Hypocenter Relocation, Determination of Velocity Model and Correction Station in Gede Volcano for December 2017 Data

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Abstract. The distribution of the volcanoes in Indonesia gives positive impacts in the form of fertile land where many residents live to grow crops. Besides having positive impacts, there are also negative impacts in the form of natural disasters. Improvement in mitigation of natural disasters is needed to avoid any form of harm and undesired losses. Information on the accuracy of earthquake parameters is an important part of natural disaster mitigation efforts. Hypocenter relocation of earthquakes is a step to improve the accuracy of earthquake parameter information. The relocation of hypocenters earthquake is performed using the Coupled Velocity-Hypocenter method. The research area is Gede volcano which is included as type A active volcanoes. The data were processed using GAD and VELEST 3.3 software resulted in epicenters that were spread around Gede and Pangrango volcanoes. The hypocentre were distributed between -2.5 – 5.2 km depths based on GAD calculated. After relocation using VELEST 3.3, they were distributed between 1.0 – 10.5 km depth. The calculated. The calculated magnitudes of volcanic earthquakes occurred in December 2017 vary between 0.6 to 2.7. the difference between the initial and final velocity models is small. After station correction step, the velocity profiles beneath the most of station is indicated as sedimentary layers, and beneath of the peak station, it is indicated as intrusive rocks.

Keywords: Volcano, hypocenter, epicenter, method, GAD, correction, station, and Coupled Velocity-Hypocenter

1. Introduction

Information about the accuracy of earthquake parameters is important for natural disaster mitigation. Hypocenter relocation is a step to get a more accurate hypocenter point to support the implementation of disaster mitigation. The purpose of hypocenter relocation using the Coupled Velocity-Hypocenter method with VELEST 3.3 software is to improve the accuracy of latitude, longitude and time of origin of initial earthquake data. The results of previous studies have stated that the hypocenter position results from relocation close to seismotectonic conditions in the Palu-Koro region and produces a small RMS value of 0.065 seconds [1,2].
2. Methodology
The P wave is the first wave to arrive and is detected by the receiver or receiving station with the velocity of the P wave (Vp) and the S wave (Vs) given by [3]:

\[
V_p = \sqrt{\frac{K + (4/3)G}{\rho}} = \sqrt{\frac{E}{\rho (1-\mu)(1+\mu)}}
\]  

(1)

and

\[
V_s = \sqrt{\frac{G}{\rho}} = \sqrt{\frac{E}{\rho 2(1+\mu)}}
\]  

(2)

K and G values in the material are always positive and value of \( \mu \) less than or equal to 0.5 [4], then it can be ascertained that the velocity of the P wave is always greater than the velocity of the S wave. In the fluid medium based on equation (2) the value of G in the fluid medium is 0, this is the cause of Vs in the fluid will be 0.

2.1 Earthquake Event Identification
In this study picking was conducted for 104 events with the number of P wave phases and S wave phases of 33 events each.

2.2 Determination of the Hypocenter Point
This research uses GAD software. The basic principle in the Geiger method, namely by calculating the residual between the time of observation (observed) and the time of calculation (calculated) [5].

2.3 Determination of the 1-D Initial Velocity Model
The Coupled Velocity-Hypocenter method is used to update the 1-D velocity model that we have previously used in GAD software. The research steps can be seen in the following flow chart in figure 1.

![Figure 1. Data processing flow diagram](image-url)
3. Results and Discussion

3.1 Hypocenter by using GAD Software and Magnitude’s Value

Figure 2 is the result of plotting for the hypocenter appearance of the GAD software. The figure shows the hypocenter point based on the magnitude of the earthquake. The depth of the hypocenter between 2.5 km above sea level for volcanic earthquake type B to a depth of 0.9 km below sea level. Type A volcanic earthquakes do not occur too much with depths ranging from 1.0 km below sea level to 5.2 km below sea level. Figure 3 is the distribution of volcanic earthquake epicenter. The number of type A volcanic earthquake events is 11 events and the number of type B volcanic earthquake events is 22 events. The epicenter was seen spreading around Mount Pangrango and the peak of Mount Gede.

![Figure 2](image1.png)

**Figure 2.** Distribution of hypocenter with magnitude’s value for volcanic earthquake on Mount Gede in December 2017 using GAD software

![Figure 3](image2.png)

**Figure 3.** Distribution of epicenter for volcanic earthquake on Mount Gede in December 2017 using GAD software
3.2 Hypocenter Results from Relocation VELEST 3.3 and Magnitude’s Value

![Graph showing hypocenter results from VELEST 3.3 and magnitude's value.](image)

Figure 4. Distribution of hypocenter with magnitude’s value for volcanic earthquake on Mount Gede in December 2017 using VELEST 3.3 software.

![Map showing epicenter distribution.](image)

Figure 5. Distribution of epicenter for volcanic earthquake on Mount Gede in December 2017 using VELEST 3.3 software.

The results of hypocenter relocation using VELEST 3.3 software illustrate that the depth of the hypocenter location of the Mount Gede earthquake between 1.5 km to 9.7 km shown in figure 4. 25 volcanic earthquake types A and 8 events B volcanic earthquake type B volcanic earthquake type A mostly occurred in Mount Gede [6]. Figure 5 shows that the spread of volcanic earthquakes occurred around the peaks of Mount Gede and Mount Pangrango. The spread of volcanic earthquakes from
VELEST 3.3 software looks more clustered in the north and south of Mount Gede. This has been confirmed by previous research that the earthquake hypocenter is concentrated between the peaks of Mount Gede and Mount Pangrango which is a fault line structure [7].

3.3 Update for the 1-D Velocity Model Using VELEST 3.3
A comparison between the initial and final 1-D velocity models of the primary and secondary waves for depth can be seen in Table 1.

| Depth (km) | Initial Vp (km/s) | Initial Vs (km/s) | Final Vp (km/s) | Final Vs (km/s) |
|------------|-------------------|-------------------|-----------------|-----------------|
| -2         | 3.66              | 1.80              | 3.66            | 2.09            |
| 1          | 4.46              | 2.59              | 4.34            | 2.72            |
| 4          | 5.45              | 2.97              | 6.10            | 3.66            |
| 15         | 7.11              | 3.68              | 7.11            | 3.68            |
| 25         | 7.99              | 4.49              | 7.99            | 4.49            |

The final model is not too different from the initial model but there is a slight difference in depth of 1 km to 4 km. Then in the layer -2 km for the P wave velocity there is no change in value, just as the depth between 15 km to 25 km, the value of the P and S wave velocity for the initial model and the final model there is no change. This shows that the initial model used approached the real situation. The initial plot graph and the end of the P wave and the S wave as shown in Figure 6.

![Figure 6](image-url)  
**Figure 6.** Comparison of the initial velocity structure and the velocity structure of the renewal results with VELEST 3.3.
3.4 Station correction results using VELEST 3.3

Table 2 shows the delay value of P wave arrival time at each seismic station, relative to the PUT reference station (delay value 0). These values are station corrections, some positive and some negative. The negative station delay time (-) indicates that the travel time of the P wave arriving at the recording station is faster than the reference station because the rock structure around the seismic station consists of denser rock (hardrock). Station delay time with a positive value (+) identifies that the rock structure around the bottom of the station consists of softer rocks such as layers of sediment, sand, or clay which cause P waves to propagate more slowly to arrive at the recording station than the reference station (Isnaini and Madlazim, 2017).

| Station | Fase | Delay Time (S) |
|---------|------|----------------|
| PUT     | P    | 0.000          |
| PUN     | P    | -0.0627        |
| CLM     | P    | 0.0022         |
| BDL     | P    | 0.0160         |
| CTK     | P    | -0.1085        |
| MKR     | P    | -0.0393        |
| MWG     | P    | 0.1431         |
| KDP     | P    | -0.1042        |

Based on confirmation from the results of previous studies that most of the area below the station is a sedimentary layer. This sedimentary layer can cause slower P wave propagation. The Central West Java region consists of sedimentary layer structures [8]. Table 2 shows the MWG station has a positive correction value which indicates that the layer around the bottom of the station is a layer of sedimentary rock. The coordinates of the MWG station itself are located in the Cianjur Regency area. This correlates with the results of previous studies that stated that most of the structure of the rock layers contained in the Cianjur regency is a sedimentary rock layer [9].

The soil layer to the south of Mount Pangrango is indicated as intrusion rock [6]. This is in accordance with the results of the correction to the PUN station located in the southern part of Mount Pangrango showing a negative value (-). A negative value (-) states that the P wave travel time is faster at the PUN station compared to the reference station.

4. Conclusion

The hypocenter of the relocation software VELEST 3.3 shows better results with a hypocenter depth from 1.0 km to 10.5 km dominated by type A volcanic earthquake. The magnitude value of each volcanic earthquake event that is calculated is around 0-3 magnitude and is included in Ultra micro and micro earthquakes that cannot be felt by humans because of their very small strength. The velocity model that results from hypocenter relocation is not much different from the initial velocity model. Station correction results based on confirmation from various previous studies are not much different, namely that most of the layers around the bottom of the station are sedimentary layers. P waves arrive faster to PUN stations than reference stations.
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