Mapping of active major faults in the Mamasa and surrounding areas using satellite gravity data and topographic features

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Abstract. The mapping of active faults in Indonesia, especially in areas near the city center is very important to determine the building code. Mamasa Regency, West Sulawesi is one of the areas that have active faults, has not been mapped well in the 2017 seismic hazard book, which is a guidebook in creating building codes in Indonesia. A total of 762 earthquakes occurred in this area from November to December 2018. This study aims to map active faults associated with the source of these earthquakes. TOPEX satellite gravity data were processed to obtain the Complete Bouguer Anomaly. The residual and regional gravity values were separated using a Gaussian filter to identify the lineation of the fault and the existing fracture zone. The multiscale second vertical derivative was also implemented to identify and characterize the fault. Topographic contour mapping was carried out to confirm the presence of fault on the surface as well as to observe the direction of fault movement. We used seven focal mechanism data from Global CMT to support the interpretation result of gravity and topographic data. The result, the main fault is a sinistral strike-slip fault with N164E strike orientation. This strike-slip fault has two sides. The movement of the strike-slip fault on these two sides causes a pull-apart which results in normal faults in the pull zone between the two faults.

Keywords: TOPEX, gravity, topography, fault map

1. Introduction
Seismic hazard mapping needs to use data on the mechanism of fault movement, whether normal fault, reverse fault, or strike-slip fault. Mamasa Regency is one of the areas that has not been mapped for local fault seismic hazard [1]. Whereas at the end of 2018, this area occurred a series of shallow tectonic earthquakes originating from local faults in the area, with the smallest magnitude of M 2.0 and the largest magnitude M 5.5 (figure 1). Gravity data is one of the easily interpreted data to model the fault movements of local faults in this area. The Second Vertical Derivative of Gravity Data is ordinarily used in Indonesia to map fault areas and to determine fault mechanisms [2, 3]. Two-dimensional and three-dimensional modeling can strengthen the hypothesis of the SVD results. As for the supporting data, focal mechanism analysis is usually used from earthquakes that have occurred in the area [3].
We used Topex gravity and topography data to obtain Complete Bouguer Anomaly (CBA) [4, 5]. The fault dip was acquired from Multi-Scale Second Vertical Derivative (MS-SVD) and two-dimensional modeling of CBA. Meanwhile, the fault strike was observed from topographic data. We also interpreted the fault movement and confirmed the gravity and topography results, from focal mechanism data. This study is expected to support the seismic hazard mapping in Mamasa.

2. Data and method
Free Air Anomaly data and topographic data were the initial data for fault modeling. Two corrections were made, particularly Bouguer correction using the slope of parasnis graph [6], and terrain correction using SRTM data [7]. The regional anomaly was separated from CBA data using a low pass filter type Gaussian filter. Furthermore, we modeled the two-dimensional density map from the incision of the regional anomaly map.

The MS-SVD method is the multi-height of upward continuation and SVD data. We used the 500-meter interval from 0 to 10000 m. Then SVD was performed with Elkins filter [8]. The point that has 0 value the location of the fault. The elevation of upward continuation assumed to be correlated with the depth of the gravity anomaly. From the fault shift in terms of various height upward continuation, the trend of the fault dip angle was obtained.

3. Results and discussion
The dominant density value in the Mamasa area and its surroundings that were inferred from parasnis graph is of 2.192 gr/cm³. The geological map informed that the dominant rock in the Mamasa region and its surroundings is the batholite intrusion of granite rocks (figure 2) [9]. However, the direct observation in Mamasa area revealed that the topsoil dominant was broken granite. Remarkably, the value of 2.192 gr/cm³ is representative because it is the average density value of solid granite and broken granite. This gravity modeling area has an area of 138.78 km².

![Figure 1. Earthquake Seismicity in November-December 2018. The red circles are earthquakes, black triangles are the seismic station, the yellow square is the Mamasa government headquarters.](image-url)
Figure 3a shows the CBA contour after the Bouguer and terrain correction. The CBA contour is overlaid with seven focal mechanism data from the Mamasa earthquake series [10]. There are two types of earthquake focal mechanisms that performed in this place. The normal focal mechanism between the strike-slip focal mechanism implies that there is graben in the middle of the fault. This is thought to be related to the low gravity anomaly zone which is a characteristic of the existence of a basin. The faulting mechanism that is common to these characteristics is the pull-apart fault mechanism. Pull-apart is a mechanism that is common in strike-slip faults. The fault dip was identified by MS-SVD in the AB line.

In the CBA data, low pass filtering was performed with a standard deviation of 0.04402 to obtain regional anomaly (figure 3b). Two-dimensional modeling of a CD line was used to confirm the presence of the fault and as a comparison of the dip value of MS-SVD, because the CD line is adjacent to the AB line.

**Figure 2.** Two-dimensional layer modeling of CBA regional data. The type of red layer is a layer of granite, while the purple layer is a layer of the Latimojong Formation. Determination of this type of layer is based on incision data geological maps.

Figure 3a shows the complete Bouguer anomaly with focal mechanism and MS-SVD slicing, and (b) regional anomaly map with two-dimensional model slicing.
Figure 4 shows the results of SVD line at various upward continuation CBA heights. There are 7 faults seen in this line. The fault in the dotted red box is a zone where the location of the seismicity of the Mamasa earthquake occurs. There are two faults facing each other which usually occur in the graben zone. The formation of the graben is shown by the movement of the blue line in figure 4.

This result is also supported by the results of the CBA contour interpretation and the focal mechanism mentioned before. This fault has a dip angle of 56 to 79 degrees.

In the modeling of two dimensions for CD line, there is a graben zone (figure 4). This is consistent with the MS-SVD results which also show the presence of grabens in the Mamasa area.

Another important fault parameter besides the dip is strike. Figure 5 shows the strike fault value observed from topographic data. However, in the three-dimensional topographic contour, it cannot be obtained that there are two strike-slip fault systems in this area. It is assumed that these two faults have
the same dominant strike of N164E. Sinistral movement is shown by the movement of topographic features that are quite identical. The western feature of the red line moves to the southeast relative to the eastern feature of the red line.

4. Conclusion
The main fault in the Mamasa Region that has been derived from earthquake focal mechanism analysis, gravity analysis, and the topographic feature is the sinistral strike-slip fault with N164E strike orientation and dip angle 56–79 degree. This strike-slip fault has two sides. This has the main contribution to cause earthquake series in November and December 2018. The movement of the strike-slip fault on these two sides causes a pull-apart which results in normal faults in the pull zone between the two faults.

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