Identification of coal layer using gravity method in Lam Apeng Aceh Besar

D Darisma¹, L Hakim¹, Marwan¹, ²,*
¹Department of Geophysical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Darussalam, Banda Aceh, 2311, Indonesia
²Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Darussalam, Banda Aceh, 2311, Indonesia

Abstract. Aceh has a coal potential of around 450 million tonnes. One of the areas identified as having coal potential is Lam Apeng, Aceh Besar. In this study, the gravity method is used to model coal layers that are different from other layers based on rock density. The data used are 99 points with a space of 50 m and a coverage area of 450x450 m. From the results of the data corrected to become a complete anomaly Bouger (CBA), it was obtained a trend with a higher gravity value towards the northeast and the lower towards the southwest of the study area. CBA data are filtered using the moving average technique to obtain regional anomalies (associated with deep structures) and residual anomalies (associated with shallow structures). Regional anomalies and residual anomalies also show the same trend as CBA. Based on the 2D modeling results of the L-L 'section, there are three different rock layers, namely alluvium layer with density 2 gr/cm³, sandy tuff layer with density 2.3 gr/cm³, and coal layer. There are three coal layers with different density values, namely layer A with density 1.68 gr/cm³, slope 125°, and layer thickness 2-4 m; layer B with density 1.71 gr/cm³, slope ± 120°, and layer thickness 7-8 m; and layer C with density 1.7 gr/cm³, slope ± 120°, and thickness 4-6 m.

1. Introduction
The human population increases every year, causing the need for energy is also increase. These energy sources can be in the form of fossil fuels and coal. Indonesia has coal reserves of 161 billion tonnes, 53 percent of which are in Sumatra, and about 47 percent are in Kalimantan. There are several provinces in Sumatra that have large amounts of coal potential, such as South Sumatra, North Sumatra, and Aceh. Coal reserves in Aceh are predicted to be 450 million tonnes [1]. One area that has potential for coal reserves in Aceh is Lam Apeng, Aceh Besar District. However, the potential in this area has never been explored. For this reason, a geophysical survey is needed to map and model the coal layer in the area.

One of the geophysical methods that can be used to determine subsurface structures is the gravity method. The gravity method has been widely used to detect subsurface anomalies and geological structures [2–4]. The advantage of the gravity method is that it can describe the subsurface conditions of the earth based on differences in gravity acceleration. The differences in the gravity value can be related to fractures, rock porosity, crack density, and changes in fluid mass [5–7]. The gravity value collected in the field is then processed to obtain rock mass density, which can be interpreted to determine the subsurface structure related to the potential of coal in the research area. The coal layer is
physically characterized by a black color and a lighter mass or lower density. Therefore, coal on a gravity map should be easily recognized [8–10].

The physiography of Aceh Besar and its surroundings is arranged as a wavy alluvium land area to the coastal lowlands with a northwest-southeast direction and a higher topography to the south. This area is known as Krueng Aceh Basin [11]. The western part of Aceh Besar is bordered by the Sumatran fault known as the Aceh Fault or including the Krueng Aceh Fault Segment. This area is located at the foot of the Bukit Barisan complex which is composed of Tertiary and Pra-Tertiary rocks. In the eastern part, the Quaternary basin is bordered by hills composed of Plio-Pleistocene rocks originating from Seulawah Volcano. In this area, there is also a Seulimum fault that stretches in a northwest-southeast.

Lam Apeng is a research area located in Seulimeum Sub-district, Aceh Besar, Province of Aceh. Based on the regional geological map, the research location is covered by alluvium (Qh), which consists of mud, sand, gravel, tuff, with a wavy shape (Figure 1). In this area, there is also the Seulimeum Formation, which consists of tuffaceous sandstones, limestone, conglomerates, and mudstone [12].

![Figure 1. Geological map of Lam Apeng area (modified from [12]).](image-url)
2. Material and methods

In this study, data measurement was carried out directly using the Scintrex CG-5 Gravimeter. The measurement points are 96 points with a distance between points of 50 m, covering an area of 450 x 450 meters according to field conditions (Figure 2). After the measurement, data correction is needed to remove noise and regional anomaly effects. The first correction is drift and tidal correction. Drift correction is performed to eliminate the effect of tool fatigue, while the tidal correction is to remove the effects of gravity from the Moon. Besides, latitude correction was also performed using the International Association of Geodesy 1967 equation.

The measured gravity data is generally not on the geoid, so it needs to be corrected for elevation, namely free air and Bouguer correction. Free air correction ignores the mass effect that may exist between the elevation at the measurement point and the sea level, whereas Bouger correction considers the mass. The last correction is terrain correction to remove topographic effects around the measurement area. All of the aforementioned corrections are done to obtain CBA data [14], [15].

Bouger anomaly is a combination of regional anomalies associated with deep structures and residual anomalies associated with shallow structures. The two anomalies must be separated to make it easier to interpret. Some of the regional anomaly separation methods were tested using the second polynomial, upward and downward continuation approach, but the results were almost the same as CBA. In this study, the anomaly separation technique used is moving average [16].

The separated residual anomaly data is then modeled using Grav2DC. The modeling results are in the form of a 2D subsurface rock density cross-sectional image, which shows the information on rock density, measurement line distance, and depth [17], [18]. The CBA value is interpreted with the geological conditions of the study area to conclude where the coal distribution is located in Lam Apeng area.

![Figure 2. Map of gravity measurement sites in Lam Apeng.](image-url)
3. Results and discussion

Field data that has been corrected into CBA data were then plotted onto the map as shown in Figure 3. The CBA values in this area range from 120-129 mGal. Areas with high anomaly values are located in the northwest of the study area, while areas with low anomalies are located in the southwest of the study area. Data with high anomalies are associated with high densities and vice versa. Because the CBA data is still influenced by regional and local components, the data was separated into regional and residual data to make it easier to interpret.

The residual data filtering process was carried out using the moving average technique. This technique separates data with a high frequency, which is considered to represent the gravity response of relatively shallow layers. The results of filtering CBA data into regional and residual anomalies can be seen in Figure 4 and Figure 5. In Figure 4, the highest regional anomaly is located in the northeast of the study area, and the lowest is in the southwest area. It is estimated that the rocks in the northeast area are more compact than the southwest area. The low and high anomaly trends are also almost the same when compared to the residual anomaly map (Figure 5). It is predicted that the rocks in the northeast area of the study area are more compact and older than the southwest area.

The difference in results between the distribution of regional anomaly density and the distribution of residual anomaly density shows a contrasting difference. One of these differences can be seen in the anomaly, which is located in the northwest. This anomaly does not exist in the regional anomaly, which indicates that the response is a local anomaly.

At the outcrop point in the regional anomaly map, the anomaly showing low density as a coal layer does not exist. This is because the coal is at a shallow depth, as shown in Figure 6. On the residual anomaly map, the location of the coal outcrop has a low density with a value of -1.5 to 1 mGal, which is located in the southwest of the study area. Based on the analysis of coal content, the variation in coal density has a value between 1.2 gr/cm$^3$ and 1.8 gr/cm$^3$ [19].

![Figure 3. Map of Complete Bouguer Anomaly Lam Apeng.](image)
Furthermore, the 2D model line A-A of the study area was modeled with GRAV2DC (Figure 5). Forward modeling was performed to predict the density of each rock layer. Through this technique, field measurement profiles are matched against the model's gravity response profile. The process continues until it is deemed fit for the geological conditions, and the error is getting smaller. This
modeling uses the Talwani principle, which creates a 2D model based on the polygon approach [20]. The model line determination was selected from the residual anomaly map with the aim that the resulting model is a local anomaly.

Figure 6 shows the results of forward modeling of the gravity anomaly, where the dotted line represents the residual anomaly, and the continuous black line represents the model. The misfit obtained was 3.08. The rock density value is determined based on the type of rock in the geological map of the study area. The 2D model in Figure 6 was then sketched out, as shown in Figure 7. There are three different layers, namely alluvium layer, coal layer, and sandy tufa layer. Along the surface layer is covered by an alluvium layer consisting of soil, gravel, and sand. This layer is estimated to have a thickness of 4 to 5 m. In some measurement areas, there is a layer of sandy tufa. This layer is estimated to have a density of 2.0 gr/cm$^3$.

![Figure 6. Two-dimensional gravity model line L-L'](image)

![Figure 7. Sketch of the gravity model](image)

Based on the results of the interpretation, there are three coal layers, namely coal layer A, coal layer B, and coal layer C (Figure 6). These three coal layers are classified as sub-bituminous coal.
Sub-bituminous is a sediment that has a moderate temperature, but this precipitate can be used for combustion. The characteristic of sub-bituminous deposits is that they contain wax and have a black color [21]. The coal layer A is exposed to the surface, which is at a distance of 150 m from the starting point of the data and at a depth of 4.5 m. This coal layer is estimated to have a slope of ± 125° with a layer thickness of 2-4 m and a density of 1.68 gr/m³. The coal layer B is estimated to be at a distance of 300 m from the starting point of the data with a slope of ± 120° and a layer thickness of 7-8 m and a density of 1.71 gr/m³. The C coal layer is estimated to be at a distance of 440 m from the starting point of the data with a slope of ± 120° and a layer thickness of 4-6 m and a density of 1.7 gr/m³.

The last layer is a sandy tuff layer, which is directly adjacent to coal and alluvium. This layer is estimated to be 5 to 220 m deep. This layer is arranged according to the shape of the surface topography, resulting in this layer sedimentation following its slope. The sandy tuff layer has a density of 2.3 gr/cm³.

4. Conclusion
This study presents an analysis of gravity data to identify the coal layer in Lam Apeng area, Aceh Besar District. The gravity data in this area shows a trend that is getting higher to the northeast of the study area and lower to the southwest. At a location with a coal outcrop, the residual anomaly is low with a value around -1.5 mGal. The reason is that coal has a soft compacting rate compared to the surrounding environment. Based on 2D modeling of the L-L’ section, there are three different layers in this area, namely alluvium layer (2 gr/cm³), coal, and sandy tuff (2.3 gr/cm³). There are 3 coal layers with different density values, namely layer A with a density 1.68 gr/cm³, a slope ± 125° and a thickness 2-4 m; layer B with a density 1.71 gr/cm³, a slope ± 120°, and a thickness 7-8 m; and layer C with a density 1.7 gr/cm³, a slope of ± 120°, and a thickness 4-6 m.

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