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Application of Time Domain Induced Polarization (TDIP) Methods to Metallic Minerals Prospect on Kasihan Region, Pacitan Regency, East Java, Indonesia

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Abstract: Metallic mineral exploration activities primarily base metals often have problems because the resources of metallic minerals located below surface are associated with the surrounding rock. Application of Induced Polarization method was carried out in the area of mineral prospects at Kasihan Village, Pacitan District, East Java. The Induced Polarization (IP) data were taken by Syscal Junior 458, using Dipole-dipole and Wenner configuration for mapping and Schlumberger configuration for sounding. Magnetic data were obtained by Geotron Magnetometer. Estimation of pyrite mineral deposit was done using modeling of Res2Dinv and RockWork15. Combination of resistivity and chargeability is conducted to identify the boundaries of mineralization zones. The high resistivity value is correlated with the content of silicate minerals in the mineralized zone, whereas the higher chargeability means high degree of metallic mineral deposits (pyrite). The assesment of two different mineralized zones in metal content is known by combining chargeability and resistivity with magnetic anomaly.

Keywords: TDIP methods, resistivity, chargeability, mineralization zone, resource.

Introduction

The existence of mineral resources in Indonesia, especially Java, is related by magmatic hydrothermal mineralization deposition. In various investigations conducted on several areas in Pacitan Regency, East Java Pprovince, we found some indication of metal mineralization hydrothermal alteration in the form of rocks and quartz veins. Investigation of the hydrothermal system which plays a role in the deposition of metallic minerals in Pacitan and surrounding area shows there are epithermal to mesothermal system, or in the zone of basemetal horizon to precious metal horizon (Setiawan and Sudarsono, 2010).

Kasihan region which has hydrothermal mineralization prospect, is very interesting to explore. Exploration activities mineralized hydrothermal deposition, ever done is geological investigations. Kasihan region is widely available in pyrite surface mineralization (Tun, 2007). Therefore, it is important to research mainly pyrite mineral deposits in this area. Research using geophysical methods-the TDIP (Time Domain Induced Polarization) method was conducted to identify the boundaries of mineralization zone. The geophysical method can delineate distribution of subsurface resistivity and chargeability, which represents zones of pyrite mineral prospects. Pyrite minerals exposed on the surface is expected to complete the information about mineral prospects in research area.

Location and Geology

Kasihan, Tegalombo subdistrict, Pacitan districts, East Java Pprovince is located (4 28'-4 29'36'') East and (8 6'-8 7'30") South. The research location is 30 km from Pacitan, and can be reached by car. This area is mountainous with elevation ranges (500-900) msl (Fig. 1).

Pacitan Regency is included in the Southern Mountains Zone East Java. Regionally, Tegalombo is covered by volcanic rocks that are included in the old andesite rock formations, also known as Besole Formation which are the oldest rocks in this area. This formation was Oligocene, intruded by dacite and andesite, accompanied by the intercalation of gaps and fissures in the form of quartz veins. The order of volcanic rocks from the north to the south of the study area, which consists of lava flows of dacite and andesite, andesite breccia, pyroclastic tuffs, and intercalation of clastic sediment such as sandstone and mudstone. Jaten Formation overlies Besole Formation, covering volcanic rocks as unconformity, aged Oligocene-Miocene. This formation consists of quartz sandstone and mudstone, which is distributed in the southern part of the study area. Above Jaten Formation, Wuni Formation was deposited which aged about Lower Miocene. This formation is exposed in the central part of the study area. The lithology of this formation consists of tuff, sandy tuffs, breccias, agglomerate, shale and limestone lenses. Wuni Formation did not change as propylitic due to intrusion of igneous rocks such as granodiorite, tonalite and quartz diorite. Furthermore, there is Nampol Formation which consists of units of claystone, sandstone and younger coal intercalation. This formation is aged Lower to Middle Miocene. Punung Formation covered Nampol Formation as unconformity. This formation is aged Lower. Punung Formation is composed of limestone unit exposed in the southwestern area of research (Sartono, 1964., Nahrowi, 1980).

Dacite intrusive rocks in the form of crack, sill and other irregularly shape are scattered throughout the area. The dacite has been metamorphosed by hydrothermal alteration, characterized by the presence of sericite. Chlorite, clay minerals and mineral ores are originated from feldspar and mafic mineral. These rocks intrude Basole Formation and Punung Formation. The intrusive rock does not give strong effect of mineralization and expected just to fill the fractures. Andesite rock is relatively younger compared to dacite intrusive rocks.

The main structure in this area is trending northwest-southeast. This path is reflected by the dacitic and diorite joints and quartz veins. Kasihan region is traversed by a regional fault which has a northeast-southwest trend, which passes through the area of Pengajaran Mount. Extrusive and intrusive rocks such as dacite, andesite and diorite respectively cause a hydrothermal process. The hydrothermal process at Besole Formation as propylitization, silicification of quartz veins and argilization, where there is a combination of mineral chlorite, calcite, pyrite, chalcopyrite, albite and epidote are mostly found in the fractures.

Sulphide minerals commonly can be found in Kasihan region. The sulphide deposits exposed in some places are characterized by greenish-gray color with varying grain sizes. Mineral content among others include pyrite, chalcopyrite, molybdenite, galena and chlorite.

Material and Methods

In simple term, IP response reflects the degree to which the subsurface is able to store electrical charge, analogous to a capacitor (Sumner, 1978). The polarization occurs at the interface between (1) a metal and a fluid (electrode polarization), and (2) a non-metal (e.g. silica or clay minerals) and a fluid (traditionally called membrane polarization). Polarization resulted from a redistribution of ions along such interfaces follows application of an electric current. Upon current termination, ions relax to the equilibrium condition. This diffusion-controlled relaxation is equivalent to a residual current flow (as observed during discharge of a capacitor) and is the source of the subsurface IP response. The IP method measures the magnitude of this polarization. In contrast, the resistivity method measures the magnitude of conduction provided by both electrolytic and surface conduction (enhanced in the presence of clay minerals). Electrode polarization

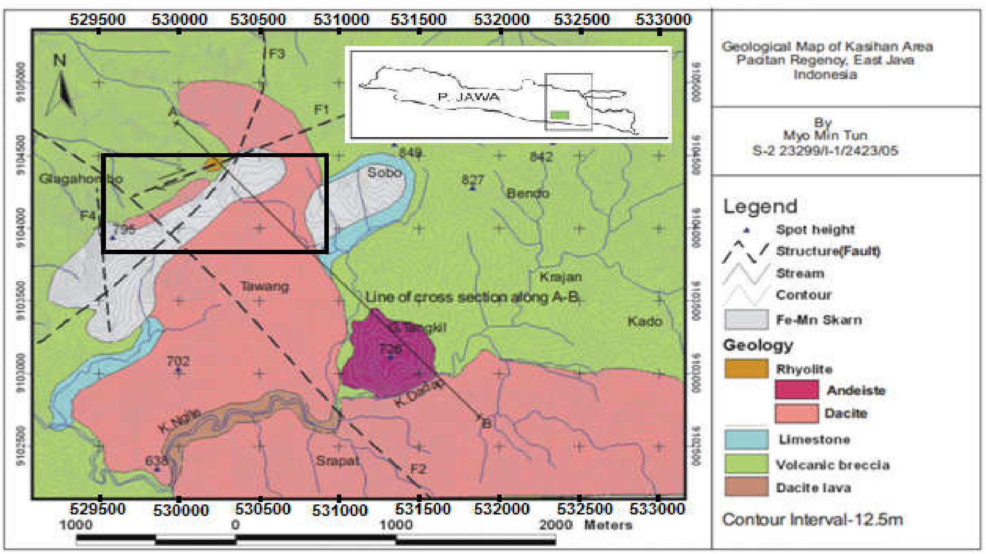


Fig. 1. Geological map of Kasihan region, Pacitan, East Java (Tun, 2007). Black box shows the location of the research area.

generally produces a larger IP response than membrane polarization (Slater and Lesmes, 2000).

In doing so, a 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). As the current is disconnected, potential will immediately be zero. However, in IP measurement, the potential will be zero for several time interval, this is called potential decay. Potential decay is due to the polarization in the subsurface medium.

At time domain, the most common measurement is the chargeability defined as (Ward, 1990) :

$$M = \frac{1}{V_0}\int_{t_1}^{t_2} V_p(t)dt$$

Where $V_p(t)$ is residual voltage integrates over time window defined between times t_1 and t_2 after termination of an applied current. V_o is the measured voltage at some time during application of the current. The unit of chargeability are quoted as millivolt per volt (mV/V).

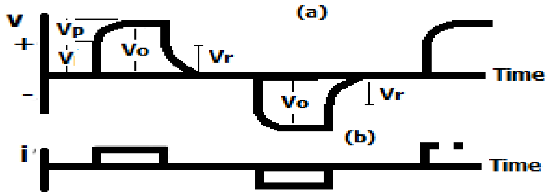


Fig. 2. (a) Time domain IP signal received showing measured parameters. (b) Current wave form : square-wave is generated low frequency.

Research using TDIP methods in Kasihan was carried out to determine the boundaries of the mineralized zones and estimate the metallic mineral resources. The resistivity and chargeability data were taken using Syscal Junior 486 Series. The five mapping lines and two-point sounding were taken. The sounding points were located around the line L1 on 160 and 180 meter. The data were taken in form of 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 grid, because there is canyon at the area. Selection of this track is to predict continuity of mineralization at vertical and horizontal directions. Design track in this study are shown in Fig. 3.

Magnetic data is also taken with the distance between the point of 20 m. The measurement points are concentrated in the middle of the area. The position of TDIP lines and magnetic data is shown in Fig. 3. The magnetic data was taken by using PPM Geotron, with accuracy of 0.1 nT. RES2DINV inversion modeling is used to obtain resistivity distribution and chargeability subsurface (Loke, 2004). The 3D modeling using RockWork15 and VES data is processed using Ver6 Progress.

Results and Discussion

TDIP data is interpreted by characteristics of resistivity and chargeability resulted from inverse modeling using Res2DInv and geological information correlation. Correlation between outcrop, geologic data and inversion modeling on the track L1 indicates that pyrite ore has a high resistivity and chargeability. The position and geometries of pyrite mineral zone and other mineral content possibilities are found by integrated data interpretation.

The pyrite outcrops are in the path of L1. Therefore, this line is used as a reference to retrieve the value of resistivity and chargeability pyrite ore. Fig. 4

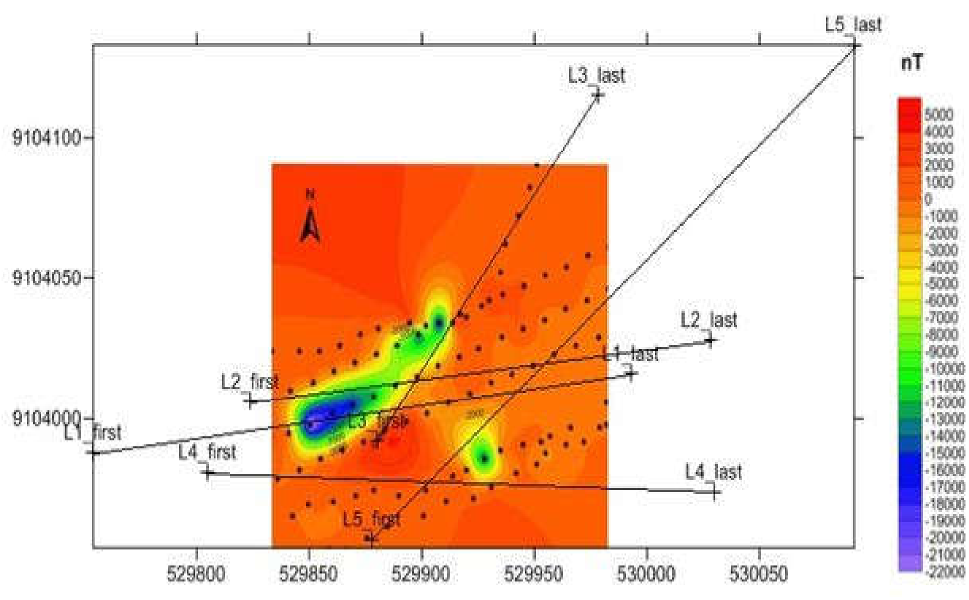


Fig. 3. Contour map of the total magnetic field anomalies. The black dot is position of the magnetic data.

shows the results of 2D inversion modeling of L1. The existence of pyrite on L1 path shown by high in resistivity and chargeability with range (100-1400) Ohm-m and (25-110) msec respectively. The chargeability and resistivity value is obtained from a 2D model in the position range (100-220) meters that igneous rock unit with a high resistivity value and low chargeability. In addition, the resistivity smaller than 100 Ohm-m is a unit of volcanic breccia, sandstone and overburden layer.

VES processing results in the form of resistivity

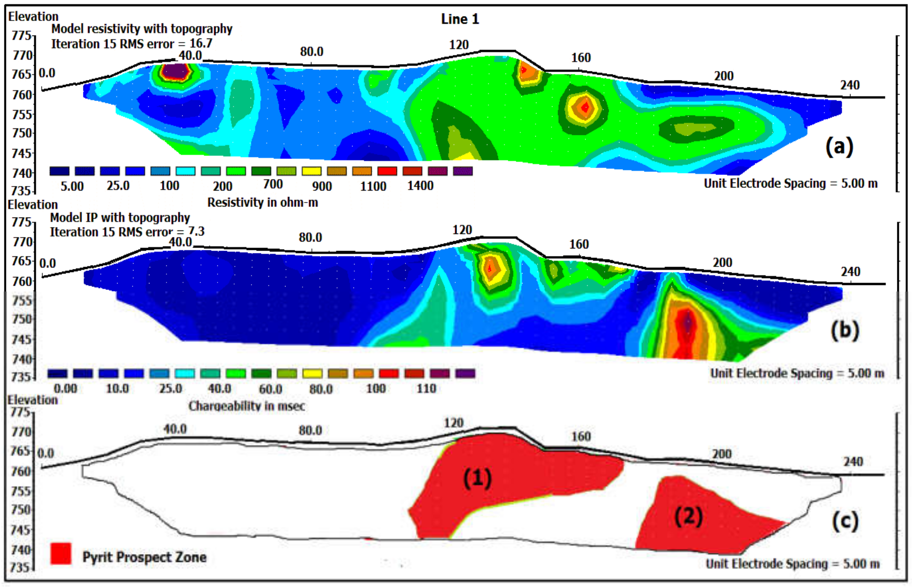


Fig. 4 (a) inversion model resistivity and (b) chargeability of line L1. (c) the interpretation prospect of pyrite.

are supported with pyrite outcrops in the area at distance (140-150) meter. The anomalies in L1 is clearly visible on the surface until it reaches a depth of 23 meters. Resistivity (100-500) Ohm-m (Fig. 4) is interpreted as a unit of dacite and andesite. For resistivity (500-1400) Ohm-m is interpreted as intrusive rocks. In position (30-60) meters there is log (Fig. 5). High resistivity obtained from the surface to a depth of 35 to 45 meters shows the existence of the pyrite mineral associated with silicate. The inversion modeling results on the track L1 until that depth higher in chargeability (up to 100ms), is indicator of higher Fe content in the pyrite.

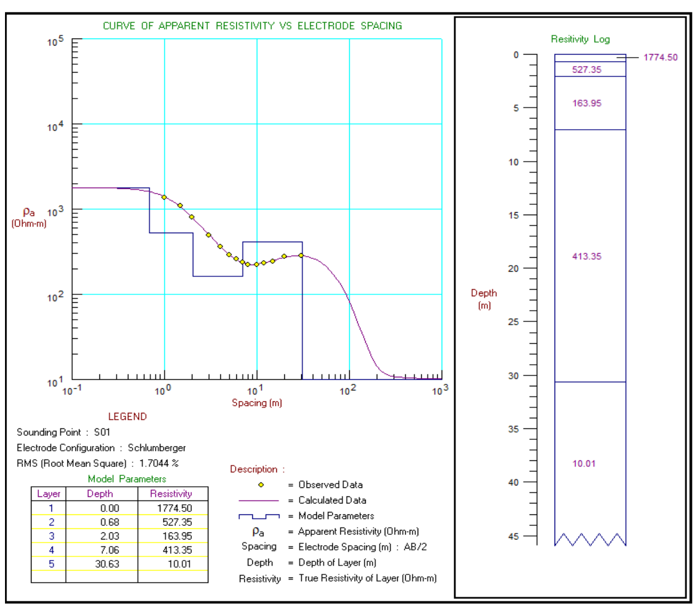


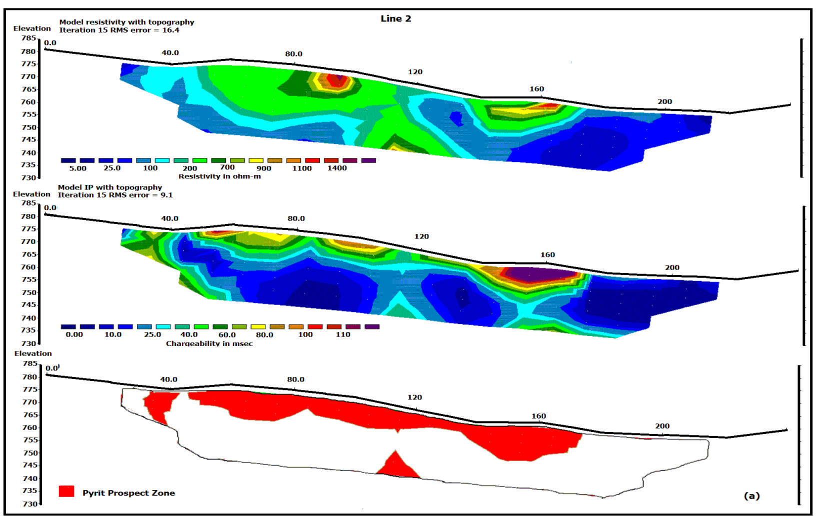
Fig. 5 The resistivity log VES at the sounding point S-01.

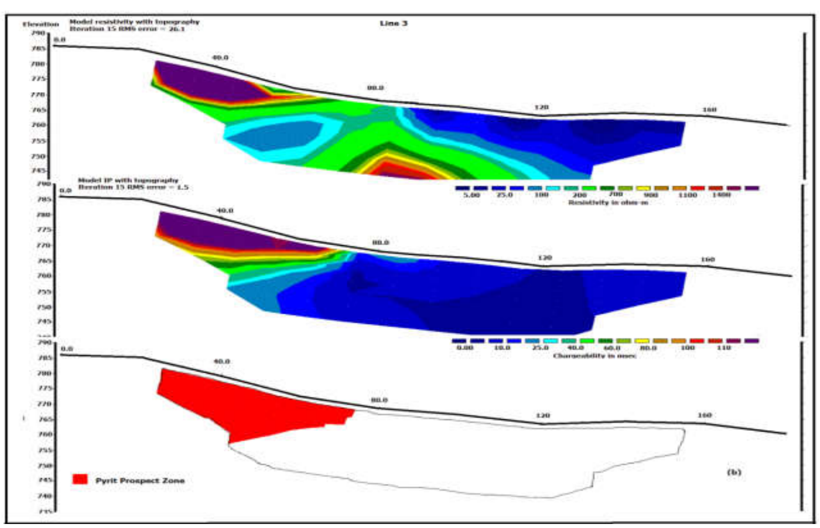
The closure with high resistivity and chargeability lay at line L2 (Fig. 6a). The anomalies indicated as pyrite are present nearly in all positions along this line. The existence of pyrite is in the position (20-160) meters, from the surface to the depth of 27 meters. In this line there is a polarizable rock known by the chargeability value. While at position about 60 meters and 160 meters in depth (21-27) meters there is low resistivity and high chargeability that is interpreted as other types of metallic minerals.

The existence of pyrite in line L3 (Fig. 6b) located at position 0 up to 80 meters, indicated with a high resistivity and chargeability. The pyrite zone is large enough, located at the end of line L3. The zone is located exactly at intersection with L2 and L1 lines (Fig. 3). Estimation of pyrite ore in this line is clearly from the surface to a depth of 27 meters. In this line at (60-120) meter, interpreted as type of igneous rock that indicated a high resistivity and low chargeability.

In line L4 anomaly, presence of pyrite is characterized by high chargeability and resistivity as shown in Fig. 6c. The potential zone L4 as pyrite in the resistivity range (100-1400) Ohm-m and chargeability (25-60) msec. The existence of potential zones of pyrite is in the line of large-sized, very clearly at position 80 to 140 meters. Pyrite is located at the surface up to 27 meter depth at L4 is also result of high resistivity anomaly and low chargeability at the position (40-60) meter and is suspected as igneous rocks.

The inversion modeling of line L5 is shown in Fig. 6d, where pyrite is also indicated anomaly with high resistivity and chargeability. Anomalies in this path can be seen clearly on the results of resistivity and chargeability inversion modeling. The position is located between 0 to 80 meters, which is the edge of the line. This anomaly is located on the surface down to 27 meters depth. At the position (220-260) meter, from the surface down to 27 meters in depth, the high





resistivity and low chargeability is interpreted as igneous rocks.

The interpretation result in all lines indicates the high value of resistivity and chargeability anomalies. Kasihan regions have rock structures that were

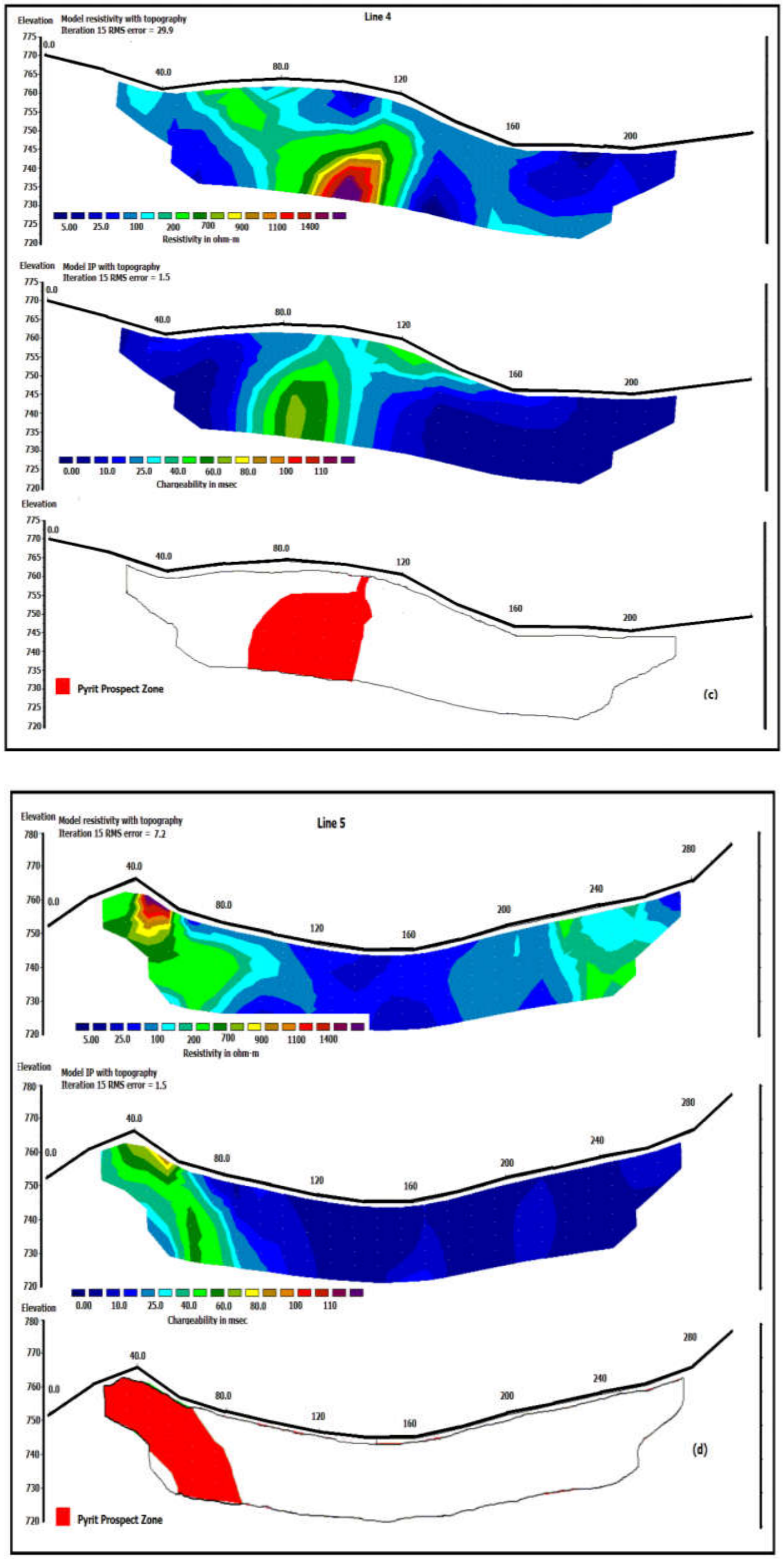


Fig. 6 Inversion modeling in resistivity and chargeability and interpretation of pyrite prospect on the line (a) L2 (b) L3 (c) L4 and (d) L5.

identified as quite big pyrite carriers. The existence of high resistivity and low chargeability also indicate other metallic minerals. However to ensure the specific type of mineral, chemical testing should be performed on rock samples carefully.

Pyrite is characterized by low resistivity and high chargeability. The existence of pyrite associated with its environment, especially silica that causes higher value in resistivity and chargeability. The higher chargeability shows that pyrite content is also getting bigger. Based on the results of the inversion modeling, geological data and outcrop, the area is divided into a few lithology as follows:

1. Overbuden, with a resistivity of <100 Ohm-m and chargeability <10 ms. Layer consists of units of breccias and sandstone.
2. Unit of dacite and weathered andesite, with resistivity values (100-500) Ohm-m and chargeability <10 ms, consists of andesite and dacite, low compacity, semi-permeable, a lava inserts or a mixture of sandstone.
3. Unit of intrusion, resistivity values (500-1400) Ohm-m and chargeability <10 ms, dominated by andesite or dacite intrusive, compact massive and highly impermeable.
4. The pyrite carrier rocks, resistivity (100-1400) Ohm-m and chargeability (25-110) msec.

3D display potential zones of pyrite.

The 3D modeling used Rockworks.15.v.2009-10.27 software. This modeling is able to interpolate the all line measurements of TDIP method. The input data parameters are the 2D inversion modeling interpretation result. The results of the 3D model of the pyrite mineralization distribution is shown in Fig. 7. Distribution of pyrite mineralization zone partially exposed around L1 and L2 that are parallel and intersect with L3. Pyrite distribution also appears arround L4 that is parallel to L1 and L2. The pyrite zone distibute at L5 which intersects L1, L2 and L4. Pyrite potential zones are marked with red color. Fig. 7 is a 3D model with a cut-off value of resistivity (100-1400) Ohm-m and chargebility (25-110) msec. The rugged topography of the area shown on the 3D modeling in position on the North-West (Fig. 7). Zone of pyrite mineralization evident at the surface to the depth of 27 meters with a predominance of steep topography.

Determining the potential of pyrite is based on resistivity and chargeability values that have been determined on the interpretation of 2D TDIP data. In this case resistivity used is (100-1400) Ohm-m and high chargeability (25-110) msec. Volume obtained for 35,000 m^3 is shown in red. Resource potential of pyrite shown in Kasihan region are big enough.

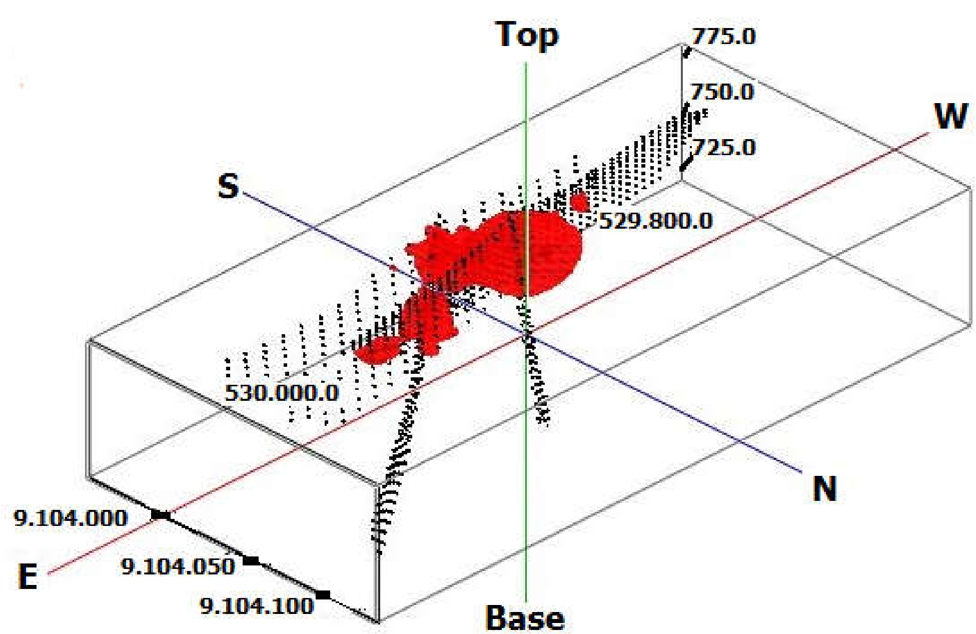


Fig. 7 Pyrite prospect zone of direction N-W.

Conclusions

Kasihan regions, Tegalombo, Pacitan Regency, East Java contained pyrite mineral resource potential that is quite large. Pyrite distributed from the West to the East, is partly exposed on the surface. The mineralized zones are areas in the middle. The pyrite is associated with carrier rock with high value of resistivity and chargeability. The value of the resistivity is (100-1400) Ohm-m and chargeability is (25-110) msec.

Based on the electrical properties in the study area, there are several lithologies, they are unit of overburden (soil) and sandstone has resistivity (5-50) Ohm-m, volcanic breccia unit (50-100) Ohm-m, units of dacite and andesite with resistivity (100-500) Ohm-m, and intrusion with resistivity (500-1400) Ohm-m. The research area is assessed with two different mineralized zones, namely pyrite and manganese. But to make sure more research is needed. It is advisable to test drill and sample measurements in more detail.

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