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Mineral Prospect Identification Using Induced polarization And Very Low Frequency-EM Methods At Sangon, Kalirejo Village, Kokap Sub-District, Kulonprogo Regency, Special Region Of Yogyakarta, Indonesia

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Abstract

A research of induced polarization and very low frequency method was carried out at Sangon Village, Kulonprogo to identify mineralization zone. The result of these methods were able to be used to support each other. Mineralization zone is shown by high resistivity and high chargeability area of induced polarization method, and is also shown by high electric current density area of very low frequency method. Interpretation of resistivity and chargeability model shows that mineralization zone is mostly located at the depth below 10 m from surface. On the other hand, interpretation of electric current density models at depth 10 m and 20 m show that mineralization zone is not well distributed respect to alteration zone, which is the character of low sulfidation epithermal type, mostly at north-south direction.

Keywords: mineralization; Induced polarization; VLF-EM; low sulfidation

I. Introduction

The research area is located at Sangon Village, about 20 km from Yogyakarta. According to its physiography, the research area is included in the Kulon Progo Mountains physiography, where indications of alteration and gold mineralization are found. It has proven, there are many people that operate the traditional mine. Gold mineral deposition occurs in fractures form hydrothermal vein contains Pyrite, Chalcopyrite, Spaleritic, Galena associated with Gold.

Mineralization processes of this area occurred in gold-copper system of low sulfidation epithermal type [1]. Control of structures and lithologies dominated by intrusive and volcanic rocks cross by sinistral strike slip fault and normal fault. The Deformation

resulted fracture filled by hydrothermal fluid, occurs low sulfidation epithermal mineralization process. The alteration formed is Propylitic and Argillic.

The use of geophysical methods for exploration of metallic ores is quite common. This research combines Very Low Frequency-EM (VLF-EM) using NWC transmitter and Time Domain Induced Polarization. The VLF-EM mapping have reflected conductive anomalies that are sulphide zone and alteration to confirmed from existing geology data. VLF-EM line section would be prime areas to look for gold mineralization. In order to identify and explore disseminated metal and sulfide mineralization zones, induced polarization (IP) measurement conducted using dipole-dipole configuration. Inversion of IP data enables to visualize of the subsurface. Induced Polarization measurement were conducted at 2 different location, Western Block and East Block. Based on VLF-EM and IP method brought integrated modeling to confirm each other on the identification of gold mineralization zone within 2D model.

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II. Basic Theory

A. Induced Polarization

Resistivity method basically aims to determine the subsurface resistivity distribution by making measurements on the ground surface. This method utilizes DC current which is injected through two metallic electrodes at the surface and potential difference as a result of the current flow in the subsurface is measured by two potential electrodes (ΔV) at the surface. However, by using Induced Polarization (IP) method, we are also able to detect conductive minerals of very low concentrations that might be missed by resistivity or EM surveys.

The IP method deals with chargeability which indicates the strength of polarization effects caused by ions in the vicinity of metallic grains rock. The measurement used in time-domain where decaying voltage measured after the current is switched off as shown in Figure 1. Chargeability is defined as the area beneath the decay curve over a certain time interval normalized by the steady-state potential difference.

$$M = \frac{A}{\Delta V} = \frac{1}{\Delta V} \int_{t_1}^{t_2} v(t) dt \quad (1)$$

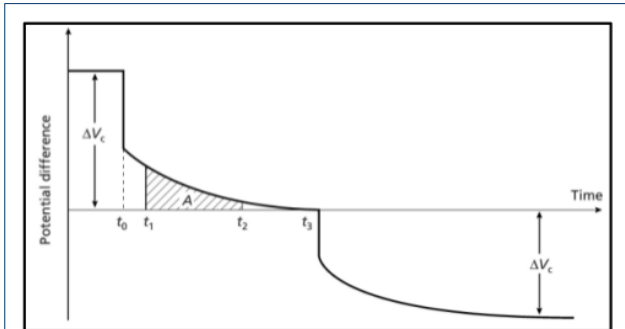


Figure 1: Chargeability in time domain IP measurement [2]

Apparent chargeability shows the duration of the polarization effect shortly after the current is switched off. If delay time takes a long time, chargeability value will be great so that could be indicated as conductive mineral.

Dipole-dipole array was used to minimize the electromagnetic coupling with geometry factor as

$$K = \pi a n(n+1)(n+2) \quad (2)$$

K is a geometric factor that depends on the arrangement of the four electrodes, a is a space between two electrodes, and n is space ratio between current electrode and potential electrode.

B. Very Low Frequency

Very Low Frequency (VLF) is one of geophysical methods which uses electromagnetic wave originated from low frequency-high power radio wave transmitter all around the world ranging 15-30 kHz. Those conditions make VLF a passive method. Its principal depends on the propagation of electromagnetic wave defined by Maxwell equation as follows:

$$\Delta \circ \mathbf{D} = \rho_f \quad (3)$$

$$\Delta \circ \mathbf{B} = 0 \quad (4)$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \quad (5)$$

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t} \quad (6)$$

with E^{\rightarrow} being the electric field vector (V/m), ρ electric charge density (C/m^3), B^{\rightarrow} magnetic induction vector (Tesla atau Weber/ m^2), D^{\rightarrow} electrical displacement (C/m^2), H^{\rightarrow} magnetic field (A/m), J electric current density (A/m^2).

Electromagnetic field measured by VLF-EM device is total complex field comprises of real component (inphase), imaginary (quadrature), total-field, and tilt-angle. The measured value of those four components are highly depend on the conductivity of subsurface target. Primary magnetic field component can be considered as a wave that horizontally propagated. If there is a conductive subsurface target, the magnetic field component from electromagnetic wave will induce that medium resulting induction current (Eddy Current), the bigger Eddy Current is, the bigger the charge density. Primary electromagnetic field of a certain VLF-EM radio transmitter has vertical electric field component and perpendicular magnetic field respective to the propagating direction at X axis [3]. The wave's propagation is shown in the following illustration 2.

The direction of the propagating wave has perpendicular against target's strike, with $\pm 45^\circ$ tolerance of deviating direction that will be automatically corrected by the device.

III. Methodology

Induced Polarization

Two different instruments were used in this research; Syscal Jr and Ares Resistivitymeter. The acquisition take place on the quartz vein. The electrode and porous pot were arranged in Dipole-Dipole configuration. The measurement used $n=6$ and $a=20$ meter. The measurement were done by injecting current to the ground via two current electrodes

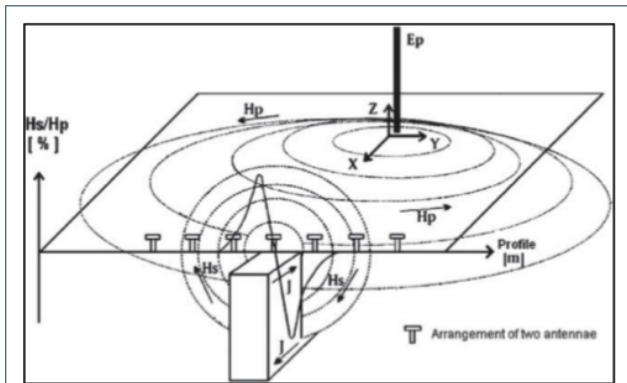


Figure 2: Electromagnetic wave propagation from transmitter generating H_p . H_p field generates H_s field when interacting with conductive material. From H_p and H_s value, tilt angle values is obtained to interpret conductive zone [4].

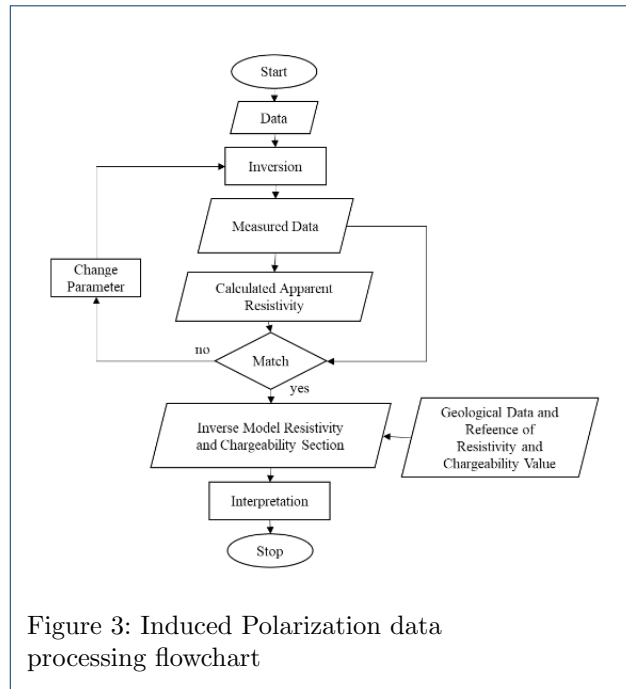


Figure 3: Induced Polarization data processing flowchart

(A and B) and measure the potential difference via two porous pots (M and N), seconder voltage when the current stopped, time needed for the voltage decay. The result from Syscal Jr are average voltage (V) measured, chargeability (M), current (I), and Self Potential. Meanwhile the result from Ares Resistivymeter are chargeability value from each window (before averaging). In this research, the number of windows used is 3.

Physical parameters that used in the processing are resistivity and chargeability values obtained on each line. For the next, we did inversion for data acquisition used Res2dinV. This inversion proposed to derive a subsurface model through measurement data (observation). The distribution of the value of chargeability in 2D is assumed as subsurface lithology. For 3D modeling use correlation for each line using Oasis Montaj.

The study area is divided into 2 zones, IP1 Zone consisting of 2 lines along 320 and 340 meters and IP2 Zone consisting of 6 lines with line lengths of 220-320 meters.

Very Low Frequency

Data is obtained from a survey conducted at Kokap District, Kulonprogo, Special Region of Yogyakarta. VLF-EM measurement had been done in 14 lines spreads in several places at Kokap District, mainly at Kalirejo Village which believed to hold a substantial amount of minerals. In the targeted area it is presumed to bear Argillic and Prophilic mineralization and this survey's objective is to map its presence and continuation overlaying andesite lithology serve as the base lithology in the surveyed area.

Data was taken by two T-VLF console sets along with sensors made by IRIS Instruments. One device powered with battery and the other uses accumulator. Both devices deployed at different lines which then the result combined and analyzed. Generally, the analysis step is done by data smoothing and several filtering, as shown below.

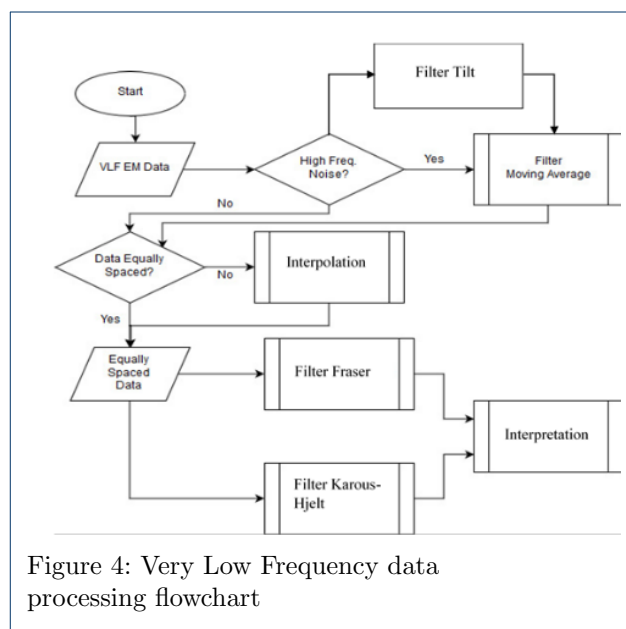


Figure 4: Very Low Frequency data processing flowchart

Quality control used in data measurement is H_{hor} value is always bigger than H_{ver} . Based on

the principal of the inducing electromagnetic wave propagation, it should be bigger than induced field of H_{ver} (Figure 3). Other thing that has to be considered is the direction of transmitter propagation should always perpendicular against target with $\pm 45^\circ$ tolerance shown by compass although the deviation will be automatically corrected by the device. Q bar reading should at least at 60%. Besides, the best transmitter used is the nearest one from survey area so we can get strong signal. Transmitter used in this research is located in Australia with transmitting frequency of 19800 Hz and incoming azimuth of 3 o'clock. Other significant consideration is the spacing of measurement points, if there's blank data gap because of impossible terrain, then it has to be interpolated since the input data has to be uniformly spaced [5].

IV. Result and Discussion

Figure 7a and 8a show the measured data we got from the field and input it into res2dinv. After that we did the inversion from the measured data and got the inversion model (Fig 7c & 8c). From the inversion model, we can calculate the data from the model. The calculated data (Fig 7b & 8b) from the model and the measured data is then compared to each other. When the calculated and the measured data is close enough, the rms error will give a small value. But when the comparison is far, the rms error will give a big value.

Induced Polarization: Western Block

There are 2 lines of Induced Polarization measurement conducted at the western block. The measurement done by using Syscal Jr. On the field there are mining borehole found at 160 m measurement. That mine used for the indication of mineralization zone. The data shows there are anomaly in the same location or meter. That anomaly has resistivity value range 130-900 ohm.m and chargeability value range 30-35 ms at 25-34 m depth. Those value used as the reference for interpreting the mineralization zone.

There are 3 other anomalies that can be interpreted as mineralization zone referring to the mine borehole. All of the three have relatively same depth with the reference and chargeability value 30-46 ms. The anomaly at the 255 and 210 meter have resistivity value for 130 ohm m, meanwhile anomaly at the 70 m has resistivity value for 130-460 ohm.m.

There is a continuity from line 1 at line 2, but the anomaly is smaller than line 1. There are 3 mineralization zone interpreted referring to the line 1 (Fig 5). The anomaly at 270 and 210 meter have the resistivity and chargeability relatively same about 130 ohm.m and 30 ms. At 150 m, there are anomaly with resistivity 130-470 ohm m and chargeability 33-55 ms.

Induced Polarization : East Block

The argillic alteration zone generally has medium to low resistivity features caused by the presence of clay minerals associated with medium-high IP. The propylitic alteration zone generally has high resistivity features due to the presence of chlorite minerals associated with medium to high IP.

- Low Chargeability: < 30% (dark blue), medium: 31 – 50% (light blue-green), high: > 50% (yellow-purple)
- Low resistivity: < 20 Ω m, medium: 21-129 Ω m, high:> 130 Ω m

In the eastern block (IP2 zone), there are 3 lines interpreted as the prospect zone, it was line 3, 4 and 5 so this paper will be discussed about those line. From the resistivity and chargeability section on line 3 (Fig. 11), the mineralized zone indicated by medium value of chargeability in range 30%–35% (1 msec = 0.1%). The medium resistivity values (21-47 ohm.m) are found on the surface at distance of 160-170 m and also found at elevation 320 m and distance of 115 m. In addition, there is also an intrusion zone at distance of 220-240 m with high resistivity and low chargeability as evidenced by the presence of andesite on the surface.

In the resistivity and chargeability section of line 4 (Figure 12), anomaly is indicated with chargeability value above 75% and for resistivity above 531 ohm.m at elevation 290-300 m. This zone is interpreted as mineralization zone, but there is no evidence for the presence of quartz veins on the surface. It may caused by the location of measurement line that near the alteration zone. In the cross-sectional resistivity and chargeability of line 5 (Fig. 13), the mineralization zone have the same characteristics as line 3, indicating a chargeability value.

From all IP measurements interpretation, we can conclude that the mineralization zones are disseminated and located below 10 meters from surface.

Very Low Frequency

VLF survey were conducted over alteration zone using 15 lines (Figure 6). The length of each line is 500 meters and data spacing is 10 meters. Instrument that used in this method is Iris T-VLF and the signal transmitter is NWC 19800 Hz located in Australia. Line X has same location with line 3 of induced polarization method.

Data processing shown by flowchart in Figure 4 has been done for each line. Filter moving average is used to smooth the field data, then filter Fraser and filter Karous-Hjelt are used to show conductivity anomaly of subsurface. The results of this process are

fraser graph and electrical current density profile. The peak of fraser graph indicates anomaly conductivity location and the higher value of electrical current density indicates area which more conductive than the lower value. Thus, mineralization zone is indicated by positive value of electrical current density. Line X interpretation (Figure 14) shows that mineralization zone interpreted by this method has the same location with mineralization zone interpreted by induced polarization method (Figure 11). It means these methods can support each other.

According to interpretation of induced polarization method, mineralization zone located mostly below 10 meters from surface. In order to identify horizontal distribution of this zone, mineralization zone interpreted by VLF method of each line is sliced at depth 10 meters and 20 meters. Then, these sliced data are interpolated with Kriging method. The results of interpolated sliced data (Figure 15 and 16) show that the mineralization zone is not well distributed respect to alteration zone, which is the character of low sulfidation epithermal type, mostly at north-south direction.

V. Conclusion

Mineral prospecting purpose of the survey can be gained by integration of two method run in the area. The VLF-EM method gives high and low anomaly. High anomaly means that the subsurface lithology is conductive. This conductive materials exist beneath the earth is confirmed by some IP lines that intersect the VLF-EM survey area. VLF-EM conductive anomaly identified by electrical current density differs alteration that contains mineralization and the one which is not. The high anomaly is then compared with IP lines. The IP lines model traced shows relatively similar to the value of VLF-EM that sliced in certain depth. The result of induced polarization method shows that mineralization zone in Kokap mostly located below 10 meters from surface, while VLF method shows that mineralization zone is not well distributed (low sulfidation epithermal type) at north-south direction.

VI. Acknowledgements

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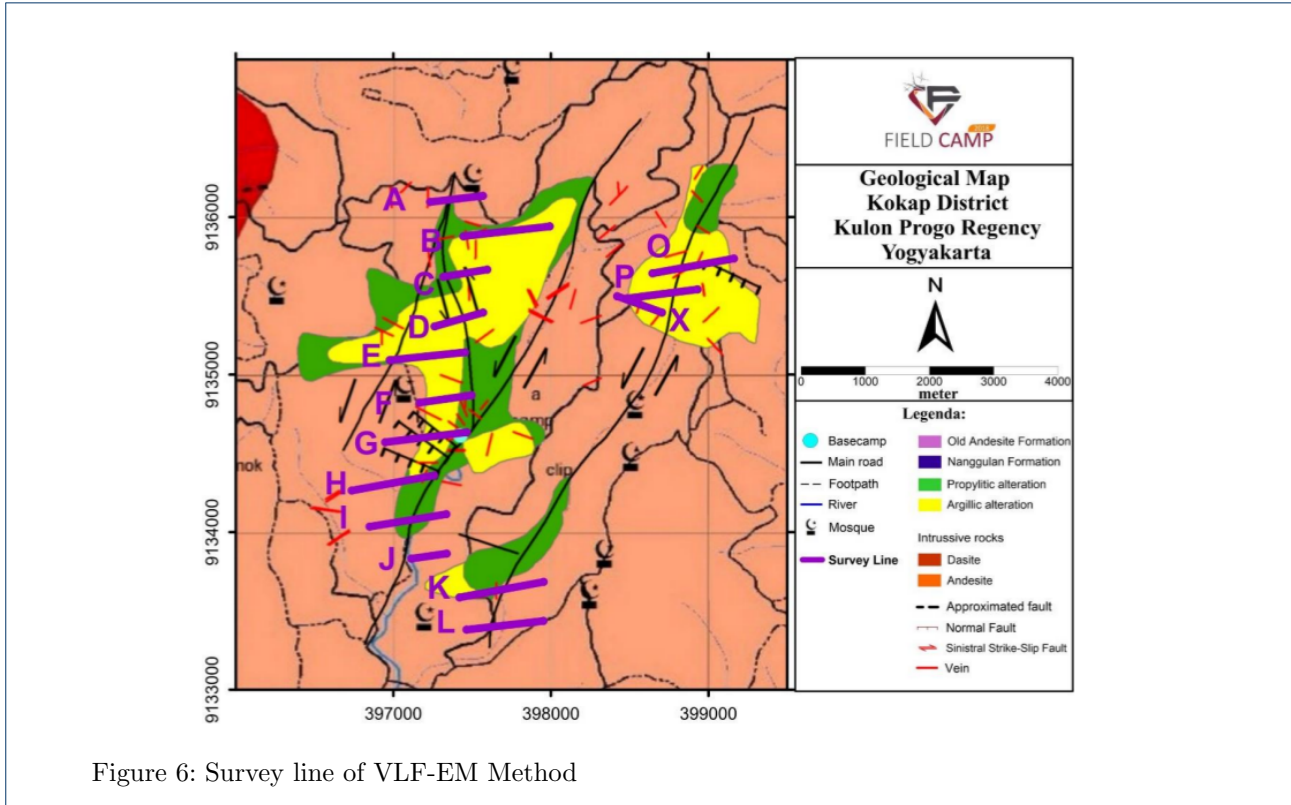
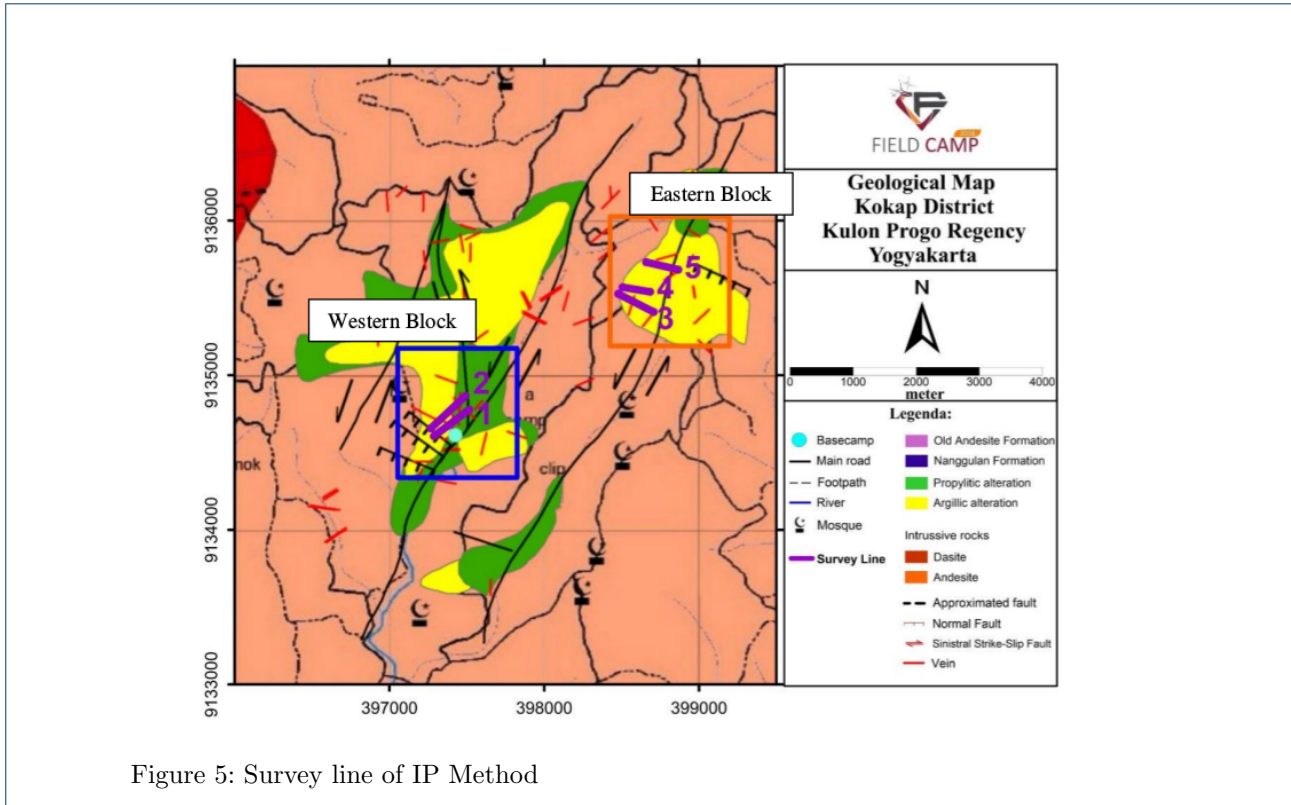
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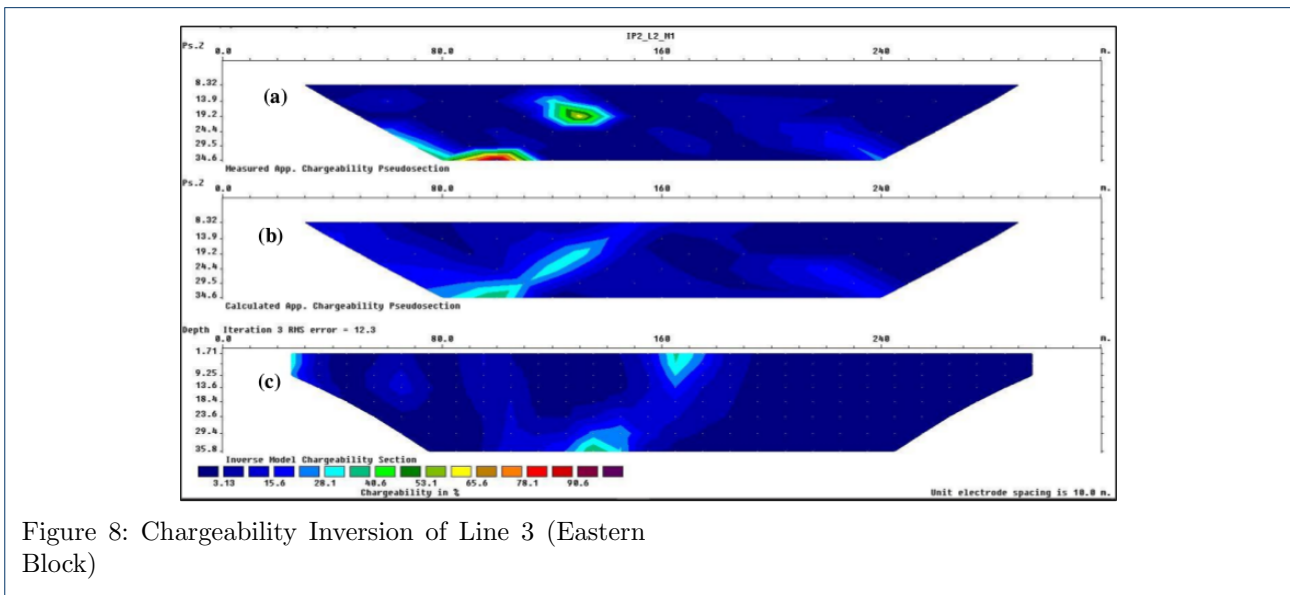
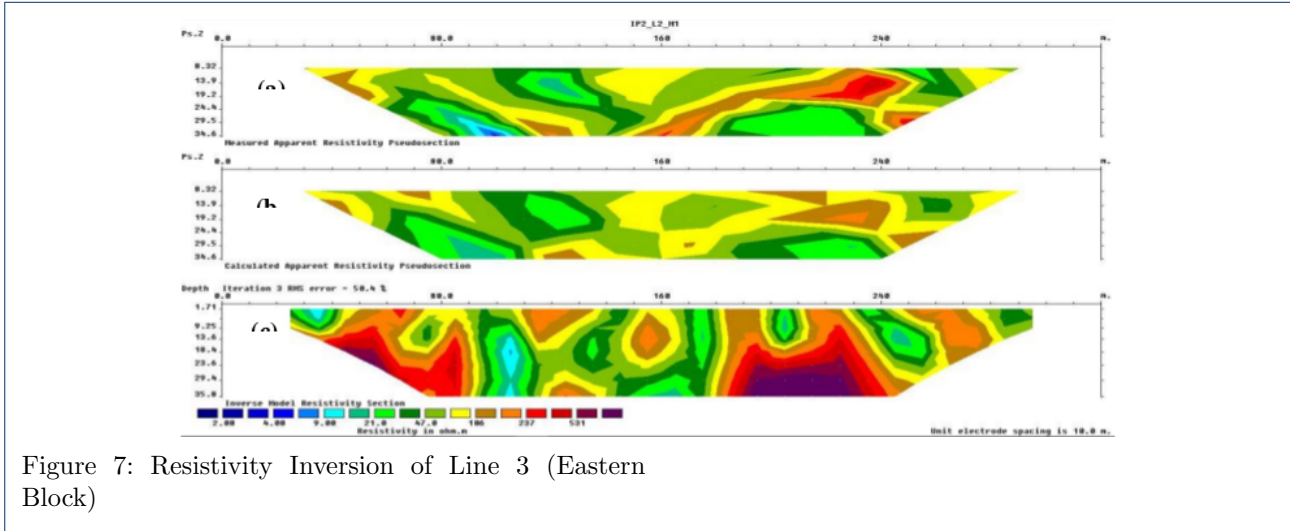
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Some Figures Available on The Next Page





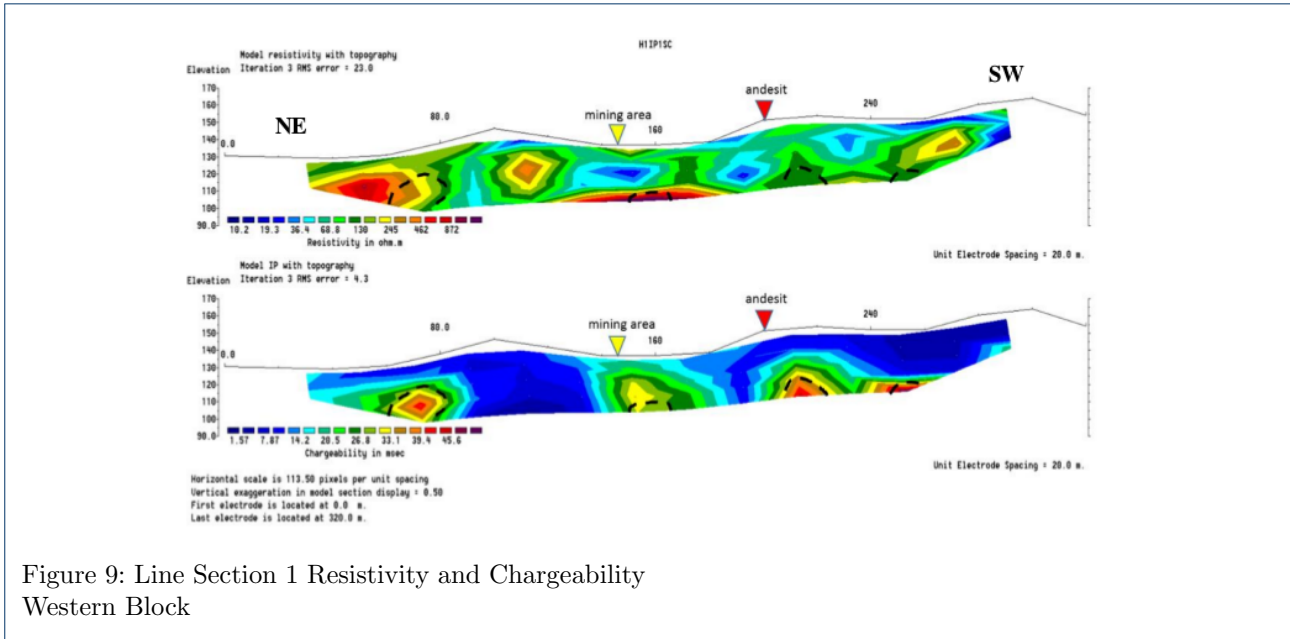


Figure 9: Line Section 1 Resistivity and Chargeability Western Block

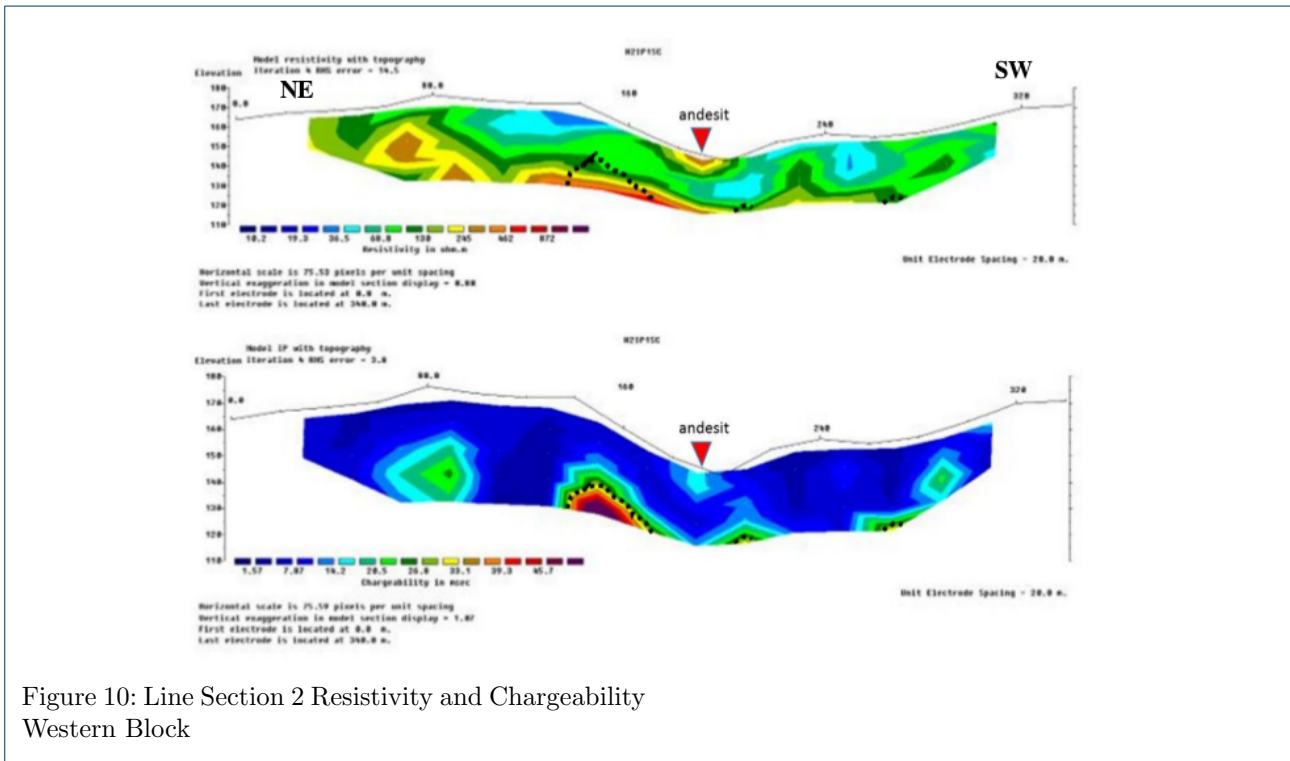


Figure 10: Line Section 2 Resistivity and Chargeability Western Block

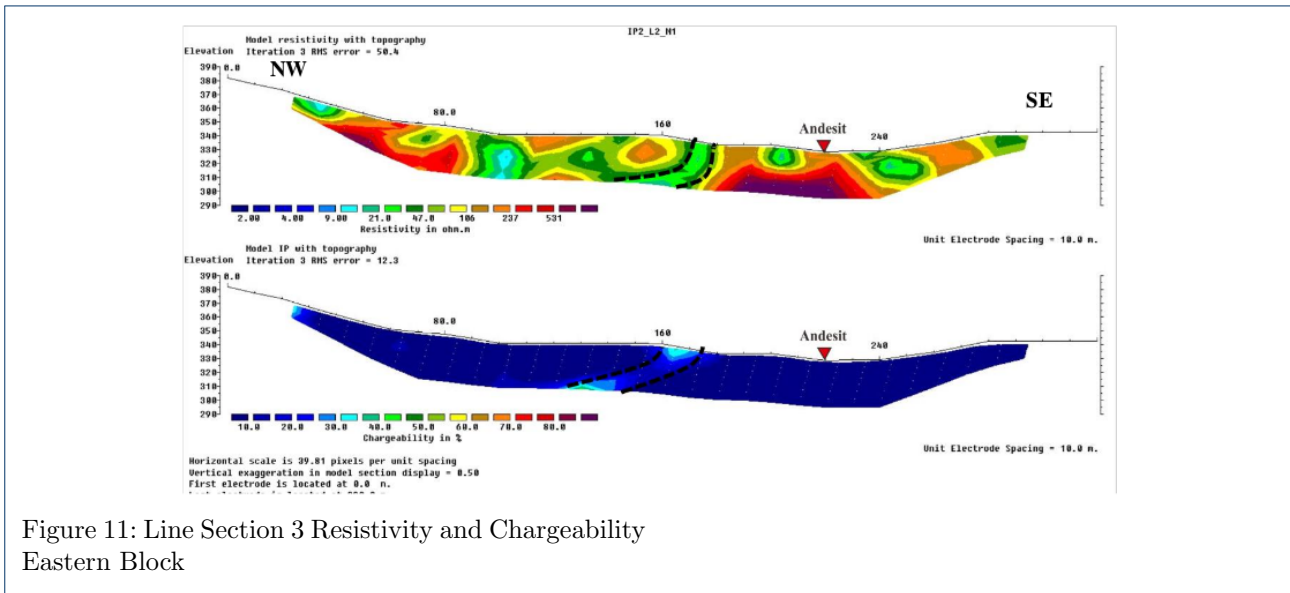


Figure 11: Line Section 3 Resistivity and Chargeability Eastern Block

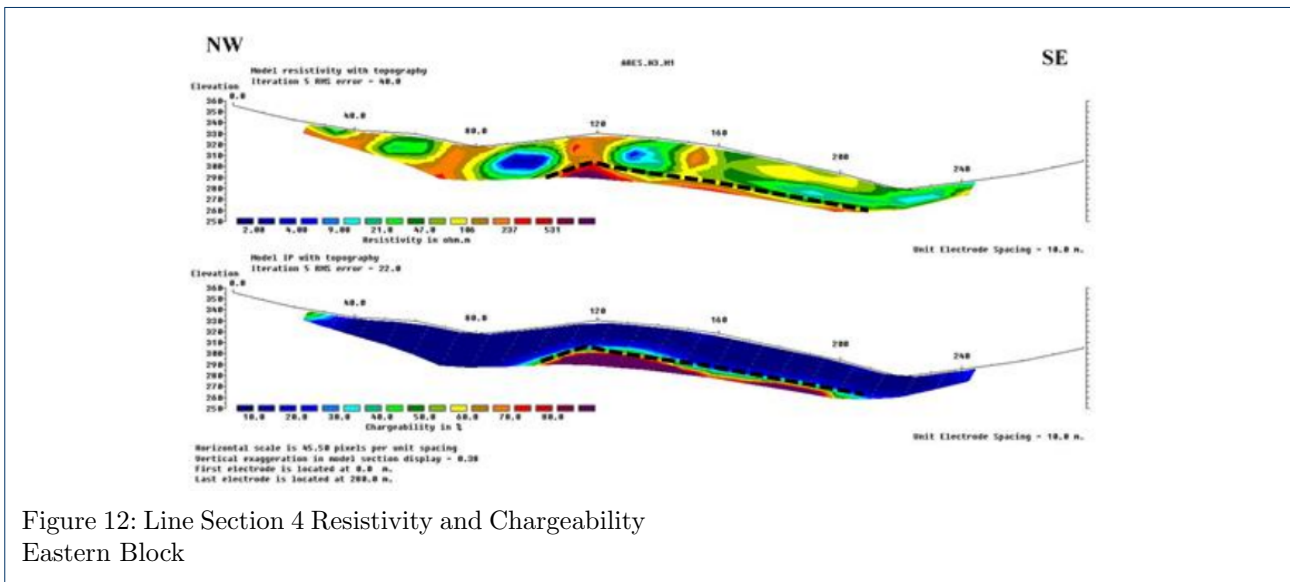


Figure 12: Line Section 4 Resistivity and Chargeability Eastern Block

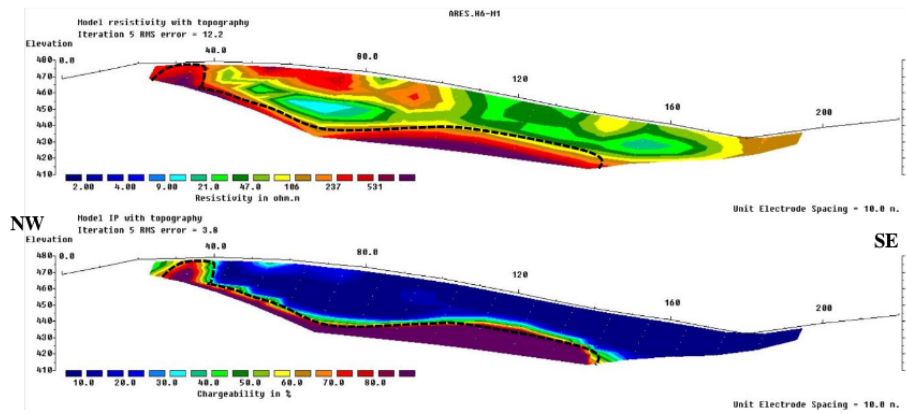
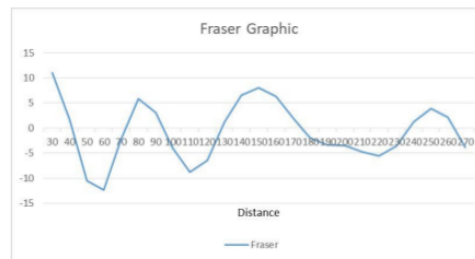
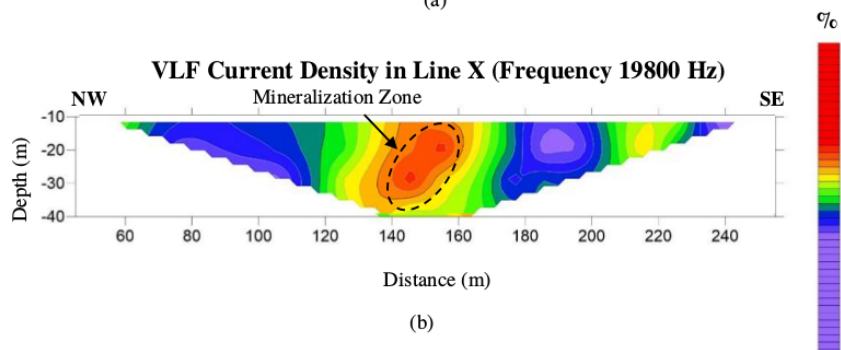


Figure 13: IP Line Section 5 Resistivity and Chargeability Eastern Block



(a)



(b)

Figure 14: a) Fraser Graph b) VLF Line X Current Density Map. Note that mineralization zone interpreted using this method has the same location with mineralization zone in line 3 of IP method.

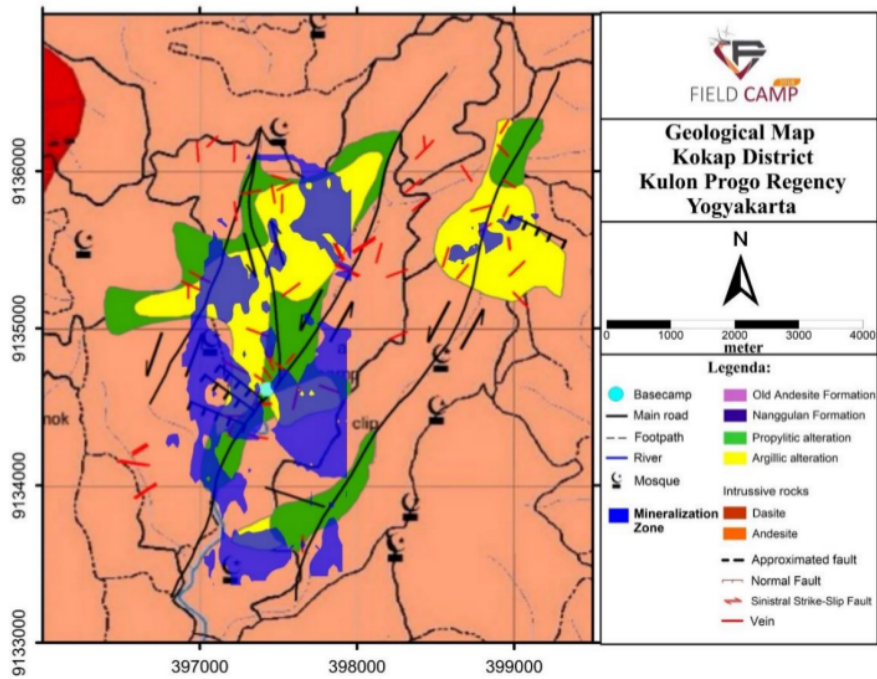


Figure 15: Mineralization zone interpreted by VLF method at depth 10 m below surface

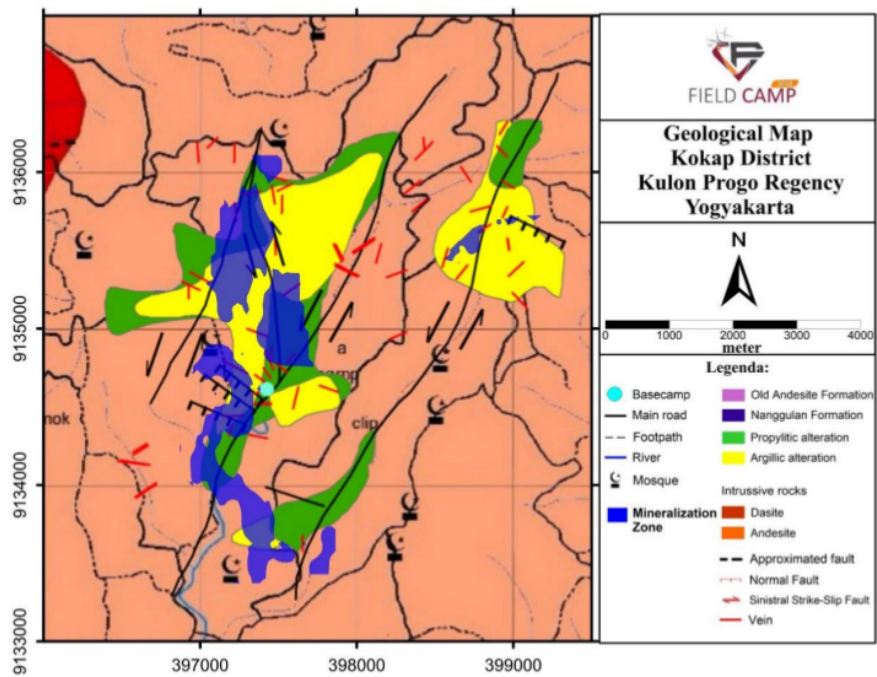


Figure 16: Mineralization zone interpreted by VLF method at depth 20 m below surface