Application of Polarization Method (IP) to Delineate the Gold Mineralization Zones in Cihonje Areas, Banyumas Regency, Province of Central Java

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Abstract. The main problem in metal mineral exploration is determining the deposits at subsurface. This deposit is associated with the surrounding rocks so it is not easy to distinguish. One of the Geophysical methods that can be used for that is the Induced Polarization (IP) method. This method produces two parameters i.e resistivity and chargeability, which very well distinguishes the metal mineral content in rocks. This study, in which the IP method was implemented, was carried out in the Cihonje area, Gumelar Subdistrict, Banyumas Regency, Central Java Province. It aimed to find out the distribution of the gold mineralization zone. The IP data with a total of nine lines were obtained through Junior Syscal 458, using Dipole-dipole configuration, with n=1 to 6 and 20 meters of electrodes spacing. The distribution of gold mineralization areas estimated using by Res2DInv and RockWork15 modeling. An attempt in combining the resistivity and chargeability values was done to identify the anomalous zone boundaries. The results showed that Cihonje area could be grouped into four zones, i.e saturated water layer, alteration, gold mineralization and non-altered volcanic rock zone. The resistivity and chargeability values are (0–100) Ωm and (0–10) ms, (0–100) Ωm and > 10 ms, > 100 Ωm and > 10 ms, > 100 Ωm and (0–10) ms respectively. The gold mineralization zone is spread into two areas, i.e the western and the eastern area which is separated by the Left Paningkaban Shear Fault.

Keywords: resistivity, chargeability and gold mineralization

1. Introduction

Indonesia is a country rich in mineral resources, especially metal minerals. This includes gold as the precious metals. Gold is used for making jewelry, a component in electronic equipment, also used in the health sector. This results in a high demand for gold in the market. However, existing gold supply or resources have not been able to compensate for the increase in demand [1]. Metal minerals in Indonesia are found in the magmatic arc region. Gold ore deposits can be formed from the deposition process of hydrothermal solutions which are closely related to the process of volcanism. Indonesia is a country that has very active volcanic activities so that the process of volcanism can be found in many places in Indonesia. This resulted in the presence of gold ore mineral deposits in several places in Indonesia such as in Cihonje Village, Gumelar District, Banyumas Regency, Central Java.
Cihonje Village, Gumelar Sub-District, Banyumas Regency is one of the areas that is estimated to have the prospect of containing gold ore. In general, the potential for gold in Banyumas Regency is relatively high. Although the location of the points is scattered, generally gold ore is found in alluvial sedimentary pathways that connect continuously to the slopes of the Slamet Volcano. Currently in the village of Cihonje there are many traditional gold mines that are managed by the local people. They traditionally mine gold by digging up soil that is thought to contain gold ore so as to form wells hundreds of meters deep.

The study on the alteration of the mineralization of the Cihonje region was carried out by some researchers [2, 3, 4, 5 and 6]. The Cihonje region has a low type of epidermal sulfidation mineralization formed at a temperature ranging from 100 - 200º C with zoning of silicified - argillic alteration [2]. The base metal and precious metal carrier rocks in the mineralized system of the study area are quartz-metallic-metallic calcite-adularia veins [6]. Epithermal vein deposits are formed due to the process of cavity filling by hydrothermal solution in the body of the rock that passes through it.

The spread of gold ore mineral deposits in the area is not known with certainty. A description of the zone of gold mineralization which is quite shallow (200-400 m) was obtained in the Cihonje area with magnetic methods with magnetic contrast values of more than 400 nT [7]. Investigation of the distribution of gold mineralization in low sulfidation epithermal environments using magnetic methods and pseudogravitation transformation in the Paningkaban - Cihonje area was carried out. The results showed that the high magnetic zone is a porphyry-microdiorite intrusion body at a depth of 700 to 800 m with susceptibility values of 0.05 - 0.25 SI. Based on this, the research in Cihonje Village was conducted using the IP method. The IP method is used because the response given by this method can distinguish the metal content in rock, so that the distribution of metal mineralization zones can be found [8]. The purpose of this study is to find out the subsurface description based on rock resistivity and chargeability values in the study area. In addition, it delineates the distribution of mineralized zones based on a combination of resistivity and chargeability values. This study produced a map of the distribution zone of gold ore mineralization, which can be used to find out potential mineral resources.

2. Geology of the Research Area
In general, the study area consisted of the morphology of the hills with very steep slopes to very gentle slopes, ridges, and valleys that relatively stretched heading to southeast-northwest. The research area is part of the physiographic zone of the Bogor-Serayu Utara and Kendeng Anticlinorium which is the result of the uplift activity of the Bandung depression zone in West Java [9].

The regional stratigraphic order of the study area is included in two regional geological maps, namely the Geological Map of Purwokerto-Tegal Sheet [9] and the Geology Sheet of the Majenang Sheet. The sheet consists of the Halang Formation (Tmph / Tmh), Site Formation (Tpt) and Member of Limestone Tapak Formation (Tptl). Whereas based on the geological mapping that has been done [10], it is known that the research area consists of three rock units i.e Sandstone Unit - Claystone, Sandstone Unit, and Limestone Unit (Figure 1).

Sandstone-Claystone Unit in the study area is filled with breccias. Sandstones in this unit, light grey coloured, have sedimentary structures in the form of parallel and cross lamination, load cast, graded bedding, and imbrications. It has fragment composition (40%) in the form of plagioclase (26%), clinopyroxene (7%), and quartz (7%), matrix and cement (60%) in the form of carbonate minerals (36%), clay minerals (12%), opaque minerals (7%), and chlorite (5%). Claystone in this unit generally has a greenish gray - yellowish brown color, its thickness is between 2cm to 50cm, and has a Fragment composition (5%) in the form of klinopiroxen (3%) and quartz (2%), matrix and cement (95%) in the form clay minerals (40%), chlorite (30%), volcanic glass (20%), and opaque minerals (5%). Meanwhile, breccia inserts are generally in a form of fragment Andesite igneous rocks. Based on the microfossil analysis, it is known that the unit of Sandstone - Claystone in Late Miocene to Early Pliocene periods (N17 - N18), referring to the equation of physical properties and age of rocks, can be compared with the Halang Formation [10].
Sandstone Unit is composed of sandstones with claystone inserts. Sandstones in this unit are grayish white colored, consisted of parallel lamination sedimentary structures, cross lamination and graded bedding (composite layers). The composition consists of fragments (35%) in the form of plagioclase (5%), quartz (4%), clinopyroxene (9) and rock fragments in the form of fossil fragments (17%), matrix and cement (65%) in the form of clay minerals (38%), carbonate minerals (10%), opaque minerals (10%) and volcanic glasses (7%). Claystone inserts have a grayish-gray light color, are loose, added with carbonate cement. Microfossil analysis in Sandstone Unit shows the age of Early Pliocene - Middle Pliocene (N18 - N21); therefore, based on the similarity of the physical properties and age of rocks, this unit can be compared with Tapak Formation [10].

Limestone Units are composed of crystalline and clastic limestones. Crystalline limestones have characteristics of yellowish white, rough crystalline texture, and massive structures. On the other hand, clastic limestone is white, fine sand sized, good sorting, consists of fragments (30%) in the form of fossil shells (10%), coral fragments (15%), and algae (5%). The matrix and cement (70%) consist of microspar and micrite. Based on the similarity of the physical properties it can be compared with the limestone members of the Tread Formation.

Figure 1. Geological Map of Paningkaban and its surroundings, Gumelar District, Banyumas Regency, Central Java Province (after Isyqi, 2016)

2.1. Structure of Geology
The research area is located on Java Island which has three dominant directions of structural alignment, namely the Meratus pattern with northeast-southwest direction, the Sundanese pattern trending north and the Javanese pattern trending west-east [11]. In addition, the study area is also influenced by the presence of two contradictory large horizontal faults in Java, namely the southwest-northeast Muria-Kebumen Horizontal Fault and the Pamanukan-Cilacap dextral Horizontal Fault directed northwest-southeast [12]. Based on the geological mapping that has been done, the Cihonje area and its surroundings (Figure 1) shows the geological structure in the form of folds, shear faults
and stiffness. Folds in the form of Syncline Cihonje, Paningkaban Anticline, Cineang Anticline and Syncline Darmakradenan. Slip fault consists of Left-Slip Fault Ride Cogrek, Left-Slip Fault Babakan, Right-Down-Slip Fault Ratadawa, Right-Slip Fault Penaruban. The joint in the form of muscular and extensions joint [1].

2.2. Alteration and Mineralization
Gold ore in the study area was found as inclusion in some galena and pyrite. This shows that gold formation comes first before it is formed as inclusion. Besides, there is also gold that fills the gap between the pyrite minerals. Alteration types found in research areas are argillic alteration, phyllic alteration, sub-profile alteration and weak sub-profile alteration. In addition, there was also a mixture of hydrothermal fluid dominated by meteoric fluid with a CO2-rich fluid. Based on research data, the type of gold deposits in the study area is a low sulfidation epithermal deposit with Carbonate-Base Metal Gold type [1].

The weak sub-profile alteration is characterized by the presence of secondary minerals not more than 25%. The secondary mineral is in the form of chlorite or smectite and some carbonate mineral. The form of sub-profile weak alterations in the study area is caused by a few hydrothermal fluids that are less reactive. In the study area the presence of sub-profile alterations is characterized by the presence of rock outcrops which are slightly greenish in color and the presence of calcite veins of 0.3 to 1 cm thick. This alteration is formed in a neutral to alkaline pH environment.

What distinguishes sub-profile alteration from weak sub-profile alteration is its alteration and mineralogic intensity. Sub-profile alteration intensity is stronger and is characterized by the presence of secondary minerals reaching 50-75%. The secondary minerals such as chlorite, clay minerals (smectite), carbonate minerals and some quartz and zeolite. Outcrop conditions in the study area are characterized by rocks that are rich in chlorite and clay minerals. In addition, in this alteration type calcite veins are associated with sulfide minerals such as pyrite, sphalerite, markitite and hematite. Rock units undergoing sub-profile alteration are a unit of repetition of gradations of claystones.

Argillic alteration has a strong alteration intensity characterized by the presence of 75 to 100% secondary minerals in the form of clay minerals (smectite, illit, kaolin), carbonate minerals, quartz and a little chlorite. The rock unit under argillic alteration in the study area is a repetition unit of gradations of claystones. In addition, it was also found some calcite veins trending north-south, northwest-southeast and northeast-northwest in the argillic alteration area. The presence of phyllic alteration is characterized by the presence of quartz, pyrite, sericite, clay minerals and carbonate minerals. This alteration has a strong intensity characterized by the presence of secondary minerals 75 to 90%. Rocks which experience alteration are diatrema breccias [1].

3. Methods

3.1. Induced Polarization and The Parameters
The IP response reflects the degree to which the subsurface is able to store electrical charge, analogous to a capacitor. This polarization occurs at the interface between a metal and a fluid (electrode polarization), and a non-metal (e.g. silica or clay minerals) and a fluid (called membrane polarization). The low frequency current or direct current (DC) is injected at two current electrodes, while the potential difference is measured on the potential electrode. The square wave generated current electrodes and the signal received at the potential electrodes (Fig. 2). When the current is disconnected, potential will immediately zero. However, in IP measurement, the potential will be zero for several time intervals, this is called potential decay. Potential decay is due to the polarization in the subsurface medium [13].
At the time domain, there is most common measurement is the chargeability defined as
\[ m = \frac{1}{V_0} \int_{t_1}^{t_2} V(t)dt \]  

(1)

Where \( V_0(t) \) is residual voltage integrates over time window defined between times \( t_1 \) and \( t_2 \) after termination of an applied current. \( V_0 \) is the measured voltage at some time during application of the current. The unit of chargeability are quoted as millivolt per volt (mV/V) and is the most commonly used quantity in time domain IP measurement. When \( V_0(t) \) and \( V_0 \) have the same units, the chargeability \( m \) is in millisecond (ms).

The subsurface geology can probably have a form as beddings with different resistivity. The resistivity measurements made on the surface show a results called apparent resistivity. The measurement is done by injecting the current through current electrodes (AB) on the ground surface and measuring the potential in potential electrodes (MN). Konfigurasi Dipole-dipole digunakan akuisisi data IP (Figure 3). Dipole-dipole configuration is used by IP data acquisition (Figure 3).

The relationship of apparent resistivity and injected current \( (I) \), potential \( (\Delta V) \) and configuration factor \( (K) \) is shown in equation (2).
\[ \rho = \frac{\Delta V}{I} K \]  

(2)

The geometry factor for the Dipole-dipole electrodes arrangement is written in equation (3). In which \( a \) is the spacing of the electrodes and \( n = 1 - 6 \) or more.
\[ K = \pi an(n + 1)(n + 2) \]  

(3)

3.2. IP measurements
Research using TDIP methods in Cihonje is an important method of analyzing minerals and estimating the metallic mineral resources. The data resistivity and chargeability were taken using Syscal Junior 486 Series. Nine lines and two-point sounding were used. The sounding points are located around the L1 line on 160 and 180 meters. The data was taken from three parallel lines (L1, L2 and L3) and two
intersect lines (L4 and L5). Line L1 is 300m length with 20m spacing and n = 1-8, Line L2 to L5 are 200 m length with spaced 20 m. The lines did not form as a grid, because there is canyon at the area. This selection of lines is to predict continuity of mineralization at vertical and horizontal directions. The design line in this study is shown in Fig. 5.

4. Result and Analysis
The inversion result with Res2Dinv [14] on all IP data, shows that the resistivity value in the study area has a range of 0 to 1200 Ωm and chargeability 0 to 110 ms. Resistivity and chargeability values are grouped into three categories, i.e low, medium and high (table I). The interpretation stage was done by correlating resistivity and chargeability values in certain zones as shown in table II.

| Resistivity-ρ(Ωm) | Chargeability-m(ms) | Scale       |
|-------------------|---------------------|-------------|
| 0 – 30            | 0-10                | Low         |
| 30-100            | 10-30               | Medium      |
| >100              | >30                 | High        |

Table 2. Correlation of resistivity, chargeability value and interpretation of the zone.

| Resistivity-ρ(Ωm) | Chargeability m(ms) | Interpretation                  |
|-------------------|---------------------|---------------------------------|
| Low – medium      | Low                 | zone of saturated water layers  |
| Low – medium      | Medium – high       | alteration                      |
| High              | Medium – high       | gold mineralization zona        |
| High              | Low                 | unaltered volcanic rocks        |

Interpretation of the study area zone is based on a combination of resistivity and chargeability values (Tables 1 and 2). There are four zones obtained, i.e the zone of saturated water layers, alteration, gold mineralization and unaltered volcanic rocks. The water saturated layer zone is characterized by low to moderate resistivity values (0 to 100 Ωm) and low chargeability (0 to 10 ms). The alteration zone is characterized by low to moderate resistivity values (0 to 100 Ωm) and moderate to high chargeability (> 10 ms). The gold mineralization zone is characterized by a high resistivity value (> 100 Ωm) and moderate to high chargeability (> 10 ms). Rocks with high resistivity values (> 100 Ωm) and low chargeability (0 to 10 ms) are identified as unaltered volcanic rocks.

4.1. Interpretation of IP
The mineralized zone on the D1 line is identified at 190 m to 230 m, with resistivity values > 30 Ωm and chargeability 19 to 50 ms. The area around the mineralized zone is from 160 to 190 m and 230 to 270 m. The initial line at points 40 to 60 m and points 80 to 170 m, there are alteration zones with low resistivity and moderate to high chargeability. There are also unaltered volcanic rocks under the mineralized zone area with resistivity values of 100 to 400 Ωm and chargeability of 0 to 4 ms.

The mineralized zone with considerable depth was found on the D2 line. The mineralized zone is at the point 180 to 200 m with a value of 80 to 100 Ωm and chargeability of 30 to 70 ms. This zone is the continuity of the mineralized zone found on the D1 line. On this D2 line there are also alteration zones, namely argillic alteration with low to moderate resistivity and moderate to high chargeability.

Three zones of mineralization scattered in locations that are slightly apart are on the D3 line. The first location is at points 100 to 130 m with resistivity values of 100 to 200 Ωm and chargeability of 30 to 70 ms (figure 4). The mineralized zone is further estimated to be the continuity of the mineralized zone found on the D1 and D2 trajectories. The mineralized zone is at points 220 to 240 m at a deep depth with resistivity values of 100 to 200 Ωm and chargeability of 22 to 30 ms. The third mineralized zone is at the end of the line at 380 to 420 m with a resistivity value of 100 to 1000 Ωm and chargeability of 22 to 30 ms. In addition, there are phyllic alteration zones with moderate resistivity values (70 to 100 Ωm) and moderate chargeability (22 to 30 ms).
Two areas of the mineralized zone with resistivity and chargeability values tend to be high on the D4 line. The first mineralized zone found at points 310 to 340 m is the continuation of the mineralized zone from D1 to D3 lines with resistivity values of 100 to 800 Ωm and chargeability of 30 to 110 ms. The second mineralized zone is estimated to be the complexity of the mineralized zone found at the end of the D3 line. This second mineralized zone has a resistivity value of 100 to 400 Ωm and chargeability of 30 to 70 ms. There are also alteration zones with low to moderate resistivity and moderate to high chargeability which are classified as argillic alteration zones.

The mineralized zone was not found on the D5 line, but there were some alteration zones and unaltered volcanic rocks. The absence of the mineralized zone on the D5 line is expected because the data retrieval line is parallel to the vein direction found in geological information. The alteration zone in the D5 line is an argillic alteration zone and has a moderate to high resistivity value and low to moderate chargeability. In addition, there are also sub-profilitic alteration zones [1] and have low to moderate resistivity and moderate chargeability.

Mineralized zones were not seen on the D6 line, but there were sub-profilitic alteration zones with low to high resistivity and chargeability values which were tend to be moderate. The end of the line D7 (390 - 420 m) has a mineralized zone with a resistivity value of 100 - 400 Ωm and chargeability of 30 to 110 ms. In addition there are alteration zones located in the middle of the line (170-210 m) with low to moderate resistivity and chargeability. The alteration zone at the end of the line has a moderate to high resistivity and chargeability value. The alteration zone found at the end of the D7 line is estimated to be a phyllic alteration zone in accordance with the geological data found in the study area [1].

On the D8 line there is a mineralized zone at points 360 to 400 m with resistivity values of 100 to 200 Ωm and chargeability of 22 to 30 ms. The mineralized zone found on this line is estimated to be the continuity of the mineralized zone found on the D7 line. In addition, there are also alteration zones which are thought to be argillic alteration zones based on the geological data of the study area. This zone has a low resistivity value and moderate to high chargeability.

The mineralized zone which is quite large was found on the D9 line, which was on the surface with resistivity values of 100 to 600 Ωm and chargeability of 30 to 70 ms. The alteration zone is estimated to be an argillic alteration zone at the beginning and middle of the line marked by low to moderate resistivity and high chargeability. The final end of the D9 line also has an alteration which is
estimated to be a sub-prolifitict alteration zone based on the geological information of the study area and has a moderate to high resistivity value and a moderate chargeability.

![Figure 5. Map of distribution of gold mineralization zones, Cihonje area and surroundings. The gold mineralization zone is divided into two, east and west](image)

4.2. Distribution Map of the Gold Mineralization Zone
Ploting the results of interpretation of all IP measurement trajectories on survey design maps is shown in figure 5. The gold mineralization zone is concentrated in the middle and east of the survey area. Most of these zones are in agrarian alteration and a small part is in phyllic alteration. The distribution of the zone of gold mineralization is divided into two areas, namely the west and east areas which are separated by the presence of Paningkaban left-strike fault. The western mineralized zone shows a continuity characterized by the presence of calcite veins or quartz carbonates. The mineralized zone in the east area is estimated to have continuity as well. The interpretation of the gold mineralization zone is quite difficult for the entire line. This is because the alteration zone is around the zone of gold mineralization. However, the alteration zone is not related to the presence of gold. Three dimensional visualization is done based on the correlation between the actual resistivity and chargeability values (figure 6). This was done to obtain a description of the distribution of gold mineralized zones to depths that match the results of penetration of the IP method used.

Based on the results of the research in Cihonje Village, Gumelar Subdistrict, Banyumas Regency, Central Java Province, two major areas of gold mineralization were obtained, namely the west and east areas. If exploitation is carried out in the research area, it is recommended to focus the mining activities on the western area. The west area is a continuation of calcite and quartz carbonate vein outcrops that can be used as a guide for the location of gold ore. Based on 3D data visualization in figure 6, there is more potential gold mineralization zone in the western area compared to the eastern area. The eastern area can be exploited because there is a gold ore content, although not as much as the
western area. There are also minor areas containing unrevealed gold ores in the form of calcite veins or quartz carbonates. Mining activities can also be done in this minor area.

![Diagram of gold mineralization zone](image)

**Figure 6.** 3D visualization of the distribution of the zone of gold mineralization in the study area

5. **Conclusion**

The subsurface resistivity and chargeability values in the study area are known to have a range of 0 to 1200 Ωm and 0 to 110 ms. The gold mineralization zone in the study area is characterized by a high resistivity value (> 100Ωm) and moderate to high chargeability (> 10 ms). The gold mineralization zone is spread over two areas namely western and eastern area which are separated by a Paningkaban left-strike fault. The mineralized zone is mostly found in alteration zones, but not all alteration zones are zones of gold mineralization.

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