Hypocenter Relocation of September 28, 2018 Palu-Donggala Earthquake Aftershocks and 1-D Seismic Velocity Model of Palu-Koro Fault System

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Abstract

An update of the local 1-D seismic velocity model and the relocation of the hypocenter of the aftershocks of the M7.4 earthquake, September 28, 2018 around the Palu-Koro fault has been done. A total of 415 aftershocks events were used in this study with 5,626 P waves and 836 S waves recorded at 29 BMKG seismograph stations. Relocation using the VELEST algorithm (Kissling, 1995) with initial seismic velocity input in the form of a 1-D model which is a combination of Koulakov et al (2007) for shallow depth (less than 24 km) and the global seismic velocity model AK135 (Kenneth et al., 1995) for depths of more than 24 km. The results of aftershock hypocenter relocation at the Palu-Donggala earthquakes showed better results marked by a hypocenter distribution pattern that was closer to the geological conditions of the Palu-Koro fault. Other results, the local seismic velocity model for the Palu-Koro fault area and its surroundings are expected to be suitable for use in further studies around the Palu-Koro fault.

Background

On September 28, 2018 at 18.02.44 local time (10.02.44 UTC) a tectonic earthquake occur with magnitude M7.7 and after that updated to magnitude M7.4 with the epicenter position at coordinates 0.20 S - 119.89 E at the direction of 25 km Northeast of Donggala, Central Sulawesi, Indonesia. (**www.inatews.bmkg.go.id**).

The cause of these earthquakes is suspected to have been triggered by the release of energy from the Palu-Koro fault (figure 1), an active sinistral strike-slip fault and located extending around the city of Palu **(Katili, 1978**). This was concluded from the distribution of the aftershocks that formed the epicenter distribution pattern around the Palu-Koro fault location, based on epicenter position data obtained at the BMKG website.

BMKG earthquake parameter data itself is preliminary data in determining the epicenter and hypocenter position of the earthquake. The inversion process to obtain position parameter (epicenter and hypocenter) uses the IASPEI91 global seismic velocity model (**Kennett, 1991**). This was done to obtain results in a short time for the purposes of rapid earthquake information and tsunami early warning.

The global seismic velocity model is well used to obtain preliminary parameters, but it is not necessarily appropriate for tectonic conditions with regional or local characteristic such as in local faults in land. Local seismic velocity models are needed in the study area to obtain more precise hypocenter and epicenter positions.

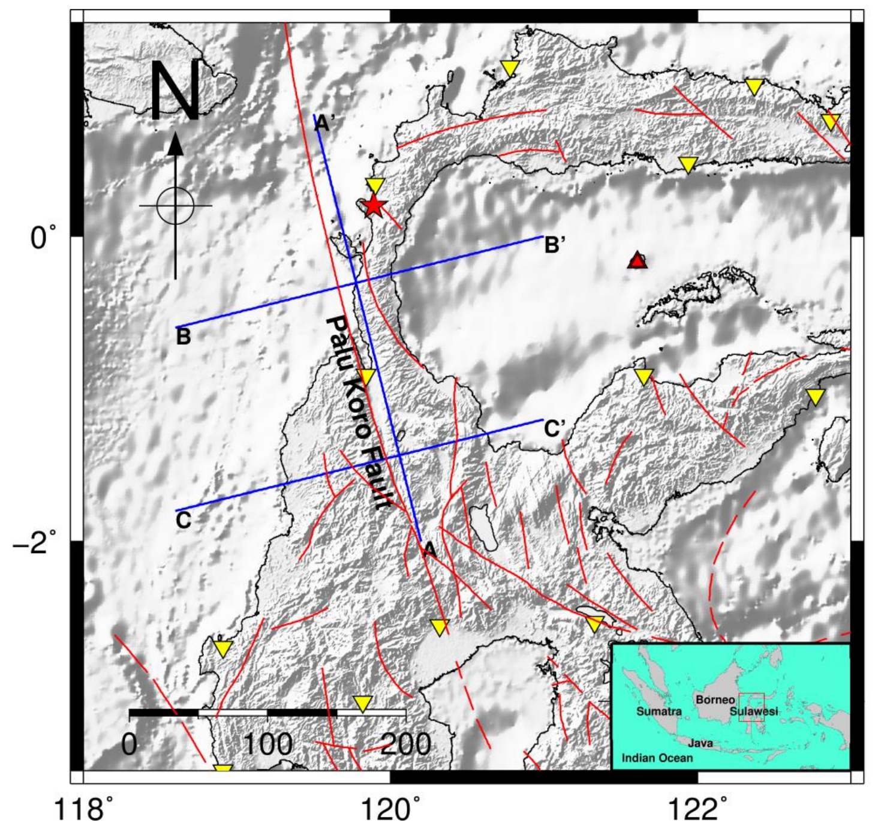

Figure 1. Palu-Koro Fault System

Study Aims
This study aims to obtain a 1-D local seismic velocity model around the Palu-Koro fault and conduct hypocenter relocation to obtain a more accurate hypocenter position that can be used in the future in the Palu-Koro Fault seismotectonic study and other studies.

Reference

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Koulakov, I., Bohm, M., Asch, G., Luhr, B-G., Manzanares, A., Brotopuspito, K. S., Fauzi, Purbawinata. M. A., Puspito, N. T., Ratdomopurbo, A., Kopp, H., Rabbel, W. dan Shevkunova, E., (2007) : P- and S velocity structure of the crust and the upper mantle beneath central Java from local tomography inversion. J. Geophys. Res., 112, B08310, doi:10.1029/2006JB004712.

https://www.globalcmt.org/CMTsearch.html

https://www.inatews.bmkg.go.id

Data and Method

The research area is around the Palu-Koro fault, data period September 28, 2018 - December 12, 2018 (figure 2).

The number of earthquake events that were used was 415 events, consisting of 5,626 phases of P-wave arrival time, and 836 phases of S-wave arrival time.

Hypocenter relocation using the VELEST algorithm (**Kissling 1995**), inversion finished at the seventh iteration after getting the most optimum results (Figure 3).

The initial seismic velocity model used is **Koulakov et al (2007**) for shallow depths up to 24 km combined with the AK135 global seismic velocity model (**Kennett et al, 1995**).

A total of 29 BMKG seismograph stations were used in this study.

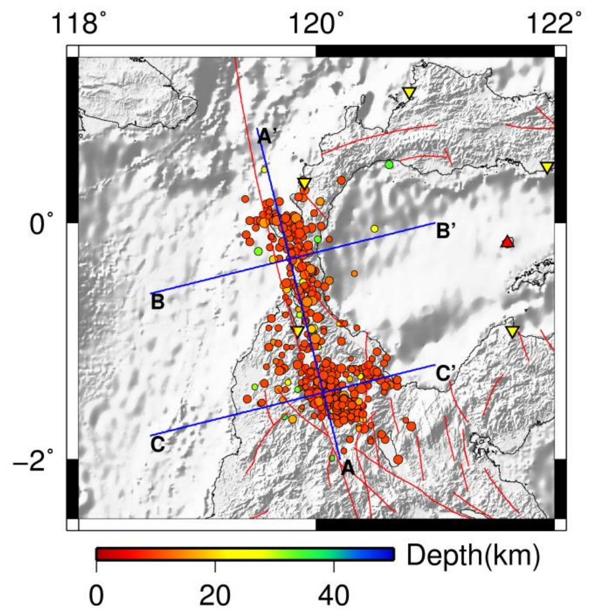


Figure 2. Epicenter distribution

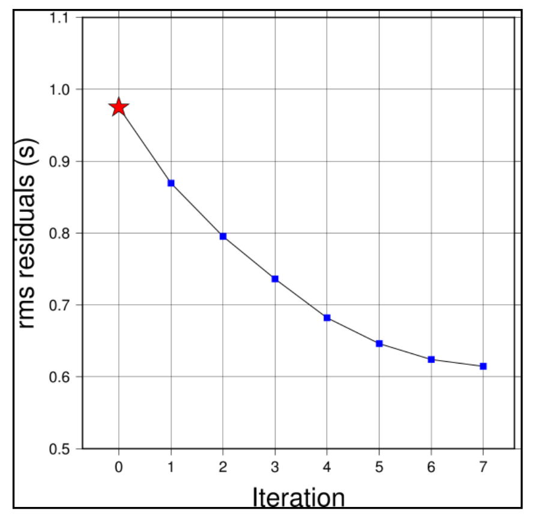


Figure 3. Iteration vs RMS Residuals Curve

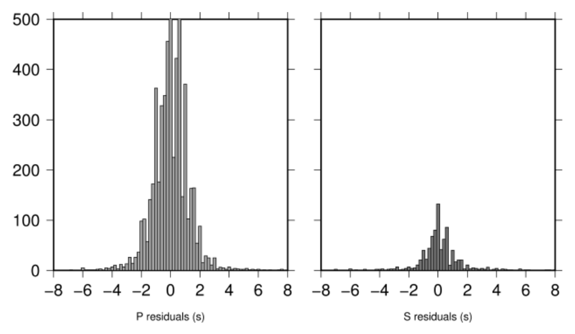


Figure 4. Travel time residual before Relocation

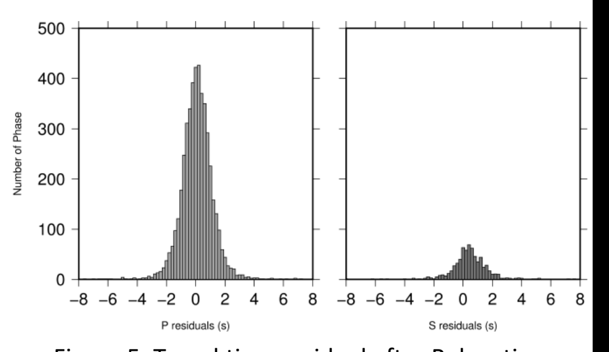


Figure 5. Travel time residual after Relocation

Result and Disscussion

Hypocenter Relocation

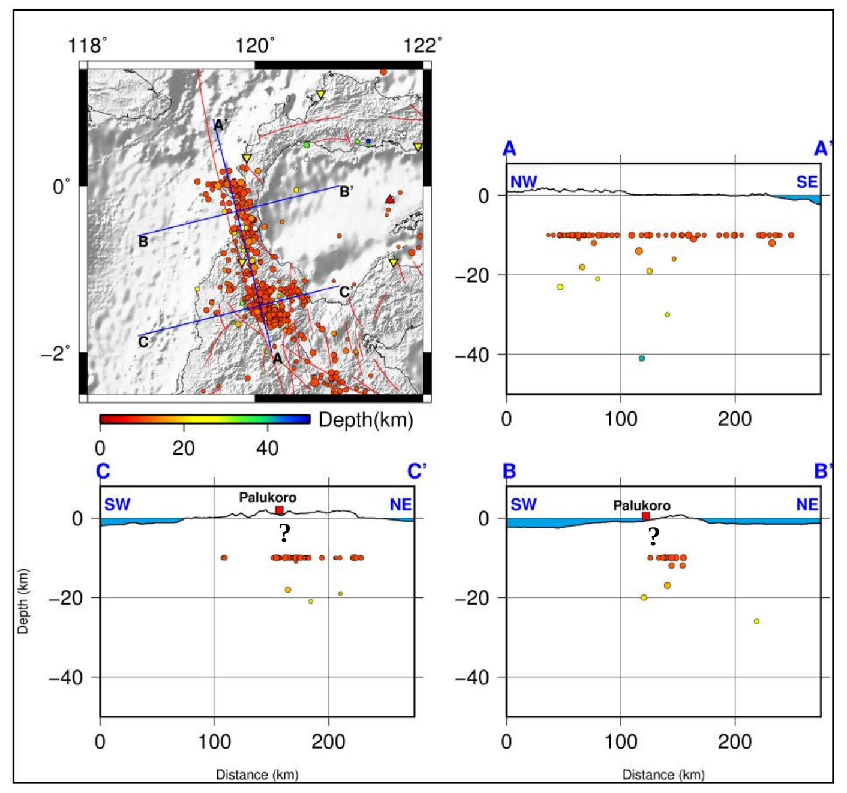


Figure 8. Hypocenter before relocation

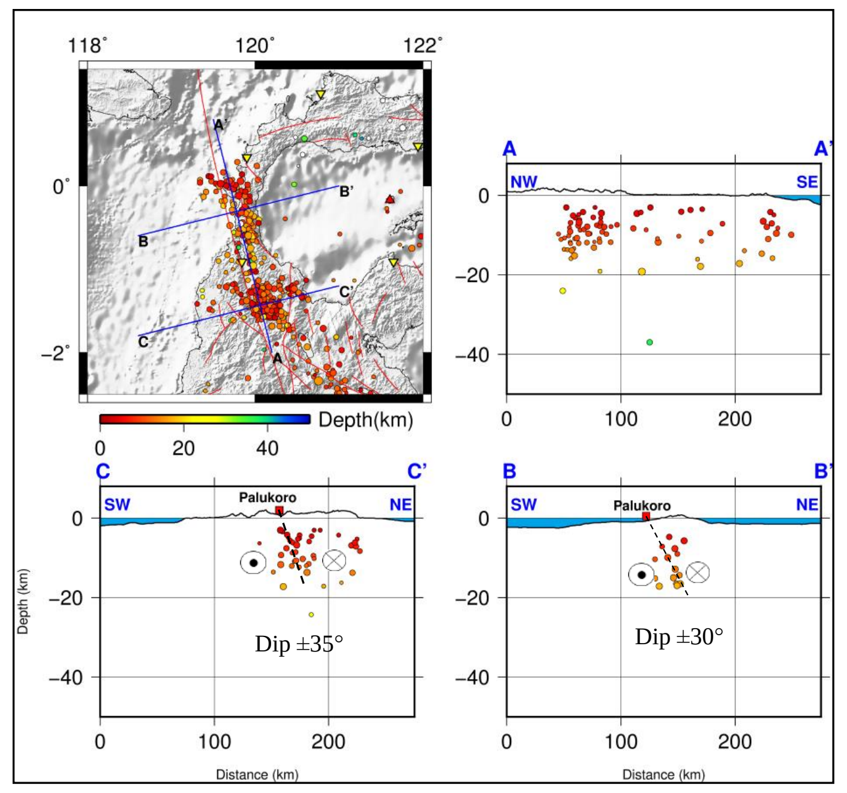
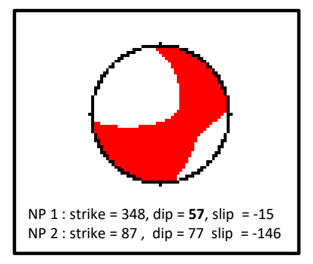


Figure 9. Hypocenter after relocation

The position of the epicenter before being relocated using BMKG preliminary data (figure 8) shows the scattered epicenter distribution. The hypocenter position before relocation is mostly at a depth of 10 km. This shows that the use of the global seismic velocity model produces the minimum optimum solution and shows the IASPEI91 global seismic velocity model is not very appropriate to determine the position of shallow hypocenter in the Palu-Koro fault area.

The results of relocation using an updated 1-D seismic velocity model for the Palu-Koro fault area in this study (figure 9) resulted in a more concentrated epicenter distribution around the Palu-Koro fault zone zone. Significant changes were seen in the hypocenter in which the hypocenter distribution formed a certain dip pattern (± 30°-35°). This is not quite approaching the results of the moment tensor of mainshock event September 28, 2018 (M7.4) which shows a dip value of 57° (**https://www.globalcmt.org/CMTsearch.html**) as can be seen in figure 11. But the point is, the dip orientation between the Mainshock and the aftershocks pattern has a same direction (tend to east-northeast). The majority hypocenter distribution is not is at a depth of 10 km again like before the relocation process.



NP 1 : strike = 348, dip = **57**, slip = -15
NP 2 : strike = 87 , dip = 77 slip = -146

Figure 11. Moment Tensor Solution for mainshock event (M..7.4) September 28, 2018 (**https://www.globalcmt.org/CMTsearch.html**)

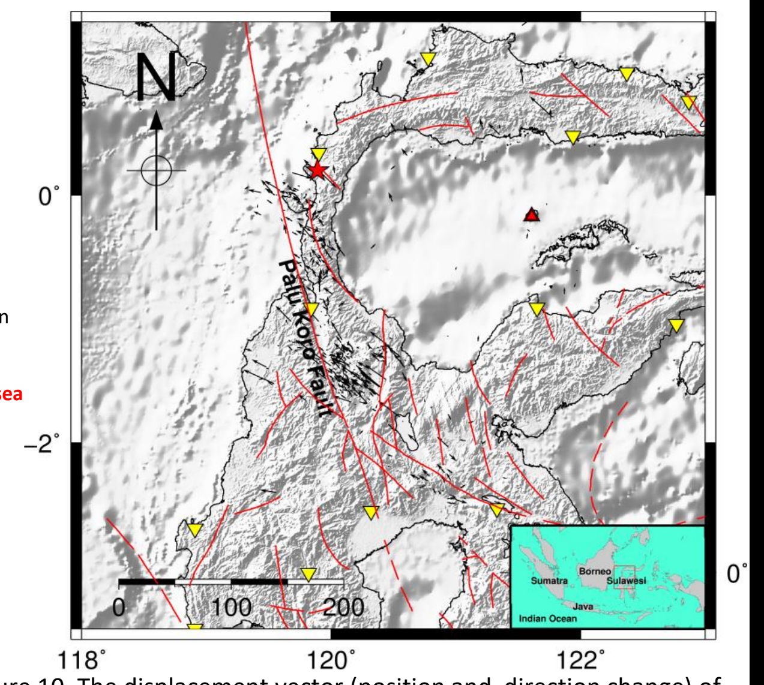


Figure 10. The displacement vector (position and direction change) of the epicenter position (before relocation and after relocation)

Result and Disscussion

Updated Seismic Velocity Model

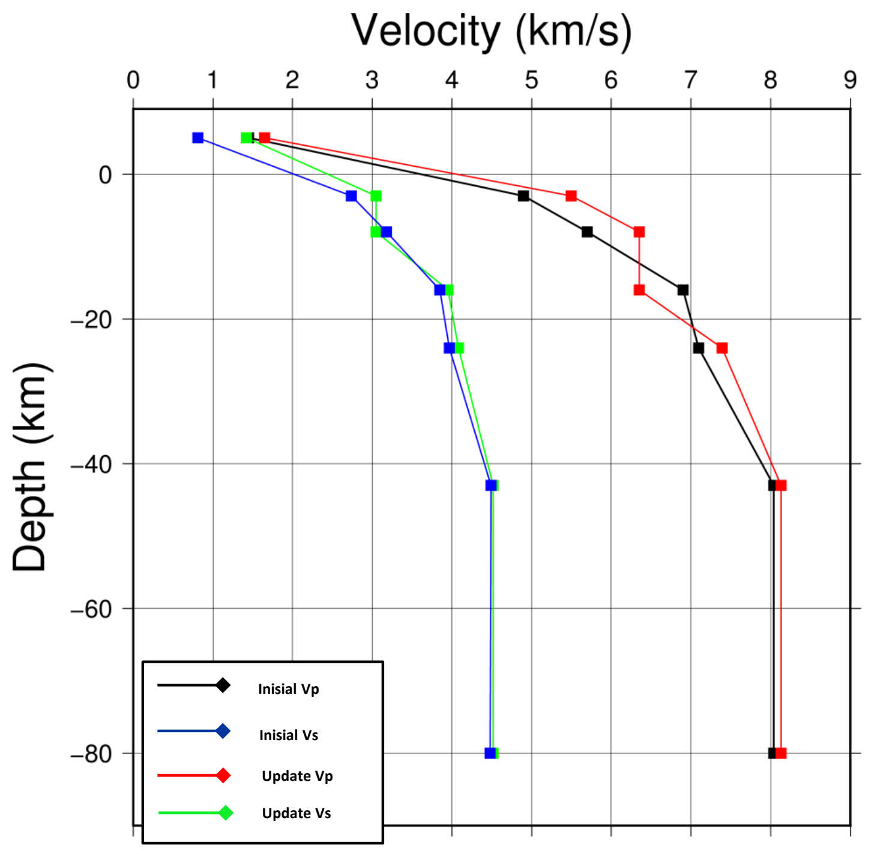


Figure 6. Initial and updated seismic velocity model

Table 1. Final seismic velocity model of Palu-Koro Fault from this study

Depth (km)	P-Wave Velocity (km/s)	S-Wave Velocity (km/s)
-5.0	1.65	1.42
3.0	5.50	3.05
8.0	6.35	3.05
16.0	6.35	3.95
24.0	7.39	4.08
43.0	8.13	4.52
80.0	8.13	4.52

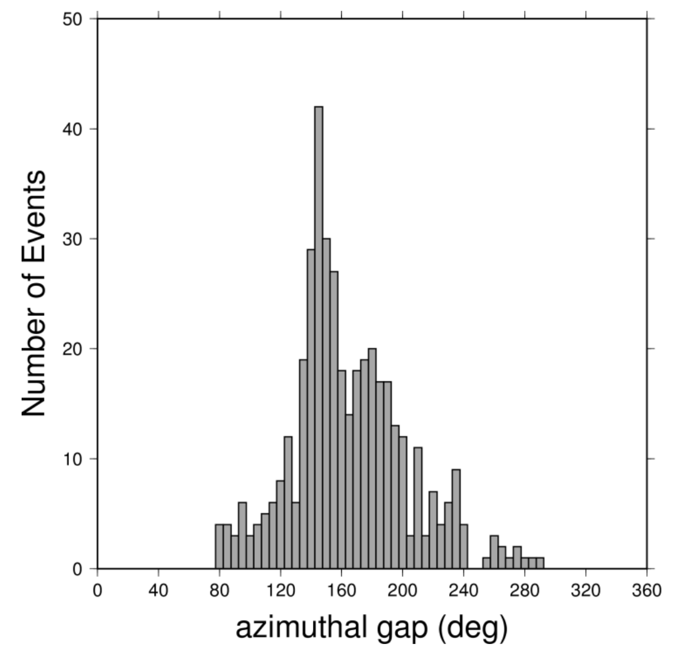


Figure 7. Azimuth Gap per-event

The latest 1-D seismic velocity model has been produced for the area around the Palu-Koro Fault system (figure 6, Table 1).

changes in the value of the total residual travel time can be seen in figure 4 (before relocation) and figure 5 (after relocation). It can be seen in the diagram that after relocation the residual travel time value decreases and the distribution approaches near zero, showing that the 1-D seismic velocity model used is approaching real subsurface conditions.

The Azimuth Gap histogram (figure 7) shows the azimuth gap distribution after relocation. The distribution of the azimuth gap values of all events, majority ranging from 80 - 240. This shows that the earthquake azimuth gap in this study was better after it was relocated.

The displacement vector (figure 10) shows the farthest displacement (position and direction change) of the epicenter position (before relocation and after relocation) is ± 36.98 km and the closest displacement epicenter position is ± 256 meters. Average epicenter displacement is ± 5.87 km. From figure 10 it can be seen that the displacement of the epicenter position tends to move towards the Palu-Koro fault line.

Conclusion

Aftershocks hypocenter relocation of the Palu-Donggala earthquake showed better results marked by the hypocenter distribution pattern that is closer to the geological conditions of the Palu-Koro fault.

A local seismic velocity model for the Palu-Koro fault area and its surroundings has been obtained and is expected to be suitable for use in further studies around the Palu-Koro fault