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Porphyry Body And Geological Structure Identification As Control Of Low Sulphidation Epithermal System In Sangon, Kokap Sub-District, Kulonprogo Regency, Special Region Of Yogyakarta, Indonesia

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Abstract

There is gravity measurement that is supported by magnetic measurement in Sangon to identify porphyry body and geological structure as low sulfidation epithermal system control. The survey area is 6.4×5.6 km for gravity method and 2.5×1.2 km for magnetic method. The value of gravity anomaly after flat plane reduction processing is 122-142 mGal which is positive anomaly located in north-eastern area and negative anomaly to 82-102 mGal located in south-western area. Whereas the magnetic residual anomaly is - 800-1300nT. Conducted 2.5 D modelling of gravity method that is based on local anomaly slice. The result of 2.5D modelling show that an intrusion body interpreted as Dacite intrusion as host rock which plays a role as heat source of mineralization system. The density of Dacite is 2.70 gr/cm3. The result of gravity modelling has correlation with the result of magnetic modelling. Based on magnetic modelling, the intrusion body is located in south-west.

Keywords: Gravity; magnetic; Sangon; Kulonprogo; 2.5 D modelling; Dacite; Intrusion; Mineralization

I. Introduction

Sangon Area, Kulonprogo District has an alteration zone that brings potential low sulfidation type of gold mineralization. This has been proved by the presence of locally managed traditional mines. This mineralization system is controlled by the presence of structures and intrusions of porphyry bodies carrying economical minerals. Intrusion of igneous rocks generally have the characteristics of closed closures on the surface forming a puncture that signifies the occurrence of magma intrusion into the surface thus lifting the area around which it is penetrated. Magma that rise to the surface has a lower density of the surrounding area so it can rise to the surface.

The main targets of intrusionary structures and bodies as control agent of mineralization can be identified by geophysical methods such as gravity and magnetic methods. The main target evidence is identified by the method is further reinforced by the results of Geophysics Expedition 2015 which resulted a low value of gravity with closed closures in the southeast as an indication of mineralization control intrusion. But because the measurement point was still too at least, the results could not be interpreted further. The integration of Magnetic and Gravity Methods on FieldCamp 2018 are expected to further demonstrate the condition of mineralized controllers in Sangon, Kulonprogo better.

II. Basic Theory

A. Gravity Anomaly

The expected result from measurement of gravity data is obtain gravity field anomaly. The basic principle of measuring gravity data is the theory of

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universal gravity, which is the attraction force (F) between two mass particles at a certain distance. The earth's gravity field (g) has a vertical direction

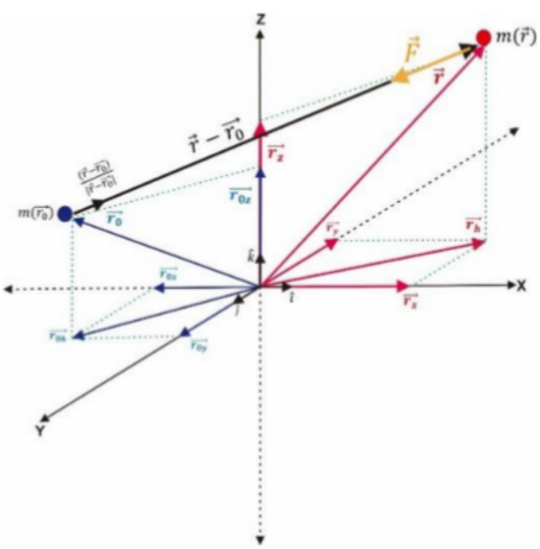

Figure 1: Schematic theory of universal gravitation, two particles of mass at a certain distance

perpendicular to the equipotential plane, whereas the gravity field due to anomalous body existence (local mass distribution) has a varying direction toward the vertical direction and is affected by its position on the anomaly. Changes in the earth's gravity field due to the existence of anomalies are called gravity anomalies (Δg). [1] used the term gravity effect (Δg) to describe the gravity field changes due to the anomaly whose value is much smaller than the earth's gravity field. In measurement, the anomalous gravity field and the earth's gravity field are measured in the vertical axis (z). Since the gravity effect is measured in the g (vertical) and $\Delta g << g$ direction g direction is not affected by the existence of the anomaly.

An anomaly of any given point on the horizontal plane can be written down,

$$\Delta g(x,y) = 2\pi G\sigma(x,y) \tag{1}$$

$\Delta g(x,y)$ is an anomaly of the function x(longitude) and y(latitude) obtained through surface measurements due to the subsurface mass distribution at $z(+)$. While $\sigma(x,y)$ is the surface density at $z=0$. The gravity anomaly on the functions of x and y is proportional to the density of the surface area on the functions of x and y anyway, so that the measured gravity anomaly value $\Delta g(x,y)$ can be represented and extrapolated into the density distribution of the area $\sigma(x,y)$ on the surface with the same contour pattern and different values between the contours of gravity anomaly and surface density contours.

B. Gravity Reduction

Mathematically it can be defined that gravity field anomaly in topography or in position (x, y, z) is the difference from the observed gravity field in topography to the theoretical gravity field ($g(\varphi)$) in topography, free air corrected gravity (g_{FA}), bouger anomaly (g_b), and terrain correction (T).

Mathematically, gravity field anomalies in topography can be expressed in terms of the following equations:

$$\Delta g(x,y,z) = g_{obs}(x,y,z) - (g(\varphi) + g_{FA} + g_b + T) \tag{2}$$

where, $\Delta g(x,y,z)$ = Gravity field anomaly in topography

Reading Scale Conversion

Reading scale conversion is used to convert the reading value in gravimeter (mV) into mGal. The reading scale conversion is varying, depending on the type of equipment used. Conversion scale reading into mGal for Lacoste & Romberg G-1118 gravymeter without feedback is as follows.

$$g_{ukur} = V_{im} + ((SB - CR) \times FFI)) \tag{3}$$

where

$$\begin{aligned} g_{ukur} &= Observed - gravitational\ field\ (mGal) \\ V_{im} &= Value\ in\ miligal\ unit\ on\ CR\ limit \\ CR &= Counter\ Reading\ (from\ the\ equipment) \\ SB &= Reading\ scale\ in\ gravitymeter \\ FFI &= Factor\ for\ interval\ (from\ the\ equipment) \end{aligned}$$

Feedback Correction

Feedback is a nonius scale of the reading scale that serves to keep the beam gravitymeter fixed on the reading line.

$$g_{TF} = g_{ukur} + \frac{FB}{1099} \times FFI \tag{4}$$

Instrument height correction

This means, that each height of one meter affects the gravitational field value of 0.3085672 mgal. Gravity value with instrument height correction is expressed by the following equation:

$$K_{TA} = -0.3085672 h_{TA} \tag{5}$$

,where

$$K_{TA} = Instrument\ height\ correction$$
$$h_{TA} = Instrument's\ height\ when\ measurement\ happens$$

The following equation (eq.5) means that every meter effects the value of gravity field 0.3085672 mGal.

Then the value of instrument height- corrected gravity (g_{TA}) is:

$$g_{TA} = g_{ukur} - K_{TA} \quad (6)$$
$$g_{TA} = g_{ukur} - (-0.3085672 h_{TA}) \quad (7)$$

Tidal Correction

Tidal correction aims to eliminate the effects that arise due to the celestial bodies, especially the moon and the sun.

The effect of maximum gravity due to the Tidal Effect is 0.33 mGal in 1 day of measurement [2] or about 3 g.u = 0.3 mgal [3] with a portion one thirds of the sun and two thirds of the month. The influence of gravity due to tidal effects on the vertical direction by [4] approached by [5] is as follows

$$K_{ps} = \frac{GM_m r}{D_m}(3\cos^2\varphi - 1) + \frac{GM_b r}{D_b}(3\cos^2\theta - 1) + \frac{3}{2}\frac{GM_b r^4}{D_b^4}(5\cos^3\theta - 3\cos\theta) \quad (8)$$

, where

$$r = Earth's\, radius$$
$$M_b = Moon's\ mass$$
$$M_m = Sun's\ mass$$
$$D_b = Earth\ to\ Moon\ distance$$
$$D_m = Earth\ to\ Sun\ distance$$
$$\theta = Geocentral\ angle\ to\ Moon$$
$$\varphi = Geocentral\ angle\ to\ Sun$$
$$K_{ps} = Tidal\ correction$$

thus the value of tidal-corrected gravity (g_{ps}) is

$$g_{ps} = g_{TA} - K_{ps} \quad (9)$$

Drift Correction

In the gravity instrument, drift is an exhaustion factor of the instrument that will affect the measured gravity value. Drift is affected by time and temperature Effect of drift is linier over time. Where the longer the measurement time the greater the influence of drift on the gravity reading. To overcome the effect of drift on the measurement time, we collect gravity data with closed loop The drift correction of the measurement can be expressed by the following equation:

$$K_d = \frac{t_n - t_0}{t'_0 - t_0}(g'_{ps0} - g_{ps0}) \quad (10)$$

$$t_n = reading\ time\ in\ point\ n\ measurement$$
$$t_0 = reading\ time\ in\ base\ point\ (first\ point)$$
$$t'_0 = reading\ time\ in\ base\ point\ (looping)$$
$$g;_{ps0} = tidal - corrected\ gravity\ reading\ in\ base\ point\ (looping)$$
$$g_{ps0} = tidal - corrected\ gravity\ reading\ in\ base\ point\ (first\ point)$$

thus the value of the drift-corrected gravity (g_d) is

$$g_d = g_{ps} - K_d \quad (11)$$

Observed Gravity

Observed gravity (g_{obs}) is the true value of gravity at the measuring point, obtained by binding the relative gravity value to the tied gravity point and the unnecessary reduction of gravity data. The tied gravity point is the known point of its absolute gravity. Gravity observation can be calculated through the following equation,

$$g_{obs} = g_0 + (g_d - g_{d0}) \quad (12)$$

, where

$$g_0 = absolute\ gravity\ value\ in\ tie\ point$$
$$g_d = drift - corrected\ gravity\ value\ in\ view\ point$$
$$g_{d0} = drift - corrected\ gravity\ in\ tie\ point (base)$$

g_{obs} value from the eq.12 is in mGal unit and in topography.

Latitude Correction

A normal gravity field located on the datum plane (at $z = 0$) as the reference point of geodesy. The normal gravity field formula in the field of datum has been established by the International Association of Geodesy (IAG) and the National Imagery and Mapping Agency (NIMA), namely:

$$g(\varphi)(x, y, 0)7 = 978032.700 \times \frac{1 + 0.0019318526524\sin^2\varphi}{\sqrt{1 - 0,00669437999014\sin^2\varphi}} \quad (13)$$

, where

$$g(\varphi) = Normal\ gravity\ field\ in\ mGal$$
$$\varphi = Latitude$$

In the latitude or normal gravity field correction, the position of the measurement point affects the calculation. From the equation it is seen that the higher the location of latitude the greater the acceleration of gravity. So the gravitational field of the earth tends to grow larger toward the poles.

Free Air Correction

The normal gravity field $g(\varphi)$ lies in the plane of datum ($z = 0$) or in the spheroidal plane, whereas $g_{obs}(x, y, z)$ is on topography. Thus, the normal gravitational field trait $g(\varphi)$ to the topography is required to be corrected with $g_{obs}(x, y, z)$. Bring the normal gravity field to topography by performing free air correction (mgal/m). Mathematically free air correction is described as follows.

$$g_{FA} \approx -0.308765h \tag{14}$$

Free-air correction only calculates the elevation between the topography surface (observation points) and the reference spheroid by ignoring the mass between them.

Bouger Correction

In the calculation of free air gravity field anomaly, the mass that lies between the datum and the topography surface is not calculated, whereas this mass greatly affects the anomalous price of the gravitational field. Then the free air anomaly will be more perfect if the mass is also calculated. Bouger correction using infinity horizontal slab approach calculation as follows

$$g_b = 2\pi\rho Gh \tag{15}$$

With ρ is the mass density of the bouger (topographic mass) and h is the measurement point height of the datum. In this research, determination of bouger density uses Parasnis method. Parasnis is done by using measurement data as same as Nettleton is. In this determination, used simple equation from complete Bouger anomaly and then linear regression is made. In the determination of Bouger density by [6] can be expressed by the following equation:

$$\Delta FAA = \left[k\Delta h - \frac{\Delta TC}{\rho_0}\right]\rho + \Delta B \tag{16}$$

, as ΔFAA is free air anomaly between base point and point of i as y-axis, $\left[k\Delta h - \frac{\Delta TC}{\rho_0}\right]$ as x-axis, and gradient is obtained $m = \rho$ as the result of Bouger density calculation.

Terrain Correction

There is mass above the Bouguer plane and a part of the lost mass below the Bouguer plane which in fact represents the existence of hills and valleys. The effect of this mass is called terrain effect. The existence of the valley will reduce the value of the gravitational field value at the point of observation, as well as the presence of the hill resulted in the reduction of the gravitational field value at the point of observation. The hill mass results in the presence of an upwardly opposite force component with the gravitational component. So the existence of valleys and hills around the observation point will reduce the value of the actual gravity field at that point, so that the calculated field correction is always positive.

Plane Reduction

Plane reduction is a process to reduce data distortion on topography caused by differences of mass distance from survey points. This process will make clearer interpretation and model building. Dampney reduces anomaly object to a mass equivalent point then projected the anomaly to a plane eith equal elevation [7]

C. Magnetic Anomaly

Magnetic force is force that is caused by the interaction of two magnetic poles that is separated by r distance. The force can be attractive if the poles have the same sign and repulsive if the poles have opposite sign [2]. According to Systeme International (SI), magnetic force theory is formulated using the analogy that magnetic poles can be considered as an electric charge, so that the force ($\overrightarrow{F}$) that is formed by q_1 and q_2 poles interaction that is separated by r can be formulated using Coulumb's Law:

$$\overrightarrow{F} = \frac{\mu_0}{4\pi}\frac{q_1 q_2}{r^2}\hat{r} \tag{17}$$

Where $\overrightarrow{F}$ is a force that acts in q_1 and q_2 in Newton, μ_0 is magnetic permeability in vacuum ($\mu_0 = 4\pi \times 10^{-7}$ H/m), and r is the distance between the two magnetic poles q_1 and q_2 [3]

Magnetic Field Strength

Magnetic field is a force in a point with a distance of r that is caused by magnetic pole q_2. From classical theory, it can be defined that magnetic field is magnetic force per unit pole q_1. Magnetic field can be formulated mathematically:

$$\overrightarrow{H} = \frac{\overrightarrow{F}}{q_1} = \frac{\mu_0 q_2}{4\pi r^2}\hat{r} \tag{18}$$

Where magnetic field is in Ampere/m [3]

Magnetic Intensity or Magnetization

Magnetic intensity can be defined as magnetic dipole moment ($\overrightarrow{m}$) per unit volume (V).

$$\overrightarrow{M} = \frac{\overrightarrow{m}}{volume} \tag{19}$$

Earth's Magnetic Field

Earth's magnetic field is generated by three main sources. Those three sources are earth main magnetic field, external magnetic field, and spatial variations of magnetic field or magnetic field anomaly where earth's main magnetic field is the dominant one. In geomagnetic field measurement, the measured field is the resultant of those three above.

Earth's Main Magnetic Field

Recent theory states that earth's main field is formed by convection current in outer core fluids that is rich in nickel and iron that rotates as the earth rotates in its axis. Rotation from conductive outer core liquids and solid inner core produces magnetic field, the mechanism is similar to that dynamo mechanism. Around 90% of earth total field is from this main field.

External Magnetic Field

External magnetic field is formed by the sources that are located outside the earth. This field has low value compared to that main field and vary rapidly in time. This field mainly can be caused by atmosphere conductivity changes, sun activity effect which periodically changes in 24 h within a range of 30 nT, diurnal variation from moon's activity which has range of 2 nT, and sun storm activity that is randomly occur and can give value within range of 1000 nT.

Magnetic Field Anomaly

Magnetic field anomaly usually can exist by the effect of magnetic materials that are distributed in rocks. Remanent, induction, or demagnetization can give different effect in the anomaly field. This variation is mainly caused by different in magnetic characteristic between one rock to another or specifically is the susceptibility of rocks.

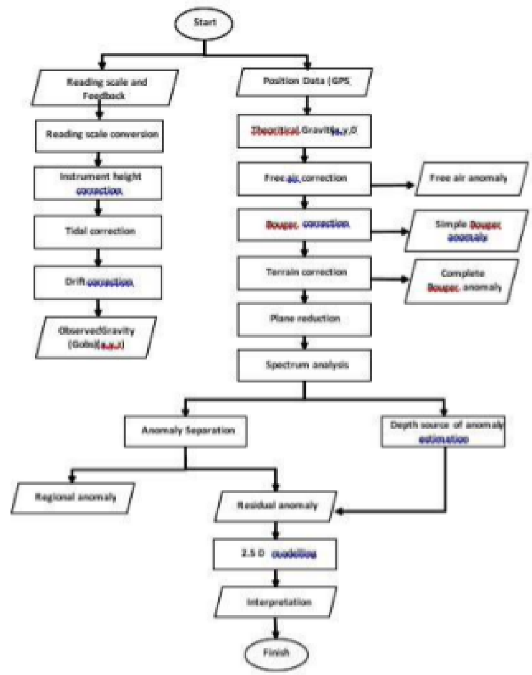

Figure 2: Gravity data processing flowchart

III. Methodology

The first gravity data retrieval is to determine the absolute value of gravity by bonding the gravity value at the base with an absolute gravity. Furthermore, gravity data retrieval is done daily using the Gravitymeter LaCoste & Romberg G-1118 Model, which is daily carried out the daily target data collection by starting from the measurement at the base point in the morning, before taking measurements for the points survey targets, then ends by re-measuring the base point at night, after taking measurements at the last point of the day. Based on the data retrieval time, it is necessary to correct drift and tidal correction. Then, at the data collection each point of measurement, taken data three times to get the average scale reading.

While taking GPS data using Trimble 4600LS to determine the precise position is to use the method of connective point. The system of this method is to tie the gravity / rover data retrieval point at the known base point of fixed positioning, so that at the point of reference the gravity data can be identified (referenced positioning).

The gravity data processing begins by converting the reading scale listed on the tool during measurement and technical corrections are made to determine the value of gravity observation. The correction is a instrument height correction, tidal, and drift and then added to the absolute value of gravity that was known at the beginning of the survey. After that, correction is done to determine theoretical gravity value. The correction is the correction of latitude (normal gravity), free air, Bouguer, and terrain. Then, to get the value of gravity anomaly is to reduce the value of observed gravity (Gobs) with theoretical gravity value. The value of gravity anomaly is called complete bouger anomaly (ABL).

ABL value still presents at the height according to their respective topography. Therefore, a flat field reduction is carried out by bringing all the measurement data points at the same elevation point. After that, the upward continuation and residual filtering are done. And at the end of the research is to do 2.5 D modelling as the final result of final interpretation.

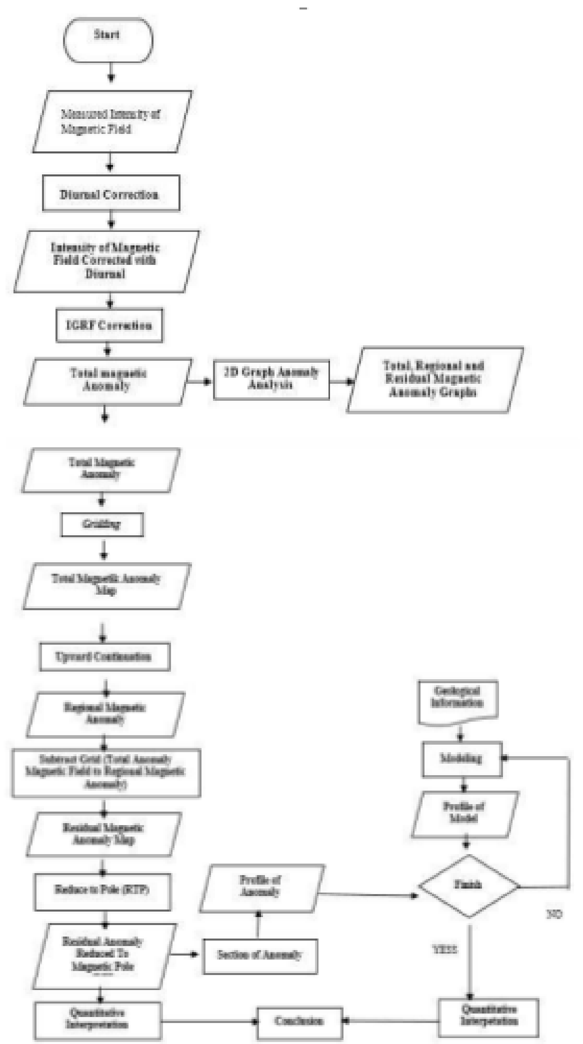

Figure 3: Magnetic Data Processing Flowchart

IV. Result and Discussion

One of the main objective in Fieldcamp 2018 is to identify the existence of intrusion (porphyry body) and existence control agent of mineralization zone in Sangon. Hydrothermal alteration in the research area is the result of the change event of rock minerals that is caused by hydrothermal fluid interaction with rock around. The fluid that brings metal liquid is from igneous rock involves control from geological structure, like fault zone. Mineralization potential in the research area is the result of precious mineral gets into rock and creates ore deposit.

According to [8], in general the process of mineralization is effected by some control factors, including:

- Hydrothermal liquid that functions as mineral carrier liquid,
- Weak zone that functions as channel for hydrothermal liquid to pass,
- Availability space for hydrothermal liquid deposition,
- Chemical reaction event from host rock with hydrothermal liquid that is possible to happen mineral ore deposition,
- Concentrate liquid that is fair high to deposit mineral ore.

Magmatic activity as heat source produces hydrothermal fluid which is the main control agent of the creation of gold deposit. Hydrothermal activity creates gold deposit in economic scale also needs heat source for enough time period. Heat source is commonly known as magma. Basaltic magma or ultra-basalt commonly creates magma body in small dimension, so that quickly turns into cold. Whereas, in Sangon, estimated the magma is acid and tends to create magma body to big dimension. Therefore, geological condition is potential to create gold in economic scale in the area of the presesence of acid igneous rock. To know the anomaly response that is caused by intrusion beneath the surface, conducted gravity measurement with large area 6.4 × 5.6 km. After processing data by reducing some effects that affects gravity value from complete bouger anomaly (ABL), but ABL is still affected by topography where point measurement is, so that ABL needs to be reduced to flat plane. After that, then the anomaly pattern becomes clearer, which is positive anomaly pattern relatives to eastern in the research area with the value is 122-142 mGal and negative anomaly pattern relatives to south-western in the research area with the value is 82-102 mGal. After reducing to flat plane is done, then the anomaly is separated

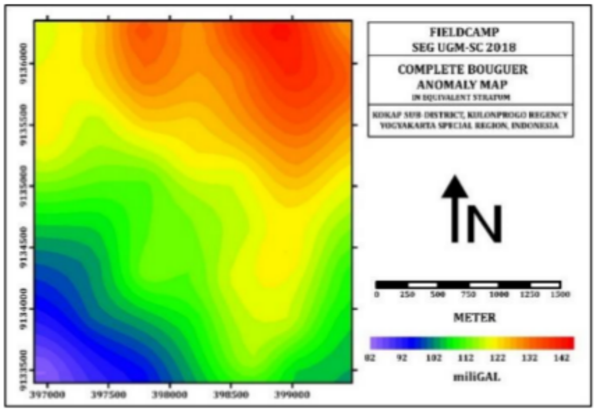

Figure 4: Complete Bouguer Anomaly Map in Equivalent Stratum shows highly positive anomaly at North-East direction

by upward continuation filter, so that we have local anomaly to slice for making model. Modelling is done by slicing research area that is suspected as shallow anomaly source. From the local anomaly map is known that positive anomaly value is in SE and in NW is the result of intrusion that becomes control agent of low sulfidation in the epithermal system of research area. The 2.5 D gravity modelling results

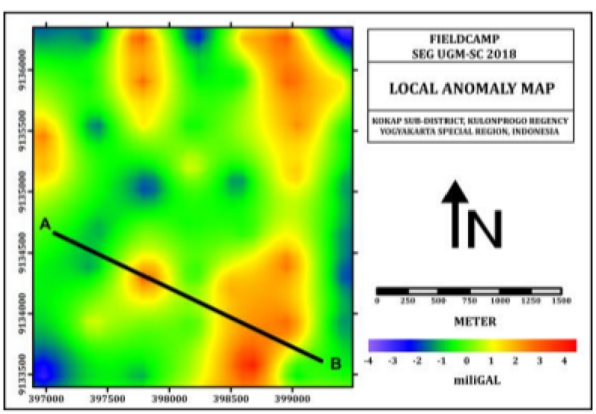

Figure 5: Slice transverses A-B cutting closed closure pattern in NW and SE is suspected as instrusion body response.

as existence of intrusion rock which is suspected as host rock and control agent of mineralization in Sangon, also response from Dacite intrusion with density 2.72 gr/cc which intrudes another older intrusion, Andesite with density 2.5 gr/cc. Two processes of these intrusions make partial damaged of mineralization, so that in some areas can't be found fresh mineral ore (not altered) in mineralization zone. It can be interpreted that intrusion radius is around 1000 m. Then, the gravity modelling correlates with magnetic modelling which suspects existence of intrusion in SW research area. Besides of heat source in the epithermal system, control agent system in mineralization zone has spatial relation between major structure and mineralization process itself. Regionally, a structure system in magmatic arc will form intrusions in which fills fracture areas exist although new fracture. So that, in the major structure area will happen some activities relate to mineral traps. Magnetic data interpretation suspects there is geological structure, fault. That fault is also can be seen from river straightness and close map contour. This fault accommodates the existence a fracture zone that is filled by hydrothermal liquid that can create vein as sulfide mineral deposited. From total magnetic anomaly we can see that anomaly range values from around -300 to 1300 nT. Total anomaly

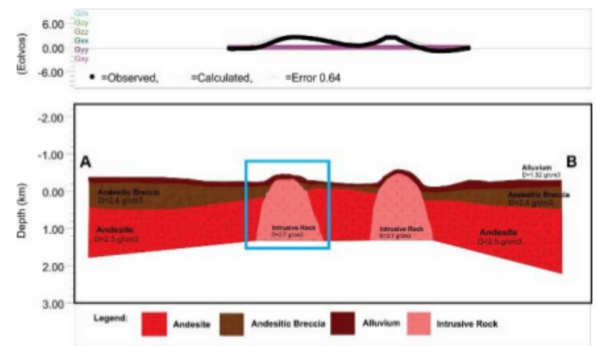

Figure 6: S2.5 D gavity modelling from slice A-B, SE-SW oriented

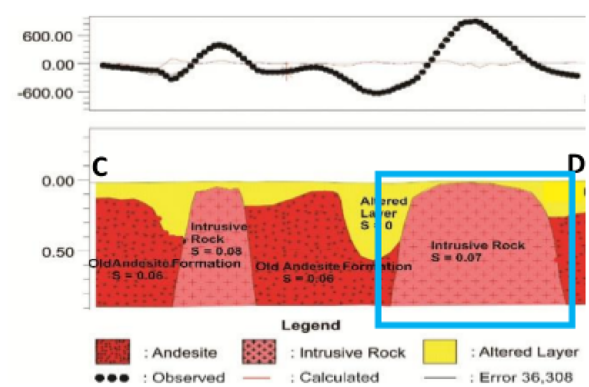

Figure 7: 2.5 D magnetic modelling which shows the same intrusion response with gravity method has

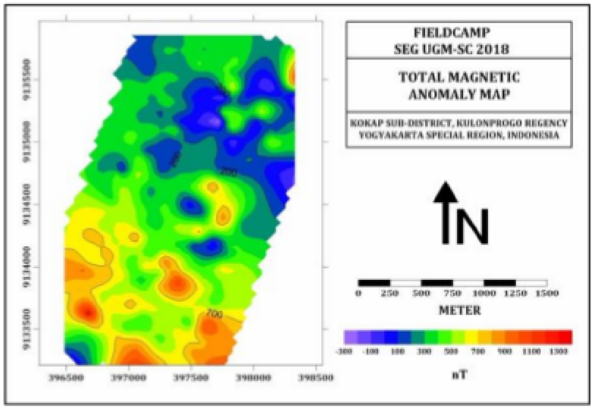

Figure 8: Total magnetic map from research area

value is likely higher in the SW in the research area, whereas low anomaly is likely in NE. Survey area has

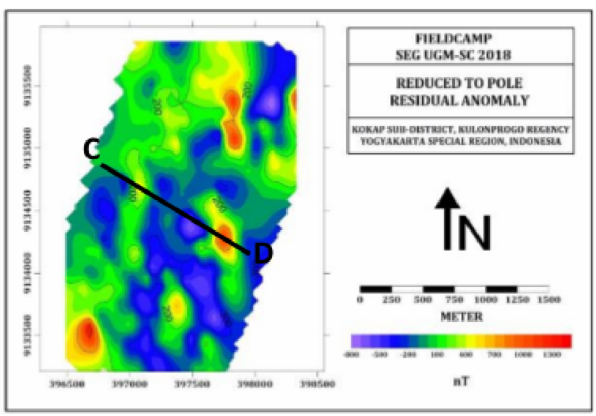

Figure 9: A reduced to pol residual anomaly (local anomaly)

inclination in the amount of -32.39^0 that will make dipole pattern with negative value in southern area and positive value in northern area. But from total magnetic anomaly map is known that in the southern anomaly has positive value, whereas in the northern area has negative value, so that it can be guessed that dipole is not a set dipole in the area.

From upward continuation anomaly 500 m is known that high regional anomaly is in SW area and low anomaly is in NE area. The interpretation is according to residual anomaly map. Residual anomaly map (local anomaly) is the result of total magnetic anomaly map reduction to regonal anomaly map. Residual anomaly map has residual anomaly values around -800 to 1300 nT. Residual anomaly map shows there is low anomaly along which is suspected as structure. In the epithermal deposit of low sulfidation can be

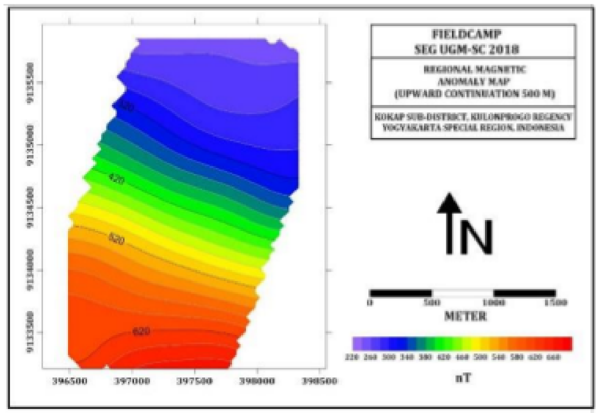

Figure 10: Upward Continuation of Magnetic Anomaly

estimated as one main factor of mineralization and alteration as weak zone structure where magma fluid can get into. Some references mention that veins and

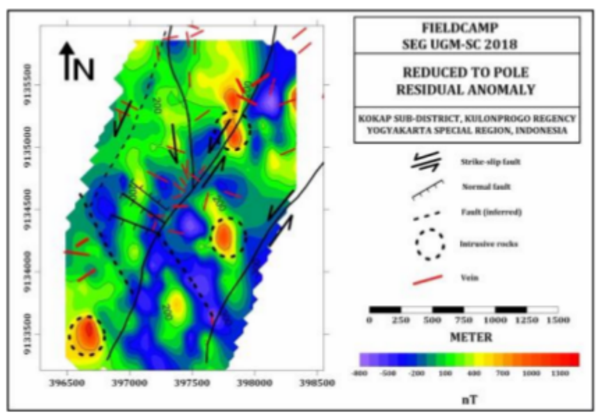

Figure 11: Interpretation of reduced to pole (RTP) residual anomaly map

alteration will be created around extensional geological structure. From residual magnetic anomaly map that has been reduced to pole, we can tell that the faults will be seen in low anomaly as the effect from debris zone and demagnetization as the intrusion outcome. Reference says that fractured fault on the surface can be delineated some adds of structure control agent SE-NW oriented.

Another important feature is there is another control agent as intrusion that is showed by high anomaly. In this research, we can find some Andesite instrusion, confirmed from Andesite mine found in the measurement point. This intrusion also can function as control agent of demagnetization in surrounded area that is symbolized by blue color and have low anomaly as the cause of demagnetization zone by hot fluid.

V. Conclusion

- There is high gravity anomaly with closed closure pattern and North-South oriented. In the eastern of research area is suspected as intrusion body response.
- After gravity and magnetic modelling by slicing both gravity and magnetic residual map show the same intrusion of Dacite body intrusion with 1000 m diameter. It is suspected as control agent of low sulfidation of epithermal system.
- Strike-slip fault can't be seen in gravity data, but it can be seen in magnetic data. It is estimated in NE-SW oriented of research area.

VI. Acknowledgements

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