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Identification of Gold Mineralization Zones Using Magnetic Data at Gunung Gupit Area, Magelang, Central Java

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Abstract

Indonesia is one of the biggest gold producing countries in the world. the discovery of new gold reserves makes the passion of the gold mining industry increase. The Gunung Gupit area of Magelang Regency in Central Java has discovered new gold potential, but has not been thoroughly explored. The magnetic method is applied to identify and determine the distribution of the presence of gold mineralized zones based on the magnetic properties of rocks. A total of 1001 points on 41 magnetic line were acquired using Proton Precession Magnetometer (PPM) Geometrics model G-856 in an area of 2.5 km^2. Field data is obtained as Magnetic Field Anomaly. Reduction to pole (RTP) and low-pass filter process is applied to the magnetic anomaly. The results showed the Gunung Gupit area was divided into 4 zones based on magnetic anomaly responses, i.e strong, medium, weak anomaly and igneous rock zones. The 2.5 D modeling result shows the presence of northwest-southeast normal fault and strike slip fault that is perpendicular to the normal fault. These faults control the hydrothermal alteration in Gunung Gupit and its surroundings. A strong mineralization zone lies between these two faults. The presence of gold and other metal minerals lies in this strong mineralization zone, and moderate alteration. The coverage area is quite wide and distributed along the two faults.

Keywords: Magnetic method, susceptibility, zone of mineralization, fault

INTRODUCTION

Indonesia is one of a country that located in The Ring of Fire and has an abundant resources of natural mineral, one of them is gold ore. Gold ore is an economically valuable mineral and has become a mineral commodity that has an important role in the country's foreign exchange income. Indonesia is one of the largest gold producing countries in the world with an average gold content of 0.5-30 ppm (Van Leeuwen, 2005). This condition makes the passion in gold mining industry in Indonesia increasing. In general, gold mining in Indonesia is located in low sulfidation epithermal depositional environments, where one of the dominant areas of this type of gold deposition environment is in Central Java (Sillitoe, 1994).

The Gunung Gupit area is part of the Menoreh Hills which lies in the Kulon Progo Mountains (Rahardjo, 1995). The discovery of gold mineralization in this area related with hydrothermal process. The hydrothermal gold deposits of the Gunung Gupit area are high sulfidation type epithermal deposits with very acidic fluids (Idrus, et al., 2013). The mineralized zones of this area indicate the intensity level of the hydrothermal process, which will greatly affect the metal mineral content present. The form of alterations was silification, advanced agriliary and propylitic. Different mineral content means different susceptibility of the rock, and it causes different magnetic anomaly responses. The distribution of mineralized zones in the study area can be determined by knowing the distribution of susceptibility values of subsurface rocks.

Geophysical Exploration is the preliminary survey to determine the content of economically valuable mineral deposits that are located below the surface of the earth. The geomagnetic method is a geophysical method that using the magnetic properties of the earth. The target of the survey using the geomagnetic method is the variation of the measured magnetic field on the surface. Geomagnetic method is used to locate the presence of mineralized zones and rock identification.

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The parameter obtained in the geomagnetic method is susceptibility. Magnetic susceptibility is defined as the degree of magnetization of materials in a magnetic field. Magnetic susceptibility has always been used as a practical tool for solving geological, geophysical and mineral problems (Andreeva, 2013; Ojo, et al, 2014; Boroomand, 2015). Many studies have been done to evaluate the application of magnetic susceptibility in different situation. Combined methods from the fields of geology, geochemistry and geophysics were applied to elucidate the regional geologic framework and identify favorable environs for mineralization. In many cases integrated geophysical methods are used for metal minerals prospecting (Mamou, 2004; Ercan, et.al, 2013; Rebeh, 2009; Zhang, et al, 2020). Magnetic methods have relatively high anomalous field measurement accuracy, instrumentation and operation in the field are relatively simple, easy and fast (Telford, 1990).

Mapping on a regional scale is done using the geomagnetic method.this mapping is used to determine the regional geological structures, detect magnetic anomalies and lithology mapping. Magnetic anomalies occur due to the susceptibility contrast in subsurface. The susceptibility contrast is caused by different mineral content in rock. the magnetic mineral has a high susceptibility give a high magnetic response. Therefore, this method is very well used to find out the distribution of magnetic susceptibility which shows the gold mineralized zone.

The purpose and objective of the study is to determine the presence of the mineralized zone of the study area based on magnetic anomaly. The data processing are Reduction to Pole (RTP) and low pass filter. This advance processing is used to determine the structure that develops and controls the mineralized zone in the Gunung Gupit area. The 2.5 D modeling results corelated with the genesis of mineralization zone of the study area.

Geological Setting

Indonesian archipelago is located in Ring of Fire zone. This location makes the tectonic setting in this country relatively unstable and it as a high occurrence of earthquake and volcanoes. This zone extends from northern Sumatra, to South part of Java. High volcanic activity in this region causes high activity of mineralization, some of which are economic ore mineralization. Deposits or mineralization that are mostly formed in this zone are epithermal type deposits (Idrus, et al., 2013).

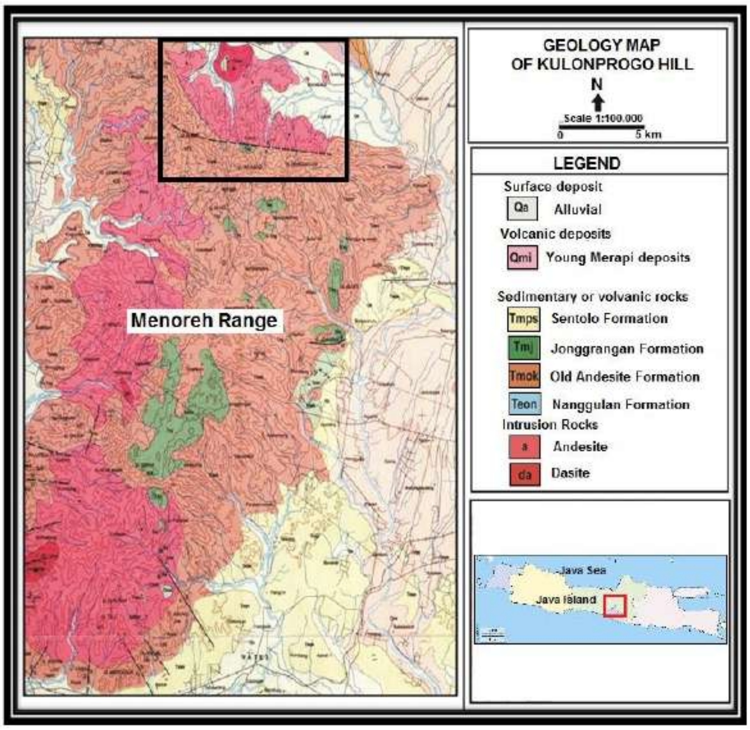

Figure 1. Regional geology of the Gunung Gupit area and its surroundings (Raharjo, et al., 1995), a black box showing the location of the research area.

Regional geomorphology of the Gunung Gupit area, Magelang is include to the Kulon Progo Mountains zone, located in the northern part at the foot of the Menoreh Hills which is the result of volcanism from the past. Some rock formations that make up the research area are the Kebobutak Formation consisting of dacite lava, andesite lava and volcanic breccia. These breccias are in the form of autoclastic breccias and andesite breccias as a result of deposited by Young Sumbing Volcano. The geological map is shown in Figure 1.

The Menoreh area consists of Basaltic andesite - andesite daggers broken through the Old Andesite Miocene Formation (Kebo Butak Formation). Mineralization is present in basaltic andesite andesite, especially among intrusion contacts. The oldest rock formations (Nangulan Formation) were observed as large boulder of xenolith in the dacitic andesite rock intrusions, while younger limestone formations were observed in outcrops south of the study area. The limestone formation may have been changed due to the process of metamorphosis into marble by other epithermal systems..

Unaltered and non-mineralized rocks are microdiorite intruding into andesite dacitites. This rock outcrop was found on the hill of Gupit. This young intrusion is likely to destroy the mineralized system in basaltic andesite and earlier dacitic andesite rocks.

RESEARCH METHOD

Research steps consist of field data acquisition, processing and interpretation. Field data obtained is magnetic intensity values and supporting data such as outcrops data and alteration map of Gunung (Idrus, et al., 2013). The geological map of the Magelang sheet and the topographic map of the Gunung Gupit area shown in fig.2

The research area located in Kebonsari Village, Borobudur District, Magelang Regency, Central Java (Figure 2a). A total of 1001 magnetic data points were acquired from the 2016 and 2020 data. This data consist of 41 lines direction N140°E, with line spacing is 50 meters and points spacing 50 meters. The survey area is approximately 2.5 km^2 with the alteration zone at the center of the survey area. Map of the distribution point of the design survey shown in Figure 2b.

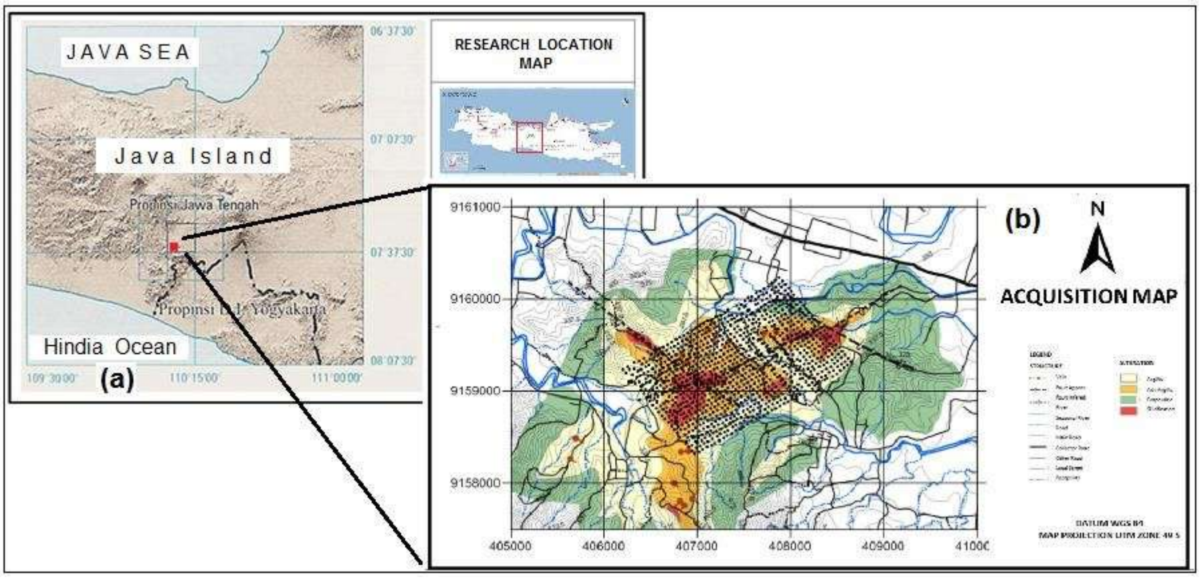

Figure 2. (a) Research location at Gunung Gupit, Muntilan, Magelang Regency, Central Java (red box) and (b) design survey and distribution of magnetic data points totaling more than 1000 points and as many as 40 lines which is directed N140°E.

The acquisition uses the Proton Precession Magnetometer (PPM) Geometrics model G-856 as a rover and base, which has high resolution of 0.1 nT. Measured total magnetic field consists of three components i.e the earth's magnetic field, external magnetic field and magnetic field anomaly. Magnetic data is processed by reduction, pole transformation (RTP), low-pass filter application and 2.5D modeling. The qualitative and quantitative interpretation stages are carried out with the support of outcrop data.

RTP is one of the magnetic data processing filters to eliminate the influence of magnetic inclination angles. RTP is applied because the magnetic anomalous dipole makes it difficult to interpret data which is generally still asymmetric in pattern. The results of the RTP show magnetic anomalies into one pole, interpreted as the position of objects causing magnetic field anomalies (Puspita and Sintia, 2017). Qualitative interpretation is done by observing and analyzing the values and contours of the obtained magnetic anomaly patterns, RTP maps and maps of band pass filter results. The presence of low value magnetic anomalies is interpreted as a zone of indicated mineralization. The quantitative interpretation process is carried out by making a 2.5D model that shows subsurface geology based on susceptibility values in the study area. The making of the 2.5D model aims to obtain the main control structure in the gold mineralization process in the study area.

RESULT AND ANALYSIS

Magnetic Anomalies

The magnetic anomaly of the Gunung Gupit Area shown in Figure 3. The total magnetic field anomaly represents the subsurface target of the study area. Contour map shows variations in anomaly values from low to high, which is between -400 nT to 900 nT. Anomaly values are classified into 4 groups i.e. very low, low, medium and high as shown in table 1.

Table 1. Classification and interpretation of anomalous magnetic field values in the Gunung Gupit area.

No	Group	Range of magnetic anomaly values (nT)	Qualitative interpretation
1	Very low	< -100	Strong mineralized zone.
2	Low	-100 - 50	Medium mineralized zone
3	Medium	50-250	Weak mineralized zone
4	High	> 250	Igneous rock

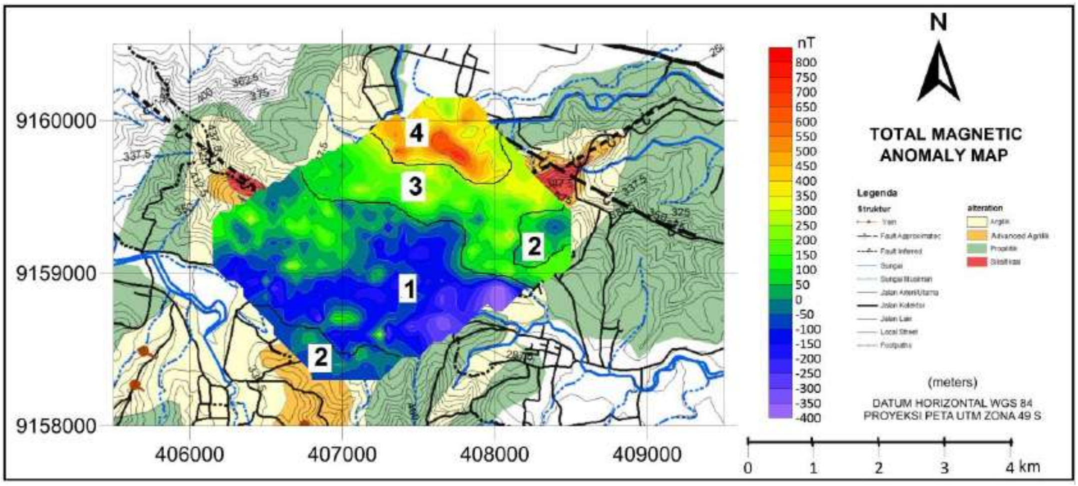

Figure 3. Contour of magnetic anomaly in the study area. The anomalous magnetic field in the study area has the lowest contour of -400 nT and the highest of 900 nT.

The Gunung Gupit area is part of the Menoreh Hills which lies in the Kulon Progo Mountains (Rahardjo, 1995). The discovery of gold mineralization in this area related with hydrothermal process. The hydrothermal gold deposits of the Gunung Gupit area are high sulfidation type epithermal deposits with very acidic fluids (Idrus, et al., 2013).

The mineralized zones of this area indicate the intensity level of the hydrothermal process, which greatly affects the metal mineral content present. The presence of differences in metal mineral content causes a difference in magnetism as indicated by the suscebtibility value of the mineralized zone. Hydrothermal altered rocks in the study area will experience a change in the value of suscebility. This results in different magnetic anomaly responses. Based on the division and distribution of the magnetic field anomaly values, they are divided into 4 zones (figure 3.). The classification of anomalous values and interpretations is shown in table 1.

1. **Zone 1;** Very low field anomaly values (less than -100 nT) are interpreted as strong mineralized zones. This zone is dominated by the presence of silification mineralization. This zone dominates the research area. Very low and low magnetic field anomaly values are shown in blue, found in the southwest part and eastern part (index no. 1) as shown in Figure 3. High metal mineral content is most likely found in this zone. Idrus et al (2003) found metal mineral content including enargite (CuAsS), chalcopyrite ($CuFeS_2$), pyrite (FeS_2), digenite (Cu_9S_5), gold (Au) and hematite (Fe_2O_3) found in this zone. But to determine the vertical and lateral distribution of metal minarals, data from another method is needed i.e. the Induced Polarization (IP) method. IP data is very suitable to be used to determine the distribution of high metal mineral content at subsurface (Yatini, et al., 2019).
2. **Zone 2**; Low anomalies (-100 to 50) nT are interpreted as medium mineralized zones. The zone of mineralization in the area of research is closely related to argillic and advanced argillic mineralization. This zone is located at the western part of the study area in Figure 3 (index no 2), which partially overlaps with the silicification zone. In this zone, silica and clay minerals are found to be quite massive. stockwork in the form of sulfides and quartz veins which are 5 - 25 cm long with 0.5 - 2 cm wide is found in Gunung Gupit Area(Idrus, et al., 2013). There is also the presence of sulfur minerals, blackish enargite, orange jarosite clay minerals, milky white and fresh hematite.
3. **Zone 3**; A moderate anomaly (50 to 250) nT is interpreted as a weak mineralized region, which is a zone of proplitic alteration. In this zone andesite lava is found which is characterized by a faneritic to faneroporphyritic texture, has a phenocryst of 0.5 - 5 mm in size, base mass <0.03-0.1mm, holocrystalline, composed of hornblenda, pyroxene, little quartz, epidote, chlorite and opaque minerals (Idrus, et al., 2013). This medium anomaly zone is mixed and close to zone 4, located in the middle of the elongated shown in green to yellow in figure 3.
4. **Zona 4;** High anomaly (> 250 nT) is interpreted as igneous rock. Andesite rocks are found in this zone.

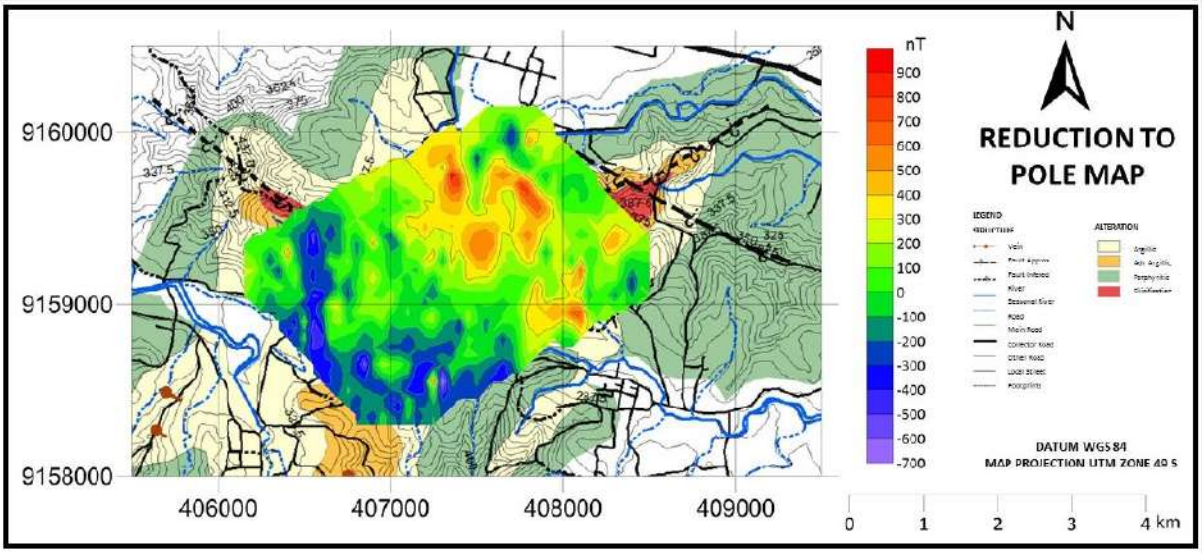

Figure 4. RTP Map of the research area

Reduction To Pole (RTP) filter results

Reduction to Pole (RTP) are needed because the magnetic anomalous dipole makes it difficult to interpret field data which are generally still asymmetric in pattern. The result of the reduction to the pole shows the magnetic anomaly into monopole, which is interpreted to position the object causing the magnetic field anomaly in subsurface. The results of RTP processing in the Gunung Gupit area are shown in figure 4.

RTP map in Figure 4 shows the range of anomaly values of -700 nT to 900 nT. High and low anomalies that lined up dominated the northeastern part of the study area. While in the southwest part of the study area is dominated by moderate anomaly. The interpretation of the reduction map to the pole is carried out qualitatively by looking at the distribution of anomalous values. High anomaly indicates a high susceptibility while a low anomaly indicates a low susceptibility. High and low anomal which side by side indicates fault, which extends from the southwest-southeast

Low-Pass Filter

Magnetic field anomaly caused by the influence of local and regional effects. Local effects that have a high frequency response are due to anomalies that are close to the surface. Whereas regional effects which are low frequency responses are caused by deep anomalies. An anomaly in this is due to the structure that contaminates the alteration of the study area. Low pass filter is applied to the magnetic field anomaly to eliminate the effect of high frequency, so that what remains is low frequency which is a manifestation of the existence of deep subsurface structures.

A low-pass filter map of the magnetic field anomaly is shown in Figure 5. The highest magnetic anomaly value is 600 nT and the lowest is -350 nT. There are high contrast anomaly that shows in this area, high (red) and very low (blue) values. The boundary extends from northwest to southeast located in the southern part of the study area. This boundary is interpreted as a northwest-southeast normal fault. The high anomaly pattern shown in Figure 5, there is also a contrast between colors. This indicates a difference, which is interpreted as a strike slip fault (dextral) in a direction almost perpendicular to the normal fault.

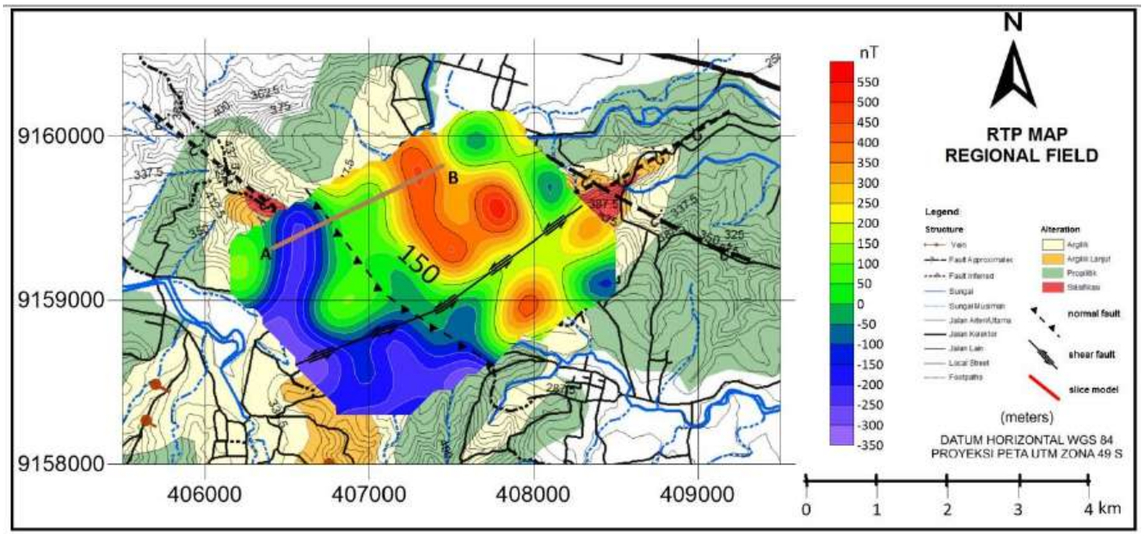

Figure 5. Map of regional magnetic field anomaly, is the result of applying a low-pass filter. High anomaly values are shown in red and low in blue. Line A-B is an profile for 2.5D modeling.

The subsurface structure indicated as a normal fault is made clear by the results of the 2.5D modeling of magnetic data. A high susceptibility value of 0.045 is interpreted as andesite igneous rock. The Gunung Gupit area is geologically dominated by andesite lava from the Kebo Butak formation. A low susceptibility value of 0.0001 is interpreted as breccias, which in the study area are autoclastic and andesite breccias. In this breccia found gold metal minerals with high Au content. The chemical analysis of some rocks, veins and river sediments taken at random showed the presence of gold with varying levels and some showed significant levels. The highest Au content (42.4 gram/ton) and Ag (112 gram/ton) in vein samples (Idrus, et al., 2013). The presence of gold and other metal minerals lies in this strong mineralization zone, and moderate alteration. The coverage area is quite wide and distributed along the two faults.

CONCLUSION

Gunung Gupit area was divided into 4 zones based on magnetic anomaly responses, i.e strong anomaly, medium anomaly, weak anomaly and igneous rock zones. The 2.5 D modeling result shows the presence of northwest-southeast normal fault and strike slip fault that is perpendicular to the normal fault. These faults control the hydrothermal alteration in Gunung Gupit and its surroundings. A strong mineralization zone lies between these two faults. The presence of gold and other metal minerals lies in this strong mineralization zone, and moderate alteration. The coverage area is quite wide and distributed along the two faults.

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