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2D Geological Structure Modeling of the Jabungan Area Based on Magnetics Method

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ABSTRACT

Magnetic secondary data processing from 30 measurement data had been carried out in Jabungan. This study gets a structural model of Jabungan subsurface using gradient analysis and 2D modeling. Initial processing performed on daily variation correction and IGFR (International Geomagnetic Reference Field) to get anomaly contour of total magnetic field. The next process is upward continuation to obtain local anomaly contour and regional anomaly with conducting reduction process to the poles to get magnetic anomaly pattern which is singular pole. We analyzed the local anomaly with gradient analysis and 2D modeling. The result of this gradient analysis showed fault structure in the northwest-southeast Jabungan and matched with a geological map of the research area. Profile sampling was carried out from contour result second vertical gradient such as cross section against the estimated fault area and process it into a graphic to decide the fault types. The graphic analysis result showed that the existence of normal fault. The 2D modeling result revealed the rocks types in Jabungan comprise sandstones, gravels, marls, tuffs, and clay stones.

Keywords: Jabungan field, magnetics, gradien analysis, normal fault, 2D modeling

1. INTRODUCTION

Jabungan Village, which is located in Banyumanik District, is one of the areas in Semarang City with steep land conditions and has several structures that look like descending faults, ascending faults, folds, and other structures based on the Magelang-Semarang Geological map sheet. Jabungan Village, which has a hilly topography and winding roads, has a population of 3,009 people[1]. Banyumanik District is classified as an area that is very prone to landslides, with the Jabungan Village included in it. This is also reinforced by validation based on landslide events in 2012 there were 50 landslide events and Jabungan was included in the fairly vulnerable class[2].

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The Downward faults were found in the northwest – southeast direction based on 3D modeling. In his research, Hidayah processed his magnetic data with a reduction filter to the poles, spectrum analysis, and anomaly separation using moving averages[5]. Then using the microtremor method, the soil shift strain in Jabungan Village is clarified as 1.8 x 10^{-2} to 4.8 x 10^{-2} which indicates a potential landslide area[6]. Based on previous research, this research was conducted using magnetic data processed with a reduction filter to the poles, upward continuation, and gradient analysis which was then modeled using 2D modeling to see the subsurface structure of Jabungan further. It is hoped that this research can complement previous research in the same coverage area, namely Jabungan and add information to the study of the Jabungan area as an area prone to landslides.

2. MATERIALS AND METHODS

2.1. The Magnetic Force

Magnetic force is a force that arises from the relationship between two magnetic poles at a certain distance. If each magnetic pole has a different direction it will form a force that attracts each other. And if each magnetic pole has the same direction then a force will be formed that repel each other. Likened to two objects or magnetic poles separated at a distance r with a charge of m_1 and m_2, respectively, then the magnetic force ($\vec{F}$) produced is as shown in equation (1):

$$F = \frac{1}{\mu} \frac{m_1 m_2}{r^2} \hat{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where is μ represent the magnetic permeability indicating the properties of a medium, $\vec{F}$ is the magnetic force, and $\hat{r}$ is the unit vector directed from m_1 to m_2 [7].

2.2. Magnetic Field

The strength of magnetic field ($\vec{H}$) is a measure of the magnitude of the magnetic field at a point in space that appears due to the force between the poles that are far from the point. The strength of the magnetic field is referred to as the magnetic force per unit magnetic pole as shown in equation (2):

$$\vec{H} = \frac{\vec{F}}{m'} = \frac{m}{\mu r^2} \hat{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where $\hat{r}$ is the distance of the measurement point from m. It is assumed that m' is greater than m, so that m' does not cause disturbance to the field $\vec{H}$ at the measurement point. The SI unit of magnetic field $\vec{H}$ is Ampere/meter (A/m), while in cgs it is dyne/pole unit [8].

2.3. Forward Modelling

Forward modeling is modeling carried out to obtain theoretical data in the field obtained from certain subsurface model parameter values. This concept is used to interpret geophysical data. If the response of a model matches the data, the model used to obtain the response can represent the subsurface conditions where the data is being measured [9].

Forward modeling can be done by making anomalous objects, namely with certain geometries and magnetic values. To get the suitability of the data from the results between the theoretical (model response) and field data, it can be done by trial and error process by changing the values of the model parameters.

2.4. Horizontal gradient

This horizontal gradient emphasizes the high anomaly contained in the magnetic data, because the maximum value indicates the lateral density of the contrast identified as fault. Horizontal Gradient is divided into two stages, namely First Horizontal Gradient (FHG) and Second Horizontal Gradient (SHG). The magnitude of the First Horizontal Gradient (x,y) is defined [9] the equation (3):

$$FHG\ H_{(x,y)} = \sqrt{\left(\frac{\partial H_{(x,y)}}{\partial x}\right)^2 \left(\frac{\partial H_{(x,y)}}{\partial y}\right)^2} \quad \ldots\ldots\ldots\ldots (3)$$

for the second horizontal gradient (x,y) is defined as the equation (4):

$$SHG\ H_{(x,y)} = \sqrt{\left(\frac{\partial^2 H_{(x,y)}}{\partial x^2}\right)^2 \left(\frac{\partial^2 H_{(x,y)}}{\partial y^2}\right)^2} \quad \ldots\ldots\ldots\ldots (4)$$

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where H represent the total magnetic field anomaly value, ∂x is the x-axis gradient value and ∂y is the y-axis gradient value.

3. RESULTS AND DISCUSSION

3.1 Magnetic Field Anomaly

The secondary magnetic data that has been obtained are then corrected to obtain the total magnetic field anomaly value. The correction includes diurnal correction to eliminate the influence of the extraterrestrial magnetic field due to solar activity and time differences. Then the IGRF (International Geomagnetic Reference Field) correction is carried out to eliminate the main magnetic field of the earth at the measurement location.

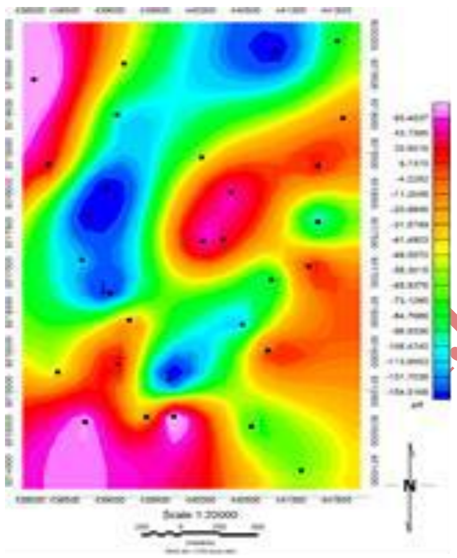

Fig. 1: Contour map of the total magnetic field anomaly. The black dot indicates the measurement location.

According to the contour map of the total magnetic field anomaly (Fig. 1), it can be seen that there are positive and negative closures, so that the total magnetic field anomaly is two-pole (dipole). The highest value of magnetic field anomaly is shown in red to pink with a value range of 6.737 nT to 60.404 nT. The lowest magnetic field anomaly value is shown in light blue to dark blue with a value range of -106.474 nT to -154.517 nT..

The total magnetic field anomaly which is still two poles is then processed with a reduction filter to the poles. Reduction to the poles is a magnetic data processing filter to eliminate the influence of two poles due to inclination and declination angles, so that a monopole magnetic field anomaly map is obtained (monopole). This filter serves to localize the magnetic field anomaly in the research area so that it is above the source of the anomaly.

The results of the reduction to the poles are shown in Fig. 2. On the contour map of the anomaly, the highest magnetic field anomaly is shown in red to pink with a value range of 12,938 nT to 64,222 nT. The lowest magnetic field anomaly value is shown in light blue to dark blue with a value range of -113.346 nT to -166.342 nT.

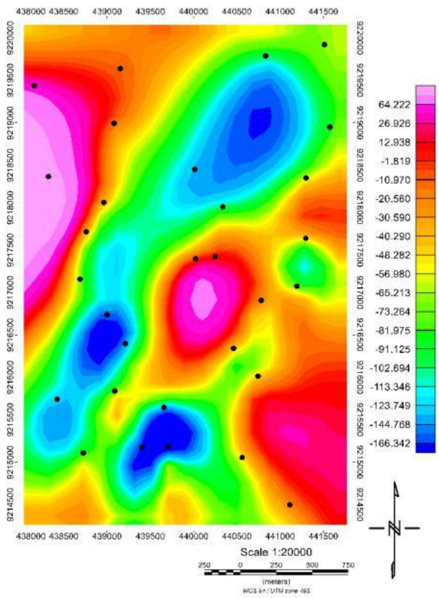

Fig.2: Contour map of the total magnetic field anomaly after being reduced to the poles.

3.2 Upward Continuation

Upward continuity is used to separate shallow local (residual) anomalies from deep regional anomalies. Upward continuation is performed on the total magnetic field anomaly map (Fig.3) that has been processed using a reduction filter to the poles.

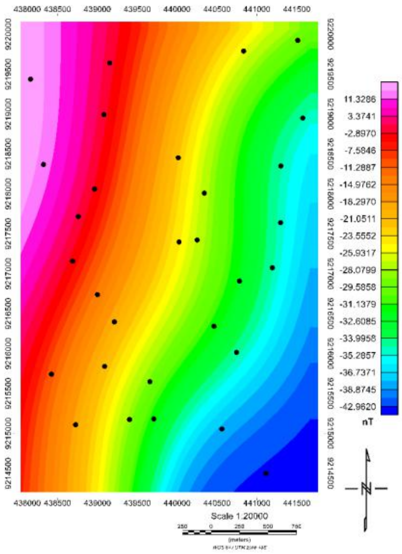

Fig.3: Contour map of the total magnetic field anomaly after continuous upwards with a lift of 2000 meters. The black dot indicates the measurement location

The upward continuation process is carried out by trial and error to see the pattern of changes in the magnetic anomaly contour at each altitude variation. Trial and error tests were carried out at an altitude of 500 meters, 1000 meters, 1500 meters, and 2000 meters. The contour map of the results of the upward continuation (Fig. 4) in the regional area. The elevation at an altitude of 2000 meters was chosen because the results of the upward continuation contour have shown a fairly good separation between local anomalies and regional anomalies.

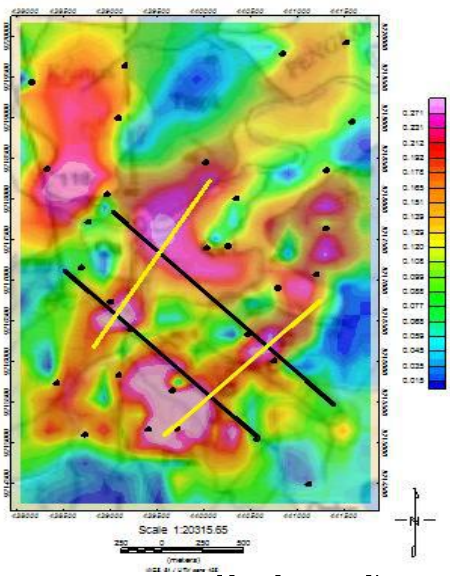

Fig. 4: Contour map of local anomalies.

In this study, a local anomaly map was used for qualitative and quantitative interpretation as shown in Figure 4. Local anomalies were obtained from the result of subtracting the total magnetic field anomaly value with regional anomaly values derived from the contour map of the anomaly from the upward continuation.

3.3. Model of the horizontal gradient

The horizontal gradient contour is obtained from the local anomaly contour map which is processed using Laplace equation derivation about the x-axis and y-axis. The results of these calculations are in the form of the first horizontal gradient contour and the second horizontal gradient contour.

The geological structure analysis in the *Jabungan* area was carried out based on information from the *Magelang-Semarang* geological map sheet as supporting data for the approximate location of the fault. The geological map is overlaid on the first horizontal gradient contour map and the second horizontal gradient contour map to compare the fault location with the results of the horizontal gradient analysis. On the *Magelang-Semarang* geological map sheet, there are two parallel fault patterns located on the border of the *Kerek* Formation and the *Kalibeng* Formation.

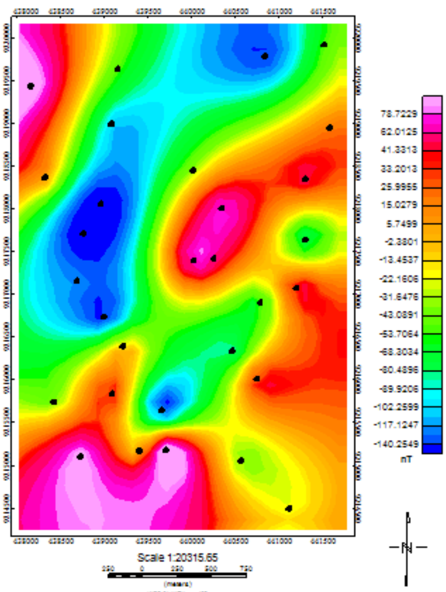

Fig. 5: Contour map of the first horizontal gradient. The black line indicates the location of the fault. The yellow line shows the maximum value of the horizontal gradient.

The first horizontal gradient map (Fig.5) contains horizontal gradient values with a value range of 0.015 nT to 0.271 nT. The highest magnetic field anomaly which is the maximum value of the horizontal gradient is shown in red to pink with a value range of 0.192 nT to 0.271 nT.

The second horizontal gradient map shown in Figure 6 contains horizontal gradient values with values ranging from 0.000004 nT to 0.00144 nT. The highest magnetic field anomaly which is the maximum value of the horizontal gradient is shown in red to pink with a value range of 0.00059 nT to 0.00144 nT.

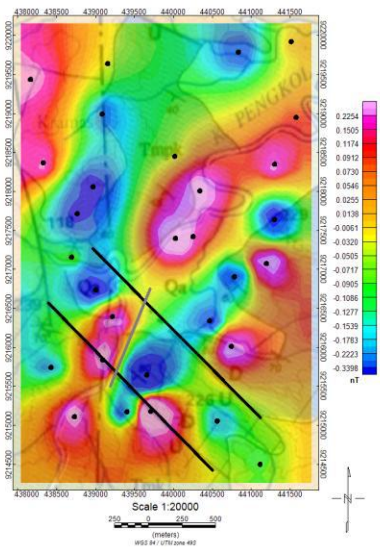

Fig. 6: Second horizontal gradient contour map. The black line indicates the location of the fault. The white line shows the maximum value of the horizontal gradient.

On the horizontal contour map, this gradient (fig.6) shows the fault structure which is from northwest to southeast. The fault in Jabungan is correlated with the maximum anomaly value of the horizontal gradient which is suspected to be a fault. This indicates that the fault in Jabungan is structurally controlled.

3.4. Model of the vertical gradient

The vertical gradient describes the presence of geological structures in the form of faults or rock contact boundaries with zero or neutral anomalous responses. The vertical gradient contour is obtained from the local anomaly contour map which is processed using Laplace equation derivation about the z-axis. The results of these calculations are in the form of the first vertical gradient contour and the second vertical gradient contour.

The geological map of the Magelang-Semarang sheet was overlaid on the first vertical gradient contour map and the second vertical gradient contour map to compare the fault location with the results of vertical gradient analysis. In the first vertical gradient map (Fig.7), there are vertical gradient values with values ranging from -0.3398 nT to 0.2254 nT.

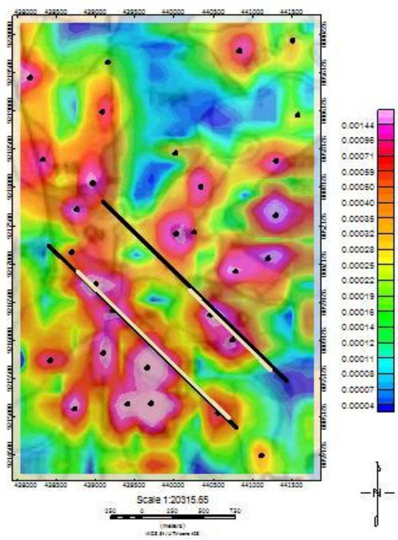

Fig.7: Contour map of the first vertical gradient. The black line indicates the location of the fault. The gray line shows the zero value of the vertical gradient

Then on the second vertical gradient map there are vertical gradient values with a value range of -0.00179 nT to 0.00186 nT. The zero value shown in the yellow contour can identify the presence of rock contacts and faults.

On this vertical gradient contour map, it shows the fault structure which is from northwest to southeast. The faults in Jabungan are correlated with the zero anomaly value of the vertical gradient which is indicated as a fault. This indicates that the fault in Jabungan is structurally controlled.

In the contour of this second vertical gradient, it is necessary to take a sample of the profile resulting from the second vertical gradient in the form of a cross section of the area that is estimated to have faults to conduct fault type analysis. There is an incision on the fault, namely the O-O' (Fig.8).

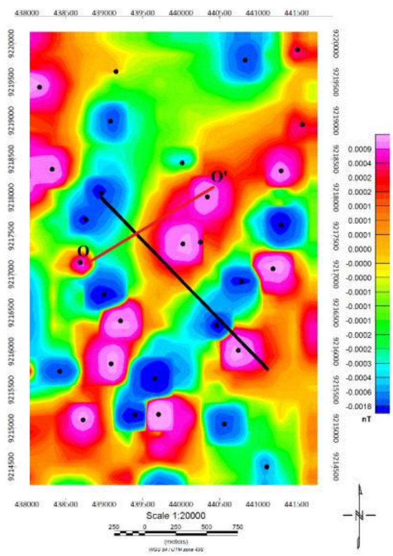

Fig.8: Cross section of the fault location through the yellow contour which shows the zero value of the vertical gradient

From these incisions, an analysis is then carried out to determine the type of fault that is displayed in graphical form. The graph of the incision results on the second vertical gradient contour map (Fig.9).

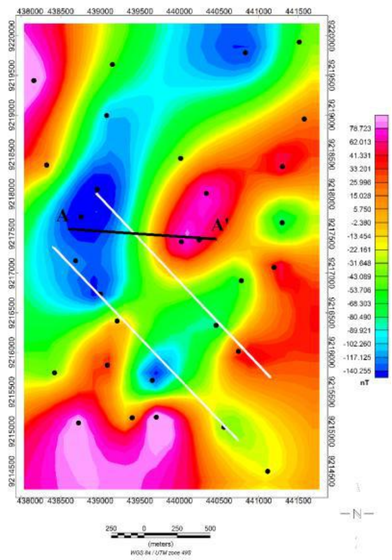

Fig. 9: Cross section of the O-O' incision

The distribution of the anomaly values can be seen from the sample profile resulting from the second vertical gradient (Figure 9). The O-O' incision has anomalous values ranging from 0.00014 nT to 0.0013 nT. From the graph it can be seen that the value of the second verticalmax is greater than the value of the second verticalmin which means that in the incision area it is indicated that there is a downward fault.

3.5. Magnetic Field Anomaly Modeling

In this study, 2D modeling was carried out to determine the subsurface structure of the research area. The process of making a 2D model begins by entering parameter values in the form of values of inclination, declination, and magnetic intensity using Oasis Montaj software. Making this model requires a review of the stratigraphic map and geological map of the study area.

The first step in creating a 2D model is to make an incision on the positive and negative closing pairs. This is done because the magnetic method is dipole (two poles). This incision is made on the residual (local) magnetic field anomaly map (Fig.10). On the residual magnetic field anomaly map there is an A-A' incision. The location of this incision is based on information on the fault area contained in the geological map of the research area.

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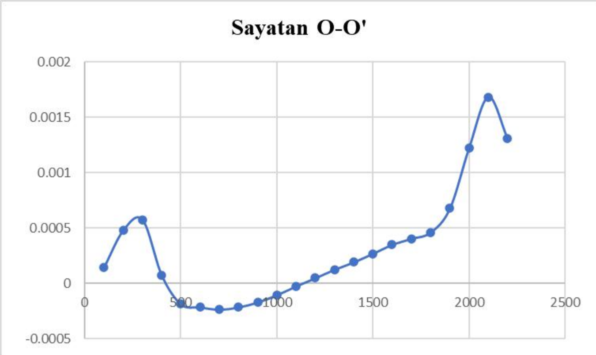

Fig.10: The incision on the residual anomaly map of the Jabungan area. The white line is the location of the fault. The black line is a modeling incision

The results of the A-A' incision which is trending from southwest to northeast carried out on the residual magnetic field anomaly map, obtained 2D modeling results (Fig.11).

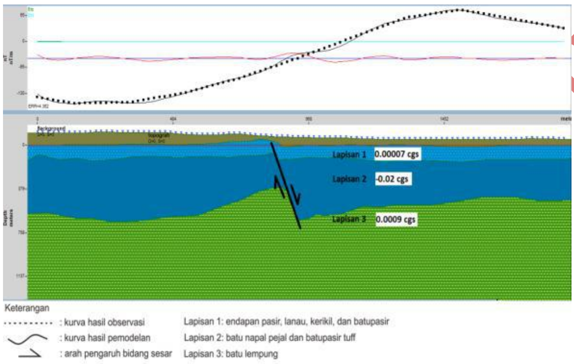

Fig.11: Results of subsurface 2D modeling from the A-A' incision

In the 2D modeling results from the A-A' incision with an incision length of 1882 meters and a depth of up to 1500 meters, there are three rock layers with different susceptibility values. The first layer was identified as sand, silt, gravel, and sandstone deposits with a susceptibility value of 0.00007 cgs. This layer is at a depth of 5 meters to 105 meters. The carrier material for this layer is estimated to be in Alluvium (Qa) deposits of Holocene age. Then the second layer was identified as solid marl and tuff sandstone which is a sedimentary rock with a susceptibility value of -0.02 cgs. This layer is at a depth of 105 meters to 900 meters. The carrier material for this layer is thought to be in the Kalibeng Formation (Tmpk) which is of Pliocene tertiary age. Then the third layer was identified as claystone which is a sedimentary rock composed of clay minerals with a susceptibility value of 0.0009 cgs. This layer is at a depth of 300 meters to 1500 meters. The carrier material for this layer is estimated to be in the Kerek Formation (Tmk) which is tertiary in the Miocene age.

The 2D modeling shows that in the past there were rock formations that were fused, but because there were opposing forces, there were parts that were lifted up and parts that fell. It can be concluded that in this incision area there is a fault. Based on the geological map of the research area, this fault is trending from northwest to southeast and is indicated as a descending fault. The results of 2D modeling which indicate the presence of a descending fault are strengthened by the results of the gradient analysis, which on the graph the second verticalmax value is greater than the second verticalmin value.

The fault in the Jabungan study area which is indicated as a descending fault is in accordance with Hidayah's research on the interpretation of the Jabungan fault area using moving averages and 3D modeling which states that the appearance in the southwest direction is estimated to be a straight line based on the geological map, while in the east direction the sea there is a down fault [4].

Then according to geoelectric measurements in areas prone to landslides in Semarang City, Jabungan Village has the potential to have a landslide due to the presence of claystone [9]. This is consistent with the results of 2D modeling that there is a layer of claystone in the Kerek Formation (Tmk).

4. CONCLUSION

Based on the results of data processing and modeling, it can be concluded that in the Jabungan research area from the results of gradient analysis and graphs from the Second Vertical Gradient (SVD) profile, as well as from 2D modeling it can be seen the subsurface structure of the study area and the type of fault. In the A-A' section, it is identified that there is a descending fault structure trending northwest-southeast and passing through 3 rock formations, namely the Alluvium Formation (Qa), Kalibeng Formation (Tmpk), and Kerek Formation (Tmk).

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