Unexpected Shallow Earthquake of August 1st, 2020 in the North of Indramayu, West Java, Indonesia

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Abstract. During the last one hundred years, there are no shallow seismicity in the north of Java. This area is dominated by intermediate and deep focus earthquakes due to the subducted Indo-Australian slab. An earthquake with magnitude Mₗ 4.5 struck Indramayu, north of West Java on August 1, 2020. According to the Agency for Meteorology, Climatology, and Geophysics (BMKG), the earthquake was felt III MMI scale in Indramayu and its vicinity. We used waveform data from BMKG seismic station in West Java, then we picked P-and S-waves arrival times from each station and hypocenter location was determined by Geiger method. We have detected Pn before Pg phase on four BMKG seismic stations, indicating a shallow crustal earthquake. Our inversion show that the earthquake occurred in 6.1805° S, 108.2612° E with 5 km focus depth at 16:24:38 GMT+7. Our focal mechanism solution was determined by using moment tensor inversion shows a strike-slip faulting, which corresponds to the active fault in the north of Indramayu.

1. Introduction
One of the high seismic hazards area in Indonesia located in West Java [1]. The complex tectonic in the area caused by the subducted Indo-Australian plate. The relocated earthquakes catalog over 50 years from EHB bulletin [2] combine with Widiyantoro et al. [3] shows this area has high seismicity (Fig. 1). Based on the BMKG data, over this period there have been 23 destructive earthquakes from magnitude 3.3 on land faults to magnitude 7.7 in the subduction zone (see the yellow stars in Figure 1). Meanwhile, there are no-existing shallow seismicity in the north of Indramayu, West Java. Hayes et al. [4] show the Indo-Australian slab beneath this area is about 230 km depth, so that the seismicity in this region is relatively sourced from intermediate to deep earthquakes. Interestingly, on August 1st, 2020, the earthquake Mₗ 4.5 shook Indramayu area in III Modified Mercalli Intensity (MMI) scale. We have obtained a more accurate hypocenter location and conducted source mechanism analysis of this event.

2. Data and Method
We extracted waveform data form the BMKG seismic stations (the black inverted triangles in Fig. 2). We used Seisgram2K program [5] to picked onset of P-and S-wave carefully. Earthquake hypocenter determination was conducted use Hypoellipse code [6] with Geiger method [7]. This method has succeeded in determining hypocenter locations in previous studies in West Java ([8,9]) and in Madiun, East Java [10]. We used ISOLA program [11] to carry out moment tensor inversion. The displacement
data from six BMKG seismic stations (JCJI, JPJI, LEM, PBJI, KPJI, and BTJI) have been inverted. We filtered the observed waveforms of 0.05 Hz to 0.09 Hz. The data processing procedure for focal mechanism analysis is as follows: converting the data from SAC to ASCII format; preparing the input files: the earthquake hypocenter location (longitude, latitude, and depth), origin time, and velocity model; selecting station; removing the instrument response, experimenting trial seismic source depth, and calculating the Green’s function. We used a 1-D velocity model from previous study [12, 13] for this research.

Figure 1. Map of relocated earthquake epicenters [2,3] in the western part of Java in the time period of 1963 to 2018, inset map is the Indonesian region. The yellow stars are the destructive earthquakes from BMKG catalog, they are not colour-coded by depth.
3. Results and Discussion

Our result shows the final hypocenter located in 6.1805° S, 108.2612° E, and 5 km focus depth (Fig. 2), which has 2.5 km and 2.8 km horizontal and depth uncertainties respectively, occurred at 16:24:38 UTC on August 1st, 2020, and RMS 0.7. The focal mechanism solution show strike-slip fault (strike 1: 47°, dip 1: 69° rake 1: -165°; strike 2: 311°, dip 2: 76°, rake 2: -22°) (Fig. 2), the best fitting of waveform inversion shows a fairly good data processing (Fig. 3).

We have determined the hypocenter locations in the north of Indramayu occurred, at 16:24:38 UTC. All of the BMKG seismic stations which recorded this event shows a strong shear wave. We have detected Pn before Pg phase on four BMKG seismic stations (JCJI, KPJI, PKJM, and SEJM) indicating a shallow crustal earthquake and the hypocenter located relatively far away from these stations.

Figure 2. Epicenter location and focal mechanism solution for the earthquake that were determined in this study (August 1, 2020). Relocated background seismicity for Mw≥ 4.0 and focal depth less than 150 km [2,3]. The red lines depict faults in the area are taken from Irsyam et al. [14]. The black inverted triangles are the BMKG seismic stations.
Our interpretation for this event is likely sourced from an active fault in this area. Generally, the felt earthquakes in Indramayu and its vicinity is caused by the shallow earthquake in Baribis fault in the south of this region. Moreover, there are sources from intermediate and deep earthquakes in the north of this area. The unexpected shallow earthquake, which was felt on August 1st, 2020, is located close to Indramayu. Thus, this earthquake probably one of the evidences that proves there has been an active fault in the north of Indramayu.

**Figure 3.** Observed and synthetic seismograms fitting process upon focal mechanism determination for August 1st, 2020, events. Red and black seismograms indicate the synthetic and observed waveforms, respectively.

Then we made the simulation of shakemap. The simulation shows that the maximum impact of the earthquake is about III to IV MMI (Modified Mercalli Intensity) scale (Fig. 4). It means that the Indramayu earthquake was felt weak to light shaking and had no potential for damage. These results are in agreement with the public report—that the earthquake was only caused more people to panic in Indramayu city.
Figure 4. Shakemap simulation of the Indramayu earthquake. We used the epicenter was located in 6.1805° S, 108.2612° E with 5 km focus depth and magnitude moment is about of 4.5.

The modelling results for the Peak Ground Acceleration (PGA) value in the Indramayu area is 2% of g or about of 20 gals and the Peak Ground Velocity (PGV) value is about 5 cm/s (Fig. 5).

Figure 5. (a) PGA modeling, (b) PGV modeling of the Indramayu earthquake on 1st August 2020.
4. Concluding Remarks

The determination of a hypocenter location of felt earthquake in the Indramayu area shows a shallow depth (about 5 km). Shake map modeled about III to IV MMI scale, while the PGA value in the area 2% of g is too small for ground acceleration and has not destroyed any infrastructures. The source mechanism solutions of this event indicate a strike-slip fault. The occurrence of this event indicates that there is possibly an active fault exist-in the north of Indramayu, West Java.

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