Identification of hydrothermal deposit mineralized zones using the induced polarization method in Kasihan Area, Pacitan, East Java

Asrafil1, I Suyanto2, S Rugayya3

1Geological Engineering Study Program, Tadulako University, Indonesia
2Geophysics Study Program, Universitas Gadjah Mada, Indonesia
3Department of Physics, Tadulako University, Indonesia

E-mail: asrafil@untad.ac.id

Abstract. The research area is one of the areas that have potential of hydrothermal deposit mineralization in Pacitan regency. This research aims to identify the presence of hydrothermal deposit mineralized zones through geophysical exploration by using induced polarization method in the study area. The induced polarization method is used to obtain anomalies in the form of contrast of resistivity and chargeability values in the study area. The results showed that the mineralized zones of hydrothermal deposit in the study area were characterized by significant anomaly contrast with the intensity of medium-high (> 100 $\Omega$m) resistivity values associated with medium-value chargeability (20-50 ms). The association of resistivity and other chargeability values shows an intense alteration zone around the metal mineral deposits zone in the subsurface.

1. Introduction

The research area is one of the areas that have potential of hydrothermal mineralization in the form of altered rock and quartz vein in Pacitan regency [1-5]. The Kasihan area has a hydrothermal mineralization prospect, very interesting to explore. It is therefore important to study the prospect of metal mineral deposits hydrothermal subsurface by applying geophysical exploration techniques.

For the exploration of mineral deposits in the field, the geophysical method used is the induced polarization method (IP). This IP method is a very well used to locate areas containing conductive minerals (metal minerals) in the subsurface by measuring parameters based on the polarization of electrodes [6].

The Kasihan area is located in the Pacitan regency, the southern part of East Java, Indonesia (figure 1.). Geographically, the study sites are at the coordinates of UTM 522916-530697 mE and 9103185-9105011 mS with an area of ± 2.8 km². This research aims to identify the presence of hydrothermal deposit mineralized zones through geophysical exploration by using induced polarization method.

2. Geologic Setting and Mineralization

2.1. Geologic Setting

The study area is occupied by the Mandalika Formation (Tomm) and the Arjosari Formation (Toma) which are associated with the relatively similar age of Early Oligocene-Early Miocene. The existence
of both formations is influenced by intrusion rock units (consisting of andesite, dacite, diorite and basal) present at the Oligocene-Miocene age. It is indication of the possibility of mineralization in the form of hydrothermal alteration as a product of contact between the two formations with regional intrusion rocks in the study area [7].

![Figure 1. Map of research area](image)

The structural system in Pacitan only develops in the North, the structure is generally West-East or Southwest-Northeast. In the field, faults typically fall down and shear are indicated by disruption of the layer's position, the scarp, drag folds and slickensides. Several river courses and rows of limestone hills are likely to be controlled by the structure [7]. The activity of structures at the time allowed a way for the occurrence of hydrothermal mineralization in rock contacts, forming an economical ore mineral deposit that later became the target of this study.

2.2. Mineralization Hydrothermal

Hydrothermal mineralization characterized by hydrothermal alterations in the study area include propylitic alteration, argillic alteration and skarn alteration [2], [5]. Propylitic alteration in the study area is characterized by the presence of calcite and chlorite minerals. The argillic alteration in the study area is characterized by the presence of mineral assembly with medium pH (4-5) and low temperature (> 200-250 ° C) in the form of kaolin and illite. Skarn alteration is characterized by the
presence of minerals with high temperatures (300-700 °C) and high pH, including quartz, calcite and clinopyroxin minerals.

The observation of rock samples in this alteration zone, obtained brownish-black rock and contains a conductive mineral that can attract magnetic objects. Identification of minerals by XRD analysis on rock samples showed the presence of iron ore minerals in the form of hematite and pyrite minerals. Microscopic analysis of ore obtained in the form of metal minerals sulfide and oxide. The metal ore minerals include pyrite, chalcopyrite, sphalerite, covellite and hematite [5].

The mineralized set and mineral alteration associations in the generally obtained research area are located in contact between the intrusions of volcanic rocks and the carbonate rocks of the Arjosari Formation, indicating the type of hydrothermal deposits into the skarn deposit type [5]. The enrichment of iron ore minerals present predominantly on the skarn deposits in the study area are classified as iron skarn. The main metal ore minerals in this iron skarn deposit are the iron oxide minerals (hematite). Hematite is concentrated in the body of rocks bearing-minerals forming large bodies. In the field found an outcrop of mineralized iron ore, where part of it was blackish brown (figure 2).

![Figure 2. Outcrop of iron ore deposits in the skarn alteration zone in the study area (modification [5])](image)

3. Methods

Measurements using induced polarization method in this study were conducted in time-domain. The parameter measured is the chargeability M, defined as area A under the decay curve in the time interval (t1-t2) normalized with the potential difference ΔVc (figure 3).

![Figure 3. Potential decay graph on the induced polarization method [8]](image)

Chargeability is measured at certain time intervals after the polarization current is disconnected. Minerals are distinguished by the characteristics of its chargeability [8].
\[ M = \frac{A}{\Delta V_c} = \frac{1}{\Delta V_c} \int_{t_1}^{t_2} v(t) \, dt \]  

(1)

In general, the IP measurement results are shown as pseudosection, in which the result of the measured readings is plotted so as to reflect the depth of penetration. Data used as input in the form of measurement configuration data, space measurement, as well as value of resistivity and chargeability and elevation of measuring point of electrode. Furthermore, to obtain 2D pseudosection profile model data with resistivity value in \(\Omega m\) unit and chargeability value in msec for each measurement path and depth estimate is done inversion calculation (data inversion calculation using Res2Dinv software). This inversion calculation data is a reference (input), then displayed in the form of 2D pseudosection model.

4. Results and Discussion

4.1. Results of IP method

IP methods measurement on the outcrop contain ore mineral deposits using three lines. The measurements acquired in the field were processed in the Res2Dinv program and resulted in pseudosections of resistivity in terms of distance versus depth, with a logarithmic graphic scale and interpolation intervals of values in the color gradation. The line layout is based on a review of the previous geological and mineralized zones, which are planned to be orthogonal in the vein of iron mineralization recognized by [5] and [9] (figure 4). The pseudosection of each lines illustrates the profile of the anomaly distribution pattern of resistivity and chargeability values visualized by the color gradation over a given range of values (figure 5).

![Modified map showing the location of the IP lines survey (5, 9)](image)

Figure 4. Modified map showing the location of the IP lines survey ([5], [9])
Figure 5. Pseudosection model of resistivity and chargeability
The obtained 2D pseudosection model describes the heterogeneity of the material subsurface of each passage, so the obtained profile is not a direct form of the geometry of a substance or material in the subsurface. Gradation colour as representative of physical parameter value (resistivity and chargeability) at pseudosection of each lines is interpreted as an alteration and weathering zone of the bedrock layer.

The resistivity value as a parameter is analyzed to determine the resistivity type of a material in flowing an electric current. The measured resistivity value in the study area has a range of values from 1 - 4000 Ωm. The chargeability value is used as an indicator of the presence of metal minerals in a rocks or subsurface material. The greater the measured chargeability value indicates that the greater the potential for the presence of metal deposits. The chargeability value measured in the study area has a range of 0 - 700 msec.

4.2. Discussion

The anomaly value of resistivity and chargeability of IP survey results is divided into three value criteria, i.e low, medium, and high indicator zone. Resistivity indicator is divided into low resistivity zone < 100 Ωm, medium resistivity zone 100-250 Ωm, and high resistivity zone is > 250 Ωm. The chargeability indicator is divided into low chargeability zones < 20 msec, medium chargeability zone 20-50 msec, and high chargeability zones are > 50 msec.

The application of zonation to the 2D pseudosection of resistivity and chargeability in Line 3 indicates that the mineralizing potential zone is in the range of medium-low value of chargeability with probability found in zones with medium-high resistivity values (figure 6). The low resistivity values associated with lower chargeability values are interpreted as alteration zones of clay minerals, which clay minerals replace the main minerals of rocks such as plagioclase and piroxin.

**Figure 6.** The 2D Pseudosection model of Line 3 (circle indicating metal mineralization zone)

The 2D pseudosection profile of IP measurements in line 2 with the same application of indicators as in the 2D pseudosection profile line 3, shows a fairly complex zone association (figure 7). Provided associations related to potential zones of metal mineralization are at the bottom of the pseudosection profile. There is also an association of medium-high chargeability with low resistivity value, this is probably related to the clay alteration that is rich in metal minerals.
Figure 7. The 2D pseudosection model of Line 2 (the circle indicates the zone of metal mineralization, the box indicates the clay alteration zone with rich of metal mineral, the triangle indicates an alteration zone in a more compact rock material).

The 2D pseudosection profile of IP measurements in Line1, shows zone associations that are almost identical to Line 2 (figure 8). There is a medium-high resistivity range associated with a high-medium range of chargeability, which is interpreted as a more compact rock material and metallic sulphide mineral enrichment by alteration occurring in the research area. It also interpreted that there is a zone of metal mineral rich clay alteration with an association of medium-high indicator of chargeability with low resistivity value.

Figure 8. The 2D pseudosection model indicator of the resistivity zone and Chargeability of trajectory 1 (trapezium indicates an alteration zone zone in a more compact rock material, the box indicates the clay alteration zone with the clay-rich mineral).
Based on the interpretation of 2D pseudo-section from three IP measurement line, information obtained regarding hydrothermal deposit mineralization shows intense alteration occurring. Several relationships related to the indicators of resistivity and chargeability of IP measurements on subsurface mineralization are as follows:

a) The mineralized zone of the metal ore body, in general, indicates a range of medium-high resistivity values associated with a low-to-medium value of chargeability.

b) The clay mineralized alteration zone, in general, indicates a range of low resistivity values associated with low chargeability values.

c) The clay mineralized zone with rich of metal mineral, generally indicates a range of low resistivity values associated with medium-high rate of chargeability.

d) The alteration zones in more compact materials that are altered with sulphide-enrichment generally show a range of medium-high resistivity values associated with medium-high rate of chargeability.

5. Conclusion

Based on the analysis and interpretation of geophysical exploration data with IP method it can be concluded that in the hydrothermal deposit zone (metal mineral oxide) in the research area is characterized by anomalous contrast with medium-high (> 100 Ωm) resistivity value associated with valuable chargeability low-moderate (<50 ms). The association of resistivity and other chargeability values shows intense alteration zones of clay and sulphide minerals in the surroundings of hydrothermal deposits in the subsurface.

References

[1] Idrus A, Warmada, I W, Setijadji L D, Widiasmoro and Titisari A D 2008 Kumpulan makalah “Pertemuan teknis potensi endapan mineral logam daerah Kabupaten Pacitan” PT. Aneka Tambang Tbk. 32-40
[2] Warmada I W, Tun, M M, Fukuda K, Alfurqon R., Imai A, Harijoko A and Watanabe K 2008 Prosiding Pertemuan Ilmiah Tahunan IAGI ke-37 Bandung Indonesia 562-568
[3] Widodo W, and Simanjuntak S, 2002 Kolokium Direktorat Inventarisasi Sumber Daya Mineral (DIM)
[4] Widodo W, Prapto A S dan Nursahan I, 2002 Kolokium Direktorat Inventarisasi Sumber Daya Mineral (DIM)
[5] Asrafill, Idrus A and Wintolo D 2017 Jurnal Geologi dan Sumberdaya Mineral 18 191-200
[6] Telford W M, Geldart L P and Sherriff R E 1990 Applied Geophysics Second Edition, Cambridge University Press Australia
[7] Samodra H, Gafour S and Tjokrosapoutro S 1992 Geology Lembar Pacitan, Jawa Pusat Penelitian dan Pengembangan Geologi Bandung
[8] Kearey P, Brooks M and Hill I 2002 An Introduction to Geophysical Exploration (Australia: Blackwell Publishing)
[9] Tun M M 2007 An Investigation of Geology and Mineralization in the Kasihan Area, Pacitan Regency, East Java, Indonesia, Unpublished Master Thesis, 125