Study of the M 2.7 Merbabu Earthquake on February 17th 2014: Is it a Volcano or Tectonic Activity?

T. Yatimantoro, S. Dewi Anugrah, S. Rohadi
Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG)

Abstract
On February 17th 2014, an earthquake occurred around the mountain of Merbabu in Central Java Indonesia. According to the Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG) the earthquake was magnitude M = 2.7 with 10 km depth. However, this small earthquake was strong enough to be felt by people surrounding the source and damaged 46 homes. The question also arose as to whether it was a volcano or a tectonic earthquake. A relocation method and earthquake focal mechanism identification were conducted in this study to review the earthquake source. A tomography method was also implemented to find out the flow of the magma. The result of this study will give an answer whether the earthquake was caused by a volcano or tectonic activity. There are similar conditions in Indonesia where a number of volcanoes are showing seismic activity that may caused by a local seismic fault which had not been identified. The existence of Comprehensive Nuclear-Test-Ban Treaty Organization’s (CTBTO)’s sensor which is closely located to Tangkuban Prahu Volcano in West Java, can be used for a similar study to investigate a possibility of an existence of an active local seismic fault near to the volcano.

1. Introduction
The last eruption of Mt. Merbabu was noted in 1797 (http://www.volcano.si.edu/). Unfortunately, we did not find any historical records regarding to the event. People seem to forget about the history of Mt. Merbabu eruption. Yet, on February 17th 2014, sound of mount brattled had caused an unrest situation for the people who live surrounding the Mt. Merbabu. They thought that the mountain erupted following the Mt. Kelud, which erupted on February 14th 2014. The brattled was continued by earthquake that strongly shaked and caused 46 homes in five hamlets suffered damage. The BMKG reported that the magnitude of earthquake was only about M = 2.7, and concluded that it was caused by a tectonic activity rather than volcanic activity of Mt. Merbabu. However, the Mt. Merbabu earthquake still remain a big question whether the earthquake was caused by plate tectonic drift or the mountain had woke from its long sleep.

2. Data and Method

a. Hypocenter Relocation
We applied software Velest 3.1 for hypocenter relocation in central Java and surroundings area and we used earthquake data from BMKG (62 earthquakes that consist of 472 P-wave arrival).

b. Validation Magnitude
To calculate magnitude we applied Tsumura formula (1967) :

\[ M = -2.53 + 2.85 \log (F - P) + 0.0014 \Delta \]

where : 
\[ F = P - \text{Duration of earthquake (sec)} \]
\[ \Delta = \text{Episcopal distance (km)} \]

c. Determined source mechanism
We applied Azntak, Prin and Pman software to determined source mechanism of Merbabu earthquake.

d. Tomography
We applied TomoDD software to calculate velocity structure and used earthquake data from BMKG and MERAMEX (Merapi Amphibious Experiment).

3. Results

Figure 2. Distribution of earthquakes that was used in calculation of hypocenter relocation and initial P-wave velocity (Koulakov et. al., 2009)

Figure 3. BMKG’s selsensological stations that was used to determined source mechanism

Figure 4. Distribution of earthquakes and initial P-wave velocity. We applied initial P-wave velocity from Wagner et. al., 2007 (depth ≤ 20 km) and Kennet et. al., 1995 (depth > 20 km)

Figure 5. a. Comparison of earthquakes before and after relocation; b. RMS error; c. Final P-wave velocity

Figure 6. a. Comparison of Merbabu EQ before and after relocation; b. Source mechanism solution of Merbabu EQ. We get the result : NP1 (strike = 19, dip = 56, rake = 103) and NP2 (strike = 177, dip = 36, rake = 72)

Table 1. Result of magnitude validation using Tsumura formula

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<tr>
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<td>46.035</td>
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<td>F-P</td>
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<td>A (km)</td>
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4. Conclusion
Based on results of our re-analysis we conclude that the Merbabu EQ is caused by tectonic activity (local fault) NOT volcanic activity.

5. References
Koulakov, et. al., P and S velocity structure of the crust and the upper mantle beneath central Java from local tomography inversion. JGR vol. 112