Preliminary Gravity Study of Pre-Tertiary and Tertiary Rock in Northern Kebumen, Central Java, Indonesia.

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Abstract. Luk Ulo Melange Complex is a Pre-Tertiary rock formation consisting of various lithological background and complicated geological structure. Located in Northern Kebumen Regency, this rock is originally interpreted as products of tectonic process caused by paleo-subduction between Indian Oceanic Plate beneath Eurasian Plate in Cretaceous age. According to previous study on geological surface investigation shows that the melange complex is tectonically overlain by Tertiary sedimentary formation. On the contrary, geophysical study of the subsurface condition of the area is still under discussion due to limited of measured data. In order to obtain detailed subsurface image, gravity profiling was measured and interpreted across both Tertiary and pre-Tertiary rock. Frequency domain filter and designed moving average filter were used to separate residual and regional anomaly. The results denote gravity value of residual anomaly varying from -5 to +5 mGal, while regional anomaly is ranging from 150-180 mGal respectively. The preliminary interpretation was developed by taking into account the geological information and also the data that was collected during field campaign. Overall, high gravity anomaly is interpreted as diabase intrusion in the middle of research area. Meanwhile, low gravity anomaly indicated clay rich rock material related to matrix content of Luk-Ulo Melange Complex in the northern area.

Keywords: Gravity, Kebumen, Luk Ulo, Melang, interpretations

1. Introduction

The outcrop of pre-Tertiary rock only exposed in three different locations in Java Island, Indonesia and one of them is in Karangsambung area, Northern Kebumen. The pre-Tertiary rock is a geological evidence of tectonic evolution occurred in the Cretaceous Age, especially the shifting of subduction zone of Indo-Australian oceanic plate beneath Eurasian plate in the southern part of Sundaland from trend of NE-SW into E-W present trend [1–4]. This research area has interesting geological setting, because pre-Tertiary melange complex and Tertiary sedimentary rock formation exist in the area. According to geological study, melange complex is tectonically overlain by Tertiary sedimentary rock formation [5]. Nonetheless, due to the limit of geological data in the surface, the interpretation of subsurface structure is still questionable. Therefore, a comprehensive geophysical research needs to be conducted in order to support subsurface geological data.
Several gravity and magnetic research had been carried out in the area [6–8]. Based on gravity and magnetic modelling [6], it had been had generally interpreted the Melange Complex in the Northern Kebumen is a composition of rocks as a product of paleo-subduction process in Cretaceous Age. However, the data qualities, in term of data resolution and quantities are still not enough to get detailed interpretation due to limitation of data acquisition. Most of the previous geophysical study in the research area only cover regional background. Hence, a higher resolution data is required to produce better subsurface model.

In addition, gravity measurement and modelling has been proven to be one of powerful geophysical method to model the subsurface geological structure. The research [6] showed that density forward modelling can be correlated to each average formation density in the subsurface to make an appropriate geological model. The purpose of this research is to obtain a higher resolution of gravity data across both pre-Tertiary and Tertiary rock in Northern Kebumen and also to interpret the result according to geological information.

2. Geological Setting

Based on [9], physiography of Central Java can be distinguished into six sections including South Serayu Mountains where the study area is involved. In general, there are two type of structural pattern in the main area. The northern part in which cover mostly of Luk-Ulo Melange Complex has structural pattern with trending of ENE-WSW [5,10]. Meanwhile in the southern part, the structural pattern mostly elongated to E-W.

![Geological Map of Kebumen and Banjarnegara](image)

**Figure 1.** Geological Map of Kebumen [11] and Banjarnegeara [12]. Luk Ulo Melange complex consist of various rock embedded such as gabbro, greywacke, schist, phylite, basalt, chert, and limestone in sheared shale matrix.

It has been already confirmed from geological information that the basement in this area is related to Luk-Ulo Melange complex [13]. The result of radiolarian fossil dating found in chert and siliceous
shale, the age of this melange complex is ranging from Early-Late Cretaceous [14]. These melange blocks consist of various rock embedded in the sheared shale matrix. Totogan and Karangsambung Formation, Eocene-Oligocene formation, tectonically overlie the mélange complex. These two formations are an alisostromal deposit which comprise sedimentary mixture of various fragment and block (olistolit) in sheared clay matrix [13]. Waturanda Formation conformably overlie Totogan and Karangsambung Formation. This formation mostly consists of volcanic breccia and sandstone which is estimated to be deposited in Early Miocene. Waturanda Formation is conformably overlain by Penosogan formation consisting of Marl and calcareous sandstone[13].

3. Methodology

3.1. Gravity Data Acquisition

In order to achieve the purpose of this study, data acquisition is designed to have appropriate station-spacing and cover both pre-Tertiary and Tertiary formation from south toward north of research area (Figure 1). A total of 116 data were measured on January 2018 along main profile, with mean stations spacing of 150m. Measurement had been done using Scintrex CG-5 Autograv Gravimeter. This gravimeter has an accuracy data resolution of approximately 1µgal. The position of each station and the elevation were measured using handheld GPS and altimeter. In order to obtain true elevation, the height that was measured using altimeter is corrected and tied to adjacent vertical geodetic benchmark. All instruments are calibrated using standard procedure in the beginning of survey for best performance. The gravity measurement adopted looping method to reduce instrument drift effect. The gravity data were tied to gravity base station which is located in LIPI Campus Karangsambung. For each gravity station, at least three data were measured with maximum approximately 10µgal error. The terrain observation of surrounding inner zone area of 10m, 50m and 75m away from the station were recorded. Near surface density of 2.48 g/cm³ was estimated using Parasnis method and then applied for terrain and Bouguer correction. Overall, standard gravity correction was done in order to obtain Bouguer anomaly.

3.2. Gravity Data Processing

For further data processing, the power spectrum of observed gravity anomaly is calculated by Fast Fourier Transform and plotted in frequency domain against logarithm power spectrum. Piece-wise linearization is used to obtain gradient of the fitting data and to estimate the cut off frequency that was used in data filtering. Figure 2 shows the result of these processes.

![Power Spectrum Analysis](image)

**Figure 2.** Power spectrum density of observed data. Piece-wise linearization method is used to analyze and calculate the cut off of regional-residual data in spectrum analysis. The wave-number (0.001) cut-off is obtained (orange dashed line).
The depth estimation of the regional anomaly, residual anomaly and noise are 3460.2 m, 167.29-525.78 m and 43 m, respectively. The low-pass/high-pass and moving average filter were used in order to perform regional-residual anomaly separation. The smoothing process of residual anomaly also was performed to get rid of the noise. The frequency and the wavelength cut-off of each filter can be derived from spectrum analysis. The result of filtered anomaly is analyzed and interpreted with geological information as the constraint.

4. Result and Discussion
The result of Bouguer anomaly of observed gravity data is in Figure 3. Overall, the Bouguer anomaly from south to north of the study varying from 66.84-100.46 mGal. Since we are working on shallow to intermediate gravity anomaly, the Bouguer anomaly should be filtered in order to separate residual and regional anomaly. As discussed before, based on spectrum analysis, wave number cut off of k=0.001 between residual and regional anomaly is obtained. The response of each applied filter in Bouguer anomaly is shown in Figure 4.

![Figure 3. Section of Bouguer Anomaly in the research area.](image)

The value of gravity anomaly resulting from moving average and low-pass filter seems to be comparable varying from +4.51 to -5.06 mGal and +4.16 to -3.54 mGal, respectively. However, in term of gravity respond concerning surface density variation, both of them are able to show positive gravity anomaly based on the presence of high density of diabase and negative anomaly in respect to low density of Karangsambung Formation. In order to make it easy to analyze, low-pass filtering is applied to get rid the noise of the residual anomaly. Meanwhile, there is not any significant difference in the regional anomaly resulting from both filters. The value of regional anomaly is varying from 65-101 mGal.

The preliminary interpretation was conducted by taking into account the geological information [10,11,13,15] and also the data that was collected during field campaign. It is interesting to note that the anomaly of the northern area which mostly cover Luk-Ulo Melange complex shows low gravity value compared to southern part. This might be related to the lithological background of Luk-Ulo Mélange Complex which was related to the proportional content of low density sheared shale matrix [13]. This result is currently in contradiction with previous regional study of gravity anomaly in Kebumen [6] that shows high gravity anomaly in the northern part. Therefore, another geophysical approach should be involved to confirm this idea. High gravity anomaly is distributed in the middle part of the section which where the diabase intrusion is exposed in the surface [15]. Unfortunately, there is not any depth datum to confirm these interpretations. Therefore, further study should be conducted to reduce the ambiguity.
Figure 4. The result after applying frequency domain filter and moving average filter on Bouguer anomaly. Applying low-pass filter on residual anomaly is used to generate free noise residual anomaly (mid). Red highlight is high gravity respond of diabase intrusion and green highlight is low gravity respond of Karangsambung Formation dominated by sheared shale.

5. Conclusion
The preliminary result shows that the low gravity anomaly is located in the northern area which mostly cover Luk-Ulo Melange Complex. This low gravity respond might be related to the lithological background of Luk-Ulo Mélange Complex that correspond to the proportional content of low density sheared shale matrix. Meanwhile, the high gravity anomaly is distributed in the middle section and interpreted as the respond of diabase intrusion.

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