The M 6.5 Ambon earthquake 26 September 2019: the source mechanism and the aftershock sequence characteristics

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Abstract. The area of Ambon, Maluku is located in the subduction zone in bands where the Australian plate meets the Eurasian plate, thus causing tectonic activities. The Ambon earthquake on 26th September 2019 with 6.5 Magnitude, while the Epicentral coordinates of the earthquake were determined as 3.53° S and 128.39° E and a focal depth of 10 km, according to the Agency for Meteorology Climatology and Geophysics, Indonesia. This earthquake was strongly felt at the biggest shock was felt with intensity VI-VII as unified in Ambon City, while several other areas are reported to have experienced small shaking, such as Intensity V in Masohi, and Intensity IV in Namlea and Namrole. We used a dataset of 24 waveforms of seven sensors, we determine a tabular solution, which have a large moment of 0.4573 x 1019 N-m, the depth is 6 km by minimizing the inversion residual. The method resulting strike and rake fault, with strike: 341.8°; dip: 81.5°; rake: 158.4°, and second nodal plane strike: 75.1°; dip: 68.6°; rake: 9.14°. The mechanisms were compared with those from other agency in agreement. The time decay intervals between mainshocks and significant aftershocks follow Mogi and Utsu’s Law but with a relatively faster rate of decay than that of aftershocks in general.

1. Introduction
The Ambon earthquake, 26th September 2019 with epicenter coordinates 3.53° S and 128.39° E at a depth of 10 km, 42 km northeast of Ambon City due to the movement of local faults, Ambon Island has a lot of potential for earthquakes and tsunamis, Ambon Island is composed of a complex tectonic arrangement [2]. Tectonically, this island has many faults which are the source of earthquakes. According to data of the National Disaster Management Agency (BNPB), the impact of the Ambon earthquake on September 26, 2019, 23 people died, injured victims occurred in Central Maluku. More than 100 people were injured in Liang Village. In Ambon City, 5 people were injured. Meanwhile, West Seram District, 1 person was injured in Waismama Village. About 15,000 residents are still displaced after the earthquake because their houses were damaged and in anticipation of aftershocks that could endanger them. Meanwhile, infrastructure damage did not only occur in the housing sector, but also educational facilities, places of worship, offices, and public facilities. Damage to houses in the affected areas reached 171 units, with details of 59 being heavily damaged, 45 moderately damaged and 67 slightly damaged. Five units of educational buildings were damaged, including several buildings at Pattimura University [6]. This paper discusses the mechanism and the decay of aftershocks of the Ambon earthquake.

Seram and Ambon are part of the Banda Arc system. The Banda Arc, located in the eastern part of Indonesia between Australia, and Sulawesi. Banda and Ambon are a region of complex and active tectonics. Convergence between Australia, Eurasia and the Pacific Sea plates ([3], [5]) results in both contraction and extension from subduction, lithospheric delamination and slab break-off [3]. Convergence of Indo-Australia, Eurasia, and Pacific plates creates the Banda Arc which is a very
complex tectonics system including a number of Microplates involved. Convergence between Australia, Eurasia, and the Pacific Sea plates ([3], [5]) results in both contraction and extension from subduction, lithospheric fracture and slab detached [3]. In the outer arc islands of Seram, Tanimbar, Babar, Timor and Sumba, the geological features have been created as a result of subduction processes. The North Seram Basin is located in the Australian plate, in the south adjacent to the Banda micro plate and the arc-continent collision belt in the margin. The northern part of the basin is bounded by the Seram trough in the north, strike-rake of the Ruru fault belt in the west, Kawa strike-rake fault belts and in the south is metamorphic thrust belts, and in the east is the terra-Aiduna strike-rake fault belt. The North Seram, and it has features of a Foreland basin. According to its structural characteristics, the basin can be divided into two second-order tectonic units: Foreland fold thrust belt and foredeep belt [9].

Figure 1. Seismicity in Ambon-Seram island and surrounding area, the star is Ambon earthquake September 26, 2019.

2. Data and Method
We use waveform data from global stations (IRIS) to obtain a reliable and accurate focal mechanism, figure 2.a shows the station distribution which used for waveform inversion. Earthquake source modeling used teleseismic waves at 24 stations 30º to 90º from the epicenter. The data for aftershocks analysis originating from the Agency for Meteorology Climatology and Geophysics (BMKG) catalogue is used to determine the patterns and estimates of the end of aftershocks decay (Fig. 2b).
The fault's during an earthquake are mathematically and geometrically represented with focal mechanism. Focal consists of the motion of two earth fault. Focal mechanisms can consist of the double-couple and symmetric tensor

$$M_{ij} = M_0(\hat{d}_i\hat{n}_j + \hat{n}_i\hat{d}_j)$$

(1)

where $\hat{d}$ and $\hat{n}$ are unit vector perpendicular to the fault along the direction of rake [1].

Decay of the aftershock sequence is determined using the decay formula, according to Mogi [6] and Utsu [8] that shows the activity level of aftershocks ($t \leq 100$ days), in the relationship between earthquake frequency and time is

$$n(t) = a e^{bt}$$

(2)

where $n$, $t$, $a$, and $b$ are number of event, time, and constant, respectively. This relation has been successfully applied to many aftershock sequences of the main shock. The process to determine the decay is fitting the equation to observational data of the aftershock.

3. Result and Discussion
This modeling is done by inverting body waves at low frequencies (0.018 - 0.091 Hz). Modeling results get a magnitude Mw6.4 (BMKG (update) M6.5, GFZ Mw6.4, IRIS Mww6.5) and an earthquake depth of 6 km (BMKG 10 km, GFZ 10 km, IRIS 18.16 km). If the epicenter of the earthquake is viewed as a point source, the modeling results show that the earthquake mechanism is a strike rake type. The focal mechanisms were compared with those from other studies. The results of the inversion of the seismic wave form are N1: Strike, dip, rake = (341.8°, 81.5°, 158.4°) and N2; (Strike, Dip, Rake) = (75.1°E, 68.6°, 9.14°).

The earthquake process can be explained by focal mechanism and energy release of the intraplate earthquake, which indicate the release of energy accumulated inside the plate tectonics. The interplate earthquakes are controlled by relative moving as a rake vector of fault plane. Verification of focal mechanisms of the fundamental concept derived using the spatial distribution of aftershock [1].
Figure 3. Focal mechanism and the waveform fitting of Ambon earthquake September 26, 2019.

Figure 4. Distribution of some earthquake focal mechanism in Ambon and surrounding area.
Figure 5. Decay of the aftershock activity of the Ambon earthquake September 26, 2019 (Source: BMKG).

Figure 6. Histogram of aftershock event of Ambon earthquake September 26, 2019 (Source: BMKG).

Based on decay relation, aftershock of the main earthquake will be ending after 46 days (Fig.5), compute using Mogi and Utsu model ([6], [8]). The aftershocks may continue after this time but difficult to separate from the background seismicity. Aftershock decay defines as the duration of aftershock activity as a function of the time to the level of background seismicity. The aftershock activities of the large earthquakes continue in some months or even years.
The background seismicity of the aftershock zone can be estimated using several approaches, mainly the background seismicity similar to the average seismicity before the main shock. The aftershock decay is dependent on background seismicity of the region. The decay of the aftershocks defined the duration as the time when the rate decreased to some fixed level (example: 1 event/day).

4. Conclusion
Based on data processing and analysis of the results, it can be determined that the Ambon earthquake was strike rake fault. This mechanism is in accordance with the regional tectonic patterns in the region. The decay pattern of aftershocks shows an exponential decay pattern according to the formula from Mogi and Utsu. The end of the aftershocks is predicted 46 days after the main earthquake. Reliable focal mechanism and accurate estimation of the aftershock decay are very important in earthquake mitigation efforts.

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