

Source parameters identification for July 17th, 2014 earthquake around Jayawijaya mountains, Indonesia

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Source parameters identification for July 17th, 2014 earthquake around Jayawijaya mountains, Indonesia

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Abstract. The relationship between volcanic activity and the occurrence of non-DC earthquakes with dominant vertical tension or pressure is known as vertical compensated-linear-vector-dipole. This study aims to identify whether the earthquake that occurred in Southwest Keerom, Papua, around Jayawijaya Mountains on July 17th, 2014 was a volcanic earthquake or tectonic earthquake based on the results of the CMT solution. The results of this study also provide reinforcement of the previous studies result both in terms of magnitude and the epicenter depth. For the magnitude, not all of the Mw volcanic earthquakes are less than 3, but it proved that there were volcanic earthquakes that had a magnitude of Mw 4.3 to 5.8. The CLVD vertical earthquake that was identified in this study was classified as a shallow earthquake.

1. Introduction

Several volcanic earthquakes have a non-double-coupled (non-DC) focal mechanism. The relationship between volcanic activity and the occurrence of non-DC earthquakes with dominant vertical tension or pressure is known as vertical compensated-linear-vector-dipole (CLVD-vertical). There are two types of CLVD that indicate earthquakes due to volcanic activity. They are CLVD vertical-T and CLVD vertical-P. In general, earthquakes with vertical CLVD vertical-T criteria occur before volcanic eruptions and earthquakes with CLVD vertical-P criteria occur after the volcano erupts [1]. Shuler et al. [1] also found that 70% of CLVD earthquakes occur around volcanoes either after or before the eruption also have magnitude, Mw between 4.3 and 5.8.

The majority of CLVD vertical earthquakes occur in subduction zones associated with basaltic-to-andesitic stratovolcano or undersea volcanoes, although the CLVD-vertical earthquake is also located on the continental split and in the volcanic hot spot area. The CLVD vertical earthquakes are associated with many types of eruption activity that are confirmed or suspected near volcanoes, including volcanic earthquake swarms as well as effusive and explosive eruptions and caldera collapse. Centroid Moment Tensor (CMT) solution is a solution of earthquake (centroid) source parameters estimation extracted by 3 components waveform inversion. CMT solutions include; 9 components of moment tensor (three of which are symmetry, so that only six tensor components are presented), scalar seismic moments (Mo), moment magnitudes (Mw), latitude, longitude and centroid depths, node orientation covering the strike angle, dip and rake. CMT solutions also provide information about the type of fault as the cause of the earthquake that includes Isometric (ISO), Double Couple (DC) and CLVD as well as reduction variance (VR).

The use of CMT solutions for monitoring the volcanic activity is still rare, including in Indonesia. So miss-information is still often be found whether the earthquake occurs is caused by volcanic activity or tectonic. For example, the earthquake that occurred in the mountains of earthquake that occurred in



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Kerom, Papua around Jayawijaya Mountains on July 17th, 2014 which had been announced by the authorized institution as a tectonic earthquake associated with a west-east trending horizontal fault. As posted on the following website: <http://www.vsi.esdm.go.id/index.php/gempabumi-a-tsunami/kejadian-gempabumi-a-tsunami/587-tanggapan-gempa-bumi-di-kerom-papua-17-juli-2014-54-sr>. This study aims to identify whether the earthquake that occurred in Southwest Keerom, Papua, around Jayawijaya Mountains on July 17th, 2014 was a volcanic earthquake or tectonic earthquake based on the results of the CMT solution.

2. Data and methods

The data used in this research is local waveform broadband 3 components data recorded by four seismic stations IA network managed by BMKG, that are WAMI, JAY, GENI and MIMI seismic stations which are downloaded from BMKG archive which can be accessed at following link: <http://202.90.198.100/webdc3/>. The four seismic stations are considered sufficient to cover the distribution of seismic stations around the earthquake location due to the location of the quake was adjacent to the state of Papua New Guinea. Therefore, in the east of the earthquake location there is no waveform data that can be accessed because there is no seismic station that records the waveform for the earthquake. The distribution of seismic stations used for inversion is shown in Figure 3.

The waveform inversion method used in this study has been implemented into the MTINV software, which can be accessed freely in: <http://crack.seismo.unr.edu/htdocs/students/Ichinose/mtinv>. More details about the basic concepts and applications can be learned from the MTINV manual and article of Ichinose et al. [2]. The frequency used for the inversion waveform in this study is the lowest frequency 0.02 Hz and the highest frequency 0.05 Hz. This frequency width is already qualified for the earthquake waveform inversion [2]. The local velocity model used for this inversion is a modification of the velocity model developed by Madlazim et al. [3]. The waveform inversion results in this study were then compared with the CMT catalogs that had been released by GLOBAL CMT and CMT Solutions was released by the German seismological institute, GFZ.

Variance Reduction (VR) is a benchmark for the reliability of CMT results. VR is expressed in 0 to 100%. When CMT inversion uses the distribution of seismic stations that enclose 4 quadrants or close to 4 quadrants and VR > 50%, then CMT solutions are categorized as reliable [4]. If the CMT solution shows the percentage of ISO > 50%, then the cause of the earthquake is explosion, if DC > 50%, then the cause of the earthquake is tectonic activity and if CLVD > 50%, then the cause of the earthquake is volcanic activity.

3. Results

We have identified the CLVD vertical shallow earthquake located near the "unrest" mountains, the Jayawijaya volcano earthquake of July 17th, 2014 and Gunung Agung earthquake of 28 September 2017. We have inverted the waveform for both of these quakes. We have identified both earthquakes equally of a vertical CLVD earthquake, but the July 17th, 2014 earthquake near Jayawijaya mountains was a CLVD vertical-P earthquake. The September 28th, 2017 quake near Mount Agung, Bali was a CLVD vertical-T earthquake. Along with the CLVD vertical earthquake that has been documented by Nettles and Ekström [5] and volcanoes by Shuler and Ekström [6] as well as by Shuler et al. [1], this study adds the number of well documented vertical CLVD earthquakes and 3.0 to 5.8 magnitude are known to occur near the volcanic center which has so far amounted about 187 and is a vertical CLVD earthquake.

The result of the waveform inversion in this study is a complete full CMT solution by figure 2. While figure 1 shows cross-correlation between variant of reduction, double couple and centroid depth. Figure 3 shows the distribution of the seismic station used for the inversion waveform and the inversion result beachball.

The results of this study also provide reinforcement of the previous studies result both in terms of magnitude and the epicenter depth. For the magnitude, not all of the Mw volcanic earthquakes are less than 3, but it proved that there were volcanic earthquakes that had a magnitude of Mw 4.3 to 5.8. Otherwise, the depth of the epicenter (centroid) could reach up to a depth of 50 km below the sea level.

In addition, the volcanic earthquake has two types of CLVD, which is the vertical CLVD-P as the result of this study (Figure 2 and Figure 3). This earthquake indicates that around the location of the earthquake there is still volcanic activity and is not followed by an eruption. This is in contrast to the CLVD vertical-T type earthquake that happened in Mount Agung, Bali September 28th, 2017 followed by an eruption [7].

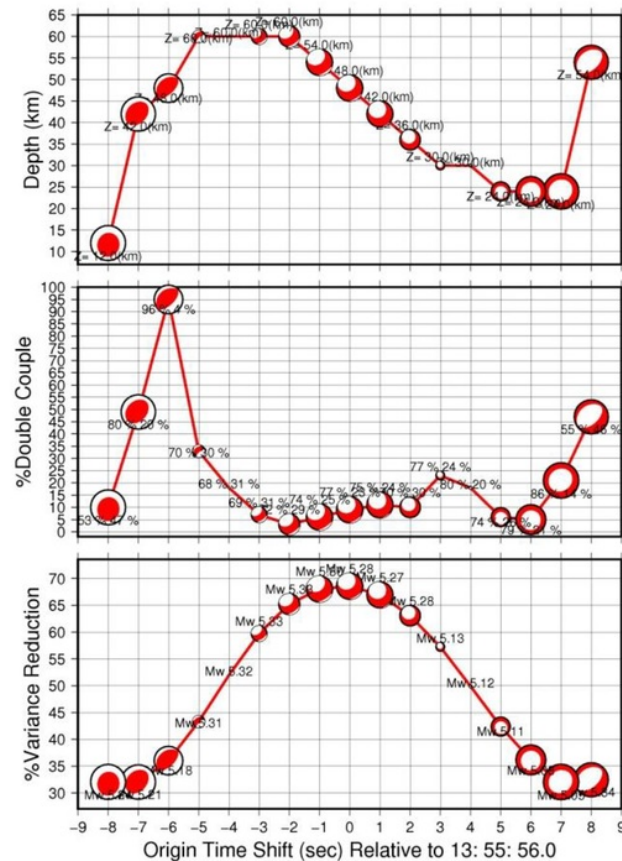


Figure 1. The inversion results in the form of cross-correlation between the variance reductions (VR), double couple (DC) and the centroid depth. The results of cross-correlation showed that in the lowest graph, the maximum VR value was 68.6% and this correlates with the low DC that was 8.9% (means that this earthquake was not a tectonic earthquake) and the depth of the earthquake was 48 km below the surface of the sea water, classified as a shallow earthquake.

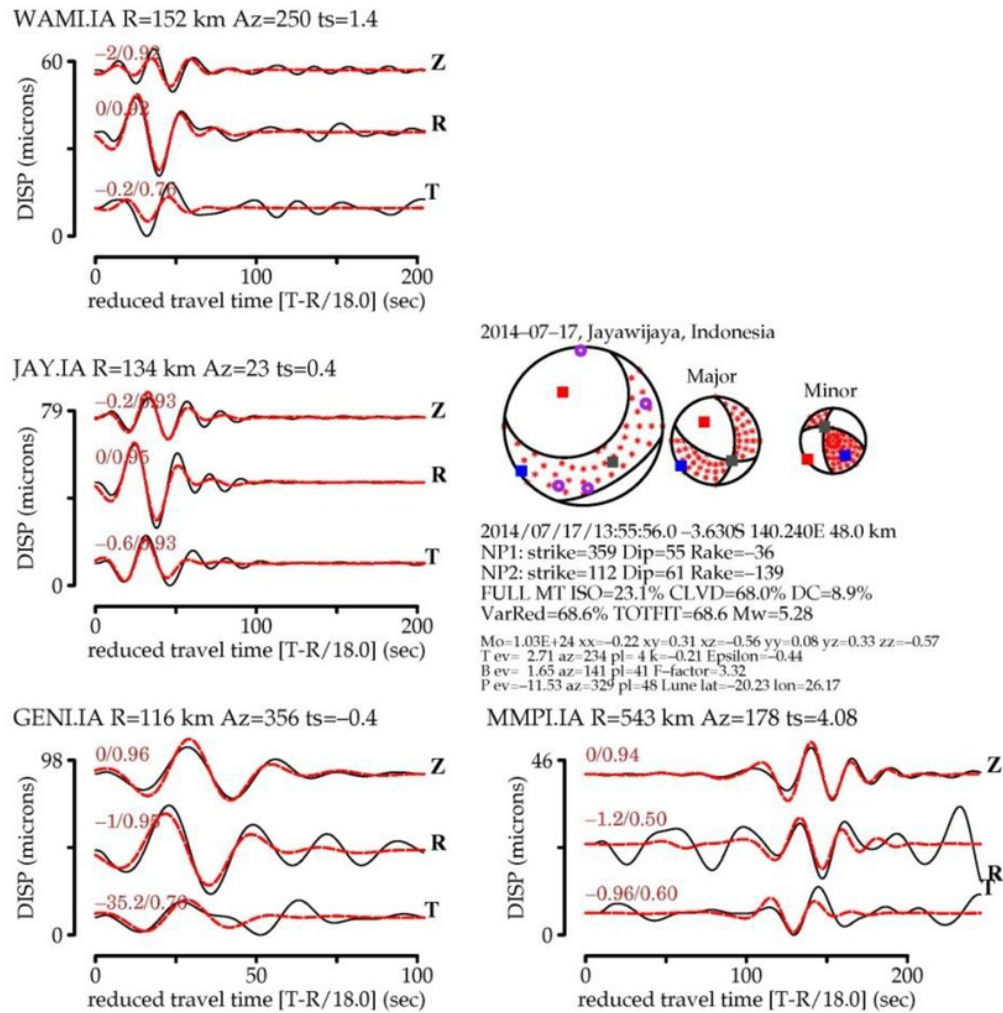


Figure 2. The inversion results in the form of fittings between observed waveforms data (black) and synthetic data (red), Isometric percentage (ISO), double couple (DC) and percentage CLVD, Mw, depth, fault plane that was represented by strike, slip, and rake, seismic moment (Mo) etc. The result of inversion in the research showed the percentage of CLVD was 68% (volcanic earthquake)

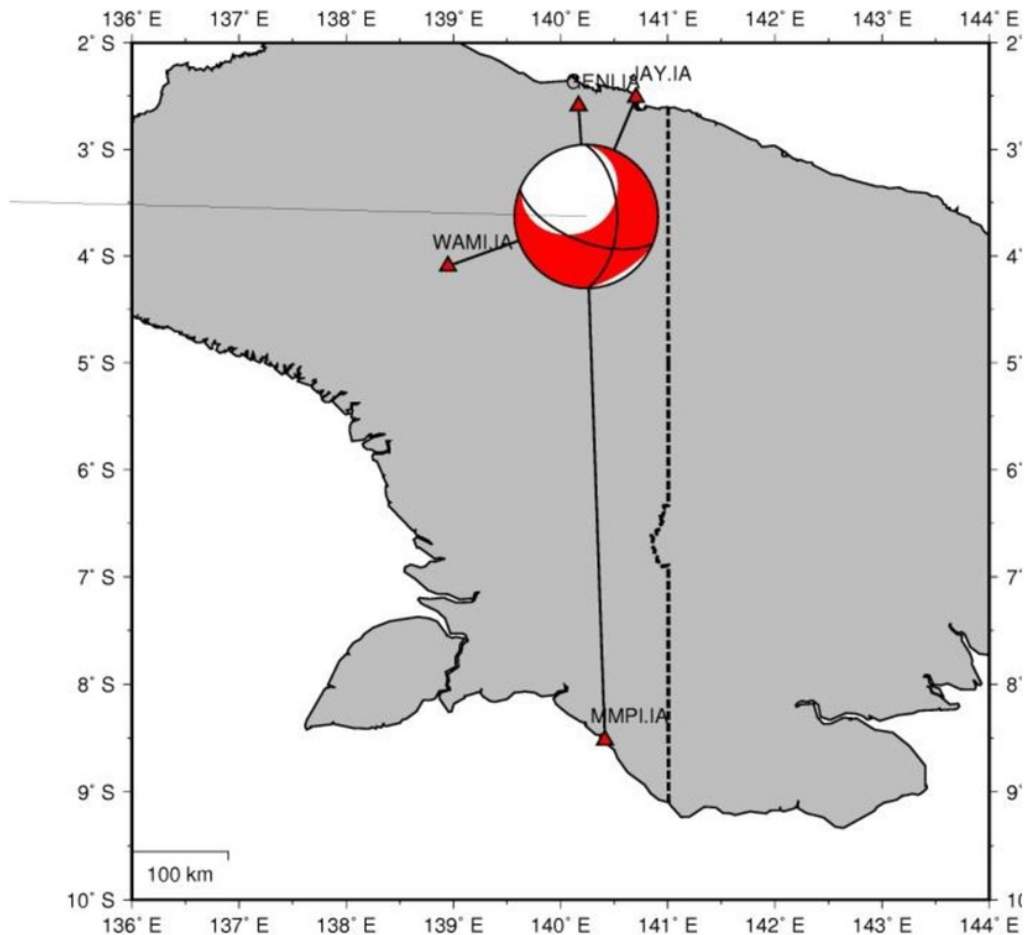


Figure 3. Beachball earthquake along with the distribution of four seismic stations used for inversion. This beachball type of inversion result is a CLVD vertical-P type.

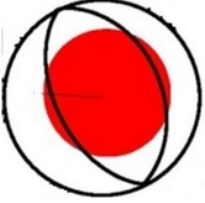
4. Discussion

The inversion results that are shown in figure 1, 2 and 3 provide information to us that $VR = 68.6\%$, $CLVD = 68\%$, 48 km depth and beachball with CLVD vertical-P type. These results can interpret that the earthquake occurred on July 17th, 2014 in the Jayawijaya mountains was a type of "riot" volcanic earthquake [1]. It is reinforced by the depth of more than 15 km. This type of "unrest" volcanic earthquake is not always followed by the eruption, this phenomenon informs us that there is volcanic activity below the surface of the Jayawijaya mountains although is not always followed by the eruption. According to some sources of mountains in Papua, there is no mountain classified as a volcano as the information

from: http://atlasnasional.bakosurtanal.go.id/fisik_lingkungan/gunung_api_detail.php?id=8&judul=Papua, but the discovery of volcanic earthquakes that occur around the mountains Jayawijaya indicates the existence of the mountain activity. Therefore, a system that monitors the activity of the mountain is required. The comparison of CMT solution from research result with GLOBAL CMT and GFZ solutions are divided into 1.

The CMT solution of the research results is very similar to the result of GLOBAL CMT solution, they are the same CLVD vertical-P type. While the GFZ CMT solution is very different from the results of this research solution and differs with GLOBAL CMT solution. The GFZ CMT solution for this earthquake shows a tectonic earthquake with a normal oblique type. However, the CMT solution from GFZ is almost identical with the result of this research solution for one component (the middle beachball in figure 2) of the 2 components for the full moment tensor (beachball on the left side of the picture 2). The left beachball on figure 2 is a full moment tensor CMT solution as it is redrawn on the map shown in figure 3.

Table 1. Comparison of CMT solutions of the research result and the GLOBAL CMT and GFZ solutions

The earthquake on July 17th, 2014 around the mountains of Papua, Indonesia			
	This Research	GLOBAL CMT	GFZ CMT
Depth (km)	48	36,8	64
Mw	5,28	5,2	5,1
Beachball			
Type of Earthquake	Volcanic, CLVD vertical-P	Volcanic, CLVD vertical-P	Tectonic, normal oblique
The earthquake on September 28 th , 2017 around Mount Agung-Bali, Indonesia before eruption			
	This Research	GLOBAL CMT	GFZ CMT
Depth (km)	9,7	Not available	Not available
Mw	3,34	Not available	Not available
Beachball		Not available	Not available
Type of Earthquake	Volcanic, CLVD vertical -T , happened before the volcano erupted	Not available	Not available

Not all seismological institutions that issue CMT solutions provide accessible parameters to identify volcanic, tectonic or explosive earthquakes, which are CLVD, DC or ISO percentages. Therefore, we need to do the inversion waveform ourselves to be able to identify the type of earthquake, although in general the type of earthquake can be interpreted from the beachball released by some seismological institutions, but we cannot expect exactly what percentage of each the CLVD, DC, and ISO.

Table 1 shows that for the earthquake with a magnitude of 4 to below GFZ seismological institutions and moreover the GLOBAL CMT does not provide CMT solutions. The CMT solution for the July 17th, 2017 earthquake around Jayawijaya Mountains, Indonesia was a volcanic earthquake with CLVD vertical-P type. While the earthquake of September 28th, 2017 around Mount Agung was a volcanic earthquake with CLVD vertical-T type.

The CLVD vertical earthquake that was identified in this study was classified as a shallow earthquake. During the inversion process, all centroid depths are fixed by the inversion algorithm up to 50 km in order not to produce shallow centroids, but the inversion results still show that a CLVD vertical earthquake occurs over 10 km from the Earth's crust and is classified as a shallow earthquake. Most CLVD vertical earthquakes occur around the 'unrest' mountain, the shallow depth estimation indicates that a vertical CLVD earthquake is likely associated with deformation within or under a volcanic building. The solutions of CMT can be used to improve earthquake and tsunami early warning system and to determine stress Coulomb [8, 9, 10].

5. Conclusion

The earthquake that occurred on July 17th, 2014 around the Jayawijaya Mountains was an "unrest" volcanic earthquake. This information showed that near the Jayawijaya Mountains there was volcano activity with CLDV vertical-P although was not always followed by the eruption. This is very different from the CMT solution for the September 28th, 2017 earthquake around Mount Agung-Bali which was an earthquake with CLDV vertical-T which always happens before the volcano erupts.

6. Recommendation

In order to predict the eruption of mounts and monitor the mountain activity more accurately, the competent authorities need to apply the CMT solution to identify volcanic earthquakes.

Acknowledgement

Our thanks go to BMKG that has allowed us to download seismogram data. Hopefully, BMKG and its employees will be more prosperous.

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