Response of Gravity, Magnetic, and Geoelectrical Resistivity Methods on Ngeni Southern Blitar Mineralization Zone

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Abstract. The research with entitle response of gravity, magnetic, and geoelectrical resistivity methods on Ngeni Southern Blitar mineralization zone has been done. This study aims to find the response of several geophysical methods of gravity, magnetic, and geoelectrical resistivity in an integrated manner. Gravity data acquisition was acquired 224 data which covers the whole region of Blitar district by using Gravity Meter La Coste & Romberg Model "G", and magnetic data acquisition were acquired 195 data which covers the southern Blitar district only by using Proton Precession Magnetometer G-856. Meanwhile geoelectrical resistivity data only done in Ngeni village which is the location of phyropilite mining with the composition content of Fe, Si, Ca, S, Cu, and Mn by using ABEM Terrameter SAS 300C. Gravity data processing was performed to obtain the Bouguer anomaly value, which included unit conversion, tidal correction, drift correction, correction of tie point, base station correction, free air correction, and Bouguer correction. Magnetic data processing has been done by some corrections i.e daily, drift, and IGRF(International Geomagnetic Reference Field) to obtain the total magnetic anomaly. From gravity data processing has been obtained the simple Bouguer anomaly value in range from -10mGal until 115mGal. From this data processing has been obtained the total magnetic anomaly value in range from -650nT until 800nT. Meanwhile from geoelectrical resistivity 3.03Ωm until 11249.91Ωm. There is a correlation between gravity anomaly, magnetic anomaly, and geoelectrical resistivity anomaly that are associated with deep anomaly, middle anomaly, and shallow anomaly.

1. Introduction
Physiographically, the southern Blitar region is part of the southern mountains that stretches from the Wonosari region of Central Java to the Blambangan peninsula in East Java. On the north of these mountains lined the volcanoes of quaternary in the Solo zone. While in the south is the Indian Ocean [1]. The southern Blitar area is bordered by Tulungagung district in the west, Kediri regency in the north, Malang regency in the east, and Indian Ocean in the south. In general these mountains are Tertiary (Oligocene, Miocene, to Pliocene) as well as Quarter, some formations are intruded by diorite, granodiorite, and dacite [2]. As a result of this intrusion, the surrounding rocks become hydrothermal alteration. As a result, in the area there are many mineralized zones that produce propylite, pyrite, or other ore minerals.

Metal minerals are generally deposit products as a result of the differentiation process and magma crystallization that occurs when the activity of the formation of igneous rocks will end. The beginning of this process begins with an intrusion process of high concentrations of hydrothermal solutions to older rocks. When the solution enters through the fractures and/or faults, an alteration processes to
occur to the rock. Alteration processes to occur to high temperatures and pressures, followed by changes in mineral composition from rocks due to the enter of hydrothermal solutions. The process of alteration can be grouped into three kinds [3], namely: argilitisation, silicification, and propilitisation.

At the time of cool accompanied by the process of chemical and physical reaction, it will be deposited newly formed minerals. The minerals formed to depend on the type of hydrothermal solution, the type of rock being penetrated, and the level of cool process that occurs to the rock itself. Rock that vary the mineral content will produce several kinds of newly formed minerals. The end result of this process will accumulate in rock pores, fractures, faults, or rock layers. While the main characteristic of the alteration region is the formation of CO\(_2\) which is the product of the alteration process. The presence and amount to CO\(_2\) depend on the type of metal, magnesium and / or potassium of rocks that intruded. In this case the alteration process is followed by the formation of pyrite (FeS\(_2\)). This genesis is usually found around the body of the sulphide mineral. Other possible sulphide minerals may form to include chalcopyrite (CuS\(_2\)) and galena (PbS) [4].

Physically, the alteration zone has a higher density and susceptibility, but lower resistivity value compared to the host rocks in the surrounding. This occurs because the alteration zone which is the accumulation of metal minerals will have a low resistivity value or high conductivity value compared with nonmetallic minerals. The existence of these physical values contrasts that resulted in the application of integrated geophysical methods can be used to determine the distribution of underground mineral deposits [5]. Therefore in this paper will be presented a research result of the response method gravity, magnetic, and geoelectrical resistivity to mineralized zone located in Ngeni of south Blitar area.

2. Methods
In this research, three geophysical methods are integrated, namely gravity, magnetic, and geoelectrical resistivity method.

2.1. Gravity Method
In principle, gravity geophysical surveys are based on Newton's law of gravity. Due to the reality that the mass of the earth is strongly influenced by other celestial bodies, especially the moon and sun, some correction in order to eliminate and reduce the error of measurement values due to them must be done in step of data processing and interpretation.

The study of gravity is based on Newton's law of gravity published by Newton in 1687 under the title Philosophiae Naturalis Principia Mathematica which states that the magnitude of the force of gravity of two masses is proportional to the multiplication of the second mass and inversely proportional to the square of the distance between the two center of mass.

\[ \overrightarrow{F}(r) = G \frac{m_1 m_2}{r^2} \hat{r} \]  

(1)

The massa of \( m \) and \( m_o \) experience a common force of gravity proportional to \( m, m_o, \) and \( r^2 \). The direction of the unit vector \( \hat{r} \) is from the source of gravity to the observation point, in this case lies in the test mass of \( m_o \) with:

- \( m, m_o \) = mass
- \( r \) = distance from \( m \) to \( m_o \)
- \( G \) = Newton's gravitational constant \( (6.672 \times 10^{-11} \text{ Nm}^2/\text{kg}^2) \)
- \( r \) = \( \left[ (x - x')^2 + (y - y')^2 + (z - z')^2 \right]^{1/2} \)
- \( \hat{r} \) = unit vector towards \( m_o \) [6]

If \( m_o \) is assumed to be a specimen of a certain mass, then dividing the gravitational force in equation (1) by \( m_o \) will result in the acceleration of gravity generated by the \( m \) at the point of the test object being, i.e.:
\[
g(r) = - G \frac{m}{r^2} \hat{r}
\]  
(3)

with \( \hat{r} \) is the unit vector that direction from mass \( m \) to the observation point \( P \), in the Cartesian coordinate,

\[
\hat{r} = \frac{1}{r} \left[ (x-x')\hat{x} + (y-y')\hat{y} + (z-z')\hat{z} \right]
\]  
(4)

The minus sign of equation (3) is necessary because of the convention factor, i.e \( \hat{r} \) leading from source to the observation point opposite to the gravitational acceleration field \( g \).

When the mass of the earth is \( M_e \) with the radius of the earth is \( R_e \), spherical and non-rotating, so the magnitude of the gravitational acceleration on the surface of the earth is [6]:

\[
g(r) = - G \frac{M_e}{R_e^2} \hat{r}
\]  
(5)

The gravitational field is conservative when the attempt to move a particle of the field is independent of the passage, but depends only on the starting and ending points. The force of gravity is a vector with a direction along a line connecting the center of two mass pieces. This force gives rise to a conservative field which can be derived from a scalar potential function with the following relations:

\[
g(r) = \nabla U(r)
\]  
(6)

If the mass is continuously distributed with density \( \rho(r_0) \) at volume \( V \), then the gravitational potential at point \( P \) is:

\[
U(r) = \int g dr = -\int \frac{Gdm}{|r-r_0|} = -G\int_V \frac{\rho(r_0)d^3r_0}{|r-r_0|}
\]  
(7)

with \( |r-r_0| = \sqrt{r^2 + r_0^2 - 2rr_0\cos\gamma} \)

which states the attempt to move a mass from an infinite point away with any passage to a point \( r \) distance from the center of mass \( m \). The function of \( U \) is called the potential of gravity or Newton's potential and the acceleration of gravity \( g \) is the potential field. Some books establish the potential of gravity as an attempt by the test particles, so in equation (6) is written \( g(r) = - \nabla U(r) \). Equation (6) follows the convention by Kellog [7] which states that the gravitational potential is the effort made by the gravitational field on the test particle and the negative of the particle's potential energy.

At the gravitational potential apply the principle of superposition, namely: the gravitational potential of a distribution of masses is the sum of the potential for each mass. The magnitude of the potential on the test particle is the sum of the vectors of the mass potential. The superposition principle can be applied to determine the gravitational potential for a continuous mass distribution. A continuous mass distribution \( m \) is a collection of very small and large masses, \( dm = \rho(x,y,z)dv \), with \( \rho(x,y,z) \) is the mass distribution density. By applying the principle of superposition gained:

\[
U(r) = G\int_V \frac{dm}{r} = G\int_V \frac{\rho(Q)}{r} dv
\]  
(8)

with the integration of \( V \), the actual volume of the mass. As usual \( P \) is an observation point, \( Q \) is the integration point and \( r \) is the distance between \( P \) and \( Q \). The density \( \rho \) has units of kg.m\(^{-3}\) in the SI system and gr.cm\(^{-3}\) in the cgs system [6].

Implementation of this gravity geophysical survey must be applied some correction: drift correction, normal gravity, free air, Bouguer, terrain, and tide. Likewise, some filtering should be applied in the data processing step, either low pass filter or high pass filters depending on the value of the acquisition data obtained. At the interpretation stage is also very needed modeling that fits with local geological target conditions. The main equipment for this gravity geophysical survey is the use of Gravitymeter La Coste & Romberg.
The magnet will always consist of two poles. The poles are always paired in nature, always in the form of bipolar or dipole. The field intensity is proportional to the flux density of the line. At the magnetic poles have a greater intensity than the middle. In the earth's main magnetic field in the equator region the field intensity is about 30,000 gamma and 60,000 gamma in the polar region. The direction of the magnetic field at the edge of the dipole is parallel to the direction of the field at its center but opposite direction [11]. In reality there is no monopolized magnetic field, but only the dipole field at the far ends of each other [9].

Implementation of this magnetic geophysical survey must be applied some corrections: drift, diurnal, and International Geomagnetic Reference Field (IGRF). Likewise, some filtering should be applied to the data processing step, either low pass filters or high pass filter depending on the value of the acquisition data obtained. At the interpretation stage is also very needed modeling that fits with
local geological target conditions. The equipment used in this magnetic survey is the Proton Precession Magnetometer (PPM).

2.3. Geoelectrical Resistivity Method
The geoelectrical resistivity method detects subsurface conditions based on the contrast of electrical properties of the earth's rocks. The application of this geoelectrical resistivity method is based on the electrical properties of the earth's resistance which assumes that if on earth surface is injected an electric current, then the earth as a conductor that has resistance will cause a certain potential difference [10].

The geoelectrical resistivity method is one of the active methods of geophysics, therefore the measurement of earth resistivity is done by injecting the current into the earth through two current electrodes (C1 and C2), and measuring the earth response to the injection current in the form of potential difference and resistance it is generated at two potential electrodes (P1 and P2). From the current value data (I), the potential difference (V), and resistance (R), we can calculate the apparent resistivity value ($\rho_a$) as follows:

$$\rho_a = k \frac{V}{I}$$  (9)

where $k$ is the geometry factor which depends on the configuration of the four electrodes that used.

The calculated resistivity value is not the actual subsurface resistivity value, but is the apparent resistivity value which is the result of the contribution resistivity response from the earth as a whole, according to the range of equipotential and equipotential currents considered to be homogeneous which gives the same resistance value for the electrode arrangement the same one. Subsequently, apparent resistivity values must be processed to be true resistivity values for each layer of Vertical Electrical Sounding (VES). The equipment used in this geoelectrical resistivity survey is OYO Mc-Ohm.

3. Results and Discussion
Gravity data is distributed among Blitar district and is located between geographical co-ordinating (112.43952°E; 7.91870°S) and (111.96268°E; 8.33120°S) with a total of 224 points of measurement data. Data processing is done to get observation value (after conversion unit, tidal correction, drift correction, tie point correction, and base station correction). Free air correction is done to return the datum to topography as a result of normal gravity correction (latitude correction). In the end the Bouguer anomaly was obtained by involving all of the corrections above and Bouguer correction which considers the dominant local rock density. Contour map of Bouguer anomaly can be seen in figure 1.

The Bouguer anomaly map is showing the rocks that cause the mineralization process. Based on the Bouguer anomaly data, the potential of mining materials primarily for primary reserves can be localized. The red color contour is a mineralized zone, otherwise the blue color contour is not a zone of mineralization. Based on the contours of the Bouguer anomaly it shows that the Ngeni zone has a high Bouguer value of about 115mGal (low anomaly located in Kelud volcano area with a value of -10mGal). Based on the local geological map, the relatively high value of Bouguer anomaly is a representation of andesite-diorite-granodiorite and limestone.

The magnetic data is distributed over the district of south Blitar and is located between the geographical coordinates (112.02731°BT; 8.33114°LS) and (112.43811°BT; 8.12586°LS) with a total of 195 measuring points. The processing of the above data must be performed to obtain the value of the total magnetic field free of noise influence, which is the effect of daily variation, drift, and anomaly in IGRF (International Geomagnetic Reference Fields). The total anomaly contour of the total processing magnetic field can be seen in figure 2. The total anomaly contours of the processing magnetic field as shown in figure 2 is a description of the distribution of mined materials having magnetic contrast values. Based on the contour of the magnetic anomaly as shown in figure 2 indicates that the Ngeni zone is a mineralized zone having a magnetic value and magnetic dipole magnitude (a
value range of about -650 nT up to 800 nT). Based on the local geological map, the relatively high magnetic field anomaly value is also a representation of andesite-diorite-granodiorite and limestone rocks. The presence of magnetic dipole pairs tending to the southwest indicates that magnetic rock anomalies which associate with metals is forward to the southwest.

![Figure 1. Contour anomaly of Bouguer on the administration map.](image)

Based on the Bouguer anomaly of gravity data and the total magnetic field anomaly of magnetic data it appears that the deep anomaly that is thought to be the cause of the potential for minerals or mineralized zones in Blitar district is distributed among southern Blitar and as the center is the Ngeni zone.

To obtain a subsurface structure that describes a shallow anomaly, a near surface geophysics approach is called geoelectrical resistivity has applied. Topographic contours and distribution of geoelectrical resistivity points in Ngeni zone can be seen in figure 3.

Based on the results of geochemical tests, the rocks in the Ngeni zone contain Mn, Cu, S, Fe, Si, and Ca content with the content values of 1.88% (spectrophotometry method), 278.63 ppm (AAS method), 18.37% spectrophotometry method), 967.319ppm (AAS method), 36.53% (gravimetry method), and 8651.145 ppm (AAS method) respectively.

Based on the modeling results and the interpretation of the geoelectrical resistivity method showed that for the ngeni_wontir_01 point the lowest resistivity value is 3.2 Ωm and the highest resistivity value is 5042.37 Ωm. For the ngeni_wontir_02 point the lowest resistivity value is 3.03 Ωm and the highest resistivity value is 542.57 Ωm. As for the point ngeni_wontir_03 the lowest resistivity value is 22.8 Ωm and the highest resistivity value is 11249.91 Ωm. Overall based on all points the lowest resistivity value is 3.03 Ωm and the highest resistivity value is 11249.91 Ωm. Based on local geological conditions, it is generally accepted that rocks with metal mineral content have very small resistivity values of less than 1 Ωm. Resistivity values between 1 Ωm to 1000 Ωm is the value of water, alluvium, and clay. Resistivity values greater than 1000Ωm are generally values of lava, andesite, diorite, granodiorite and limestones. Figure 4 is resistivity cross section of the Ngeni zone.
Figure 2. Contour anomaly of the total magnetic field on the administration map.

Figure 3. Topographic contours and distribution of geoelectrical resistivity point in Ngeni zone.
4. Conclusion

Based on the research that has been done, it can be concluded the things as follows:

1) Based on the contours of the Bouguer anomaly shows that the Ngeni zone has a high Bouguer value of about 115mGal, which is a representation of andesite-diorite-granodiorite and limestone.

2) Based on the contours of magnetic anomaly indicates that the Ngeni zone is a mineralized zone that has a magnetic value magnetic value and a large magnetic dipole (a value range of about -650nT up to 800 nT). It is a representation of andesite-diorite-granodiorite and limestone rocks. The presence of magnetic dipole pairs tending to the southwest indicates that magnetic rock anomalies associate with metals heading southwest.

3) Based on the results of modeling and interpretation of the geoelectrical resistivity method showed that overall the lowest resistivity value is 3.03Ωm and the highest resistivity value is 11249.91 Ωm. This suggests that rocks with metal mineral content have very small resistivity values of less than 1 Ωm. Resistivity values between 1Ωm to 1000 Ωm is the value of water, alluvium, and clay. Resistivity values greater than 1000Ωm are generally values of lava, andesite, diorite, granodiorite and limestone.

4) Based on the results of geochemical tests, rocks in the Ngeni zone contain Mn, Cu, S, Fe, Si, and Ca contents with content of 1.88%, 278.63ppm, 18.37%, 967.319ppm, 36.53 %, and 8651.145ppm respectively.

5) There is a correlation between anomalous gravity, magnetic, and geoelectrical resistivity that associated with an anomaly of deep, middle, and shallow respectively.

Figure 4. Resistivity cross section of the Ngeni zone.
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