Jurnal Geofisika (2023) Vol. 21, No. 01 hal. 26-28

Analysis of Local Active Faults in Western Java from Hypocenter Relocation Using BMKG Data

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Submit: 12 Juli 2022; Revised: 25 Desember 2022; Accepted: 07 Maret 2023

Abstract: *We have conducted hypocenter relocation in the region of western Java that focuses on shallow depth (less than 30 km) events within a magnitude range of 2.0 to 4.9. We use a double-difference relocation method and broadband waveform data recorded by the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) regional seismic network in the western part of Java. Our results show earthquake clusters around previously unknown active faults in an area that spans the Cipamingkis fault zone, Garsela fault zone, Baribis fault zone, and an earthquake swarm in Bogor-Bayah fault zone. The dense BMKG seismic stations in the study region are particularly useful for improving the detection of small earthquake sources from local active faults. These hypocenter relocation results can be used for further seismic studies in the western Java region, such as body wave tomography and probabilistic seismic hazard analysis.*

Keywords: *Hypocenter relocation, western Java, active faults.*

1 INTRODUCTION

The addition of the BMKG seismic stations in Western Java, which have now been in place for the past 12 years, has greatly improved our ability to detect small earthquakes from previously unidentified faults. Western Java experiences some of the most intense tectonic activity in Indonesia (Supendi et al., 2018a) due to the subduction of the Indo-Australian plate beneath Eurasia, which has have produced a variety of terrestrial faults, including the Baribis, Lembang, Cimandiri, and Garsela Faults (Irsyam et al., 2020). Our seismicity study in Western Java is important to better understand the tectonics of the region, especially for local active faults close to densely populated areas.

In this study, we use data recorded since 2009 to performed earthquake hypocenter relocation for shallow earthquakes with depths less than 30 km (Supendi et al., 2018a) to analyze and support seismic hazard mapping. This was done using a double-difference method, which we have previously successfully applied to relocate earthquakes in Sumatra (Nugraha et al., 2018a); West Java (Supendi et al., 2018a), Madiun, East Java (Santoso et al., 2018); Poso, Sulawesi (Supendi et al., 2018b), and West Halmahera, North Maluku (Nugraha et al., 2018b).

2 DATA AND METHOD

The data exploited in this study are earthquake body wave arrival times from the BMKG earthquake catalog for the period January 2016 to November 2020. A total of 630 events of magnitude ML 2.0 to 4.9 at depths of less than 30 km were detected during this period, resulting in a total of 9267 P-phase and 8324 S-phase arrival times.

The HypoDD program (Waldhauser, 2001) was used to implement the double-difference method (Waldhauser and Ellsworth, 2000) to relocate hypocenters. The method assumes that if the distance between the hypocenter pair is much less than the distance between the hypocenters and the recording station, then ray paths of hypocenter pairs recorded by a common station are considered to be similar and hence propagate through essentially the same medium. Residuals between calculated and observed travel-time differences were minimized using HypoDD in an iterative procedure that employed a 1-D seismic velocity model from a previous study (Koulakov et al., 2007) combined with AK135 (Kennett et al., 1995).

3 RESULT AND DISCUSSION

We successfully relocated 529 of the 656 shallow earthquakes detected by BMKG in western Java (Figure 1). Travel-time residuals associated with hypocenter relocation of all events are shown in Figure 2 Based on the relocated events, there are several earthquake clusters (dashed blue boxes) that are likely related to local active faults in the area. The vertical cross-sections along these faults are shown in Figure 3.

Earthquake clusters in the Garsela fault zone form a lineament with a southwest-northeast trend and focal mechanisms suggest a right-lateral fault (Supendi et al., 2018a). There were destructive earthquakes that caused damage to a number of houses and buildings in the south of the Bandung and Garut districts on November 6, 2016 (M 4.2), and July 18, 2017 (M 3.9), and the focal mechanism solutions show strike-slip and normal faults, respectively (Supendi et

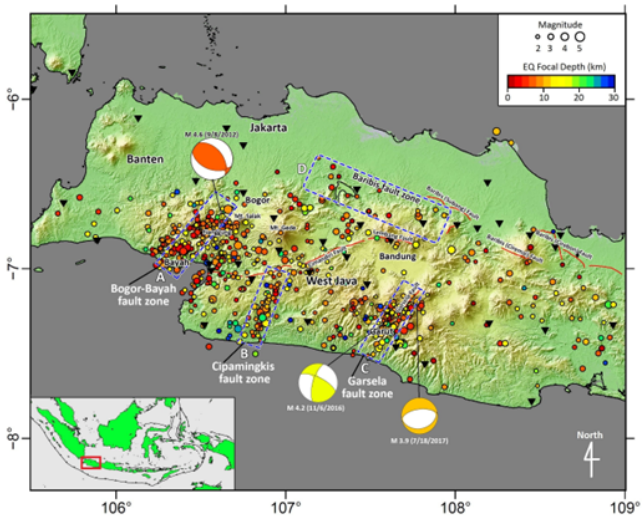

Figure 1. Earthquake map of western Java based on hypoDD hypocenter relocations from BMKG data (M ≥2) in the time period January 2016 to November 2020, combined with results from our previous study (Supendi et al., 2018a) from 2009 to 2015. Blue dashed boxes indicate local active fault zones. The red lines are the major crustal faults in the region sourced from Irsyam et al. (2020). The epicenters around Lembang and Cimandiri faults are from Supendi et al. (2018a). The black inverted triangles denote the location of BMKG seismic stations that are used in this study. Focal mechanisms are from Supendi et al. (2018a,c). Inset map is the location of the study area with respect to the Indonesian region.

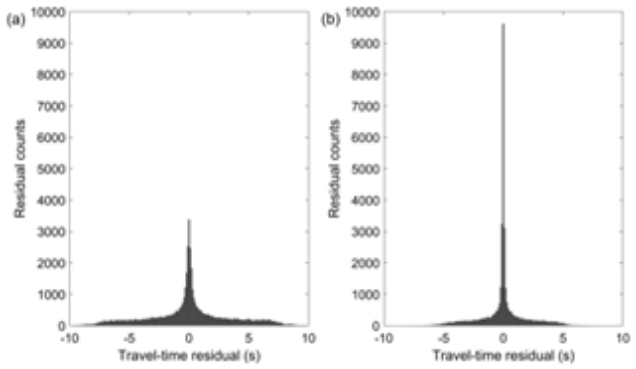

Figure 2. Travel-time residual histogram of event pairs (a) before relocation, (b) after relocation using HypoDD.

al., 2018c) (Figure 1). Since August 2019, there have been swarm earthquakes around the Bogor area, West Java. Several events were felt by people in the region and caused slight damage to several houses in the Nanggung sub-district Bogor. The seismicity in the area is probably due to a combination of tectonic and volcanic activity, and our previous study results (Supendi et al., 2018a) show that a destructive earthquake occurred in the Bogor-Bayah zone on September 8, 2012 (M 4.6) on a thrust fault (Figure 1).

According to Gunawan and Widiyantoro (2019) the Cipamingkis Fault has a southwest-northeast orientation. The area exhibits a relative lack of seismic activity; however, since 2018 it has significantly increased, and until the time of this study we have relocated 76 events with magnitude

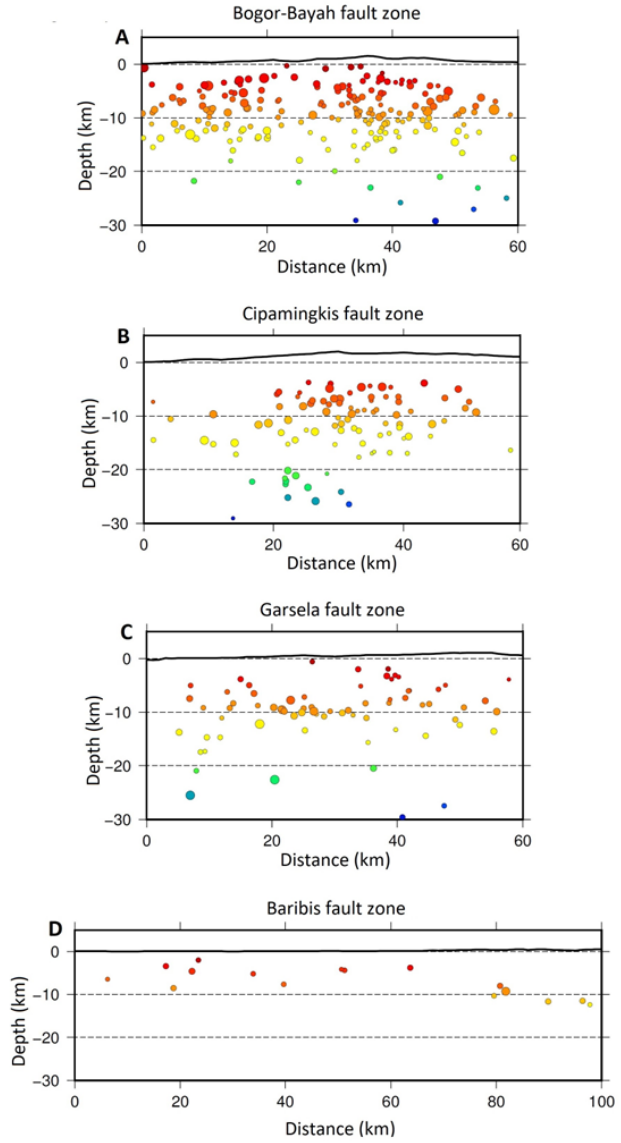

Figure 3. Vertical cross-sections of relocated hypocenters for the Bogor-Bayah fault zone, Cipamingkis fault zone, Garsela fault zone, and Baribis fault zone. The cross-section locations are shown in Figure 1.

ML 2.2-4.5. Meanwhile, we have also found an earthquake cluster extending along the Baribis fault zone leading to Jakarta, where previously there was a lack of seismic activity in this area. This has proven that the addition of a denser network of BMKG seismic stations has increased the detection of small earthquakes that were previously not well recorded.

4 CONCLUSION

We carried out hypocenter relocation using the double-difference method and BMKG catalogue data in order to relocate 529 shallow earthquakes (depth less than 30 km) in western Java from January 2016 to November 2020. The relocation results show earthquake clusters around local active faults in western Java, namely the Cipamingkis fault zone,

Garsela fault zone, Baribis fault zone, and swarm earthquakes around the Bogor area. As well as detecting previously unrecognised active segments of terrestrial faults, namely a part of the Baribis fault zone near Jakarta, the results of the study are useful for further analysis of seismic hazard in western Java.

ACKNOWLEDGEMENT

We thank BMKG for access to the earthquake data used in this analysis.

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