Application of Induced Polarization Methods to Estimate Saprolite and Limonite Deposits, Kolo Bawah Area, Morowali Regency, Central Sulawesi

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Abstract — Interpretation of Induced Polarization data to estimate saprolite and limonite deposits carried out. The case studies at Kolo Bawah, Morowali Central of Sulawesi. The 20 lines data acquisition with 200m length. Topography at the area is range of hill with medium to high slopes. The IP data processed and resulted the chargeability and resistivity parameters, and plotting at depth section To find the resistivity and chargeability at depth in all lines used RES2DIV. The section at the lines found vertical and horizontal distribution of resistivity and chargeability of the rock. The 20 section interpreted to distribution of nickel laterite i.e. saprolite and limonite.

I. INTRODUCTION

The growing human needs led to the birth of a wide range of minerals. In his case for myriad minerals needed by the industry to be able to produce goods that are needed. One of the many metal materials used were nickel. Its use in various industries makes exploration of this mining is getting improved
to

Laterite element (PGE) deposits in large layered formations are mined primarily for their PGEs, rather than as in magmatic nickel-copper-(PGE) sulfide deposits, where PGEs are a by-product [1]. Nickel is used as an alloy of metals that are widely used in many industrial metal [2]. Nickel is mainly formed along with chrome and platinum in ultramafic rock like peridotite, good metamorphic. There are two types of nickel deposits are purely commercial. As a result of residual concentrations of nickel, silica, and in the process of weathering of ultramafik igneous as well as deposits of nickel-copper sulfide, which is usually associated with pyrites, magnetite, and calcopryt.

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Latterite layer, the layer is overburden limonite and saprolite. It is located on the surface, poor Ni but rich in Fe element. Limonite is located below, have the highest nickel content. The result of weathering is rich in elements of Ni. While saprolite is the first result weathering. Saprolite is characterized by the presence of sporoidal weathering along joint and fractures. Changes in nickel content in saprolite and bedrock in gradual. Saprolite still a boulders from the bedrock. Saprolite has a nickel content is lower than limonite, but higher than bedrock, i.e. between 1.8% up to 2.5%. It is located between limonite and bedrock.

The existence of a conductor in rocks can be distinguished from the value of resistivity. To make sure the metal deposits in the rocks is characterized by the value of chargeability. Rock containing metals will have low resistivity and high chargeability.

The Induced Polarization (IP) is a geophysical method that uses resistivity and chargeability properties for understanding distribution of rock in subsurface. With IP method known spread of nickel laterite. Analysis of resistivity and chargeability attempted to distinguish layers of limonite and saprolite of IP data in the path that is created. Nickel laterite deposits resulting from the calculation of the reserve of limonite and saprolite. To obtain an overview of distribution limonite and saprolite, are expected to contribute in the mining plan will be carried out.

II. OBJECTIVE

The investigation is intended to obtain data and information on the potential of nickel in the Kolo Bawah area, Central Sulawesi. The goal is to find out a quantitative as well as reserves of nickel in the areas, so that it could consider the possibility of developing its potential. Geophysical Induced Polarization method (IP) is then able to know the condition of subsurface based on the physical properties of the material or rocks, then it can be known to subsurface conditions in the area of inquiry the value of resistivity and chargeability rocks.

III. GEOLOGY

Kolo Bawah regions and surround included in Mandala Geology of Eastern and Western Sulawesi, with a boundary Palu Koro fault nearly North-South direction. The rock outcropped as Latimojong Formation, Matano Formation, Ultramafic Rock and Pompangeo Complex.

Latimojong Formation composed of inter bedded with slate, wache, fillit, claystone, quartzite limestone, inserted rijang
Nickel Laterite deposits in the ultramafik belt. Ultramafik rocks are considered to source, which is the result of the movement of tectonic plates in the Cretaceous era-Pacific plate moving Tertiary when subduct to the Eurasian plate. These rocks are serpentinitity by tropical weathering during the very long time, so as to produce nickel and cobalt laterite.

IV. NICKEL LATERITE DEPOSIT.

Mineral deposits are one or more minerals or certain elements are concentrated or accumulate due to natural processes on area in the crust. Mineral deposits that exist in nature are not all of them are economically. Factors that affect whether or not an economically viable deposits of minerals is a form, the volume of deposits, metal content, geographic location, technology and cost in processing. Thus the sediment with small and mineral volumes with low value minerals are still allowed to be mined economically [2].

The process of forming nickel laterite ore of weathering processes initiated ultramafik rocks (dunit or peridotit). Ultramafik rocks are composed of the mineral olivine, pyroxene, amphibole and mica. Olivine in the rocks have about 0.3% nickel content. Ultramafik rocks containing nickel is undergoing the process of serpentinisation, i.e. the process of fill cracks or joint by a later experienced mineral serpentin chemical process caused the influence of the soil. Furthermore by local climate influences source rock having physics and chemistry weathering. The process resulted in the formation of nickel laterite deposits.

In the high rainfall, water will enter the cracks caused the destruction of the minerals constituents of the source rock. Mg, Si, Ni and Fe dissolves and carried in accordance with the land and water flow will produce new minerals at mineral redeposition process. In solution, Fe oxides and form the Hydroxide that later formed the Ferri settles near sub surface into hematite, goetite, and cobaltite. The fissures ultramafik rock some Mg settles yielding magnesite, dolomite and are calcite which known as the roots of weathering.

As a consequence the occurrence of chemical weathering that particles are deposited either in the form of residual concentration deposit or concentration gap deposit. In this replenishment process filled cracks among other by garnierite, quartz and crisopras as a result of deposition of the gap concentration. Results of sediment concentration of residue resulting in zone saprolite.

Elements which are laging like Fe, Al, Mn, Co and Ni bound as oxide/hydroxide minerals such as hematite, goetite, and limonite. Cobaltite producing laterite zone. As a result of this process will form the order of the layers of overburden, layers of laterite and bedrock. Based on the nickel content, the nickel laterite layer may be conceived then consists of layers of limonite and saprolite where the nickel layers content nickel over 2% saprolite and limonite have 1%. Formation process of nickel laterite deposits have steps as follows [2]:

- Rock origin: ultramafik according to the classification table of rocks containing Ni, with the crystal lattice pyroxene and olivine.
- The initial processes comes from hydrothermal serpentin or peridotit serpentinit, then process of laterites because climate, chemical and as well as vegetation activity.
- The chemical process of occurrence of laterite deposits The solution containing the mineral olivine CO₂ turns into serpentin and magnesit.

\[
2\text{MgSiO}_3 + \text{CO}_2 + 2\text{H}_2\text{O} \rightarrow \text{H}_2\text{MgSi}_2\text{O}_6 + \text{MgCO}_3
\]

Hydration process changed olivine and piroksin be serpentin Mg₂SiO₄ + MgSiO₃ + 2H₂O \rightarrow H₂Mg₂Si₃O₁₀

The next process is a result of climate, i.e. rainwater leaching on the zone led to rock. In the end zone with three types of rocks are formed which are:

a. Zone rock reduction in aqueous solution containing Ni, Mg and Si.

b. When leaching silicates containing Ni, replace with Mg, Si and Ni.

c. Enrichment process also occurs, that is the addition of the colloid is rich in elements Ni, Mg and Si.

Deposits of nickel laterite profile can be differentiated into overburden, limonite, saprolite, bedrock. Secondary nickel deposits are deposits of residue concentration results between parent rocks containing nickel suffered a serpentinit process. Then by the local climate are having physical and chemical weathering (primary). As a consequence the chemical weathering, colloidal particles which are then deposited.

Fig 1. The Main seat of the Arc Magnatic metals mineralization [6]

Fig 2. Crosssection nickel laterite deposit
Deposition of sediment concentration of the residue concentration gap. As a result of this process will form the center of the layers of sediment is known as A, B, C and D (Overburden, Limonite, Saponite, Bedrock). Profile cross-section laterite deposits are shown in Fig 2.

V. DATA ACQUISITION

Survey locations at at Kolo Bawah, Morowali Central of Sulawesi. Morowali Regency located in the border of Central Sulawesi and Southeast Sulawesi. The survey areas about 125 acre at Kolo Bawah are mineral deposit especially nickel laterite (Fig 3).

Equipment used in the data acquisition is a set of IP-Meter, consisting of:
- IP Scintrex, include Motor Generator TSQ-4, Transmitter Control TSQ-3, Receiver Time Domain IPR-12
- Support Equipment, including: 1 GPS Garmin, current and potential electrodes, device tool set, multimeter, compass, Handy-Talky (HT) etc.
- Porouspot electrode filled CuSO4 solution. It used to prevent the occurrence of polarization on the potential electrode.

The IP data acquisition consist 20 lines, with a length of 200 meters. The coordinates of the points in each line in the UTM (Universal Transverse Mercator) and the base of the tip coordinate in geographic coordinates and azimuth each path can be seen in Table 1.

Electrode Configuration

Measurement of IP mapping using Dipole-dipole configuration. Electrode current and potential move together, so that the retrieved value are lateral apparent resistivity. Electrode spacing used is 10 meters to 20 m. Dipole-dipole configuration of electrodes has a geometry factor \( K = \frac{2}{\pi} \times r \times \text{Res}(n^2 + 1) \) [3]. The resistivity data measured plotted at points which corresponds to \( n (n = 1 \text{ to } 8) \), with a demonstrated level of apparent depth. Results of the measurements use a space between the electrode current and potential that the width of the electrodes will provide information on the structure of the subsurface. Thus, Dipole-dipole configuration can be considered effective use in mapping, both vertical and horizontal.

V. DATA PROCESSING

The apparent resistivity \( (p_a) \) and chargeability \( (M_a) \) are plotted with pseudodepth plot section technique. The resistivity and chargeability values data is plotted at the point. This point is the intersection of a line drawn from midpoint of the electrode the current and electrode potential with angle of 45° to the horizontal.

The crosspoint is considered the position of the data that is measured. To obtain value of true resistivity and chargeability in each line then done by invers modeling with RES2DINV [4]. The example of result invers modeling Line01 seen at Fig 4.
VI. INTERPRETATION.

Interpretation of data is done by looking at the characteristics or the value trend of resistivity and chargeability that obtained from the results of modeling with RES2DINV which is in correlated with geological information. The interpretation of the position of the presence of nickel laterite with a nickel content of more than 1.2%. The nickel laterite has a resistivity value is relatively low compared to the surrounding rock resistivity (40 to 150 ohm-m). This generally laterite is layers with nickel content high enough. In addition there is a boulders of laterite with higher resistivity (150 to 400 ohm-m). While the chargeability will be relatively high, though not always apply. Thus interpretation of the existence of nickel laterite will be directed to low resistivity and high chargeability [5].

![Fig 5. The interpretation based on the value of resistivity and chargeability Line02.](image)

Results interpretation of each line, beneath the surface there are layer that is divided into several units, as follow:
1. Overburden with a high resistivity value (> 350 ohm-m)
2. The saprolite layer have the resistivity 150 to 400 ohm-m
3. The limonite layer, the resistivity of 40 to 150 ohm-m.
4. Bedrock, with high resistivity (> 700 ohm-meter).

The existence of a polarizable rock known from the value of chargeability. The higher the value of the chargeability, then the metal mineral content higher.

**Reserves Calculation**

Calculation of deposit of nickel laterite based on formulas, large deposit of nickel laterite cross-sectional area x width estimation x density. Cross-sectional area (m²) obtained from the results of RES2DINV based on the value of resistivity and chargeability. Approximate width (m) take into consideration the large cross-section and the presence nickel laterite in other lines. While the density of nickel laterite = 2.5 ton/m³.

Example calculation of nickel laterite Line02 in the Fig 5.

Because Line02 is adjacent (to the South) and parallel with Line01, then the pattern as Line01 repeated in Line02. Saprolite lying from the middle until the end of the path is continuum from Line01. Bedrock does not appear until a depth of over 25 m. High value in chargeability indicates the possibility of other metal minerals in some parts of the Line02. The calculation takes into account the existence of a backup is performed with Line01. Deposit of limonite are : 315,000 tons (2,100 x 60 x 2.5 tons) and saprolite are: 93,000 tons (620 x 60 x 2.5 tons).

The same step do on all lines, so that the results obtained of deposit limonite and saprolite at Kolo Bawah, Morowali Regency. Total deposit of limonite and saprolite earned on all paths in Table II, then the number of limonite 2,996,480 tons and saprolite of 2,664,610 tons. The total of laterite nickel deposits which is the sum between the layers of limonite and saprolite are 5,661,090 tons or 5.67 million tonnes.

<table>
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<th>Saprolite (t)</th>
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VII. ANALYSIS.

Nickel laterite deposits in the belt ultramafik are potential. Ultramafik rocks are considered to source. These rocks are the result of the movement of tectonic plates in the Tertiary Cretaceous, when the Pacific plate moves subduct the Eurasian plate. These rocks are serpentinit by tropical weathering during periods, resulting in deposits of cobalt-nickel-laterite. Nickel and cobalt in garnierite and manganese oxide minerals are concentrated mainly on the saprolite layer. A layer of sediment is generally composed of several meters, limonite and saprolite overburden which is a layer of nickel ore.

There are no tserpit on the area that is able to assist the interpretation. To that end the auxiliary data used as the surface outcrops are found in the survey area. Most of the outcrops are located on the slopes of the area. In general there are two dominant outcrops, namely saprolite and limonite. Both these outcrops are part of the nickel laterite.

The second physical form these outcrops can be distinguished clearly. Limonite red soil, while saprolite more compact with the appearance of green on some parts. Nickel content on both of them are definitely not yet known, but in general the nickel content of saprolite is greater than limonite. Generally at Fig 2., then limonite has the Ni 0.8 to 1.5%, while the saprolite 1.4 to 3%.

Referring to the previous information and the surface outcrops, then it can be argued that:
- An area with low nickel concentration and there is at the top of the soil, or overburden, with high resistivity values.
- Areas with high concentrations of nickel and contained in the central part, is a mixed with nickel laterite boulder. The value of resistivity low up to medium relatively.

Nickel laterite is divided into two types, i.e the physical
appearance of limonite nickel with red soil and low resistivity. Saprolite nickel with physical are more compact and there is a section with a green color, has a value of medium resistivity. The lower part of the bedrock with high resistivity value, is an area with low nickel concentration.

VIII. CONCLUSION

1. In all survey areas containing nickel but different in content. The potential nickel content on the limonite and saprolite layer.

2. Deposit on survey area consists of four parts, on the surface layer of overburden or soil, a layer of nickel laterite consisting of limonite and saprolite and lastly bedrock. The pattern of layers generally follows the shape of the topography.

3. The thickness of the limonite range from 10 to 30 metres, whereas saprolite is 10 to 25 metres, except for Line07 and Line09. Under the Line07 and Line09 are all in the form of limonite.

4. The reserves are calculated by combining the continuum between a path with the next path, results limonite is 2,996,480 tonnes and 2,664,610 tonnes of saprolite.

5. There are indications of the existence possibility of other metals mineral that is indicated by the high chargeability in some places.

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REFERENCES


