

Analysis of the destructive earthquakes end of 2017 (Mw 6.9) and early 2018 (Mw 6.1) south of West Java, Indonesia

Pepen Supendi^{1*}, *Supriyanto Rohadi*¹, *Dwikorita Karnawati*¹, *Andri Dian Nugraha*², *Sri Widiyantoro*^{2,3}, *Daryono*¹, and *Muzli*¹

¹Agency for Meteorology, Climatology, and Geophysics (BMKG), Jakarta, 10610, Indonesia

²Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Bandung, 40132, Indonesia

³Faculty of Engineering, Maranatha Christian University, Bandung, 40164, Indonesia

Abstract. On December 15, 2017, and January 23, 2018, there were destructive earthquakes to the south of West Java, Indonesia, with Mw 6.9 and Mw 6.1, respectively. We have determined the hypocenter location for both mainshocks through re-picking of the P- and S-wave arrival times recorded by the Agency for Meteorology, Climatology, and Geophysics (BMKG) seismic stations in West Java and its vicinity. We have then relocated the aftershocks for both events. We have also conducted focal mechanism analysis to estimate the type of fault slip. Our results show the 2017 and 2018 events occurred in the intra-slab at 108.6 km and 46.5 km depths, respectively. The focal mechanism solution shows a thrust fault type with the strike direction almost perpendicular to the trench for the 2017 event, and it is almost parallel to the trench for the 2018 event.

1 Introduction

West Java has one of the highest seismic hazards of any region in Indonesia [1]. This area lies within a highly complex tectonic region resulting from the subduction of the Indo-Australian and Sunda blocks. The Indo-Australian plate moves with an approximate convergence velocity of 70 mm/yr [2]. The relocated earthquake catalog from previous studies [3–5] shows high seismicity in the area, distribution of the earthquake hypocenter is getting deeper from the trench to West Java. Over the past two decades, there have been two destructive events in the south of Western Java, i.e. the 2006 (Mw 7.8) Java earthquake and tsunami [6,7] and 2009 (Mw 7.0) earthquake [8] that caused many of casualties. Based on the BMKG data, West Java and its surrounding areas were shaken by the earthquakes at the end of 2017 (December 15, 2017) Mw 6.9 and in early 2018 (January 23, 2018) Mw 6.1. It caused damages to hundreds of houses and public facilities and among them causing fatalities (www.bnpb.go.id). The purpose of this study was to determine precise hypocenter locations of the two mainshocks. In addition, we have also determined focal mechanism solutions to assess the fault type and relocated the aftershocks for both events.

* Corresponding author: pepen_geophysics@yahoo.com

2 Method

We have used the Seisgram2K [9] to re-picked the arrival times for the mainshock of the 2017 (Mw 6.9) and 2018 (Mw 6.1) events on the 3-component waveforms recorded by the BMKG seismic station in the western Java and south of Sumatra. The earthquake hypocenter determination used Hypoellipse code [10] with the Geiger method [11]. To validate the quality of the re-picking, we plot the Wadati diagram (Fig. 1). The V_p/V_s ratios are 1.756 and 1.729 for the 2017 and 2018 events, respectively. We used ISOLA program [12] to calculate of moment tensor inversion. The waveforms were using low-pass filter with a frequency of 0.02 Hz to 0.05 Hz. We used a 1-D velocity model extracted from AK135 [13] for hypocenter and focal mechanism determination.

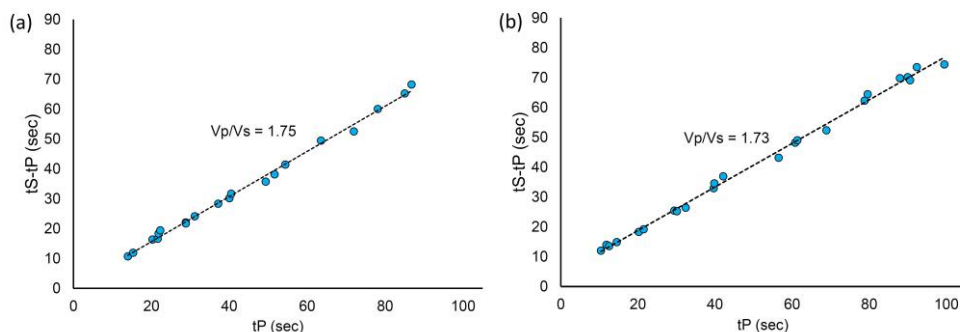


Fig. 1. Wadati diagram for (a) December 15, 2017, event; and (b) January 23, 2018, event.

3 Results and discussion

We have determined the hypocenter location in a more precise way for both mainshocks that occurred in to the south of West Java. The first event occurred on December 15, 2017, at 16:47:55 UTC at coordinates 7.7148° S; 108.1218° E, 108.6 km depth, 0.7 km horizontal uncertainty, 0.8 km depth uncertainty, and Root Mean Square 0.7. While the second event occurred on January 23, 2018, at 06:34:50 UTC at coordinates 7.3242° S; 105.9539° E, 46.5 km depth, 0.6 km horizontal uncertainty, 4.5 km depth uncertainty, and Root Mean Square 0.6. We have relocated 13 and 54 aftershocks (magnitude less than Mw 5.0) for 2017 and 2018 events, respectively (Fig. 2). We have verified the relocated aftershocks through histograms of residual travel-times (Fig. 3), which depict good results, i.e., the residuals are almost zero.

Focal mechanism solutions showed the type of mainshocks is oblique dominant thrust fault for both events (Fig. 2). The best fitting of synthetic and observed waveforms are shown in Fig. 4. The strike direction is almost perpendicular to the trench for the 2017 event, and it is nearly parallel to the trench for the 2018 event. Suardi et al. [8] show the strike almost perpendicular to the trench of the 2009 event, which is probably due to a strong slab pull beneath the region.

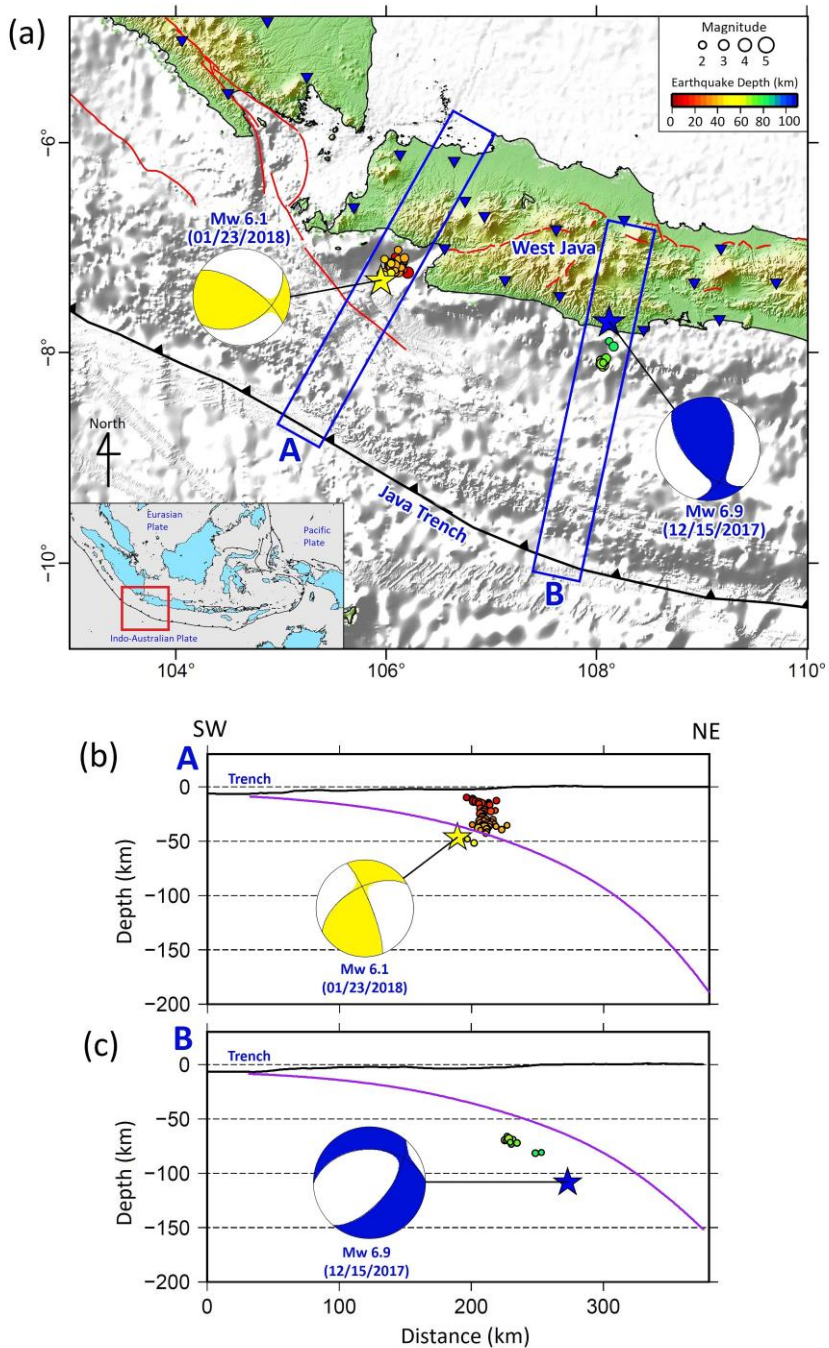


Fig. 2. (a) The epicenters and focal mechanism solutions for both mainshocks (yellow and blue stars) and the aftershocks (red to green circles). Inset is the location of the study area with respect to the Indonesian region. Vertical cross sections for: (b) Mw 6.9 (15 Dec 2017) and (c) Mw 6.1 (23 Jan 2018) events. The purple line in (b) and (c) is a 1-D slab model extracted from Hayes et al. [14].

The 2017 event (Mw 6.9) occurred at 108.6 km depth in the intra-slab. The aftershocks of this event were relatively fewer than the aftershocks of the 2018 event. This is probably owing to the deeper hypocenters and the magnitude which is quite small. Therefore, some aftershocks were not recorded properly by the BMKG seismic stations. Whereas the 2018 event (M6.1) occurred at 46.5 km depth, the aftershocks have shown an upright pattern. Sirait et al. [15] show that the events were caused by upward fluid migration.

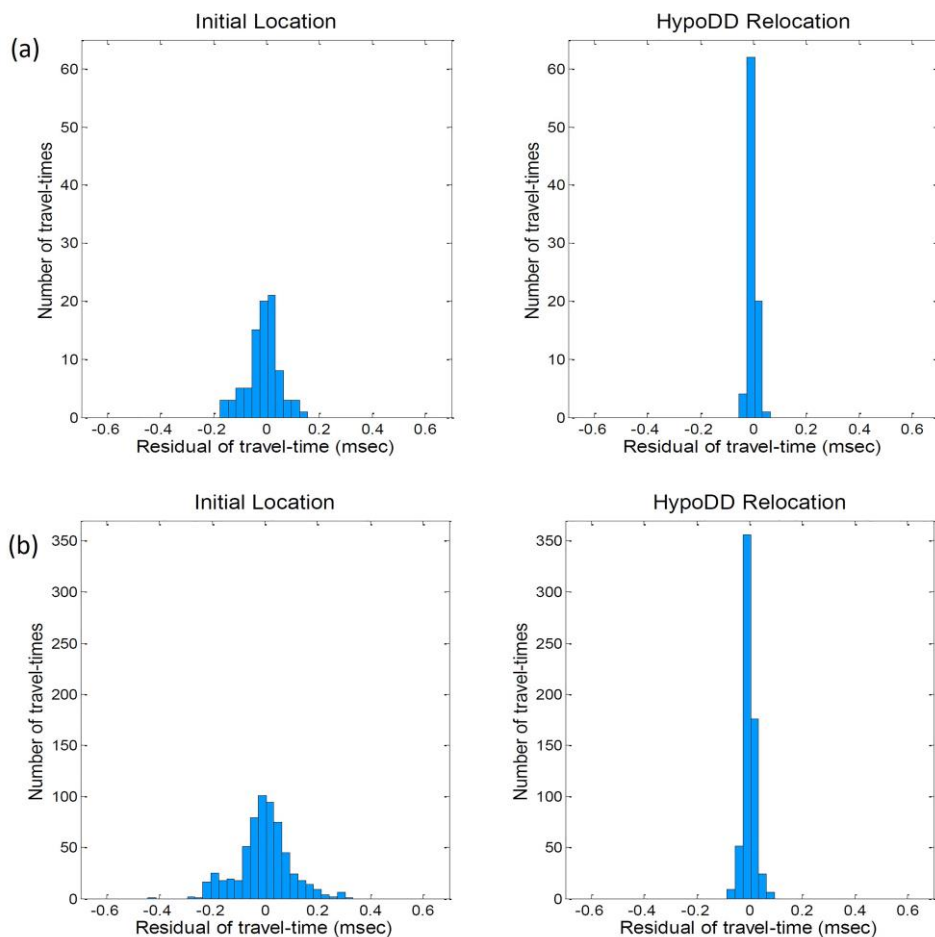


Fig. 3. Residual of travel-times of aftershocks for initial location (left) after relocation (right) for: (a) December 15, 2017; and (b) January 23, 2018, events.

Both of these events have occurred in the subduction zone to the south of West Java. According to the previous study from Irsyam et al. [1] and Hanifa et al. [16], the megathrust zone south of West Java has the potential to produce an earthquake with a maximum magnitude \sim Mw 8.7. On the other hand, based on a recent study from Widiyantoro et al. [5], if two segments of megathrust south of West and East Java rupture simultaneously, it can produce Mw 9.1 and will cause tsunami heights that can reach \sim 4.5 m on average. Are these two events as a foreshock to the potentially larger earthquake? or are these related to the slow energy release in the area? The presence of the seismic gap zone south of West Java was confirmed based on seismicity and GPS data [5]. Therefore, further study, investigation, and mitigation are needed to minimize of earthquake impact in the future.

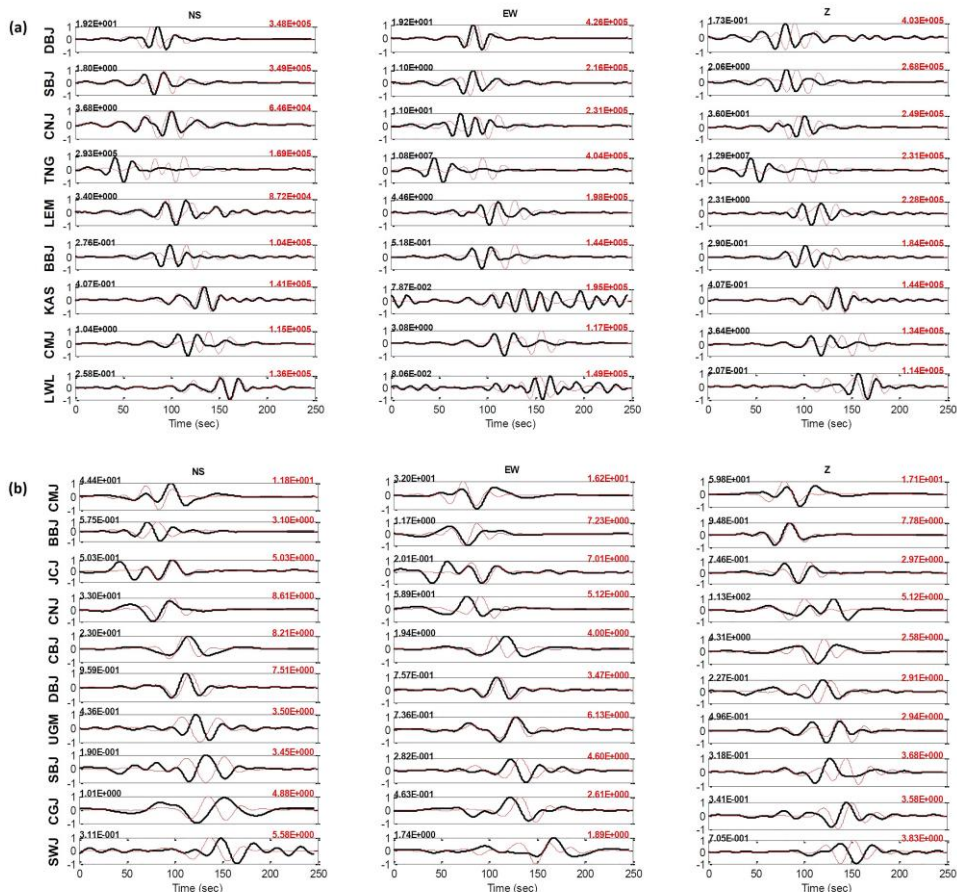


Fig. 4. Waveform fitting of focal mechanism solution for (a) December 15, 2017, event; and (b) January 23, 2018, event. The synthetic and observed waveforms depicted in red and black, respectively.

4 Conclusion

The 2017 and 2018 mainshocks occurred in a precise way in the intra-slab at 108.6 km and 46.5 km depths, respectively. The relocated aftershocks for the 2018 event show the upright pattern and the 2017 event show less aftershocks. The focal mechanism result shows a thrust fault type with the strike direction almost perpendicular to the trench for the 2017 event, and it is almost parallel to the trench for the 2018 event.

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References

1. M. Irsyam, P. R. Cummins, M. Asrurifak, L. Faizal, D. H. Natawidjaja, S. Widiyantoro, I. Meilano, W. Triyoso, A. Rudiyanto, S. Hidayati, M. Ridwan, N. R. Hanifa, and A. J. Syahbana, *Earthquake Spectra* **875529302095120** (2020)
2. Y. Bock, L. Prawirodirdjo, J. F. Genrich, C. W. Stevens, R. McCaffrey, C. Subarya, S. S. O. Puntodewo, and E. Calais, *Journal of Geophysical Research* **108**, (2003)
3. A. D. Nugraha, H. A. Shiddiqi, S. Widiyantoro, C. H. Thurber, J. D. Pesicek, H. Zhang, S. H. Wiyono, M. Ramdhan, Wandono, and M. Irsyam, *Seismological Research Letters* **89**, 603 (2018)
4. P. Supendi, A. D. Nugraha, N. T. Puspito, S. Widiyantoro, and D. Daryono, *Geoscience Letters* **5**, (2018)
5. S. Widiyantoro, E. Gunawan, A. Muhari, N. Rawlinson, J. Mori, N. R. Hanifa, S. Susilo, P. Supendi, H. A. Shiddiqi, A. D. Nugraha, and H. E. Putra, *Sci Rep* **10**, 15274 (2020)
6. J. Mori, W. D. Mooney, Afnimar, S. Kurniawan, A. I. Anaya, and S. Widiyantoro, *Seismological Research Letters* **78**, 201 (2007)
7. E. Gunawan, S. Widiyantoro, G. I. Marliyani, E. Sunarti, R. Ida, and A. R. Gusman, *Physics of the Earth and Planetary Interiors* **291**, 54 (2019)
8. I. Suardi, Afnimar, S. Widiyantoro, and Y. Yagi, *International Journal of Tomography & Simulation* **25**, (2014)
9. A. Lomax and A. Michelini, *Geophysical Journal International* **176**, 200 (2009)
10. J. C. Lahr, *Open-File Report* (USGS Publications Warehouse, 1999)
11. L. Geiger, *Bulletin St. Louis University* **8**, 60 (1912)
12. E. N. Sokos and J. Zahradnik, *Computers & Geosciences* **34**, 967 (2008)
13. B. L. N. Kennett, E. R. Engdahl, and R. Buland, *Geophysical Journal International* **122**, 108 (1995)
14. G. P. Hayes, G. L. Moore, D. E. Portner, M. Hearne, H. Flamme, M. Furtney, and G. M. Smoczyk, *Science* **362**, 58 (2018)
15. A. M. M. Sirait, A. S. Meltzer, F. Waldhauser, J. C. Stachnik, D. Daryono, I. Fatchurochman, J. Jatnika, and A. S. Sembiring, *Bulletin of the Seismological Society of America* (2020)
16. N. R. Hanifa, T. Sagiya, F. Kimata, J. Efendi, H. Z. Abidin, and I. Meilano, *Earth and Planetary Science Letters* **401**, 159 (2014)
17. P. Wessel and W. H. F. Smith, *Eos, Transactions American Geophysical Union* **79**, 579 (1998)