# Identification of Porphyry Deposit Based on Time Domain Induced Polarization Data Analysis in The Papua Region

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***Abstract***

Papua is one of the islands in Indonesia which has an abundance of economic metal mineralization in Indonesia. The types of mineralized deposits on the island of Papua are porphyry, skarn, and epithermal, where porphyry deposits are identified in the study area, which was identified early by geological conditions. The purpose of this study is to identify the presence of a porphyry deposit system in the study area based on Time Domain Induced Polarization (TDIP) data analysis. The TDIP measurements are carried out on an area of 2.24km$^2$, with a total of 3 lines oriented southeast-northwest along 3 km. Based on TDIP data analysis, there's low resistivity values (5.99 – 41.1) ohm-m correlated with high chargeability values (246 – 344) mV/V at an elevation of 500m identified as potassic bodies while at the top there are sericitic-clay-chlorite and serisitic-clay alterations -pyrite, which has a metal sulfide mineral content which is more dominant than the clay mineral content up to 1100m elevations.

***Keywords:*** *Papua, Porfiri, Time Domain Induced Polarization, resistivity, chargeability*

## I. Introduction

Metal mineralization is the process of depositing valuable, economically viable minerals in one place. Indonesia is an archipelagic country formed by the convergence of subduction of the Eurasian, Indo-Australian and Pacific continental plates. This tectonic process resulted in the emergence of magmatism activity in several areas in Indonesia, this process was the cause of the initial occurrence of metal ore mineralization [1] One of the regions in Indonesia that produces metal mineralization is the island of Papua.

Papua Island was formed as a result of 2 major tectonic processes (Fig. 1), beginning with the collision of the Pacific Ocean plate with the Indo-Australian plate during the Oligocene, then followed by a reversal process of subduction of the islands resulting from the collision with the Australian Craton during the Miocene. The presence of young magmatism activity in the Pliocene period until now in the form of dioritic to monzonitic intrusions, these intrusive rocks form metal mineralization deposits such as porphyry, skarn, and epithermal at the top [2].

The island of Papua by metallogeny [1] has several proven mineral deposits potential, including copper and gold, as found in Grasberg and Ertsberg (Fig. 1). The research area which is located in the middle part of Papua is geologically composed of clastic sedimentary rocks and intrusive rocks. Igneous rock intrusions in the study area from old to young are diorite, monzodiorite, monzonite, and granodiorite. The structure in the study area is a shear fault dominated by sinistral shear faults, with the dominant orientations being NW-SE and NE-SW.

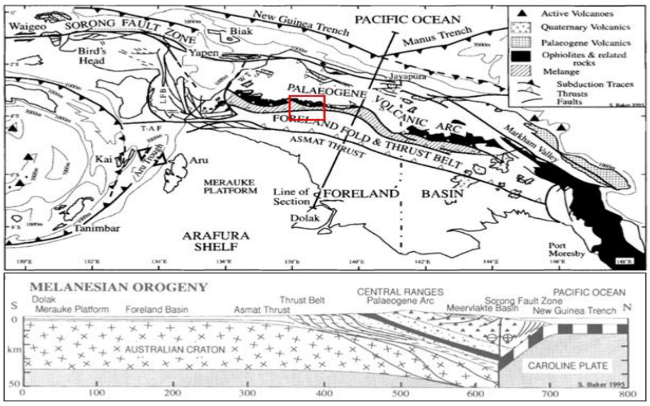


**Figure 1.** Orogenic Melanesia in Papua with Cross Section Interpretation

Metalogenically, the study area is in the porphyry and skarn mineralization zone (Fig. 2), porphyry deposits formed as a result of multiple intrusions more than twice with intermediate to felsic rock properties, there are four types of intermediate rock intrusion in the study area, has a related potential the formation of a porphyry deposit system in the area [3].

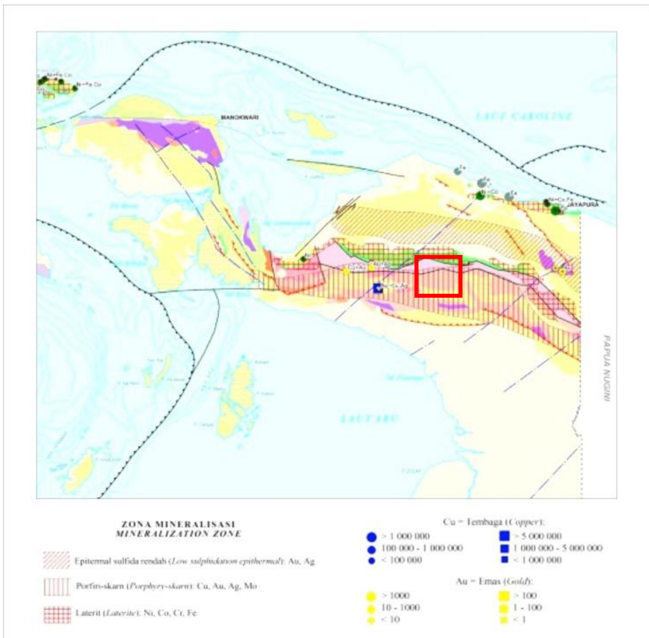


**Figure 2.** Map of Papua's Metalogeny with Proven Resources and Mineralization System Zoning

A geophysical approach is used to determine the presence of metal sulfide mineralization zones, one of the geophysical methods that is considered effective in metal mineral exploration is the Time Domain Induced Polarization method [3]. The Time Domain Induced Polarization (TDIP) method measures the polarization decay time of a metal mineral to determine its presence. Previous research has shown that the Time Domain Induced Polarization method can be used to delineate gold mineralized zones [7]. The gold mineralization zone is characterized by high resistivity values and high chargeability values as a response to altered igneous rocks containing metallic mineralization in the form of gold.

The purpose of this study is to identify the presence of a porphyry deposit system in the study area based on Time Domain Induced Polarization data analysis.

## II. Materials and Methods

This research was conducted using a geophysical approach in the form of Time Domain Induced Polarization (TDIP) datas. TDIP method calculates the potential decay time of a material to determine the polarization of a material, in this case, metal sulfide mineralsn [4]–[6].

Data processing in this study was carried out using measurement data consisting of three tracks with an orientation of Southeast – Northwest, with a 2,800-meter long track, where the distance between the tracks was 400 meters. The measurement area of TDIP is 2.24 km2. The electrode configuration used in this study is the Dipole-Dipole configuration. The next measurement data is calculated to get the apparent resistivity and chargeability values, then the data is entered into the inversion software i.e. res2dinv to get a pseudo section cross-section [7], [8], [9]. In this inversion processing, there are several methods of data processing and quality control carried out to get the desired results and have minimum noise.

### *A. Mesh Parameter*

Setting Mesh Parameter is the first step before doing the inversion process. This process is needed to organize and adapt the data to the inversion process, because the characteristics of each data are different. This method consists of three main parameters, namely Finite-Mesh Grid Size, Use Finite-Element Method, and Mesh Refinement. Finite-Mesh Grid Size is a parameter to determine the datum distance on a series of electrodes, in this study 4 nodes were arranged on each electrode to increase the accuracy of the data. The Use Finite-Element Method is a parameter to determine the type of forward modeling associated with calculated data [9], as well as the shape of the inverse cross-section (Fig. 3). This study uses the finite-element method in forward modeling related to the contrast of the data on the topographic contact and uses the trapezoidal type to produce a cross-section according to the pseudo section of the dipole-dipole array.

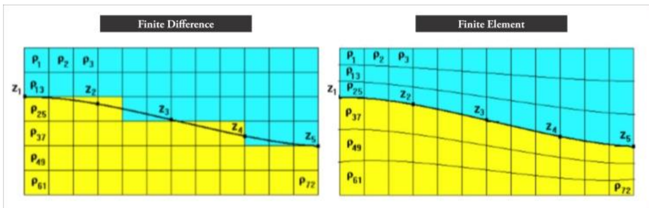


**Figure 3**. Mesh parameters at Finite Difference and Finite Element Method

Mesh refinement is a parameter used to adjust the mesh type in the forward modeling process, with the contrast of the resistivity values in the data. This study uses a normal mesh type with a resistivity contrast of less than 50.

### *B. Exterminate Bad Datum Point*

This process is a quality control of resistivity and chargeability data. An exterminate bad datum is carried out before and after the inversion process, if the RMS error value resulting from the inversion is more than 76, then on the resistivity and chargeability data it is necessary to carry out an exterminate bad datum Point process (Fig. 4). The datum points that are considered bad are datum points that have random positions or cross-over with other datums. The cause of the datum is not in accordance with the dipole-dipole array, one of which is due to differences in topography measurements that cause the datum to have an inappropriate depth, but it can also caused by insufficient injection current to reach the depth of the target datum [10], [11]

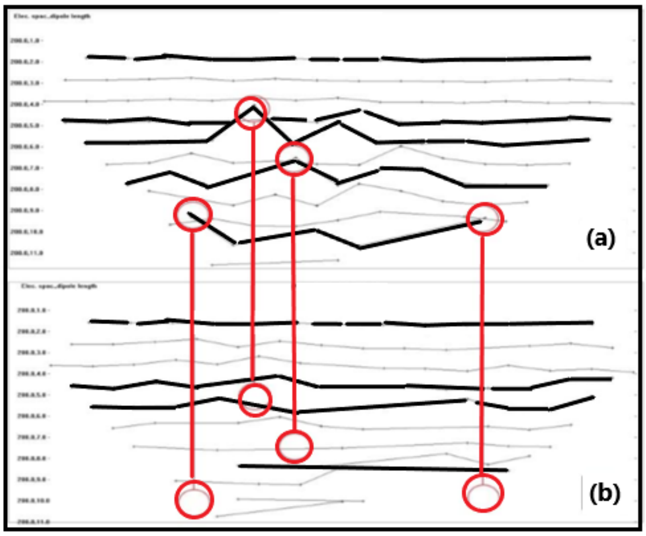


**Figure 4.** Exterminate Bad Datum Process, (a) there are 4 bad datum points that cross over, (b) pseudo section after deleting bad datum point.

### *C. Least-Square Inversion*

The resistivity and chargeability cross sections are made by performing an inversion process on each recorded data. One of the inversion methods for geoelectrical inversion is Least-Square Inversion. Least-Square inversion uses a calculation in the form of a square of the difference between the calculated data and the observation data [12]. This study uses Least-Square¸ inversion with the aim of obtaining inversion data that is close to the observation data with minimum noise, and obtaining data contrast that is not too far apart. The least-square inversion in this study was carried out using the smoothness constraint method to obtain a smooth anomaly.

## III. Results and Discussions

Alterations formed in porphyry deposits vertically from top to bottom are potassic alteration, sericitic -clay-chlorite, serisitic-clay-pyrite, and horizontally there is propylitic alteration. potassic and serisitic-clay-chlorite alteration have high metal sulfide mineral content, such as bornite and chalcopyrite , so the TDIP method is considered effective for delineating the alteration zone as a metal sulfide mineralization zone, resistivity, and chargeability analysis, cross-sectional correlation analysis, anomaly continuity analysis, and three-dimensional analysis of the porphyry deposit system.

### *A. Resistivity dan Chargeability Analysis*

The results of the TDIP geoelectric inversion data consisting of resistivity and chargeability cross sections were interpreted to determine the alteration zone and mineralization in porphyry deposits.

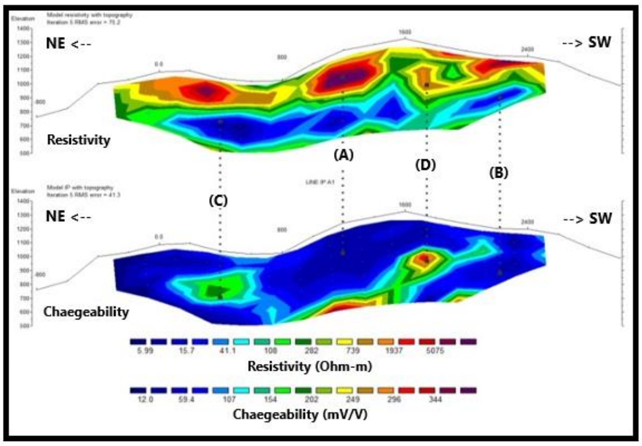


**Figure 5.** Resistivity and chargeability section Line 1 with interpretation code refers to a geological condition in table 1

In the TDIP trajectory (Fig. 5), there is a pattern of low resistivity and high chargeability anomalies (code C) at the 200th meter, it can be interpreted that this zone is a strong alteration zone [13], which can be associated with sericite alteration with sulfide minerals being more dominant than the mineral clay (Table. 1). The high resistivity value and high chargeability in the cross-section are a response to the massive quartz vein zone with high sulfide content, the area is at 1800 meters, a depth of 400 meters below the surface, there are other zones which are interpreted with different geological conditions on the track. first, which can be seen in the form of an interpretation code. This interpretation code and interpretation table also applies to the other two TDIP tracks (Table 1)

**Table 1.** Interpretation Table for each TDIP Line

| Code | Resistivity | | Chargeability | | Interpretation |
|---|---|---|---|---|---|
| | High | Low | High | Low | |
| A | ✓ | | | ✓ | Weak Alteration, Fresh Rock, Exoskarn with minor sulphide, Silica-rich Zone |
| B | | ✓ | | ✓ | Cavity Structure, Clay-rich zone, Sericitic Alteration (Sericite>Sulphide) |
| C | | ✓ | ✓ | | Strong Alteration, Vein sphread zone, Sericitic Alteration (Sulphide>Sericite) |
| D | ✓ | | ✓ | | Silification Zone, Major Sulphide in Vein Quartz, Weak Altered with High Magnetite |

### *B. Section Correlation Analysis*

In the TDIP geoelectrical section which consists of 3 tracks, 3D correlation is performed to delineate the continuity of the resistivity and chargeability data (Fig. 6). In the resistivity cross-section correlation (above), there is a continuous low resistivity value in the middle of the cross-section, tends to be massive on the L1 and L2 lines to form a large closure, but on the next track in the southeastern part the low resistivity value tends not to form a large closure (but still shows continuity).

It can be interpreted that there is a continuous north-south structure but in the southeastern part of L2 and L3 the structure is dominated by clay mineral alteration (Table 2). A high resistivity anomaly is found in the western part of each track, which can be interpreted as a continuation of fresh intrusive igneous rocks, or has not been completely altered.

In the chargeability cross-section correlation (below), the high chargeability anomaly which is interpreted as a rich sulfide zone carrying metal mineralization tends to be spotted in various places, but there are massive high chargeability values at the bottom of the L800 and L1000 tracks which can be associated with the sericite alteration zone at targeted porphyry bodies (Table 3).

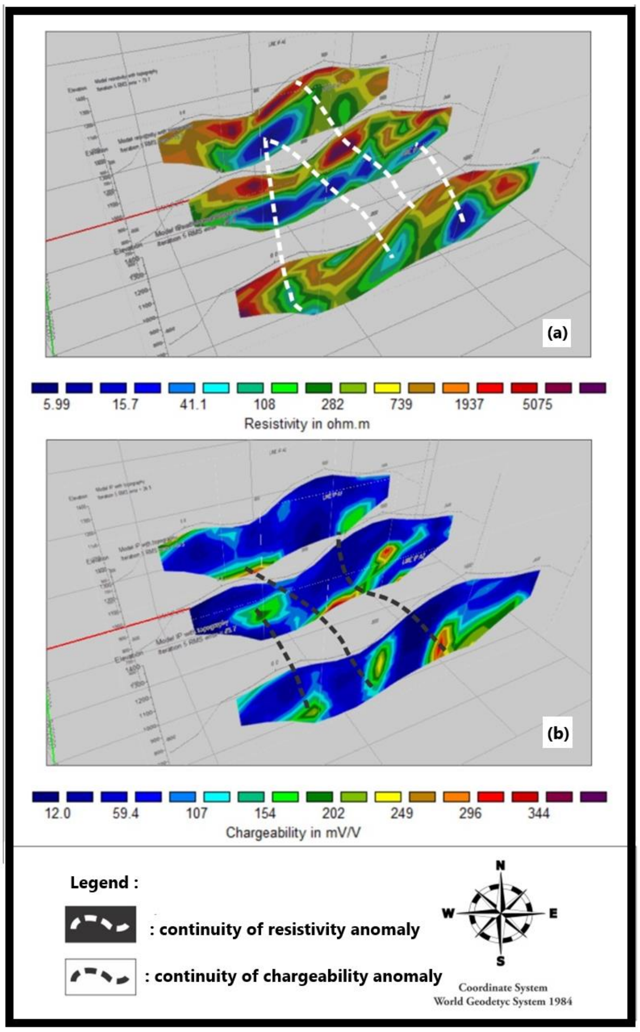


**Figure 6.** TDIP geoelectrical correlation to determine the continuity of the anomaly that is the target in the form of mineralized areas (a) resistivity and (b) chargeability.

**Table 2.** Classification of Resistivity Values Against the Geological Condition of the Research Area

| No | Classification | Resistivity Range (Ohm-m) | Interpretation |
|---|---|---|---|
| 1 | Low | < 215 | Clay mineral, Strong alteration |
| 2 | Medium | 215-2670 | The moderate alteration, Fresh rock with moderate silica, Quartz Vein, SCC alteration |
| 3 | High | >2670 | Fresh rock, Quartz vein, Propylitic alteration |

**Table 3.** Classification of Chargeability Values Against the Geological Condition of the Research Area

| No | Classification | Chargeability Range (mV/V) | Interpretation |
|---|---|---|---|
| 1 | Low | < 80 | Clay mineral with minor sulphide, barren ore |
| 2 | Medium | 80-215 | Rich of both clay and sulphide minerals, weak alteration |
| 3 | High | >215 | Sulphide dominant, Sericite alteration, Vein with high ore |

**Anomaly Continuity Analysis**

The resistivity and chargeability values in the TDIP geoelectric, are made in the form of horizontal distribution with different elevations, with an elevation difference of 200 meters, starting from an elevation of 500m to an elevation of 1300m, then stacked vertically (Fig. 7).

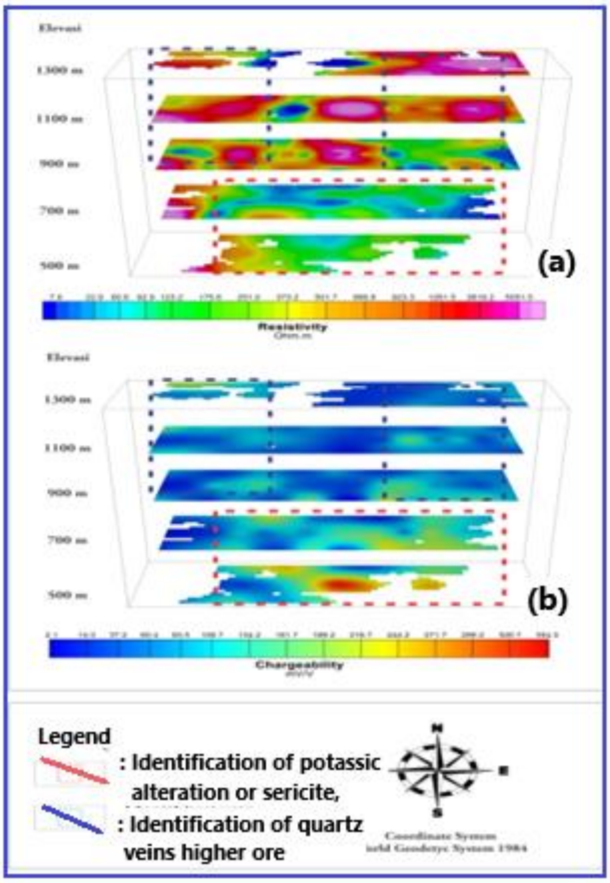


**Figure 7.** Stacking plan map TDIP to find out the horizontal continuity for each elevation per 200 meter (a) resistivity and (b) chargeability

Based on the stacking plan map of Resistivity data (Fig. 7), there is a low resistivity anomaly at the bottom right of the map, this low resistivity anomaly pattern continues to an elevation of 700m, while when the elevation gets to 1300m the anomaly pattern changes to high resistivity. Low resistivity values at an elevation of 500 to 700m are interpreted as zones with structures or veins that spread and the presence of a large amount of clay minerals, when viewed and compared with the stacking plan map Chargeability at the same elevation, the low resistivity value is correlated with the high chargeability value, based on it can be interpreted that the low resistivity and high chargeability zones are an indication of the presence of potassic alteration to potassic or neritic-clay-chlorite alteration.

On the stacking plan map of 900 to 1300m elevation resistivity, there are high resistivity anomalies on the left and right of the map, the high resistivity values are correlated with moderate chargeability values, which are interpreted as quartz vein zones that spread with high sulfide content in response to nericitic-alteration changes. clay-pyrite.

### *C. Porphyry Deposit Setting Analysis*

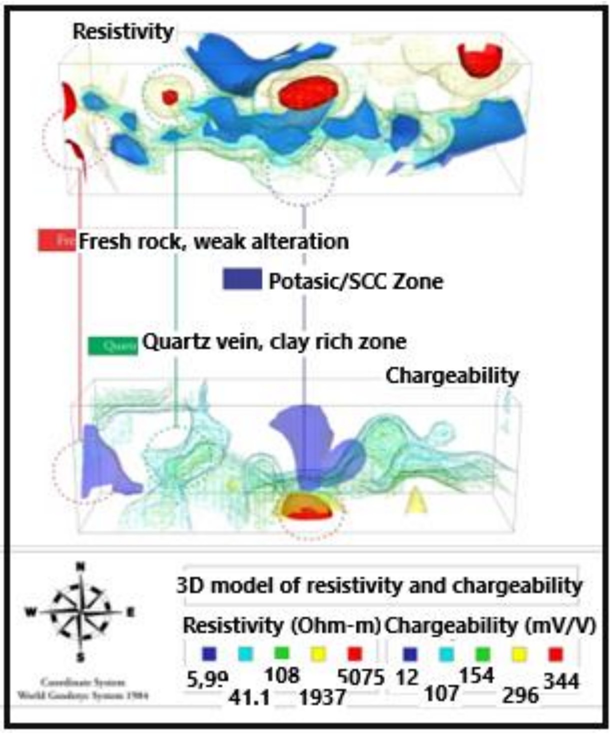


**Figure 8.** 3D Model of iso-surface resistivity and chargeability

Based on 3D iso surface resistivity modeling (Fig. 8), there is a high resistivity anomaly pattern in the west, and correlated with low chargeability values, the zone is interpreted as fresh or unaltered igneous rock or quartz vein barren ore zone. The middle part is south of the 3D model, there is a low resistivity anomaly which is correlated with a high chargeability anomaly. The zone is interpreted as potassic or sericitic-clay-chlorite alteration with sulfide content that dominates compared to clay content, as well as vein spread zone which makes the resistivity value low.

The upper zone of the potassic body has a low resistivity anomaly which correlates with a high chargeability anomaly, the zone is interpreted as a continuation from the serisitic-clay-chlorite zone to the serisitic-clay-pyrite, with a sulfide content that is almost comparable to the clay content so that the chargeability response has a value which is being.

Based on the 3D isosurface model, the porphyry deposit system in the study area consists of potassic alteration at a depth of 500 meters with serisitic-clay-chlorite and serisitic-clay-pyrite alterations in the upper part, which has quite abundant sulfide mineralization, while prophylitic alteration is located around the potassic body with host rock in the form of igneous rock that has not been completely altered.

## IV. CONCLUSIONS

The results of the Time Domain Induced Polarization Data analysis that has been carried out in the research area, there is a correlation between resistivity and chargeability values related to the porphyry deposit system in the study area. Low resistivity values (5.99 – 41.1) ohm-m correlated with high chargeability values (246 – 344) mV/V at an elevation of 500m identified as potassic bodies while at the top there are sericitic-clay-chlorite and serisitic-clay alterations -pyrite, which has a metal sulfide mineral content which is more dominant than the clay mineral content.

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