Earthquake Swarm Analysis around Mt. Salak, West Java, Indonesia, Using BMKG Data from August 10 to November 24, 2019

Pepen Supendi1,2, Nanang T. Puspito2,3, Andri Dian Nugraha2,3, Sri Widiantoro2,3,4, Chalid Idham Abdullah5, Daryono1, Dwikorita Karnawati1, Supriyanto Rohadi1, Zulfakriza2,3, David P. Sahara2,3

1 Agency for Meteorology, Climatology and Geophysics (BMKG), Jakarta, Indonesia
2 Center for Earthquake Science and Technology (CEST), Research Center for Disaster Mitigation, Institut Teknologi Bandung, Bandung 40132, Indonesia
3 Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Bandung 40132, Indonesia
4 Faculty of Engineering, Maranatha Christian University, Bandung 40164, Indonesia
5 Geodynamic and Sedimentology Research Group, Faculty of Earth Sciences and Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia

pepen_geophysics@yahoo.com

Abstract. Earthquake swarms commonly come approximately active tectonic and volcanic area. Interestingly, the swarm events occurred ~23 km southwest from Mt. Salak-Bogor, West Java, Indonesia, from August 10 to November 24, 2019, and were recorded by local/regional network of the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG). Our previous study showed that in this area a destructive Ml 4.6 earthquake with thrust faulting occurred on September 8, 2012. The double-difference method was applied to update the hypocenter locations from the BMKG data. In the time period of ~3.5 months, we relocated 79 swarm events with ~9.4 km depth average for local magnitude (ML) 2.2 to 4.2. The source mechanism result for selected events shows a strike-slip faulting. Our interpretation is that these swarm events are probably related to stress change due to volcano-tectonic activity.

1. Introduction
On August 10, 2019, there was a swarm activity around 23 km in the SW direction from Mt. Salak-Bogor, West Java. Up to November 24, 2019, BMKG recorded 92 swarm earthquakes in this area. Several events were weak to light shaking and caused slight damage to several houses in Nanggung sub-district, Bogor. Previous studies show that West Java has a high tectonic activity due to active faults on land, that consists of Baribis, Lembang, Cimandiri, and Garsela Faults [1] that are adjacent to high population density area. Interestingly, these swarm events are not located on these faults. The seismic sequences types have been classified by Mogi [2] into three types, i.e., foreshocks-mainshock-aftershocks; mainshock-aftershock; and swarm. The swarm earthquake is characterized by the continuous seismic activity with a relatively small magnitude without any major earthquakes. Some
areas in Indonesia that have occurred of the earthquake swarms i.e., in Madiun, East Java [3]; Jailolo, around Bekancan, North Sumatra [4]; and West Halmahera, North Maluku [5]. This research aims to obtain a more precise hypocenter location and to analyze the source mechanism of the earthquakes swarm.

2. Data and Method
We used the BMKG arrival-times data from 10 August to 24 November 2019. There were 92 events, consist of 654 P-phase and 592 S-phase arrival times; with focal depths of less than 30 km and local magnitude (M_L) 2.2 to 4.2. We applied Double-Difference method [6] to relocate hypocenters using the HypoDD program [7]. We processed the waveform data with frequency 0.04 Hz to 0.09 Hz from BMKG seismic stations in Western Java and its vicinity to conduct moment tensor inversion by using ISOLA package [8]. We utilized the AK135 velocity model [9] in the research.

![Figure 1](image1.png)

**Figure 1.** Map view of the research area (inside the black box), inset shows the Indonesian region. Red lines depict crustal faults extracted from Irsyam et al. [1]. The BMKG seismic stations is depicted by the blue inverted triangles.

3. Results and Discussion
Generally, 73 out of 92 relocated swarm earthquakes around southwest of Mt. Salak, Bogor (Figure 2) shows there are two clusters (dashed blue circles in Figure 2) that probably related to different sources,
namely cluster 1 is probably caused by volcano-tectonic activity in the southwest of Mt. Salak. The M$_{L}$ 4.6 Bogor crustal earthquake (September 8, 2012) with thrust faulting was occurred in the cluster 1 area and caused buildings damage [10].

Based on the geological map by Effendi et al. [11], the Bogor zone is composed of volcanic and intrusive rocks. Subsurface structure of Mt. Salak and its surrounding in West Java as part of a modern volcanic arc is dominated by heat source beneath the surface manifested as hot springs in the area. Stress changes due to the increase of hot material probably generated to activate a local active fault in cluster 1. On the other hand, cluster 2 is probably caused by another active fault (Citarik fault zone?) close to the Cimandiri Fault. Our vertical cross-sections show that the fixed depth has been revised (Figure 3). Generally, the focal depth in each cluster is less than 20 km, on average 9.4 km depth. The focal mechanism solution for the selected event (M$_{L}$ > 3.5) shows a strike-slip fault type.
Figure 3. Map view and cross-section of the swarm earthquakes (red to green dots) around Mt. Salak-Bogor. (a) Initial locations from BMKG catalog. (b) After relocation; 73 events respectively.

4. Concluding Remarks
Hypocenter relocation of swarm earthquakes indicates an improvement in hypocentre locations. Initial earthquakes at a fixed depth have been updated. There are swarm earthquakes around and beneath the Bogor area, which are probably caused by both tectonic (local fault) and volcanic activities.

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