterwards, the data were recorded by seismograph and stored in SEG2 file data.

2.1. Data Acquisition, Processing, and Interpretation

The data acquisition in this study used In-Line technique by arranging a geophone along the track with a distance between geophones along 5 meters and a track length of 60 meters. Then, connect them with the trigger to the seismograph. Furthermore, it is given a vibration source at both ends of the trajectory called the forward source and the reverse source alternately. The initial data with the SEG2 extension cannot yet be used for data processing, therefore it is necessary to be cleaned from noises and killed the bad traces to achieve signal to noise ratio using Vista7, and then picking the first break to determine the first arrival time of the primary wave.

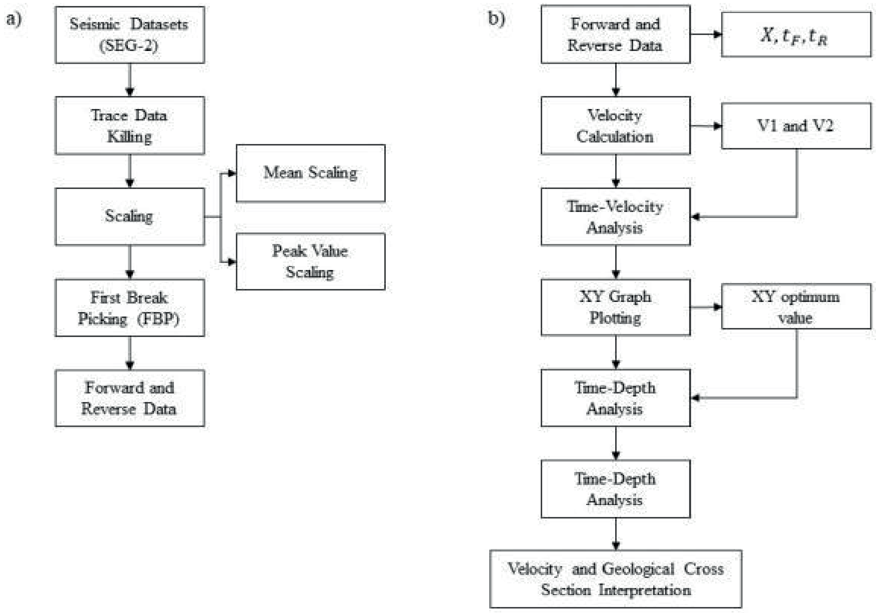

Figure 2: Flow chart of 2D seismic refraction processing, a). Raw datasets recorded by seismograph were inputted to Vista 7 for data cleansing and travel time value picking, and b). The analysis and interpretation of Forward and Reverse travel time values using GUI GRM2D.

After obtaining the time and distance value, data processing can be carried out using Generalized Reciprocal Method (GRM) analysis functions by time-velocity, time-depth, and depth analysis functions using the MATLAB® GRM2D GUI that has been created. The velocity interval, then, can be visualized as geological and seismic cross section as results after data processing is successfully carried out.

3. RESULT AND DISCUSSION

Seismic wave propagation analysis is in accordance with Fermat principles revealing waves will propagate with the shortest time. Waves propagating on the surface must

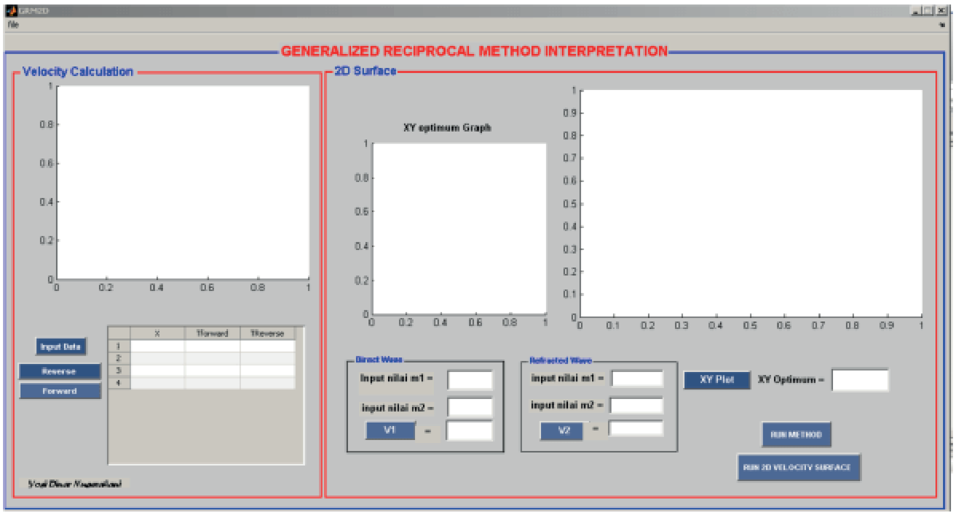

Figure 3: Graphical User Interface (GUI) of GRM2D which created using MATLAB for Generalized Reciprocal Method (GRM) 2D seismic data interpretation. This GUI is able to calculate the velocity values converted from First Break Picking of travel time data and plotted in XY optimum graph as well as cross section visualization in the right side.

have a shorter trajectory than the waves that propagate beneath the earth's surface, which is called by body waves. Meanwhile, according to the basic assumption of seismic wave, it meets the principles of Huygens and Snell's Law. In the distribution of body waves below the earth's surface, it applies the Snell's Principle which states that the waves will be refracted and reflected at the limit of two mediums, when the propagation of the wave touches the layer boundary, then, the wave will be refracted into a new wave when passing through the medium with high elasticity [10].

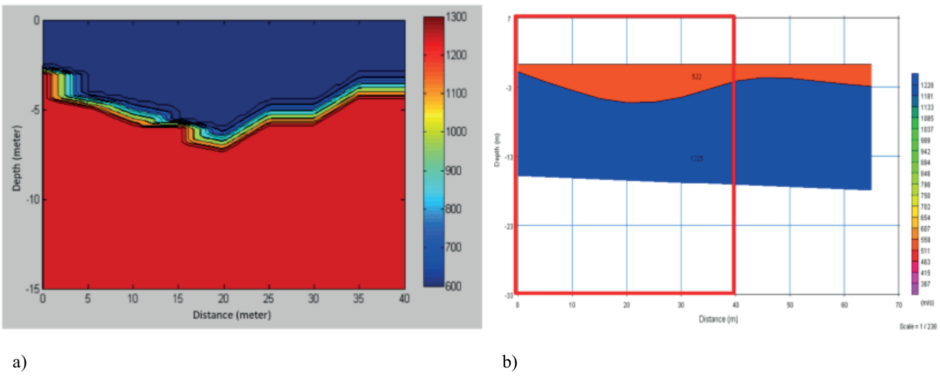

Figure 4: GRM2D visualization result showing a). Velocity distribution of seismic cross section, and b). 2D seismic profile inverted by SeisImager/2D, red rectangle shows the part calculated by GRM2D.

Based on the cross-sectional images of velocity and geology obtained can be analyzed each layer has a different velocity propagation, it can be seen in Figure 4 that the layer indicated by blue has a velocity interval between 500 m/s - 700 m/s, the light blue color layer has velocity interval of about 800 m/s, a green layer with a velocity interval of 900 m/s, a yellow layer with a velocity interval of about 1000 m/s and a layer with a brown color has a velocity interval of about 1200 m/s. The depth value obtained is about 6,054 meters as the boundary of weathered rock and bed rock in the below of it. In order to test the accuracy of data processing results using GRM2D, the depth data and seismic cross-sectional form that has been obtained compared to the data processed using professional seismic data processing software, SeisImager, with the comparison result as show in the table and figure below.

Table 1: Comparison of weathered rock depth between GRM2D GUI and SeisImager, it reveals that there are no significant differences in the depth values.

GeophoneDistance (meter)	Depth (meter) GRM2D GUI	Depth (meter) SeisImager
0	2.66	2.56
5	3.32	3.58
10	4.30	4.45
15	5.50	5.89
20	6.05	6.03
25	4.56	5.07
30	4.18	4.65
35	2.96	3.37
40	2.80	2.50

As shown by Figure 4, the first layer in green color with a velocity interval between 500-1000 m/s is defined as a weathered zone with a layer thickness of about 6 meters, the weathered zone is a layer composed of Andesit Enstatit Lava based on the geological map of Manglayang Mountain in Figure 5. The weathered zone indicated by the pink part (Mgr), this weathered zone comes from volcanic rock formations composed of pyroclastic breccia rocks and enstatite lava. During the Holocene Period or about 20,000 years, the pyroclastic breccia rocks were resulting from sedimentation of igneous rocks formed from explosive volcanic eruptions. The characteristics of this pyroclastic breccia rock has angular fragments, brownish gray, with brown weathered soil in the form of fine sand with a size of 2 mm - 64 mm.

Table 2: Geological time and volcanic stratigraphy unit of Manglayang Mountain and its surroundings.

Age		Volcanic Stratigraphy Unit	
Era	Period	Symbol	Volcanic Rock Name
Quaternary	Holocene	Mgl Mgt Prl Prt	Andesit Enstatit Lava unit of Manglayang Pyroclastic Breccia units Andesit Enstatit Lava unit of Pangparang Pyroclastic Breccia units - Andesit Enstatit Lava unit of Pangparang
	Pleistocen	Agl	Pyroclastic Breccia units - Augit Basalt Lava

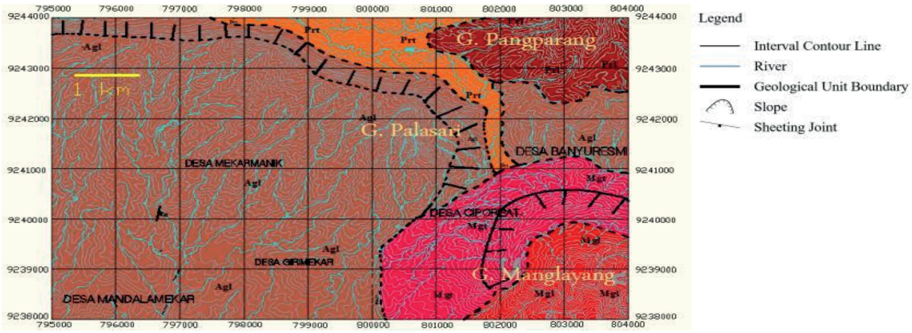

Figure 5: Geological Settings of Manglayang Mountain showing several distribution volcanic stratigraphic units [11] .

In the interval velocity of 1000-1300 m/s indicated in yellow in Figure 5 is a layer with its constituent materials which is interpreted as clay soil, clay soil has microscopic to submicroscopic sizes [12]. Clay soil comes from weathering the chemical elements that make up the rocks, in a dry state the clay soil becomes very hard but at medium water content this soil will be plasticity condition, and in conditions with high water content, this soil is soft textured. The minerals that make up rocks from clay soil include olivine, felspar, pyroxins, amphiboles and mica.

4. CONCLUSION

Based on the speed value distribution pattern in the 2D cross-section model, it can be identified that the first layer with a propagation speed of 599 m/s is a weathered zone which is the result of weathering of pyroclastic breccia rocks and andesite lava with a thickness of 5 m. and the second layer with a propagation speed of 1363 m/s is a zone of clay rocks resulting from weathering of rock constituent minerals due to weather factors and organisms.

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