International Journal of Hydrological and Environmental for Sustainability
Volume 1, Issue 3, 108-119
e_ISSN: 2828-5050
https://www.journal.foundae.com/index.php/ijhes

Application of Induced Polarization and Resistivity to the Determination of the Location of Minerals in Extrusive Rock Area, Southern Mountains of Java, Indonesia

Moh Saparun*
Department of Electrical Engineering,
Universitas Haluoleo,
INDONESIA

Rajabal Akbar
Department of Maritime,
Politeknik Negeri Bengkalis,
INDONESIA

Mahmuddin Marbun
Department of Mechanical Engineering,
Universitas Teuku Umar,
INDONESIA

Aparna Dixit
Department of Basic Sciences and Humanities,
Pranveer Singh Institute of Technology,
INDIA

Arti Saxena
Department of Electronics and Communication,
Pranveer Singh Institute of Technology,
INDIA

***Correspondence: E-mail:** msaparun@gmail.com

Article Info

Article history:

Received: September 19, 2022
Revised: October 28, 2022
Accepted: November 09, 2022

Abstract

Mountainous areas often have a lot of natural wealth. The existence of geological appearances in the form of outcrops which are products of intrusion and alteration, indicates that the Pacitan area is a mineralized zone. In this study, geophysical measurements were carried out using the Induced Polarization (IP) method in the area where mineralization was suspected. The polarization induction method is expected to prove the presence of a mineralized zone in the Pacitan area. From the research results, line 1, line 4, line 5, line 6 and line 7 are areas with high chargeability values. So it can be proven that the area with high resistivity and high chargeability is an area with mineralization. Judging from the geological conditions on the surface, there are also outcrops which show that there is an intrusion and the result of alteration. So it can be concluded that the area has a fairly high mineralization. In measuring the correlation between magnetic anomalies and IP, the results are very supportive of each other that the area is a mineralized area, if we look at the resistivity, and chargebility.

Keywords: induced polarization (IP); mineral zones; resistivity; chargeability; geophysics; extrusive rock

To cite this article: Saparun, M., Akbar, R., Marbun, M., Dixit, A. and Saxena, A. (2022). Application of Induced Polarization and Resistivity to the Determination of the Location of Minerals in Extrusive Rock Area, Southern Mountains of Java, Indonesia. *International Journal of Hydrological and Environmental for Sustainability, 1*(3), 108-119. https://doi.org/10.58524/ijhes.v1i3.137

INTRODUCTION

The Pacitan area is included in the Southern Mountains zone of East Java, Indonesia. The oldest rock formation in Pacitan is the Besole Formation which is composed of extrusive rock consisting of tonalite, dacite, andesite and dacitan tuff (Baharuddin & Permanadewi, 2012). At the bottom is pillow lava with polymic breccia inserts (which fragments consist of andesite, tuff, and limestone igneous rocks). This formation was deposited in a marine environment and is of Early Miocene age (Fadhlan & Intan, 2008). Above the Besole formation, the Jaten Formation was deposited inconsistently, which is composed of quartz sandstone, tuffaceous sandstone, siltstone, claystone, marl, and marl limestone, coal and conglomerate were inserted in some places between siltstone and claystone, and

wood fossils that had been silicified were often found. This formation was deposited in a fluviatile/parafic environment to the sea, Middle Miocene age (Skinner et al., 2004).

The Wuni Formation is deposited above the Besole Formation which is composed of alternating agglomerate breccias with coarse tuffaceous sandstones, siltstones and the upper part is reef limestone. The Besole Formation was deposited in a coastal to neritic environment influenced by volcanic activity, aged Middle Miocene (Reinout W. van Bemmelen, 1970). The Nampol Formation overlaps harmoniously above the Wuni Formation, which is composed of repeating sandy claystone containing coal with limestone and tuff. The Nampol Formation is probably of Middle Miocene age. The Punung Formation overlaps with the Nampol Formation, which is composed of layered limestones and reefs, deposited in a shallow marine environment, of Middle Miocene age (Parmin et al., 2019).

The existence of geological appearances in the form of outcrops which are products of intrusion and alteration, indicates that the Pacitan area is a mineralized zone. It is necessary to carry out geophysical measurements that match the properties of the mineralized zone, such as measuring resistivity and (Winters & Cawvey, 2015). Therefore, geophysical measurements were carried out using the Polarization Induction method. The polarization induction method is expected to prove the presence of a mineralized zone in the Pacitan area. Mineralized zones are often associated with high IP response and low resistivity. The Argillic Alteration Zone generally has low to moderate resistivity characteristics caused by the presence of clay minerals associated with medium to high IP (Thoreau & Prayer, 2000). Propylitic Alteration Zones generally have high resistivity characteristics due to the presence of associated chlorite minerals with medium to high IP. The silicification Alteration Zone generally has moderate to high resistivity characteristics due to the compactness of rocks and silica minerals associated with moderate IP (Iler, 1955).

Induced Polarization Method

The Induced Polarization method is one of the geoelectrical methods that is often used in the exploration of base metal minerals (Zhao et al., 2020). This method is often used in the exploration of base metal minerals because of polarization events or phenomena that occur in a rock medium. The polarization phenomenon that occurs indicates the presence of subsurface metallic minerals, including gold minerals (Sadjab et al., 2020).

The principle of the polarization induction method is to observe the polarization effect that occurs due to the induced current passing through it. The measured polarization effect is expressed in chargeability, PFE (Percent Frequency Effect) , and MF (Metal Factor) depending on the domain used in the measurement process. This polarization induction method has a fairly good accuracy, this can be seen from its ability to detect a small amount of metallic minerals, ranging from 0.5% of the rock volume can still be detected as an anomaly (Savira & Suharsono, 2013).

The Induced Polarization or IP method uses the electrical properties and polarizability of rocks as a basis. Current is sent through the current electrode and the voltage will be measured at the potential electrode (Prastowo et al., 2019). If the electric current is cut off suddenly, the voltage should also be immediately zero. In reality the voltage decreases exponentially, then for a certain time interval a few seconds or minutes) the voltage will become zero. This effect is known as induced polarization (Siregar & Kurniawan, 2018).

The phenomenon of induced polarization (**Figure 1**) can be explained using four electrodes A, M, N, B. A and B are current electrodes used to inject current into the ground, while M and N are potential electrodes used to measure potential difference. When an electric current is flowed into the medium, energy is stored in the medium in the form of mechanical energy, electrical energy or chemical energy (Maryanto, 2017). When the electric current is cut off, the energy stored in the medium will be released again in the form of electrical energy which in the IP method is measured as the decay potential V (t).

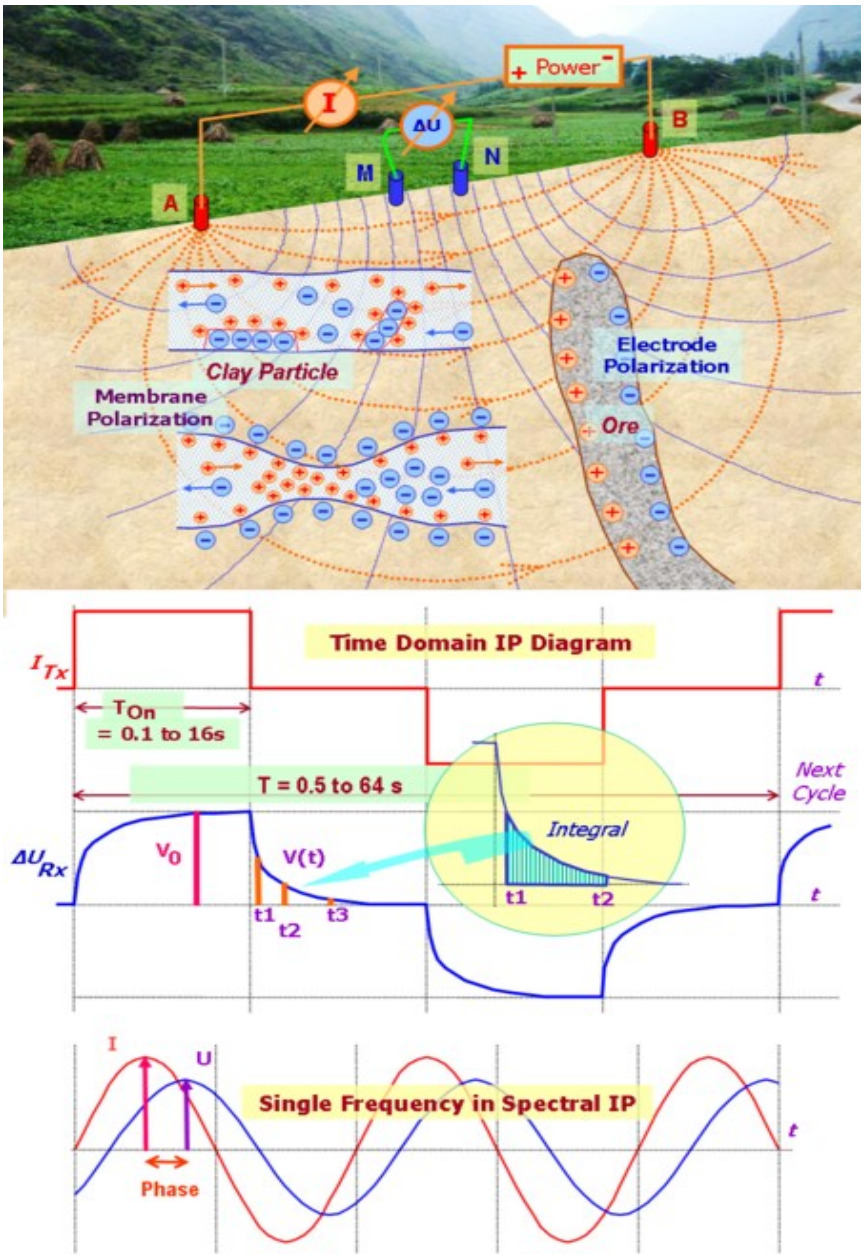

Figure 1. Illustration of Induced Polarization Method

In **Figure 1** it can be seen that membrane polarization occurs in the pores of rocks containing negatively charged clay minerals that are in contact with the solution. Because of its negative charge, clay minerals will be able to attract positive ions around their surface and expand in the electrolyte. This accumulation of charge will hinder the passage of electric current through it so that there is an obstacle along the pores of rocks containing clay minerals. With the formation of barriers in the form of membranes, the mobility of ions will be reduced so that a concentration gradient of ions is formed which opposes the electric current through it. This symptom indicates the presence of polarization.

In another concept, there is also the phenomenon of electrode polarization which occurs when the conductive minerals of the rock come into contact with the solution in the pores of the rock. Rock minerals containing conductive minerals are seen as an electrode in the electrolyte, so that at first there will be an oxidation and reduction reaction process (redox reaction) due to the emergence of a potential difference between the conductive mineral and the solution until an equilibrium occurs. In this equilibrium state there will be a process of combining and releasing charges between the metal and the solution in equal amounts, and absolutely no current will flow. If there is interference from the outside, for example the influence of the current flowing, then the equilibrium state will be disturbed so that it will cause a polarization in the electrolyte known as electrode polarization.

Based on Ohm's law, it is known that the magnitude of the voltage V of a material depends on the strength of the current I and the electrical resistance R which is formulated as follows:

$$V = IR \qquad (1)$$

The study of electrical resistance from geophysics can be understood in the context of the flow of current through a subsurface medium consisting of layers of materials with different resistivities. For simplicity, all layers are assumed to be horizontal. The resistivity of a material is a measurement of how well the material resists the flow of electric current (Muthamilselvan et al., 2019).

Direct electric current is flowed into the medium through a pair of current electrodes and measures the potential difference that arises in a pair of potential electrodes after the main current is turned off, so that the secondary current from the conductive rock will be measured and will decay with time, and at the potential electrode a decay potential is measured V(t). Electric current is flowed in the opposite direction, after the current is turned off there will also be a potential decay V(t), so the measurement is always carried out in the order of giving positive (+), off (zero) and negative (-) electric currents (Anthony, 2017). Calculated parameters are:

1. Chargeability

$$M = \frac{1}{V_c}\int_{t_1}^{t_2} V(t)dt \qquad (2)$$

2. Effect IP (%)

$$IP\ (\%) = \frac{V_{t_1}}{V_P} \times 100\% \qquad (3)$$

Where I is the current flowing in the medium, V_0 is the voltage when the current flows, while V_1 is the polarization voltage when the current is cut off. However, in practice it is difficult to determine the value of V_1, but only residual voltage is obtained, V_t, in a short time after the current is disconnected so that equation (4) can be written:

$$M = \frac{V_0 - V_1}{V_0} = 1 - \frac{1}{100}\ IP\ (\%) \qquad (4)$$

METHOD

In this study, the Induced Polarization (IP) method uses a dipole-dipole electrode configuration with a arrangement **Figure 2**. Current electrode C_1 = A_1 and C_2 = B_2 placed at a distance a = 20 m, and electrode potential P_1 = P dan P_2 = Q also placed at a distance of 20 m. Electrode P_1 and P_2 placed outside the current electrode but still in one survey line with a distance of C_2-P_1 in the amount of n, where n = 1, 2, 3, and 4. Research using the IP method was carried out on 11-15 May 2014 in Kasihan Village, Pacitan. Trajectory map overlaid with geological map (**Figure 3**) Pacitan area, mountainous area of extrusive rock.

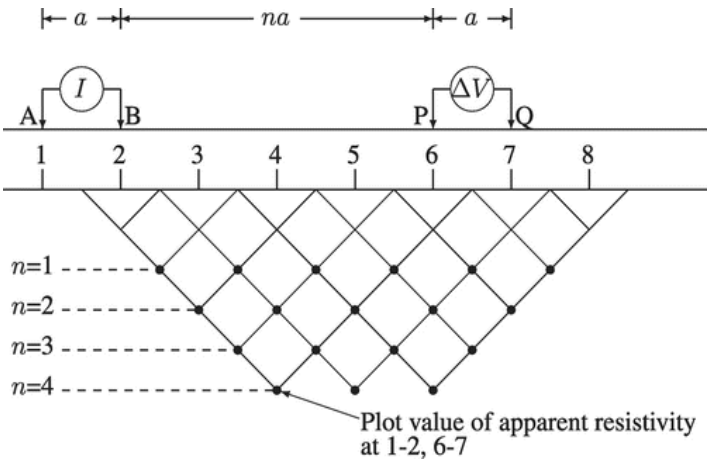

Figure 2. Illustration of the dipole-dipole configuration in the Induced Polarization (IP) method

The geological structure that controls this area is a fault zone (estimated) that crosses northeast - southwest (Tumpak Pengilon - Bunder). The other fault zone is in Kempes - Bunder (north-south) following the bend of Kali Dadap. The expanse of the geophysical survey in this workshop (for certain methods) is directed to cut perpendicular to this fault zone, so it is hoped that it can complete the interpretation of the geological structure in this area. Other geological structures are intensive joints and fractures. In some sandstone-marble outcrops and sandy conglomerates there is groundwater seepage through interlayer gaps and fractures, which is a good example of reservoir conditions in highly permeable petroleum or geothermal fields.

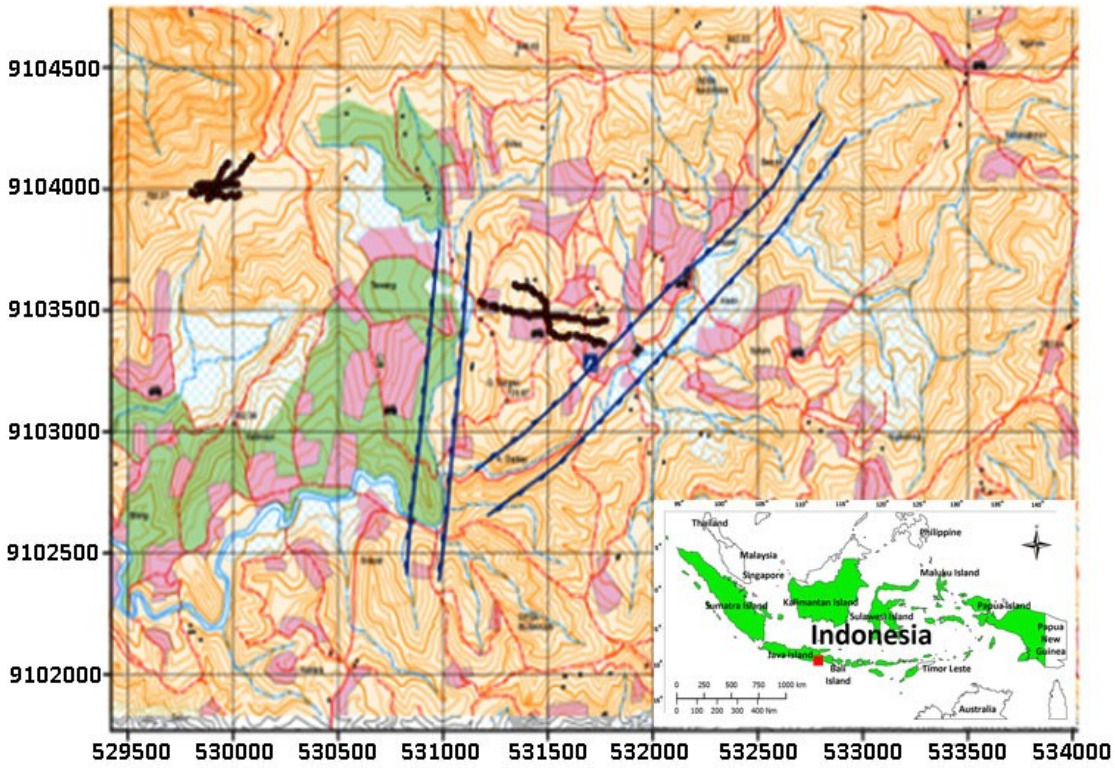

Figure 3. Contour map of this study

Kasihan Village, Tegalombo District, Pacitan, East Java, Indonesia is an area that often occurs landslides and the impact is quite extensive (**Figure 3**). Utilization of surface geological information is used as initial data to interpret subsurface data. Some of the rocks exposed in the study area are dominated by volcanic rocks or volcanic rocks, clastic sedimentary rocks and breakthrough rocks. Most of these rocks have undergone weathering and high alteration processes so that they have changed their properties to become clayey. The position of these rocks will be unstable when saturated with water.

Research Target and Tools

The object of this research is an anomaly which is predicted to be an anomaly of the rocks that are below the ground surface along the research trajectory. The tools and materials used in this research are: 1. 1 junior syscal IP meter unit: to read the measured current, voltage, and charge ability values, 1 car battery as a voltage source; 2. Current and voltage electrodes: as conductors of electric current and voltage; 3. Current and voltage electrode connecting wires; 4. Crocodile clamp: as a connector between cables; 5. Hammers are used to drive current electrodes; 6. Porospot: as a potential electrode containing $CuSO_4$ solution; 7. $CuSO_4$ solution is used as an electrolyte solution; 8. Compass, GPS and rollmeter to determine the direction and distance of the track; 9. Umbrella is used to protect the instrument so that it is easy to read the measured value; 10. Hoe and trowel: make holes for planting pots; 11. HT is used as a means of communication between the operator of the reader and the operator of the installer of the pots; 12. Laptop equipped with RES2DIV software to map contours showing variations in chargeability and resistivity towards lateral and depth.

RESULTS AND DISCUSSION

The measurements were carried out in Kasihan Village, Tegalombo District, Pacitan Regency. In the measurement using the IP method, the number of lines in this measurement is 7 lines, where one of the lines intersects with the path of the resistivity and chargebility measurement results and can be correlated.

From the results of data acquisition that has been carried out in the range of 0 m to 480 m, **Figure 4** shows that the high resistivity value is at x = 160 m to x = 280 m, but has a low chargeability, this area is estimated as an area where there are rocks andhesite frozen but not an outcrop because of its low chargeability. While at position x = 350 m to 380 m, it is indicated that the area is an igneous intrusion because there is high resistivity and high chargeability as well as an indication of mineral differentiation. If this measurement is continued, there may be an outcrop at the next point, due to resistivity and chargeability anomalies.

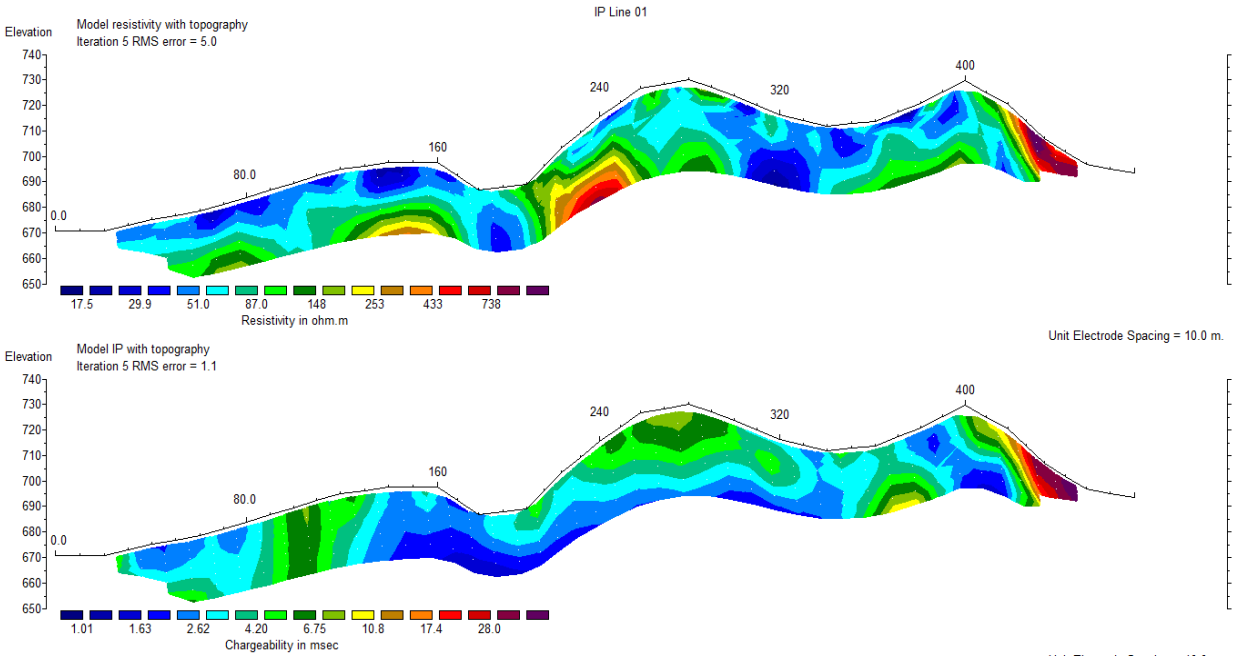

Figure 4. IP data interpretation on line 1

Based on **Figure 5**, the resistivity value and Chargeability value, on track 2 with RES2DIV modeling it can be seen that at an altitude or elevation of 720 and a depth of 40m (n=4), the resistivity value is 466 ohm.m and the Chargeability value is 23.1 msec, this indicates in the area of There is mineralization that occurs in igneous rocks, namely the mineral pyrite. There is a mineralized zone on the 320 m track, which is metallic minerals.

More results on line 3 (**Figure 6**), based on the measurement results obtained on line 3 at a distance of 80 m there is material with a fairly high chargerbility value with a fairly high resistivity value as well. If it is connected with the magnetic measurements made previously, it can be seen that the total anomaly can be seen at the same location where the local anomaly value is quite large.

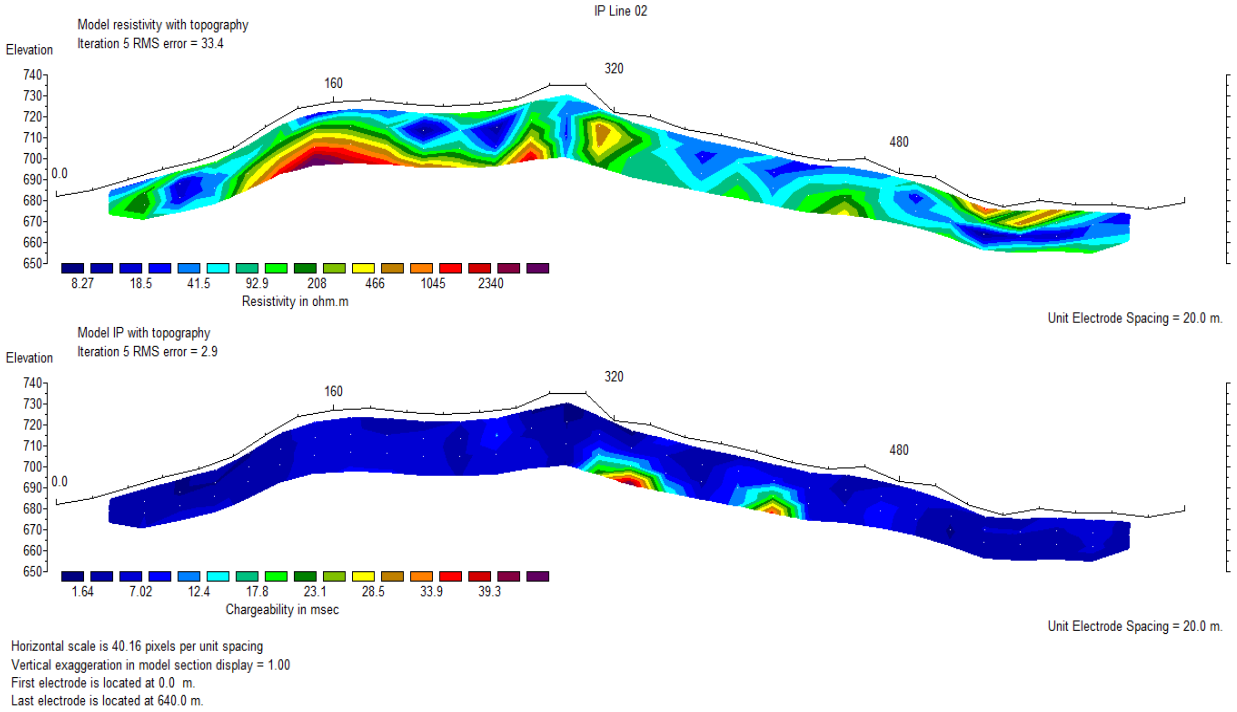

Figure 5. IP data interpretation on line 2

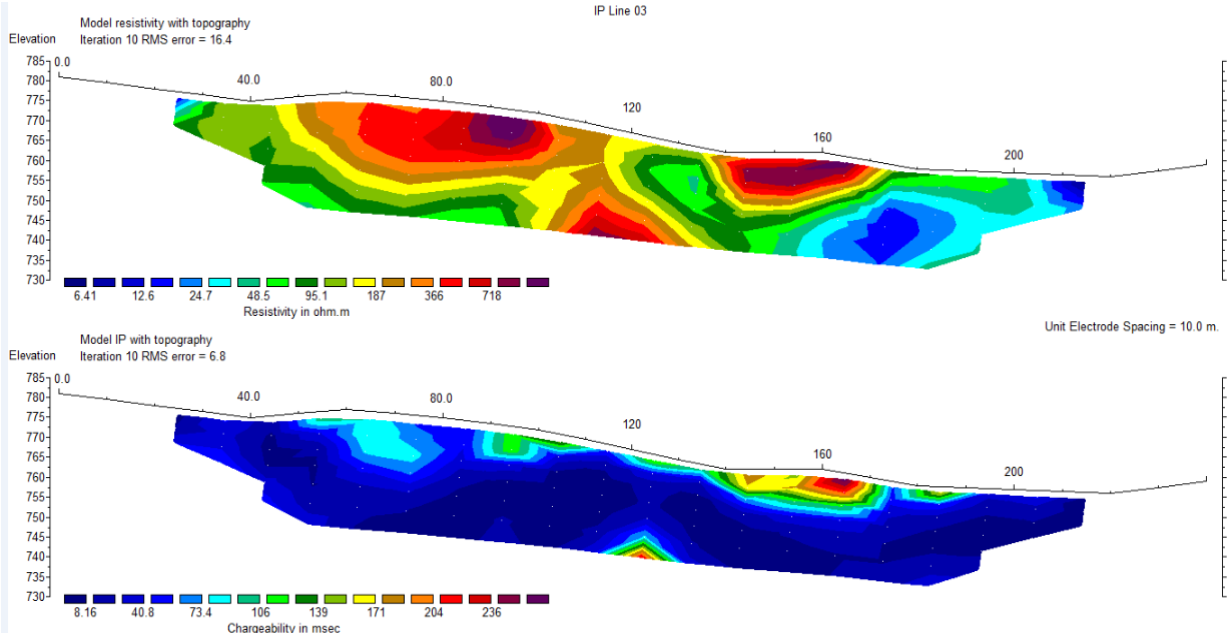

Figure 6. IP data interpretation on line 3

In the interpretation of line 4 (**Figure 7**), there is a high resistivity value and a high chargeability in the initial position. This can be assessed as an outcrop or location of mineralization. Because in the mineralized zone there is a high resistivity and chargeability to store energy. It is the storage of electrical energy that will cause the SP graph to decay for a long time due to the large energy storage capacity of the metal.

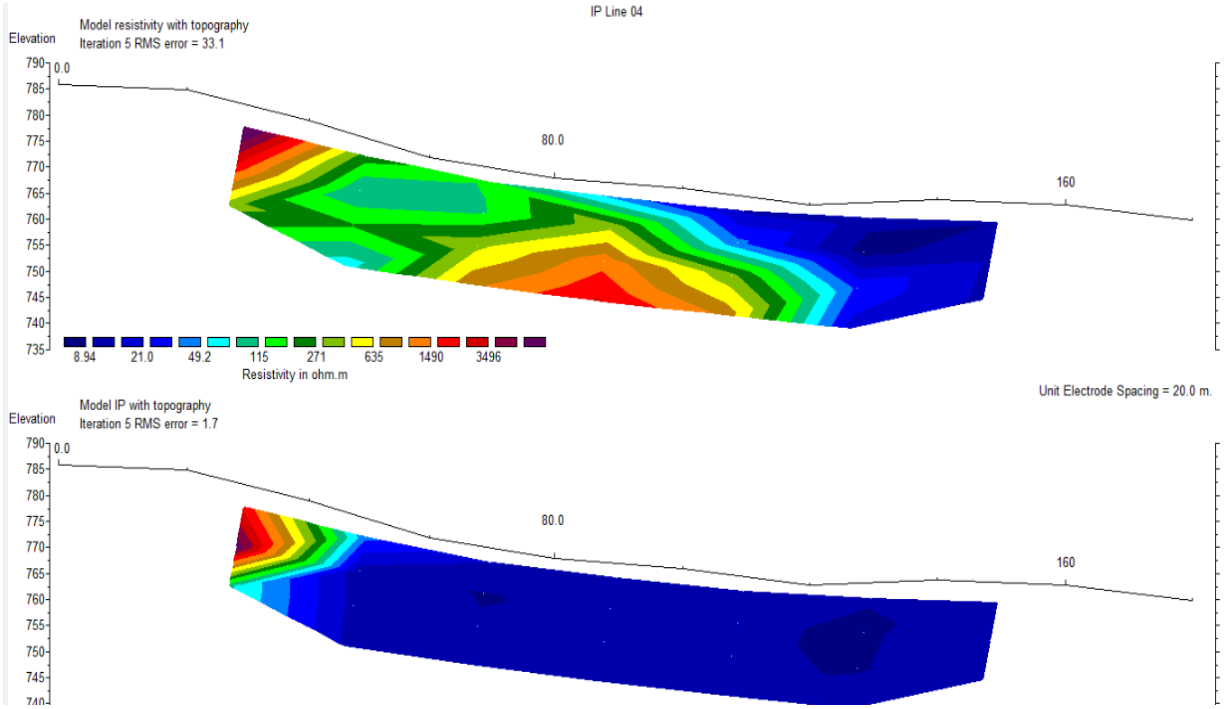

Figure 7. IP data interpretation on line 4

Data acquisition was carried out with 2 lines crossing each other, namely line 5 (**Figure 8**) which leads east to west and line 6 (**Figure 9**) which leads to southwest – northeast, from these 2 lines the chargeability value is quite high. Between 54 - 64 m sec which is located at x = 80-90 m on line 5 and x = 40-60 m, but has a fairly low resistivity, it is estimated that this area contains a zone of mineral differentiation. If the 2 lines are in a cross section, there will be an alignment between the mineral zones on lines 5 and 6.

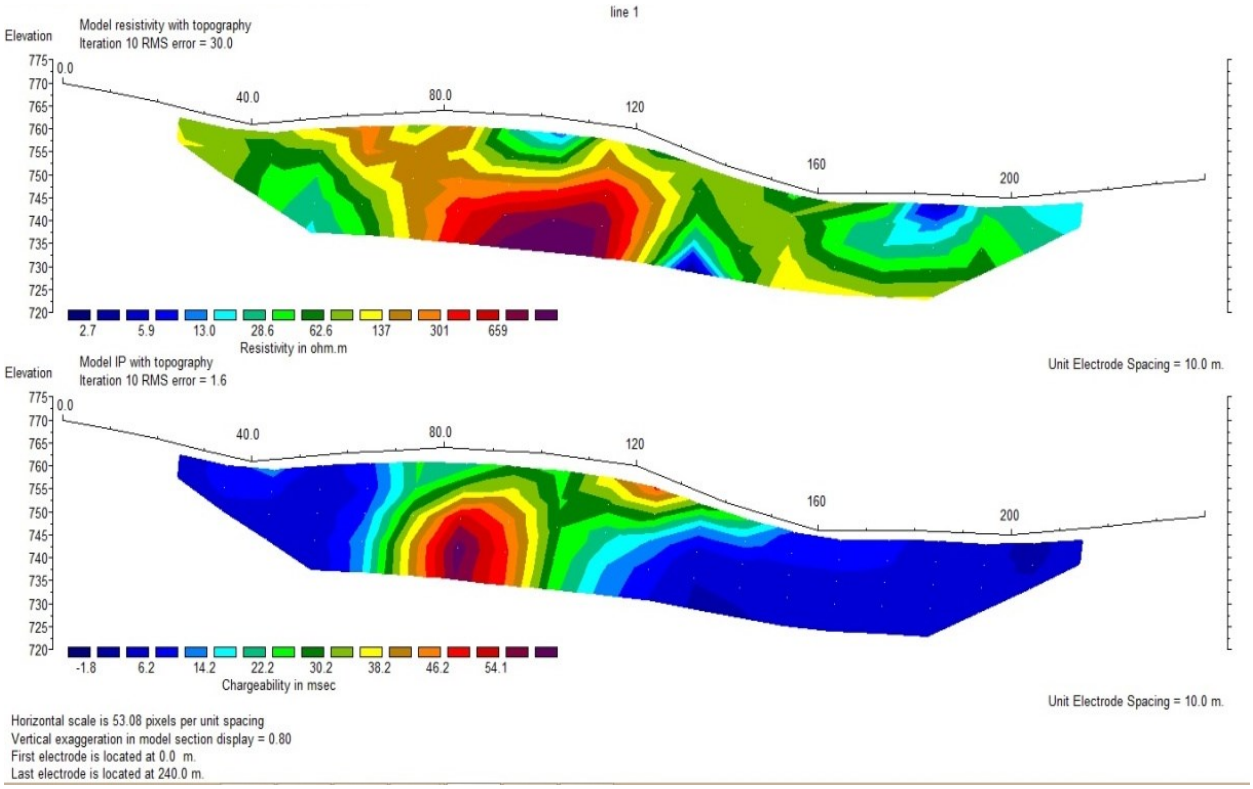

Figure 8. IP data interpretation on line 5

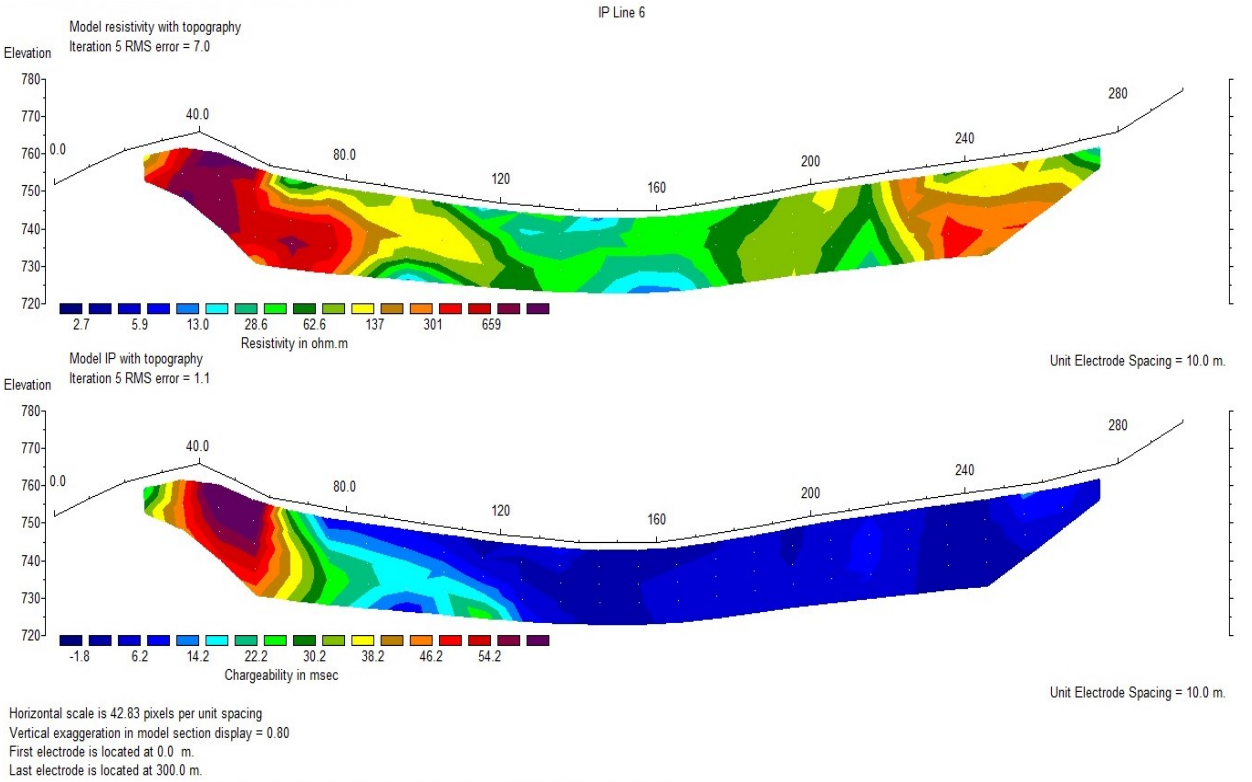

Figure 9. IP data interpretation on line 6

From the results of the correlation (**Figure 10**) of the resistivity between Line 5 and Line 6, it is found that the results are similar for the results at a distance of 120 meters. The correlation results show the similarity of high resistivity values, so it can be interpreted that the area has high resistivity with high accuracy.

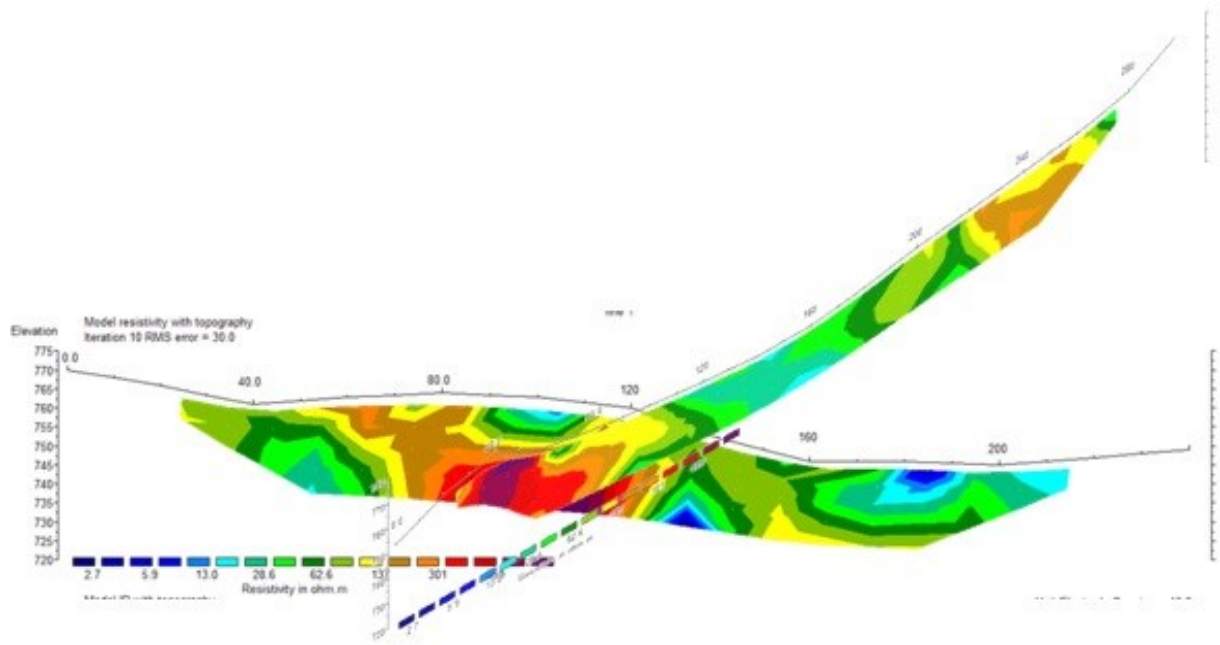

Figure 10. Correlation between Interpretation of resistivity IP line 5 and IP line 6

From the results of the chargeability correlation (**Figure 11**) between Line 5 and Line 6, it is found that the results are similar for the results at a distance of 120 meters. The correlation results show the similarity of high chargeability values, so it can be interpreted that the area has high

chargeability with high accuracy, and it can be estimated that the area is a mineralized area because there is high resistivity and chargeability.

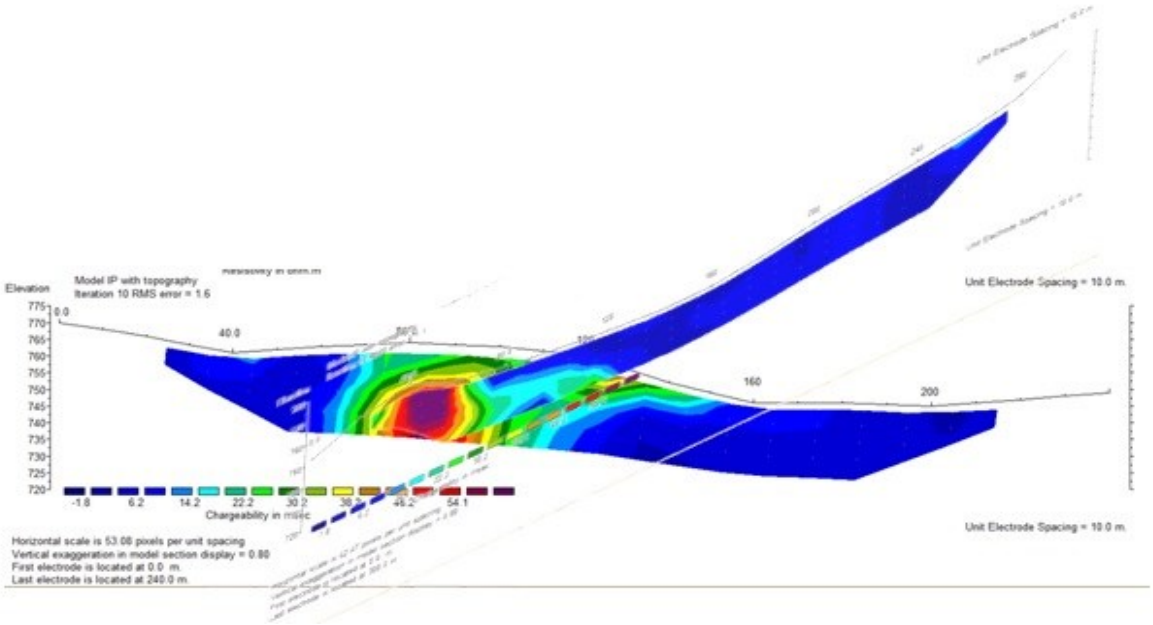

Figure 11. Correlation between Interpretation of chargeability IP line 5 and IP line 6

Based on (**Figure 12**) in line 7, the resistivity values ranged from 4.19 - 1829 ohm and the changerability values ranged from 0.5-14.5. This high resistivity value is indicated by the presence of a geological structure in the form of an intrusion, with a resistivity value of 136-500 m. Intrusion in the form of igneous rock where this intrusion is supported by the presence of igneous rock outcrops on the 500-540 trajectory. The changerability value does not indicate an anomaly value that identifies metal mineralization because the value obtained is quite low.

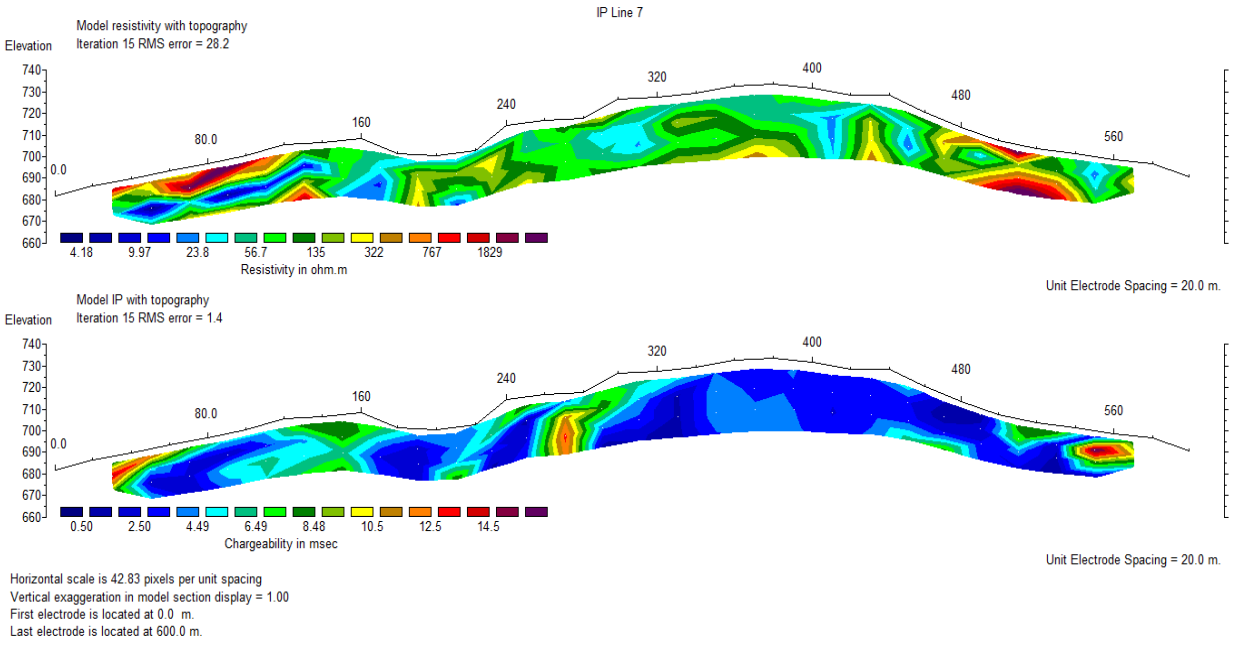

Figure 12. IP data interpretation on line 7

In line 7, the low anomaly pattern is thought to be in the form of clay minerals in large quantities, such as Smectite and Ilit and Kaolin which are above or around rocks that have high

resistivity values, namely 200-600 m which are thought to be volcanic rocks. The presence of Smectite and Ilit and Kaolin in the weathered zone triggers landslides, especially if the weather is saturated with water, considering that Pacitan Regency has a high intensity of rainfall. In addition to rainfall, topography, slope, local geology and weather factors, in principle, landslides that occur in this location are also caused by the inability of the force to hold the rock position when a driving force occurs. Retaining forces are generally influenced by rock strength and soil strength, in this study, which acts as a retaining force, it is possible that volcanic rocks are more massive than the weathered rocks around them. When the thick weather is filled with water, the volcanic rock that acts as bedrock is no longer able to withstand the mass movement above it, so landslides occur which are triggered by the accumulation of water stored on the slopes.

CONCLUSION

Based on the results of the research that has been done, it can be proven that areas with high resistivity and chargeability are areas that have mineralization. Judging from the geological conditions on the surface, there are also outcrops that indicate intrusion and alteration results. So it can be concluded that the area has a fairly high mineralization. In measuring the correlation between magnetic anomaly and IP, the results strongly support each other that the area is a mineralized area, if we look at the magnetic anomaly, resistivity, and chargebility. Some of the rocks exposed in the study area are dominated by volcanic rocks or volcanic rocks, clastic sedimentary rocks and breakthrough rocks. Most of these rocks have undergone weathering and high alteration processes so that they have changed their nature to become clayey. The position of these rocks will be unstable when saturated with water. The low anomaly pattern with a resistivity value of 20-50 m is thought to be in the form of clay minerals in large quantities, such as Smectite and Ilit and Kaolin which are above or around rocks that have high resistivity values, namely 200-1200 m, which are suspected to be volcanic rocks that act as bedrock.

ACKNOWLEDGMENT

The authors would like to thank all reviewers who have provided suggestions to improve this article. The authors also thanks Gadjah Mada University, Indonesia for assisting in providing geophysical survey tools.

CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

REFERENCES

Anthony, T. B. (2017). Hydrogeochemistry of groundwater within the lateritic profiles over migmatite and pegmatised schist of Ibadan, Nigeria. *Journal of Geology and Mining Research*, *9*(4), 28–42. https://doi.org/10.5897/jgmr2016.0261

Baharuddin, & Permanadewi, S. (2012). Indikasi Batuan Adakitik Di Pacitan, Jawa Timur. *Journal Sumber Daya Geologi Indonesia*, *22*(4), 209–215.

Fadhlan, M., & Intan, S. (2008). 638-Article Text-2040-1-10-20200221.pdf. *AMERTA Journal Penelitian Dan Pengembangan Arkeologi*, *26*(1), 1–22.

Iler, R. K. (1955). *The colloid chemistry of silica and silicates* (Vol. 80, Issue 1). LWW.

Maryanto, S. (2017). Geo Techno Park potential at Arjuno-Welirang Volcano hosted geothermal area, Batu, East Java, Indonesia (Multi geophysical approach). *AIP Conference Proceedings*,

1908(2017). https://doi.org/10.1063/1.5012712

Muthamilselvan, A., Rajasekaran, N., & Suresh, R. (2019). Mapping of hard rock aquifer system and artificial recharge zonation through remote sensing and GIS approach in parts of Perambalur District of Tamil Nadu, India. *Journal of Groundwater Science and Engineering*, *7*(3), 264–281. https://doi.org/10.19637/j.cnki.2305-7068.2019.03.007

Parmin, P., Nuangchalerm, P., & El, R. A. Z. (2019). Exploring the Indigenous Knowledge of Java North Coast Community (Pantura) Using the Science Integrated Learning (SIL) Model for Science Content Development. *Journal for the Education of Gifted Young*, *7*(March), 71–83.

Prastowo, R., Huda, S., Umam, R., Jermsittiparsert, K., Prasetiyo, A. E., Tortop, H. S., & Syazali, M. (2019). Academic Achievement And Conceptual Understanding Of Electrodynamics: Applications Geoelectric Using Cooperative Learning Model. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *8*(2), 165–175. https://doi.org/10.24042/jipfalbiruni.v0i0.4614

Reinout W. van Bemmelen. (1970). General geology of Indonesia and adjacent archipelagoes. In *The geology of Indonesia* (2nd ed., p. 732). Nijhoff. http://www.worldcat.org/wcidentities/lccn-n87821184

Sadjab, B. A., Indrayana, I. P. T., Iwamony, S., & Umam, R. (2020). Investigation of The Distribution and Fe Content of Iron Sand at Wari Ino Beach Tobelo Using Resistivity Method with Werner-Schlumberger Configuration. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *9*(1), 141–160. https://doi.org/10.24042/jipfalbiruni.v9i1.5394

Savira, F., & Suharsono, Y. (2013). Information on Conductivity Measurement. *Journal of Chemical Information and Modeling*, *01*(01), 1689–1699.

Siregar, R. N., & Kurniawan, W. B. (2018). 2D Interpretation of Subsurface Hot Spring Geothermal Structure in Nyelanding Village Through Schlumberger Geoelectricity Configuration Method. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *7*(1), 81. https://doi.org/10.24042/jipfalbiruni.v7i1.2324

Skinner, B. J., Porter, S. C., & Park, J. (2004). *Dynamic Earth An Introduction to Physical Geology* (Fifth Edit). John Wiley & Sons.

Thoreau, H. D., & Prayer, Y. I. (2000). *Rocks & Minerals* (p. 38).

Winters, M. S., & Cawvey, M. (2015). Governance obstacles to geothermal energy development in Indonesia. *Journal of Current Southeast Asian Affairs*, *34*(1), 27–56. https://doi.org/10.1177/186810341503400102

Zhao, H., Zhang, J., Chen, H., Wang, L., & Yang, Z. (2020). Localization of groundwater contaminant sources using artificially enhanced catchment. *Water (Switzerland)*, *12*(7). https://doi.org/10.3390/w12071949