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Identification of Iron Ore Deposit in Sub-Surface Using Electrical Resistivity and Induced Polarization Methods in Nangabulik, Central Kalimantan

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Abstrak. Nangabulik, Kabupaten Lamandau merupakan salah satu daerah di Kalimantan Tengah yang memiliki potensi akan sumberdaya mineral bijih besi. Metode yang cocok digunakan untuk menganalisis model distribusi nilai *resistivity* dan *chargeability* di bawah permukaan yang dapat menginterpretasi distribusi sebaran bijih besi dan menyelidiki keberadaan zona kemenerusan bijih besi adala metode geolistrik dan IP. Konfigurasi yang digunakan adalah *Wenner Alpha* dengan 4 lintasan yang masing-masing panjangnya 235 m. Berdasarkan hasil inversi 2D nilai *resistivity* berkisar 21,15 – 96.153,51 Ωm dan *chargeability* 23,6 – 542,58 ms. Endapan bijih besi ditemukan pada lintasan GL-01, GL-02, dan GL-04 yang ditandai dengan nilai *resistivity* 614,22 – 5.803,90 Ωm dan kontras *chargeability* berkisar 212,32 – 542,58 ms. Nilai resistivitas besar terjadi akibat adanya rongga antar fragmen bijih besi yang berbentuk kerikil – bongkah dengan butiran batuan piroklastik yang terisi udara. Berdasarkan model 3D tidak ditemukan adanya zona kemenerusan endapan bijih besi pada daerah penelitian. Jumlah endapan yang diduga sumberdaya bijih besi di daerah penelitian, pada area seluas ± 6 hektar sebesar 41.036 ton.

Kata Kunci: *Endapan Bijih Besi, Nangabulik, Polarisasi Terinduksi, Resistivitas, Wenner Alpha*

Abstract. Nangabulik, Lamandau Regency was one of territories in Central Borneo that has potential for iron ore resources. The method that is suitable for analyzing the distribution model of the resistivity and chargeability values below the surface that can interpret the distribution of iron ore distribution and the presence of iron ore continuity zones is the geoelectric and IP method. Configuration used is Wenner Alpha with 4 passes, each of which length is 235 m. Based on the 2D inversion result, resistivity and chargeability values were 21,15 – 96.153,51 Ωm and chargeability 23,6 – 542,58 ms. Iron ore deposit is to be found at GL-01, GL-02, and GL-04 tracks marked by resistivity value 614,22 – 5.803,90 Ωm and contrast in chargeability value around 212,32 – 542,58 ms. Large resistivity value due to porous between pebble–boulder iron ore fragments shape with pyroclastic rock grains filled the air. Based on the 3D model there was not found alignment zone of iron ore deposit at the research region. Total estimated deposit iron ore resource in the research region, at area ± 6 hectares is 41.036 tons.

Keywords: *Electrical Resistivity, Induced Polarization, Iron Ore Deposit, Nangabulik, Wenner Alpha*

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INTRODUCTION

Geology of Research Area

Based on Fig. 1 Lamandau Regency is eastern part of the Sunda Shelf and borders the Barito Basin. At that time this area experienced uplift accompanied by volcanic activity which resulted in the Kuayan Formation [1]. Based on data from the Pangkalanbuun sheet, the research area is included in the pyroclastic rock unit of the Kuayan Formation (*TRvk*). This formation is composed of pyroclastic rocks (rocks resulting from ancient volcanic eruptions) with rock types of breccia, lava, tuffaceous sandstone, and tuff which are estimated to be Triassic in age and have weathered [2].

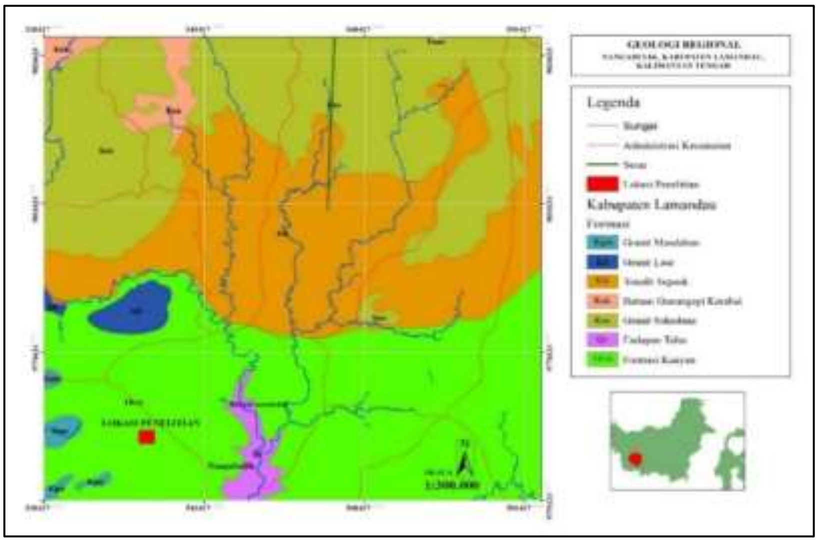


Figure. 1 Regional Geology Map of Lamandau Regency [2].

Iron Ore

Iron ore is the rock that contains iron elements or there are iron deposits in it. Economical iron deposits are generally in the form of magnetite, hematite, limonite, and siderite [3]. Iron ore deposits can be formed primary or secondary. Primary iron ore deposits can be formed by magmatic, contact metasomatic, and hydrothermal processes. Secondary iron ore deposits occur due to weathering, transportation, and sedimentation processes [4].

Laterite deposit is a type of residual deposit produced by weathering processes that occur in ultramafic-mafic rocks involving decomposition, re-deposition, and chemical accumulation. The process of weathering of ultramafic-mafic rocks is carried out intensively due to the influence of relatively small slope factors, groundwater, and weather, resulting in lateritic soils that still contain boulders of hematite and goethite iron ore in the size of granule-pebble [4].

Figure. 2 Iron Ore Fragments in Soil Layer on Any Places Forming the Lens [5].

Figure. 3 Boulders of Iron Ore are Dominated Hematite and Magnetite with weak magnetic character [5].

The results of the geological survey (Figs. 2 and 3) show the presence of lateritic iron ore deposits which are mostly hematite in the form of a sub-angular lens-angular (angled), granule-boulder formed as fragments in a clay-sand sized matrix, the result of weathering of pyroclastic rocks of the Kuayan Formation. In some places, there are fragments of magnetite iron ore with weak magnetic characteristic [5].

Electrical Resistivity

Electrical resistivity method is one of the geoelectrical methods used to investigate subsurface structures based on differences in rock resistivity. Basis of the resistivity method is Ohm's law Eq. (1).

$$V = IR \tag{1}$$

where each constant *R* is the resistance and is measured in units of when the current (*I*) is in ampere and voltage (*V*) is in volts [6].

If the parameter used to identify Ohm's Law is a certain material (copper wire) then its resistance will depend on the dimension of that material [7]. Relationship between resistance (*R*) and the dimension of a straight conductor material with length (*L*) and surface area (*A*) is:

$$\rho = R\left({}^{A}/_{L}\right) \tag{2}$$

Geoelectric measurements are usually carried out by injecting electric current (I) into the earth through two current electrodes, *C1* and *C2*, then the potential difference (*V*) that occurs is measured through two potential electrodes, *P1* and *P2* as shown in Fig. 2. The current value (*I*, unit mA) and electric potential difference (V, unit mV) are obtained so that the resistivity value (ρ_a, unit m) can be calculated using Eq. (3).

$$\rho_a = K\frac{V}{I} \tag{3}$$

where *K* is a geometric factor that depends on the arrangement of the electrodes [4].

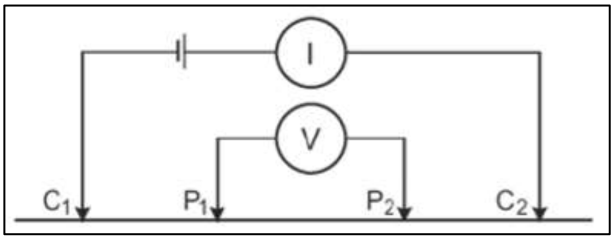
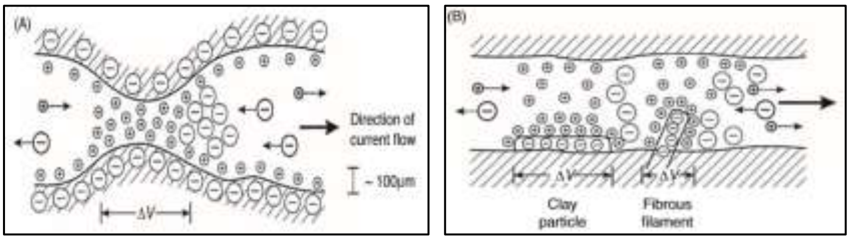


Figure. 4 Array of Four Electrodes on Geoelectric Method [4].

Induced Polarization (IP)

The phenomenon of induced polarization occurs when a current is injected and then the current is turned off. The voltage or potential that is measured after the current is turned off does not immediately become zero. The measured potential decreases slowly towards zero which is called overvoltage decay. The ratio between the voltage when the current is turned off and the voltage when the current is injected is called chargeability. Polarization is caused by two main sources namely electrode polarization and membrane polarization [3].



(a) (b)

Figure. 5 Membrane Polarization, (a) a constriction within a channel between mineral grains, and (b) negatively charged clay particles and fibrous elements along the sides of a channel. [3].

Based on Fig. 5a is the membrane polarization caused by the narrowing of the pores. When the current enters the pores, there is an accumulation of positive ions near the negative ions on the membrane wall. On Fig. 5b shows the membrane polarization due to the presence of clay particles in the rock pores. Clay particles containing a negative charge attract positive charges in the electrolyte solution. The negative charge scattered in the electrolyte solution will move away from the clay particles. The accumulated positive charge will inhibit the electrons originating from the injected electric current when a potential difference is given [3].

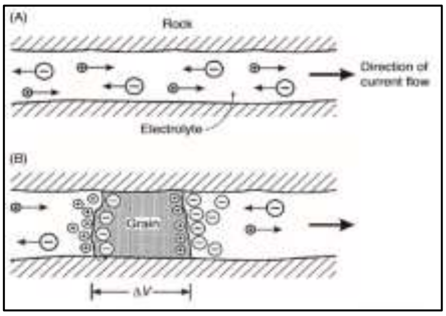


Figure. 6 Grain (electrode) polarization (a) Unrestricted electrolytic flow in an open channel (b) Polarization of an electronically conductive grain, blocking a channel [3].

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Based on Fig. 6a depicts the polarization of the electrode in the pores of the rock containing the electrolyte solution. Positive ions flow in the direction of current flow. Negative ions flow in the opposite direction to the direction of current flow. In Fig. 6b describes the polarization of the electrodes in the pores of rock containing minerals. Positive and negative charges are polarized at the boundary between metallic minerals and the solution when an electric current is applied [3].

METHODS

This research was conducted in Nangabulik, Bulik District, Lamandau Regency, Central Kalimantan Province. This data is included in the area of the Mining Business Permit of PT. D. The type of configuration used is Wenner Alpha. Reason using this configuration because Wenner Alpha has low depth penetration, high sensitivity to lateral inhomogeneities, and good vertical resolution [3]. This is appropriate for identification iron ore distribution laterally and has relatively shallow depth. Geoelectric data used as many as 4 tracks with length of 235 m with a space between the electrodes of 5 m.

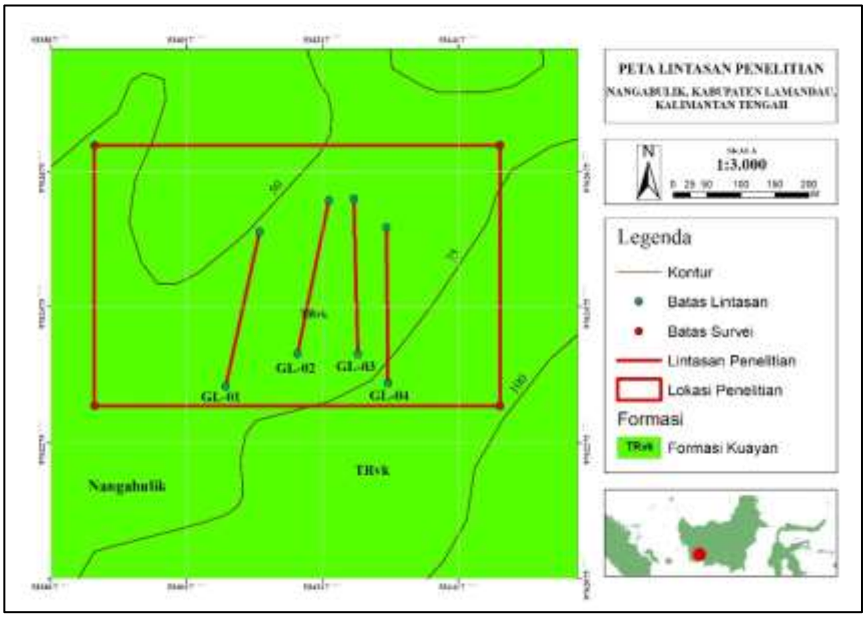

Figure. 7 Survey Tracks Design of Resistivity and Induced Polarization (IP) Methods

2D modeling of Resistivity and IP data using Res2Dinv software. This program uses the iteration method to start the initial model and try to minimize the difference between the calculated and measured resistivity and apparent chargeability values or to obtain an improved model where the calculated resistivity and apparent chargeability values are equal to or close to the measured values [6].

Then 3D modeling was carried out based on the results of 2D inversion using Geosoft Oasis Montaj software. The 3D model made is the correlation of the IP (chargeability) values of entire track so that it can be seen clearly whether or not there is a continuity zone for iron ore deposits.

Process of calculating iron ore deposits in the research area using Voxler software. Volume calculations used the iso-Surface module. Iso-surface is a representation of the distribution of data values (actual chargeability) in the form of a 3D model. Estimated volume of iron ore resources is the value of the volume iso-value. The following is a research flow chart.

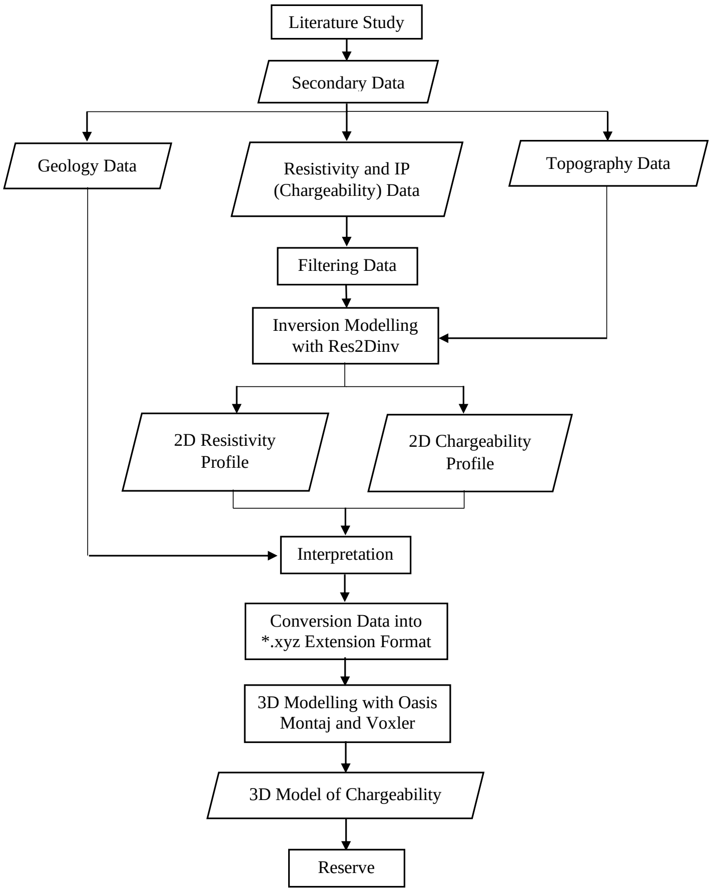

Figure. 8 Research Flow Chart

RESULTS AND DISCUSSION

Result of 2D Modelling and Interpretation

Based on result of inversion modeling obtained a 2D resistivity and induced polarization (chargeability) cross-sectional model of the entire track, then correlated with the geological data of the research area, it can be interpreted to indicate the presence of iron ore deposits on each track, as follows.

GL-01 Track

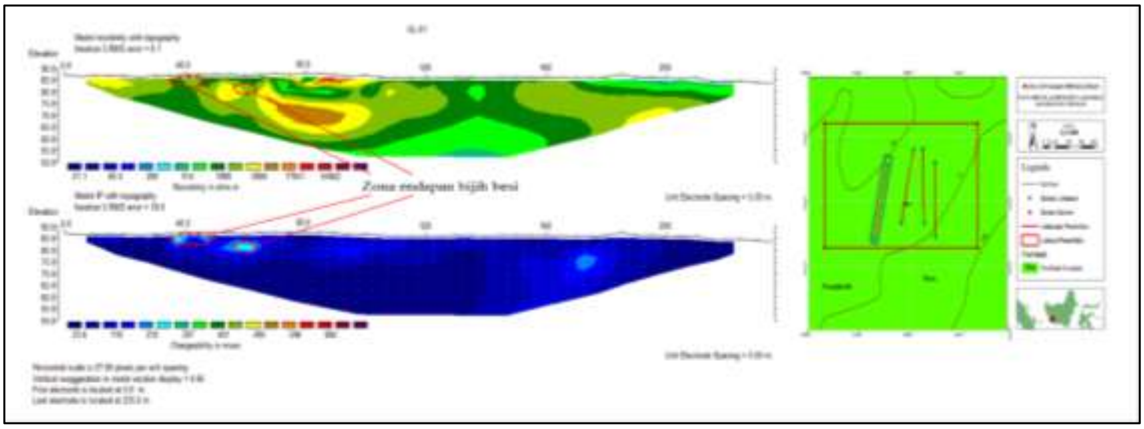

Figure. 9 Result of Inversion Modelling and Interpretation from Resistivity and Chargeability Profiles on GL-01 Track

Based on Fig. 9 obtained the resistivity value which is in the range of numbers 350,33 – 31.280,02 Ωm with the value of chargeability being in the interval of numbers 23,6 – 259,50 ms. In a 2D cross-section of chargeability, it can be seen that the chargeability value contrasts with a value range of 212,32 – 259,50 ms which is interpreted as having iron ore deposits, which correlates with a resistivity value range of 1.076,89 – 5.803,90 Ωm. So it can be seen that on the GL-01 track there are 2 iron ore deposits which are summarized in Tbl. 1.

Table. 1 Distribution of Iron Ore Deposit on GL-01 Track

Length (m)	Depth (m)	Resistivity (Ωm)	Chargeability (ms)
35 – 47,5	1,25 – 2,56	1.076,89 – 3.310,33	212,32 – 259,50
55 – 65	2,56 – 6,38	1.888,09 – 5.803,90	212,32 – 259,50

GL-02 Track

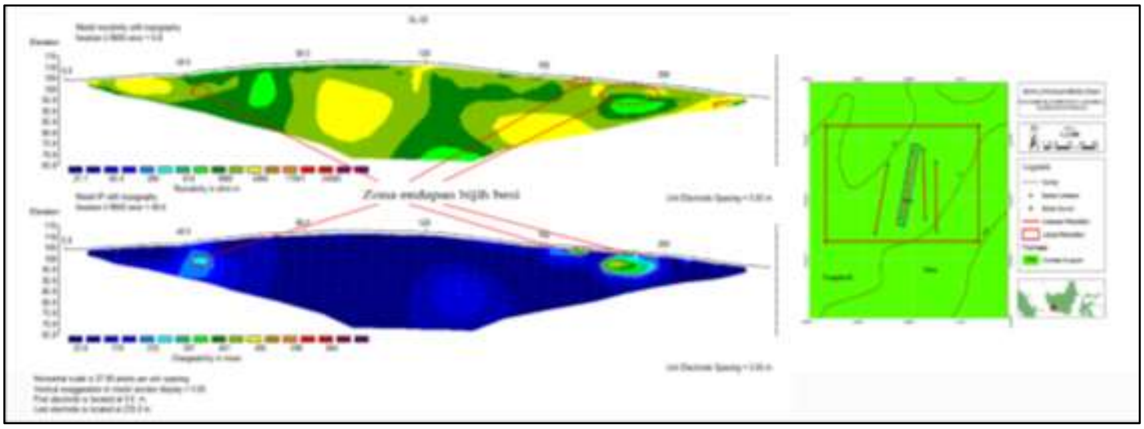

Figure. 10 Result of Inversion Modelling and Interpretation from Resistivity and Chargeability Profiles on GL-02 Track

Based on Fig. 10, resistivity value is obtained which is in interval of 614,22 – 10.175,81 Ωm with the chargeability value is in the interval of 23,6 – 542,58 ms. In the 2D cross-section of chargeability, it can be seen that the chargeability value contrasts with a value range of 212,32 – 542,58 ms which is interpreted as having iron ore deposits, which correlates with a resistivity value range of 614,22 – 5.803,90 Ωm. So it can be seen that on the GL-02 track there are 3 iron ore deposits which are summarized in Tbl. 2.

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Table. 2 Distribution of Iron Ore Deposit on GL-02 Track

Length (m)	Depth (m)	Resistivity (Ωm)	Chargeability (ms)
40 – 45	6,38 – 12,4	1.888,09 – 3.310,33	212,32 – 259,50
170 – 175	1,25 – 2,56	1.888,09 – 3.310,33	212,32 – 448,22
180 – 197.5	1,25 – 9,39	614,22 – 5.803,90	212,32 – 542,58

GL-03 Track

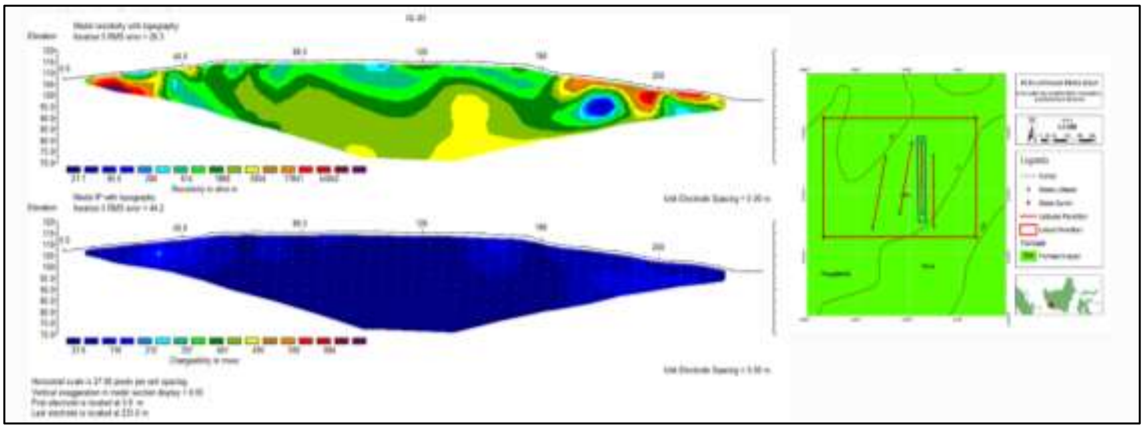

Figure. 11 Result of Inversion Modelling and Interpretation from Resistivity and Chargeability Profiles on GL-03 Track

Based on Fig. 11, resistivity value is obtained which is in the interval of 21,15 – 96.153,51 Ωm with chargeability value is in the interval of 23,6 – 212,32 ms. In 2D cross-section of chargeability, there is no contrast between the chargeability value of the iron ore deposit and the chargeability value of the surrounding rock. So it can be seen that there is no iron ore deposit on the GL-03 track.

GL-04 Track

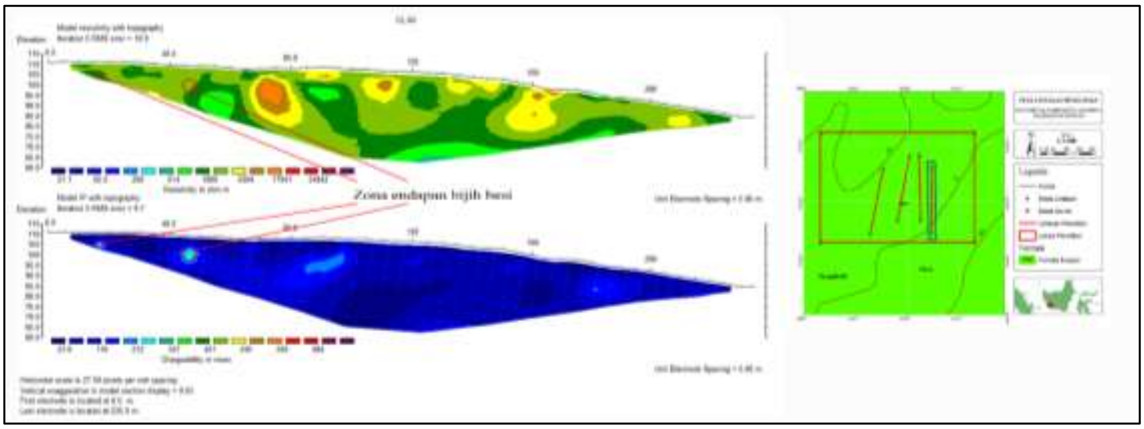

Figure. 12 Result of Inversion Modelling and Interpretation from Resistivity and Chargeability Profiles on GL-04 Track

Based on Fig. 12 obtained resistivity value which is in the interval number 350,33 – 17.840,95 Ωm with the value of chargeability is in interval number 23,6 – 306,68 ms. In the 2D cross-section of chargeability, it can be seen that the chargeability value contrasts with a value range of 212,32 – 306,68 ms which is interpreted as having iron ore deposits, which are correlated with a resistivity value range of 1.076,89 – 3.310,33 Ωm. So it can be seen that on the GL-04 track there are 2 iron ore deposits.

Table. 3 Distribution of Iron Ore Deposit on GL-01 Track

Length (m)	Depth (m)	Resistivity (Ωm)	Chargeability (ms)
15 – 17,5	6,38 – 9,39	1.076,89 – 1.888,09	212,32 – 259,50
45 – 50	6,38 – 12,4	1.076,89 – 3.310,33	212,32 – 306,68

Resistivity value of iron ore deposits is relatively high, ranging from 614,22 Ωm, this condition is thought to occur due to the presence of cavities between iron ore fragments in the form of granule - boulders with pyroclastic rock grains filled with air, resulting in high resistivity. Generally, iron ore and other metal ores have a low resistivity range (below 100 Ωm), especially in massive iron ore bodies, not as fragments in other rock matrices.

All resistivity cross-sections in 4 geoelectric lines do not show a contrasting resistivity value range (resistivity anomaly) with the resistivity value of the surrounding rock so that in interpreting the presence of iron ore deposits below the surface it only refers to the chargeability value, where the contrast chargeability value (IP anomaly) with the chargeability value of the surrounding rock indicating the presence of iron ore below the surface ranging from 212,32 – 542,58 ms.

Distribution of Sub-Surface Iron Ore Deposits

Based on correlation of chargeability values in the form of 3D model (Fig. 13) there was no indication of a continuous zone of iron ore deposits in the study area. This is due to the location of iron ore deposits (marked by sky blue-purple) which have a chargeability value of 212,32 – 542,58 ms spread over certain locations on each track and do not show a straight line of iron ore deposits between two or more tracks.

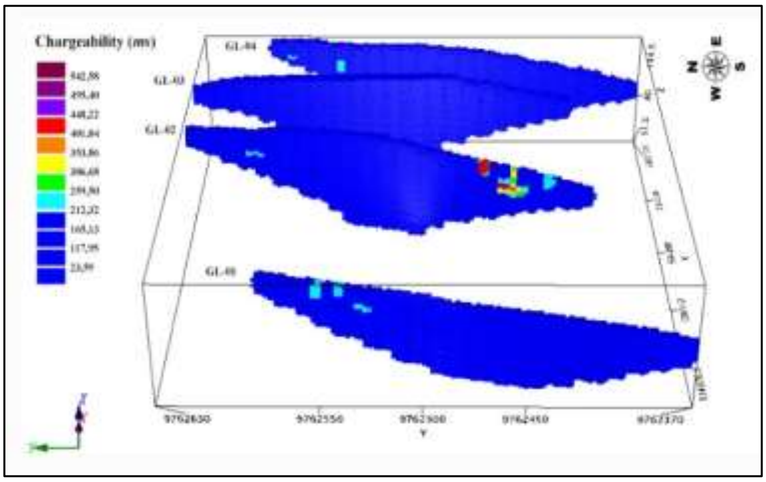

Figure. 13 3D Model Based of Inversion Result Chargeability Correlation All of Tracks

Iron Ore Reserves

Based on the results of 3D iso-surface modeling (Fig. 14) it is known that the volume of iron ore deposits in the study area within an area of ± 6 hectares is estimated to be around 10.259 m^3. This calculation is done by calculating the volume of the iron ore deposit zone which has a chargeability value of 212,32 ms. The results of the calculation of the volume of iron ore deposits are classified as resources. If the iron ore density is assumed to be 4 g/cm^3 [8], then the ore deposit resources in an area of ± 6 hectares are as follows.

Mass = volume × density
= 10.259 m^3 × 4.000 kg/m^3
= 41.036 tons

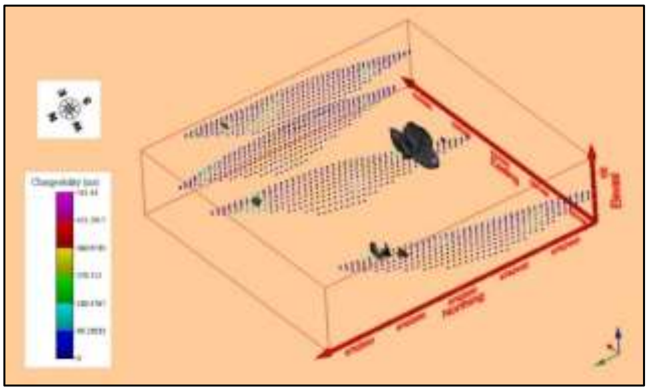

Figure 14. Distribution of Iron Ore Deposit Based of 3D Modelling Result

CONCLUSIONS

Based on results, it can be concluded that the inversion modeling of the resistivity value distribution range from 21,15 – 96.153,51 Ωm and chargeability 23,6 – 542,58 ms below the surface. Iron ore deposits in the study area are found in pyroclastic rock units of the Kuayan Formation which are indicated by resistivity values ranging from 614.22 – 5.803,90 Ωm and contrasting chargeability values ranging from 212,32 – 542,58 ms found on the GL-01 track, GL-02, and GL-04. Large resistivity value occurs due to the presence of cavities between fragments of iron ore in the form of granule-boulder with pyroclastic rock grains of clay-sand filled with air.

Result of 3D model of correlation between chargeability of the entire track, there was no indication of a continuous zone of iron ore deposits in the study area. This is due to the location of iron ore deposits scattered in certain locations on each track and does not show a straight line of iron ore deposits between two or more tracks. And resource of iron ore deposits in this research location in area of ± 6 hectares is 41.036 tons.

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