APPLICATION OF UPWARD CONTINUATION FILTER FOR GEOMAGNETIC DATA INTERPRETATION IN GONDANG, BOJONEGORO AREA

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ABSTRACT

In the Gondang area, Bojonegoro, East Java, there were manifestations of hot springs and mud pools. This can be an indication of certain geological conditions. The description of these conditions can be done by measuring the geomagnetic method. A total geomagnetic anomaly has been generated through some geomagnetic values recorded in the region, which has been corrected using IGRF correction and diurnal correction. These steps were done to reduce external influences on the real value of the data. This research will use several variations of values in the Upward Continuation filter and one of them will be chosen to proceed as a model. Upward Continuation Filter is a process of transforming potential field data from a flat plane towards the higher plane. The purpose of this study is to compare the results of contour maps on several variations of the Upward Continuation value, to obtain the results of the separation of residual and regional anomalies using the Upward Continuation method, and to determine the value of the susceptibility distribution of inversion modeling in the Gondang region, Bojonegoro. Based on the results of data processing, it is known that the upward continuation value used is 100mdatum with a magnetic intensity value in the regional anomaly of 106.5 nT to 509.0. While the value of the residual anomaly is -232.1 nT to 159.4 nT. The 3D model was made using this residual anomaly which shows the low susceptibility distribution value in the range of -0.0298 to - 0.0135 SI around the manifestation area, whereas the high susceptibility value has a value range of 0.0114 to 0.0466 SI interpreted as rock intrusion. Rock intrusion occurs within the area around the manifestation of mud pools.

Keyword: Geomagnetic anomaly, susceptibility, upward continuation

Introduction

The geomagnetic method is one of the geophysical methods used to model subsurface conditions. Data measurement is expected to be able to show the actual geological conditions. In the case study of Gondang, Bojonegoro, East Java, the exemplified of hot springs and mud pools were manifested. This can be an indication of certain geological conditions (Khalil, 2016). This depiction can be seen through variations in the distribution of rock susceptibility namely, the ability to accept the magnetic properties of the earth's magnetic field. This research is expected to produce susceptibility distribution from 3D inversion modeling in Gondang, Bojonegoro. Previously, the geomagnetic method was successfully used to identify the susceptibility distribution (Maubana, W., et al, 2019)

The measurement will produce a total magnetic anomaly that can be separated into regional magnetic anomalies and residual magnetic anomalies. The usual separation method used is Upward Continuation. The separation with Upward Continuation has several reflection variations which are themain source in the interpretation of geomagnetic data, hence this is the reason why this study becomes interesting. Thus, this study also discusses the comparison of the results of several Continuation variations.

Geomagnetic data interpretation has been carried out to inversion modeling of the results of the separation of local regional anomalies with Upward Continuation conducted by Maubana et al (2019). The research succeeded in identifying the geothermal reservoir through geomagnetic data. Based on the succeed of several previous studies, the authors are interested in applying the Upward Continuation filter to interpret geomagnetic data in Gondang, Bojonegoro.

Geological Setting

This research area is located in Gondang, Bojonegoro, East Java. The physiography of the study area is the Kendeng Zone in the south, which consists of rough hills with steep slopes. According to Van Bemelen (1949), this zone is a limestone mountainrange in the northern part of Java Island which stretches from east to west. This research area is located above several formations. Based on the references from Rahardjo Wartono (2007), the stratigraphy formation of this research area starts from the oldest one, which called the Kerek Formation. This unique formation has its lithology in the form of repetition of interlocking claystone, marl, sandstone tuff sandstone, and sandstone tuff. This iteration shows a typical sedimentary structure known as graded bedding.

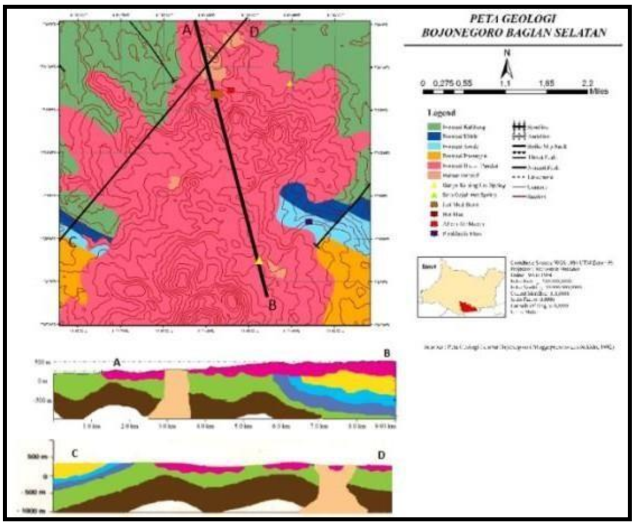

Figure 1. Peta Geological Map of Gondang (Bemellen, V., 1949)

Above the Kerek Formation, there is the Kalibeng Formation which consists of two divided parts, the top and the bottom. At the bottom, there are several thin layers of sandstone that are heading towards the western part of Kendeng which develops into a stream of sediment flow and identified as a member of the lot. The upper formation of the Kalibeng is referred to the Pliocene-age Sonde Formation which composed of Klitik Members located above the Sonde Formation. This formation consists of a yellowish-white calciteite lithology unit. The top formation is the Pucangan Formation which develops as volcanic facies and black clay facies. Its volcanic facies develop as lava deposits that hitch a ride above the Kalibeng Formation. In the study area, volcanic breccias located at the manifestation location were found in the Banyukuning and Jari hot spring pools. In the study area, there is rock intrusion which estimated to be a pyroxene andesite that cuts along the Kalibeng formation towards the volcanic breccia facies.

Methodology

Measurement of Magnetic Data

The data in this study were obtained through a process of data acquisition and retrieval carried out on September 2, 2019 to September 9, 2019 at 94 measurement points scattered in several villages in Gondang District, Bojonegoro with a GSM-19T Proton Magnetometer. The acquisition design used in this study is as follows:

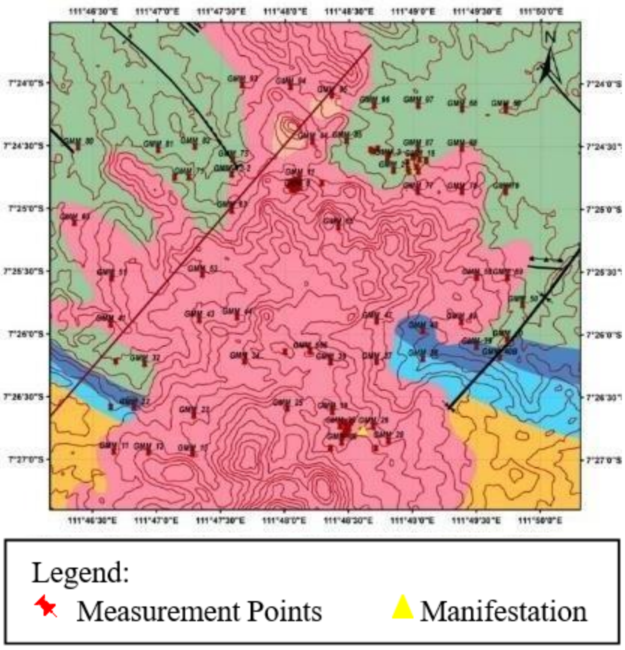

Figure 2. The measurement data point of the research in the study area

Magnetic Data Processing

The magnetic data that has been collected will be processed by correcting it first due to the many factors that affect the value of magnetic intensity. Corrections to be made are daily corrections and IGRF corrections (Utama, W., et al, 2016).

IGRF correction can be done automatically via the NOAA website or software such as Oasis Montaj. Meanwhile, the daily correction needs to be calculated by interpolating the intensity values that are on the base according to the time available on the rover or mobile device used (Lutfi, 2017).

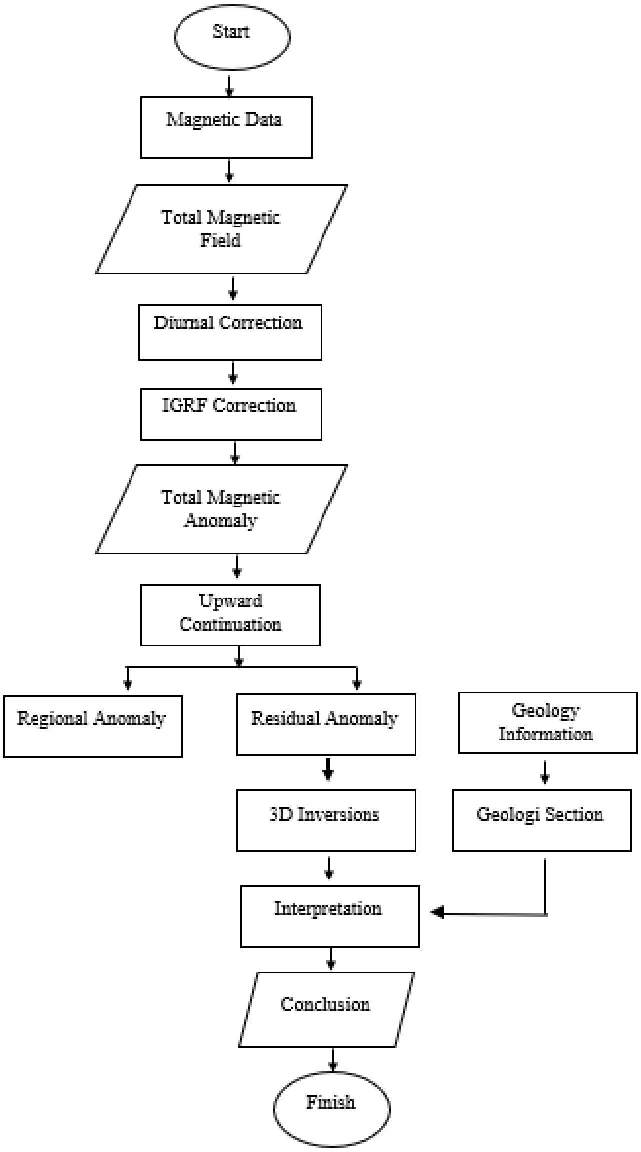

Figure 3. Flowchart of Research

$$H_a = \frac{(H_{max} - H_{min})}{2} \quad (1)$$

Where H_a is the reference of magnetic field value to get the diurnal correction value. H_{max} is the maximum magnetic field value recorded by Proton Precession Magnetometer (PPM) while H_{min} is the minimum magnetic field value.

$$= H_a - H_h \quad (2)$$

H_{kh} is the daily correction of the magnetic field and H_h is the value of the daily magnetic field. After getting the daily value of magnetic field correction, an interpolation is performed at each time the data is retrieved on the rover.

$$= H_l + H_{kh} \quad (3)$$

Where H_{th} is magnetic field that has been corrected daily at the time of measurement by the rover.

The corrected result is total anomaly which will be filtered with upward continuation. In this filter, the amount to be used will be entered manually according to the desired height, but this can be seen with the noises that have been lost. In the geomagnetic method of data processing, this process is used as a low filter to eliminate unrelated topography to the survey so that the anomaly results obtained are more clearly visible (Rekswanda, 2017).

$$U(x, y, z_0 - \Delta z) = \frac{|\Delta z|}{2\pi} . \int_{-\alpha}^{\alpha}\int_{-\alpha}^{\alpha} \frac{(x', y', z_0)}{R^3} dx'dy' \quad (4)$$

With R = $|x - x'|^2 + |y - y'|^2 + \Delta z^2$ and $U(x, y, z_0)$ = value of the potential field in the continuation yield field, while Δz is distance or height removal and $U(x', y', z_0)$ is the value of the potential field in the actual field of observation (Δz = 0).If the potential field, for example, the U field is measured on the surface z = z_0 and has a Fourier transform F[U]. The Fourier transform representation for equation (4) can be found by transforming both sides of the equation into the Fourier domain and applying the Fourier convolution (Blakely, 1995).

$$[U_u] = [U][\psi_u] \quad (5)$$

Where $F[Uu]$ is a Fourier transform of field that is continued upwards. All that is needed is an analytical expression for $[\psi u]$ which can be found from the Fourier transfer in equation (4).

Need to know that

$$\psi_u(x, y, \Delta z) = -\frac{1}{2\pi}\frac{\partial}{\partial \Delta z}\frac{1}{r} \quad (6)$$

Where $r = \sqrt{x^2 + y^2 + \Delta z^2}$. Therefore, Fourier transform form the equation (6) is

$$F[\psi_u] = -\frac{1}{2\pi}\frac{\partial}{\partial \Delta z} F\left[\frac{1}{r}\right]$$
$$= -\frac{\partial}{\partial z}\frac{e^{-|k|\Delta z}}{|k|}$$
$$= e^{-\Delta z|k|} \quad , \Delta z > \quad (7)$$

Then it is necessary to do a comparison between the result of each data.

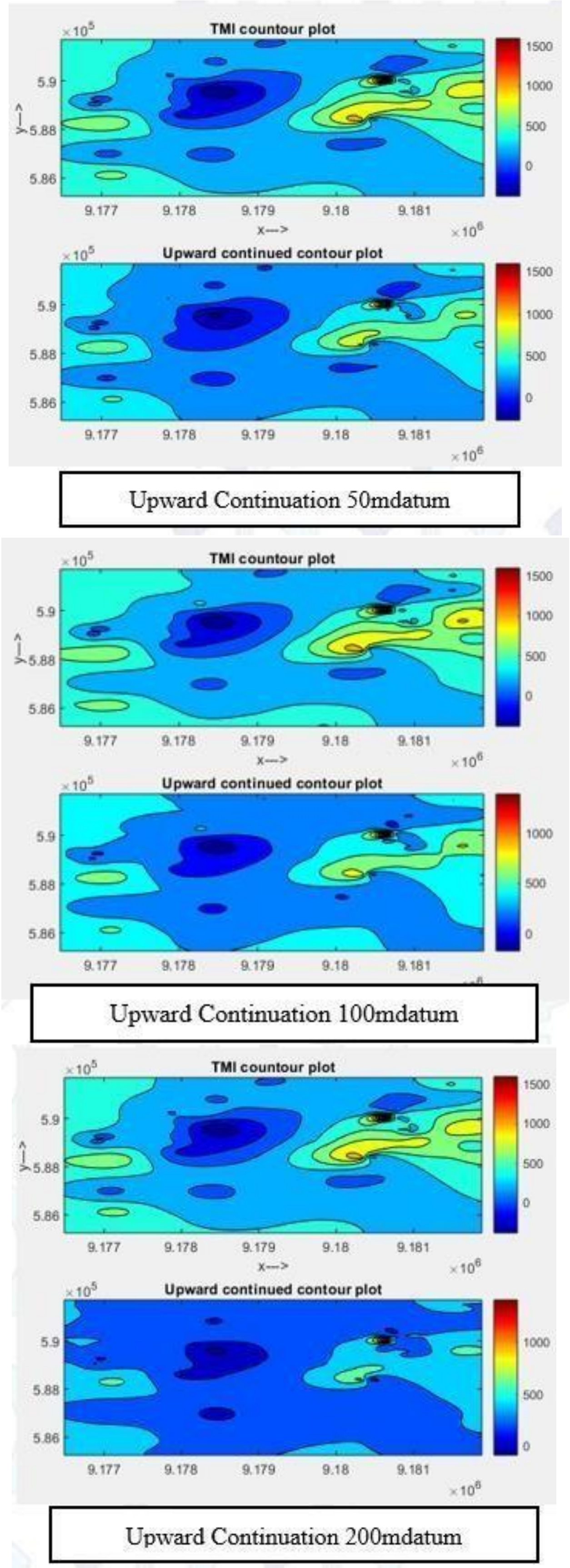

Figure 4. Comparison of datums in the Upward Continuation filter

In this study, regional anomalies were obtained through a map of total magnetic anomalies that had been continued upwards. The next step is to get a map of residual anomalies by reducing total manic anomalies with regional anomalies. This reduction is done with the Grid Math feature on the *Oasis Montaj software.*

It also made a geological cross-section with an incision that passes through 2 points of manifestation and also 3D modeling inversion. 3D modeling inversion using the VOXI feature on Oasis Montaj. The calculation of matrix inversion on this inversion uses the Singular Value Decomposition or SVD technique (Press et al, 1987) which is relatively more stable. In this technique, certain values can be ignored or considered zero and not included in the calculation of solutions (Grandis H. 2009). This calculation involves the norm model and also the norm data where both norms (ʎ) are searched for the optimum value.

In this process, the model fits in observational data and also to fit the existing geological conditions. It is necessary to do several iterations to produce optimum results when the model approaches the observation value as well as its geology.

Result and Discussion

The total magnetic anomaly produced in Figure 5 shows the value of the variation of magnetic intensity from the range of 44595 nT to 44610. Low-intensity values (tend to be blue) are found in the manifestation areas such as mud pools, Selogajah, and also Banyukuning. Manifestations of hot water and mud can be categorized as diamagnetic, where susceptibility is very low due to the number of electrons being even and paired so that the magnetization level is low, which is required with low-intensity values in the measurement results of this study.

The comparisons between 50, 100, and 200 mdatum are obtained through trial-and-error results until anomalous maps show fairly clear points in areas of interest, especially at 3 points of manifestation. Between the three datum values, the writer visually determines that the 100mdatum value is appropriate to proceed in modeling. The choice of 100mdatum (figure 4) for the upward continuation value because it has removed residual effects on the total intensity value compared to the 50mdatum lift value, but it is also does not eliminate much of the information intensity value of the data as in the appointment with a 200mdatum value. These upward continuation maps illustrate changes in anomalous characters with increased observations of the distance of the magnetic source, and are also useful as a lowpass filter. Thus, continued data up to 100m provides an excellent integrated view of the study area that is not distorted by local anomalies, high amplitude, and high gradients from magnetic sources in the shallows of the study area. It is clear that the weakening of shallow source anomalies in the upward continuation process enables a clearer or enhanced view of deeper anomalous sources (Blakely, 1996).

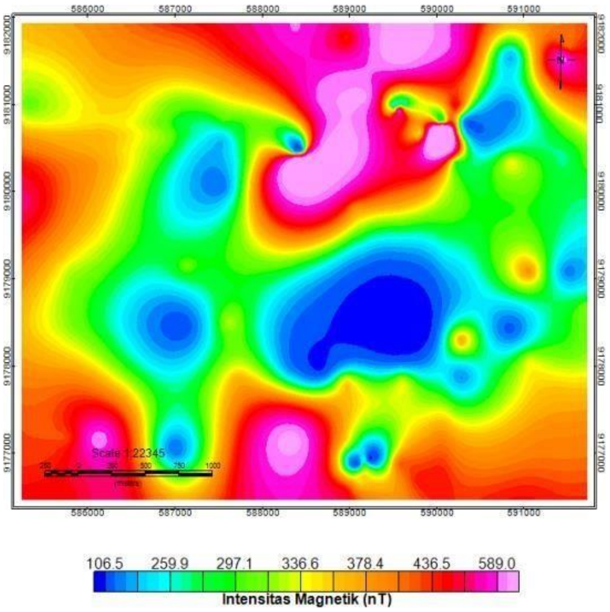

Figure 5. Total Magnetic Anomaly Map in Gondang

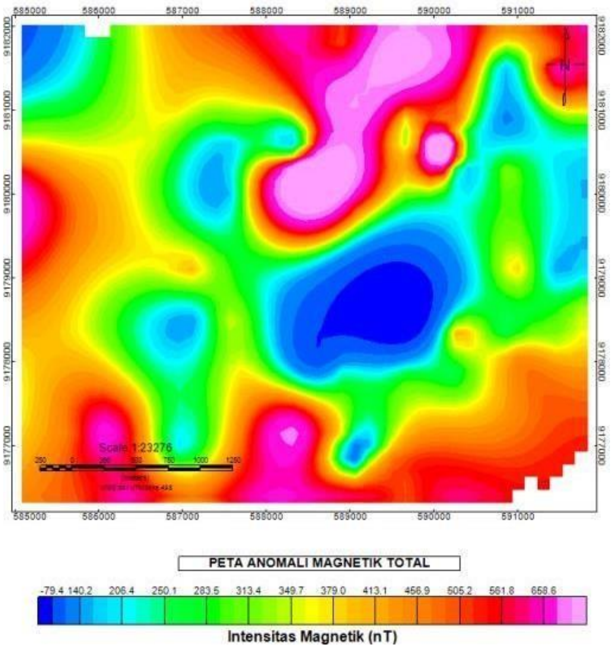

Figure 6. Regional Magnetic Anomaly Map in Gondang

Residual anomalies explain the distribution of subsurface geological structures clearer and more specifically, hence that is why this study uses a residual magnetic anomaly since it is considered as the most suitable for the interpretation of magnetic anomalies. The residual anomaly values depicted in Figure 7 show areas of low intensity with a range of -232 nT to -110 nT. This can be interpreted with low susceptibility by the low magnetism of the mud and hot water types.

A low susceptibility value can occur in the event of demagnetization. Manifestations in hot tubs have quite high temperatures.

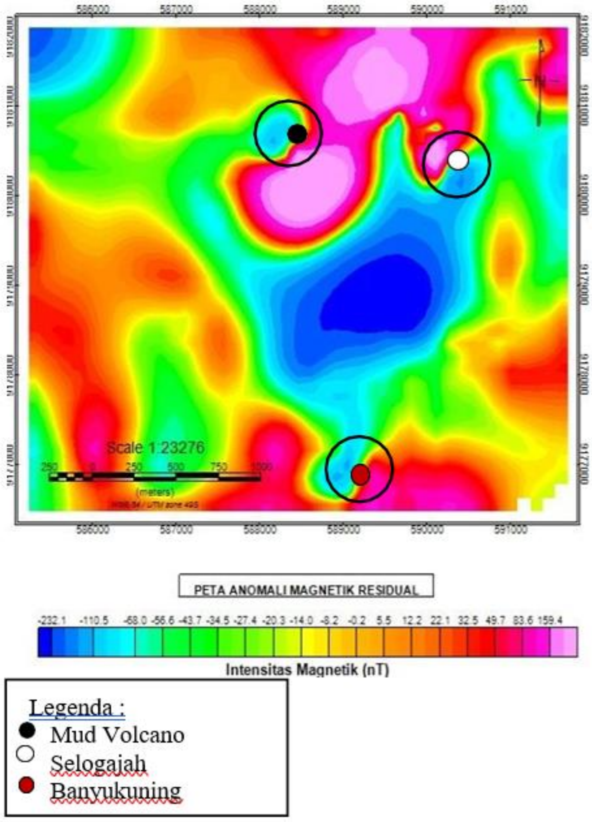

Figure 7. Residual Magnetic Anomaly Map in Gondang

Susceptibility has an influence on, namely the smaller and negative value of susceptibility in rocks, then, in theory, these rocks are diamagnetic at fairly high temperatures. This is because when rocks are diamagnetic, the electron shells will be completed and filled with paired electrons. If it is influenced by an external magnetic field, the spin of electrons will produce the direction of the magnetic moment that is opposite to the direction of the external field strength and produce a resultant which directed towards negative direction, so that a susceptibility relationship to a constant value can be obtained. Therefore, the low susceptibility value can be assumed as a manifestation of mud and hot water.

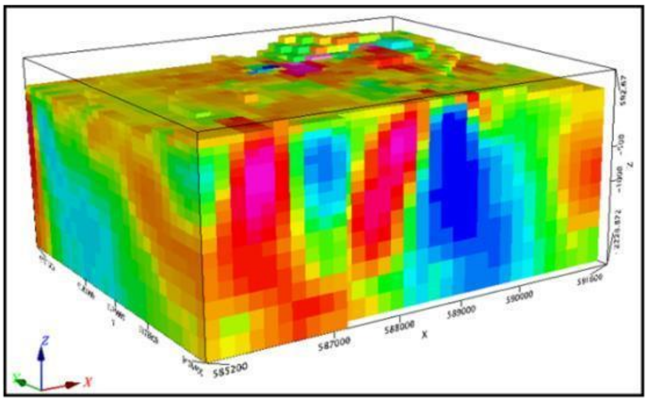

Figure 8. Results of 3D inversion of residual anomalies in the study area

The residual anomaly map is the modeled inversely (figure 8). From the results of magnetic data processing, 3D modeling interpretation can be made especially on the path connecting the manifestations of Jari and Banyukuning hot spring pools which can be seen through slicing (figure 9). These manifestations indicate certain conditions below the surface. This can be seen through the results of modeling that has been done and through the validation of the geological incision as well. Based on the track above (figure 9) it can be assumed that the rock intrusion is characterized by a susceptibility value of 0.0084-0.0446 SI (pink to dark red). This intrusion stone usually regarded as pyroxene andesite because the rock susceptibility is very high. In addition, compared to geological incisions, there is rock intrusion around the location of intrusion manifestations of mud pools and Selogajah. This can be interpreted as the existence of mud pools and hot tubs due to the correlation between events and rock intrusion.

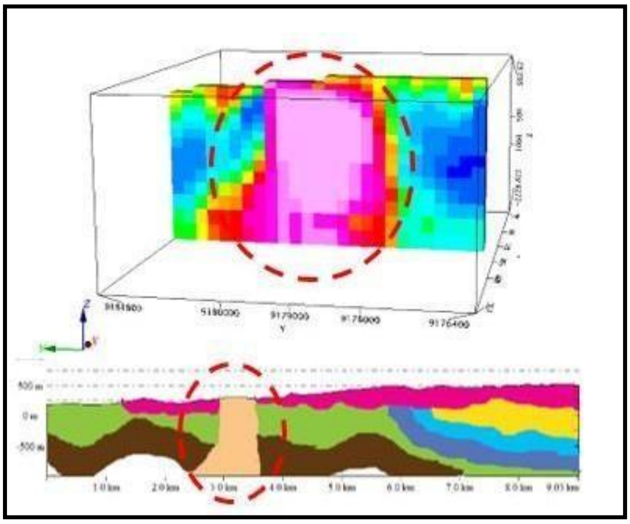

Figure 9. Comparison of geological section with the inversion model of the Jari mud volcano – Banyukuning

In addition to the path above, there is also an incision that crosses a mud pool and Selogajah (figure 10) showing rock intrusions that are marked by red to pink. In accordance to what has been mentioned above, this value has a high susceptibility with a range of 0.0114 to 0.0466 SI. If reflected in the geological conditions, the intrusive rocks are pyroxene andesite, whereas the rocks around it are shown at -0.0023 to 0.0068 SI which can be predicted to enter the Kerek formation with tuff sandstone.

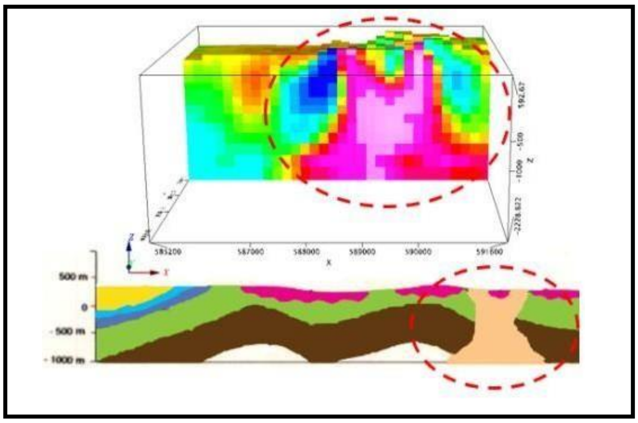

Figure 10. Comparison of geological incisions with the inversion model of the Selogajah Hot-Jari Mud Volcano

In the model above (figure 10) the upper layer susceptibility value is assumed to be breccia volcanic rock, which can be found in the top layer at the study site (Kendeng Zone) marked in blue. In this inversion model, the blue value has a susceptibility value of -0.0319 to -0.0057. This very small magnetic value can occur due to demagnetization. The green color in the inversion model can be interpreted as a Kalibeng formation with susceptibility value of -0.0061 to 0.0012. As previously explained, the intrusion of rocks with this path is quite clearly visible with the pink symbol on the inversion model and the beige color on the geological incision. Likewise, the Kerek formation as the oldest formation in the study area can be clearly seen more in the geological incision by comparing the inversion model at the susceptibility value of -0.0033 SI.

Conclusion

The 100m datum value applied in part to the upward continuation value of the total magnetic anomaly is the most suitable result as a regional anomaly because it removes residual effects without losing geological information. The results value of the upward continuation is 106.5 nT to 509.0 nT.

Meanwhile, results with 50mdatum still show noises and results with 200m datum eliminates too much geological information. After obtaining a regional anomaly, a residual anomaly can be obtained by reducing the total magnetic anomaly against the regional anomaly. The residual anomaly magnetic intensity value is -232.1 nT to 159.4 nT

Low rock susceptibility distribution values based on inversion models are in areas of manifestation with values ranging from -0.0298 to -0.0135 SI and high susceptibility values with values ranging from 0.0114 to 0.0466 SI which can be interpreted as andesite pyroxene intrusion rocks.

Mapping subsurface conditions shows the intrusion of rocks which interpreted as andesite pyroxene as the youngest formation, the formation underneath is volcanic breccia and Kerek formation which is the oldest formation in the study area.

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