The Possibly of the November-December 2018 earthquakes caused by hydrothermal in the Mamasa and surrounding areas derived by the earthquake relocation data

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Abstract. During the last two months in 2018, 761 earthquakes occur in Mamasa Region, west Celebes. These earthquakes are not lying in known active faults in Celebes and not have mainshock. About 287 earthquakes felt by local society. Mapping for detailed seismicity in this region is crucial to know the source of this earthquake sequence. The Inversion from arrival time catalog was performed to derive the 1-D local velocity model. The initial velocity model is obtained by combining ak135 for spherical average structure and local velocity model in Palu Koro Region that has been studied previously. The new local velocity model was used to compute double-difference relocation, while data input was arrival time catalog from Meteorological Climatological and geophysical agency. We successfully relocate 752 earthquakes with fine residual value 0 until 0.032 seconds. The trend of this earthquake sequence was spread but the main linearization is N 80 W, but it still makes a trend from a 48-degree dip angle. With the number of earthquakes in a narrow area and shallow depth within a short period of time, it should be suspected that there is a contact between faults and hot springs in the area so that these earthquakes can occur.

1. Introduction

One month after the massive earthquake in the Palu Koro fault Mw Global CMT 7.6 a series of earthquakes occurred in the area of Mamasa Regency and its surroundings [1] [2]. 761 earthquakes detected by BMKG (Indonesian Meteorological Climatological and Geophysical Agency) with the largest magnitude M 5.5 [2]. Because there are very few stations around the epicenter, the smallest magnitude that can be analyzed is only M 2.0. Research on this series of earthquakes in several regions in Indonesia has previously been carried out [3] [4]. This earthquake series is not in the active fault zone [5] but surrounded by non-volcanic hot springs [6]. One typical swarm earthquake is in a hydrothermal or geothermal zone [7]. So this study tries to see whether there is a connection between hydrothermal regions in this Mamasa region and the swarm earthquake that occurs during November and December 2018.

Waldhauser and Ellsworth proposed a double difference relocation method to describe the linearization of the Hayward fault in California [8]. The success of this relocation method depends on the 1-dimensional velocity model used, besides the accuracy of picking arrival time. In Indonesia, this double-difference relocation method has also been used frequently [9][10]. For this reason, we use a combination of the nearest local velocity model that has been previously studied in the Palu Koro area.
and the global velocity model ak135 [12]. It is expected that the application of the double difference method relocation in earthquake series around Mamasa can describe the line structure that causes this earthquake series.

2. Data and Method

2.1. Data
The data we use are arrival time catalog BMKG data from 1 November - 31 December 2018 with coordinates 3.76 S - 2.45 S and 118.7 E - 120.3 E. We use a combination of local and global velocity models to accommodate the heterogeneity of layers above 20 km. In the previous local velocity model, this layer is considered homogeneous [11]. We chose the ak135 spherical model to describe this heterogeneity. Table 1 shows the value of Vp and the depth of each layer. While the value of Vp / Vs used is 1.73.

Table 1. Mixed 1-D Local Velocity Model

| Depth (km) | Velocity (kms⁻¹) |
|-----------|------------------|
| 0 – 3     | 1.45             |
| 3 – 3.3   | 1.65             |
| 3.3 – 10  | 5.80             |
| 10 – 20   | 5.99             |
| 20 – 30   | 6.17             |
| 30 – etc  | 8.08             |

2.2. Method
The double difference method is based on the assumption that if there are two hypocenters with a distance smaller than the distance to the recording station, then the ray path of the two earthquakes is considered the same (Figure 1).

Figure 1. Double difference scheme [8].
The double difference method is based on the assumption that if there are two hypocenters with a distance smaller than the distance to the recording station, then the ray path of the two earthquakes is
considered the same. The residual between the observed travel time differences and calculated for earthquake pairs at each station was minimized with the weighted least squares using the singular value decomposition method (SVD). The solution is found by iteratively adjusting the vector differences between the closest hypocentral pairs, with the location and partial derivatives being updated every iteration [8].

3. Result and Discussion

The difference in travel time calculation with a small travel time of observation or residuals shows the accuracy of the results of good relocation. 99 percent of the total earthquakes which initially have residual value varies from -1.6 to 1.6 seconds, its position and origin time can be fixed to have residual value from -0.4 to 0.4 seconds. This also indicates that the velocity model used is accurate enough to be applied in the Mamasa area.

![Figure 2. Histogram of Earthquakes residual before (left) and after relocation (right).](image)

The results of the relocation indicate a fracture trend in the northwest-southeast direction (Fig. 3). Two incisions are made to clearly show the structure of the fault trend. The seismicity trend makes the strike angle 352 degrees or N 8 W. Hamilton explained that this fault is a Sadang fault with a sinistral strike-slip fault type [13]. Whereas Satyana et al. explain that this fault is a continuation of the Walanae fault [14]. In the geological map, this fault is named by Masupu fault [15]. The AB incision is made in the direction of the fault strike direction while the CD incision is made perpendicular to the AB incision.
Figure 3. Earthquake epicenters before relocation (left) and after relocation (right).

From both incisions, seismicity is concentrated at a depth of 5 to 15 km. CD incisions show this seismicity forms a fracture zone, not a fault field. Even though there is a trend of a 48-degree dip angle (Figure 4).

Figure 4. Cross section of AB line (left) and cross section of CD line (right). The black line in the CD cross section is the trend of dip.

The hypocenter from this earthquake series are shallow. This allows a connection of this earthquake series with the features of the spring on the surface. Figure 5 shows the hot spring points in the earthquake area. The heat and chemical properties of this hot water are thought to be rock weathering in the area. So that when subjected to stress from the surrounding tectonic forces, the rocks in the area will easily break and form a series of swarm earthquakes in the area.
4. Conclusion

We successfully mapped the hypocenter distribution of the Mamasa area swarm earthquake. Obtained a fault feature with strike direction N 8 W with dip angle 46-50. The hypocenter concentration at a depth of 8-15 km shows the center of this swarm earthquake series. With the number of earthquakes in a narrow area and shallow depth within a short period of time, it should be suspected that there is a contact between faults and hot springs in the area so that these earthquakes can occur.

5. References

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