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The gravity data observation of the Cimandiri fault zone, West Java, Indonesia

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Abstract. One of the important faults in Java Islands, Indonesia is the Cimandiri fault zone. It is said the fault has the potential to generate a large earthquake in the near future. Therefore, for mitigating the risk because of the sudden earthquake around the fault in the future and understanding the character of the fault, the investigation around the fault has been applied by using the gravity method. There were 42 gravity sites which deployed in the surrounding of the fault and acquired by using a gravimeter. All necessary corrections such as tidal, instrument drift, latitude, free-air, Bouguer, topographical corrections have been applied. The results presented that the higher amplitude of the residual gravity anomalies values relates to some mountains zone in the study area. It is possibly associated with the volcanic rocks in these areas. In addition, the low amplitude of the residual gravity anomalies is associated with the location of the Cimandiri fault zone and some low elevation areas, which is possibly caused by the existence of the sedimentary products in these areas.

1. Introduction

Since Indonesia is a meeting point of several active tectonic plates in the world, the tectonic setting of Indonesia is very complex. The plates comprise of Eurasia, Australian, Indian, Sunda, Caroline, Philippine Sea, and Pacific Plates. The result of the interaction between the Indian and Australian Plates, which move toward the northeast at a rate of about 50-80 mm/year relative to the Eurasian Plate, is the Sunda arc [1].

As regional preliminary screening tools, we apply the gravity method in this study. The analysis of gravity data has two distinct aspects: qualitative and quantitative. The qualitative process is largely map-based and dominates the early stages of a study. Qualitative gravity interpretation can be defined as the creative integration of data distributions or gravity anomaly fields with geology and physics. Whereas, the locations, depths, shapes and density contrasts of geological bodies are to be defined as accurately as possible in quantitative gravity interpretation [2]. In this study, our focus is the qualitative gravity interpretation.

The area of this study is the Cimandiri fault zone (from now on, CFZ). It is the boundary between the Bandung zone and the southern mountain [3, 4]. It is located on the eastward of the transitional zone between the frontal subduction of Java and the oblique subduction of Sumatra [5]. This fault zone extends from the Gulf of Pelabuhan Ratu to Bandung area through populated cities such as
Pelabuhan Ratu, Sukabumi, and Bandung. It is said the CFZ has the potential to generate a large earthquake in the near future. Therefore, to understand the characteristic of the fault and mitigate the risk because of the sudden earthquake around the fault in the future, the investigation around the fault has been carried out by applying the gravity method in this paper.

2. Regional Geological Setting
A morphological and structural study in West Java has first conducted by the previous study [3]. The results indicate that there are four distinct morphological and structural units in West Java: (1) the northern coastal plain of West Java, (2) the folded mountains of Bogor, (3) the Bandung zone, which mostly covered by recent volcanic products, and (4) the southern mountain of West Java. The CFZ is a boundary between the Bandung zone and the southern mountains, located along the Cimandiri River and mostly covered by recent volcanic products [3-5, 7]. It runs SW-NE, from Pelabuhan Ratu to Padalarang near Bandung. The length of the CFZ is about 100 km. During this time, the northern part of West Java acted as a magmatic arc while the Bandung-Cimandiri zones and the southern mountains were forearc and trench regions, respectively. The actual direction of the CFZ is an inheritance of the trend of this subduction zone. Numerous faults and folds can be observed near the CFZ [7]. The CFZ has the geological strike of N70-80°E and the horizontal displacement of 0.5-1.7 cm/yr on the surface [5, 6]. Some moderate-magnitude earthquakes also have occurred along the CFZ [3, 4, 6, 8, 9]

3. Data Observation and Methods
Figures 1 shows the topographic map of the 42 gravity sites. The gravity data were acquired by using a gravimeter CG-5 produced by Scintrex Autograv with the precision of 1 microGal. The interpretation of the gravity anomaly has some procedures which consist of many special techniques and depend on the analysis goals and the data-set quality [10]. In this study, all necessary corrections such as tidal, instrument drift, latitude, free-air, Bouguer, topographical corrections have been applied to the measured gravity data to obtain complete Bouguer data [e.g. 11, 12]. Free air and Bouguer corrections
were calculated using the International Association of Geodesy 1967 formula. The average density of 1.9 g/cm² was calculated by the Parasnis method [13]. Topographic corrections were calculated using the Hammer method over the topographic DEM map that has a maximal image with a raster resolution of 90 m. The complete Bouguer anomaly map was drawn by using the gridding method of Kriging and its grid spacing 1460 m.

In order to determine the gravity anomalies associated with the sources of our interest, the separation of a regional-residual of Bouguer anomaly was applied. There are several methods can be applied, from the more empirical to the more analytic ones [see, e.g. 11]. The moving average method was used to separate the deep and shallow effects. In this computing, an 18 km × 18 km window is used.

In this study, we also used the WGM2012 gravity anomalies as the model and compared it with the calculated Bouguer anomaly. The model is obtained by applying a spherical harmonic approach which using theoretical developments on the Earth global gravity models (EGM2008 and DTU10) and the 1°×1° resolution terrain corrections from ETOPO1 model [14].

4. Results and Discussion

Figures 2 (a) and (b) show the calculated Bouguer anomaly map and that of the WGM2012 model in the study region, respectively. From these figures, it is found that the Bouguer anomalies vary from 90 to 270 mGal. Meanwhile, the Bouguer anomalies of the WGM2012 model vary between 100 and 400 mGal. Both present the similar tendency: the Bouguer anomalies generally decrease toward the Bandung-Cimandiri zone, and the highest anomaly values remain in the southern mountains. In addition, the calculated Bouguer anomaly also shows that the location of the CFZ is between the high and low values of the Bouguer anomaly, as presented in figure 2 (a).

The presence of deep and large structures in the study area can generate the regional trend on the Bouguer anomaly. These effects in the gravity field are the large wavelength anomalies. It can cover the effect of smaller and more superficial ones on the gravity data. Therefore, we need to calculate the residual gravity anomaly. It is calculated by the reducing regional gravity field from the Bouguer gravity field. The anomalies indicate a clear gravity contrast in the study area. The maps of regional and residual anomalies are given in figures 3 (a) and (b), respectively. The values of regional anomalies vary from 90 to 270 mGal. They vary between -24 and 40 mGal, as presented in figure 3 (b). The higher amplitude (> 1 mGal) of the residual gravity anomalies relates to some mountains zone in the study area such as Mt. Halimun, Mt. Pangrango, Mt. Talaga, Mt. Kendeng, and Mt. Tangkuban Perahu. It is possibly caused by the existence of the volcanic rocks in those mountains. The volcanic rocks can produce the higher amplitude of the anomalies [15].

The low amplitude (< 0 mGal) of the residual gravity anomalies are demonstrated by some areas such as Pelabuhan Ratu area, Sukabumi area Cirata Dam and Bandung area. It is possibly caused by the geological condition of these areas, which is dominated by the fluvial to shallow marine sediments also outcrop in this zone [3-5, 7]. The sedimentary products contribute to the amplitude decrease of the residual gravity anomalies [15]. The low amplitude anomaly is also presented by the CFZ location which marked by the black-line border in figure 3 (b). Topographically, the CFZ is located along the Cimandiri River and mostly covered by the sedimentary volcanic products (alluvial) [3-5, 7]. The same characteristic is also presented by some gravity studies in the fault zone which covered by the sedimentary products [e.g. 15, 16]. These results confirm that the residual gravity anomalies present the clear gravity contrast which could be regarded as the indicator to determine the effects of geological sources in the study area.
Figure 2. (a) The calculated Bouguer anomalies map from the observed data. The red squares indicate the gravity observation sites and the CFZ location is presented by the black lines. (b) The Bouguer gravity anomalies map of the WGM2012 model. The black-line border indicates the location of the CFZ.
5. Conclusions
In order to know the characteristic of the Cimandiri fault zone, West Java, Indonesia more detail, the 42 gravity sites investigation by using a gravimeter CG-5 produced by Scintrex Autograv has been conducted. All corrections which are needed by the gravity data have been applied. The results present that there are the clear positive (higher) and negative (low) residual gravity anomalies. The higher amplitude of the residual gravity anomalies is possibly associated with some volcanic rocks in some mountains in the study area. The low amplitude of the residual gravity anomalies relates to the location of the Cimandiri fault zone and some low elevation area such as Pelabuhan Ratu, Sukabumi and Bandung area. It possibly happens since these areas are covered by sedimentary products.
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