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RESEARCH ARTICLE

Application of Audio Frequency Magnetotelluric (AMT) Method for Nickel Mineral Exploration in Area Laeya District, South Konawe Regency, Southeast Sulawesi Province, Indonesia

Jeremy Patrio P. Ramba[1], Hasria[2]*, Jamhir Safani[3], Arisona[1], G.M. Lucki Junursyah[4]

[1] *Master of Physics, Halu Oleo University, Kendari, Indonesia*
[2] *Geological Engineering, Halu Oleo University, Kendari, Indonesia*
[3] *Geophysicial Engineering, Halu Oleo University, Kendari, Indonesia*
[4] *Geological Survey Center, Geological Agency, Ministry of Energy and Mineral Resources, Bandung, Indonesia*

* Corresponding author : hasriageologi@gmail.com
Tel.:+62-852-4185-7853
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Abstract

The AMT (Audio Frequency Magnetotelluric) method is a geophysical method that uses natural sources (passive method) so it does not require artificial sources and is very effective in mapping the resistivity contrast of subsurface rocks. The AMT (Audio Frequency Magnetotelluric) method is a geophysical method that uses natural sources (passive method) so it does not require artificial sources and is very effective in mapping the contrast of subsurface rock resistivity. This study aims to determine the coherence and nickel mineralization zones in the Laeya District area, South Konawe Regency, Southeast Sulawesi Province using the AMT method and supported by using drill data. The coherence of AMT data in the Laeya District area, South Konawe Regency based on the magnitude and phase curves of apparent resistivity after the XPR selection process experienced a significant increase in data quality at all points indicated at point LY02 from 49.09% coherence to 78.32%. Nickel mineralization zone based on 2D cross-section data of AMT resistivity and Drilling data in Laeya District, South Konawe Regency shows the distribution of nickel enrichment areas which are qualitatively marked by light blue color with resistivity values of 11 to 21 Ohm m located at points LY03, LY04, LY06, LY07 and LY08. Drilling data shows the presence of limonite layers at drill points DHB15 and DHB16. The presence of Sulawesi Molasa which is a feature of nickel deposits in the South Konawe area is also detected in the 2D cross-section.

Keywords: AMT (Audio Frequency Magnetotelluric) Method, Coherence, Nickel Laterite

1. Introduction

Indonesia is one of the countries that has abundant natural resources. One of them is nickel minerals, nickel is one of the minerals that has high economic value, and is one of the main commodities that generates quite a lot of foreign exchange. In its development, finding the existence of nickel minerals is not easy, an in-depth scientific study is needed to be able to determine the existence of nickel minerals that have high economic value, one of which is studying geophysics and geology to make it easier for us to determine the nickel mineralization zone.

Laterite nickel deposits are a type of deposit formed from the weathering of ultramafic rocks to form nickel ore enrichment (Golightly, J.P., 1981; Ahmad, 2001; Elias, 2002; Gleeson et al., 2003). The research area is located in the area Laeya District, South Konawe Regency, Southeast Sulawesi Province. Based on (Raivel and Firman, 2020; Hasria et al., 2021; Asfar et al., 2023; Hasria and Septiana, 2024) that the South Konawe area, part of its area is covered by the Sulawesi Molasses and in the research area based on observations it has a fairly thick Sulawesi Molasses so that the depth of the laterite nickel deposits is difficult to detect. Therefore, one way used to overcome this problem is to use the AMT method.

Nowadays, many industrial sectors are developing technology in the field of mineral exploration, to make it easier to localize the nickel mineralization zone, one of which is by using the AMT method. The AMT (Audio Frequency Magnetotelluric) method is a geophysical method that can be applied to search for natural resources such as minerals (Wenping et al., 2023 and Di et al., 2020), oil and natural gas (He et al., 2020). The AMT method uses natural sources (passive methods) that are controlled so that they do not require artificial sources. This AMT method is very effective in mapping the resistivity contrast of subsurface rocks, but its application in shallow exploration is still rare (Zonge and Hughes, 1991).

This study aims to determine the nickel mineralization zone in areaLaeya District, South Konawe Regency using the AMT method and supported by using drilling data. The application of the AMT method can be an innovation because there are still many mines in Southeast Sulawesi that have not been preceded by geophysical exploration stages, resulting in ineffective mining operations and causing high levels of environmental damage. In addition, a geophysical method is needed for shallow exploration that has a wide coverage with a relatively short data acquisition duration. It is expected that the application of this method can solve the problem of mineral exploration in determining the mineralization zone, especially nickel in Area Laeya District, South Konawe Regency and can correlate existing drill data and correlate it with the local geology of the measurement area.

2. Geological Setting

Morphologically, the southern tip of the Southeast Arm of Sulawesi is dominated by the morphology of plains and hills. In some parts, mountains appear, such as the Rumbia and Mendoke Mountains. Generally, this plain is a wide alluvium plain on the right and left of the river, while the morphology of the hills consists of low and high hills. The low hills are much wider than the high hills. The research area itself is included in the low hills category. The low hills morphological unit extends widely in the north of Kendari and the southern tip of the Southeast Arm. This unit consists of small and low hills with undulating morphology. The rocks that make up this unit are mainly Mesozoic and Tertiary clastic sedimentary rocks.

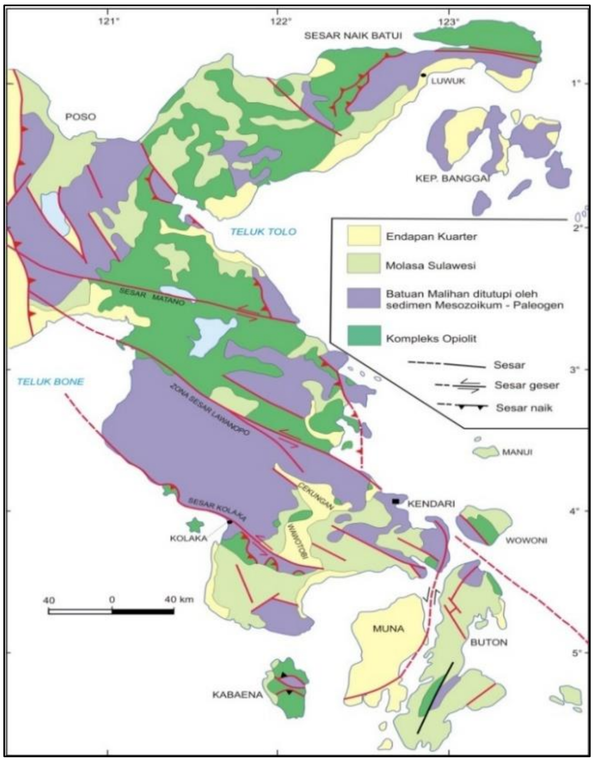

Fig 1. Stratigraphic Map of the Southeastern Arm of Sulawesi modified from (Surono, 2013)

Stratigraphically, there are three main n the research area, namely the continental plate, the ophiolite complex and the Sulawesi molasse. The continental plate in the Southeast Arm of Sulawesi was named the Southeast Sulawesi Continental Terrane and the Matarombeo Plate by Surono (1994). These two plates of different types collided and were then overlain by the Sulawesi Molasse deposits. The Ophiolite Complex in the Southeast Arm of Sulawesi is part of the East Sulawesi Ophiolite Belt. The rocks forming this belt are dominated by ultramafic and mafic rocks and pelagic sediments. The ophiolite complex is separated from the Southeast Sulawesi Continental Plate in the Tangkelamboke Mountains by the Lawanopo Fault System (Figure 1). In several places, this ophiolite complex is thrust-upward onto metamorphic rocks and/or continental margin sedimentary layers. This shows that before being torn by the Lawanopo Fault, this complex had been thrust-upward onto the continental plate. The Sulawesi Molasses are widespread in the Southeast Arm of Sulawesi and consist of clastic and carbonate sedimentary rocks. Clastic sedimentary rocks consist of conglomerates, sandstones, and siltstones (Langkowala Formation), sandy marl mudstones (Boepinang Formation), and local sandstones associated with coral reefs (Eemoiko Formation). Regionally, the structures formed on Sulawesi Island have various scales (regional and local) including subduction and collision zones, thrust faults, faults, and folds.

Structurally, geological structures that developed in Sulawesi and the surrounding areas are the North Sulawesi Trench, Palu-Koro Fault System, Batui Thrust, Poso Thrust, Walanae Fault, and ocean expansion in the Makassar Strait. These regional structures are generally closely related to the westward movement of several continental plates. The contact between the ophiolite complex and the Southeast Sulawesi Continental Plate is always a fault. The imbrication zone formed because the ophiolite was thrust onto the continental plate can be found from the East Arm to the tip of the Southeast Sulawesi Arm (Sidarto and Bachri, 2013).

3. AMT Methods and Data Acquisition

The AMT method is a well-known exploration technique used to measure fluctuations in natural electric and magnetic fields over a wide frequency range. These fluctuations originate from the ionosphere associated with solar activity at low frequencies and the wider world with thunderstorm and lightning activity at higher frequencies. This technique does not require artificial sources and transmitters. However, its advantages are small with low magnitude and the ability to vary natural signals.

Audio Frequency Magnetotelluric (AMT) method data were obtained from measurements in September 2022 in Area Laeya District, South Konawe Regency. Data collection in this study was carried out in 2 track spans with a track length of 1000 meters and track II 1000 meters, the distance between measurement points is 250 meters and the distance between tracks is 250 meters. The track in this study was stretched from South to North.

This study was conducted to determine the coherence of AMT data based on the magnitude and phase curves of pseudo resistivity after the XPR selection process and to determine the nickel mineralization zone based on 2D cross-section data of AMT resistivity and Drill data. Data processing used Microsoft Excel 2010 software, SSMT 2000 software and WinGLink software. During processing, data was processed by determining the coherence value of AMT data before and after the robust process and after the XPR process using Microsoft Excel 2010 software and SSMT 2000 software. 1D and 2D inversions were performed using Winglink software. 1D inversion was performed by creating an estimation model of the phase and period curves. 2D inversion was performed by interpolating the 1D inversion model.

4. Data Coherence Analysis

The quality of magnetotelluric data can be quantitatively determined based on its coherence value. The coherence value is a quantity that states the relationship between electric and magnetic fields that are perpendicular to each other. Data is considered coherent if the Ex and Hy values are the same, as well as Ey and Hx, which are 1 or in percentage is 100%. This ideal condition is difficult to occur because the data signal will always receive natural interference, therefore the coherence value approaching 1 (one) is good data (Rodi and Mackie, 2001; Simpson and Bahr, 2005; Phoenix Geophysics, 2005; Mwakirani, 2012).

Qualitatively, coherence can be seen from the pseudo-resistance curve model. A smoother curve will have a higher coherence value than a curve that has a lot of data outside the curve pattern (outliers). Point LY02 clearly shows the function of the robust process and XPR selection where the curve model becomes smoother and the coherence value increases. The resistivity curve (Ohm-m.) And frequency (Hz) and the increase in coherence to the robust process and XPR selection for point LY02 are shown in Figure 3 to Figure 5.

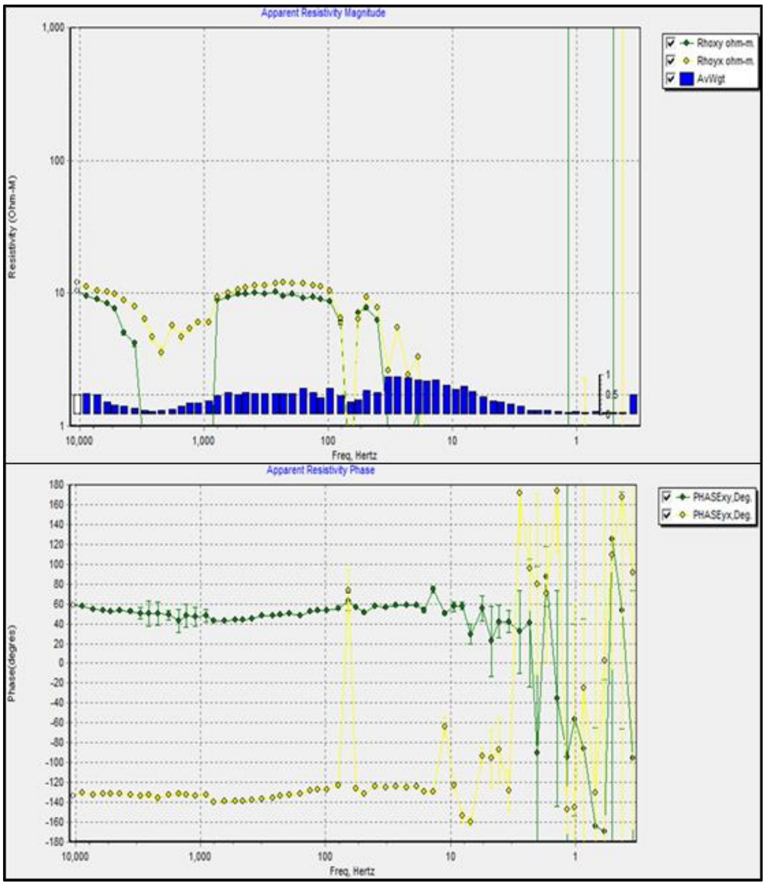

Fig 2. Apparent resistivity curve of LY02 with raw data coherence of 49.09%

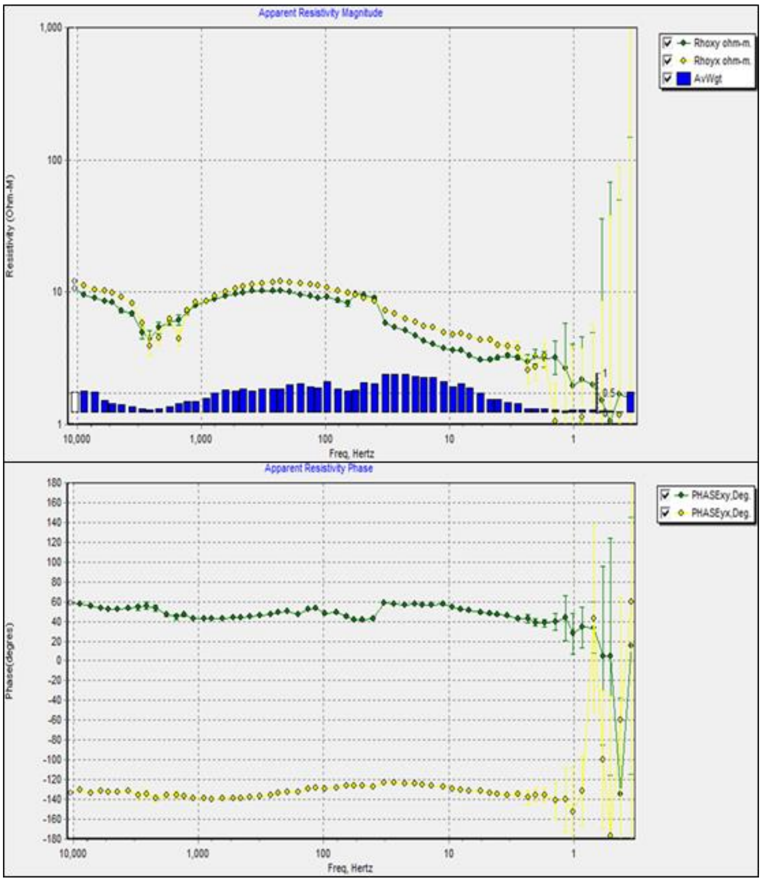

Fig 3. Apparent resistivity curve of LY02 with coherence after robust process of 78.32%

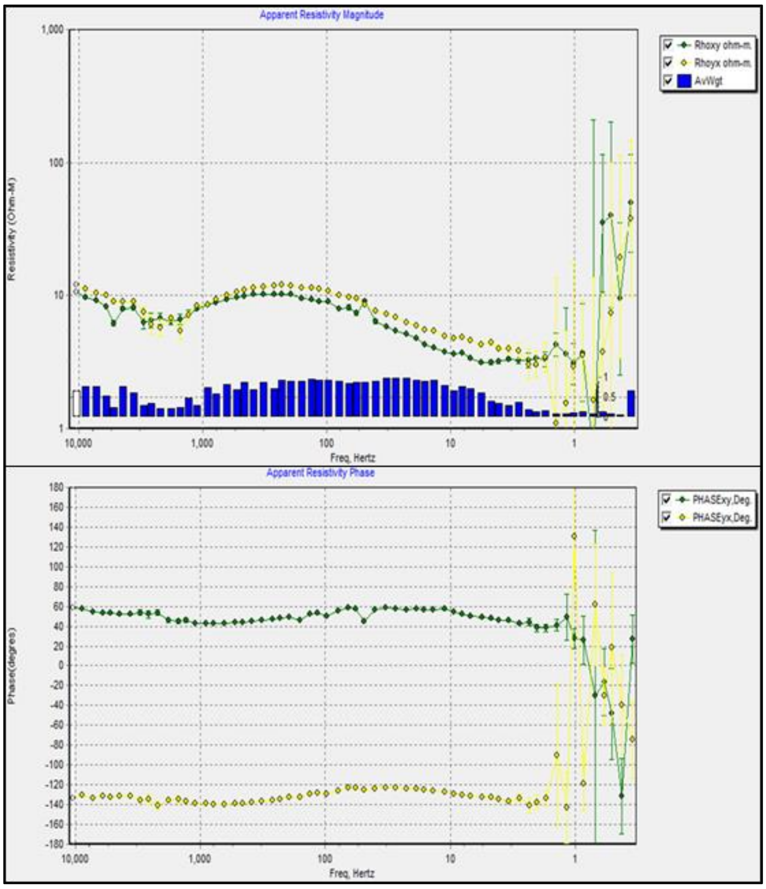

Fig 4. Apparent resistivity curve of LY02 with coherence after XPR selection process of 85.02%

5. Analysis of 2D Models Using WinGlink Software Based on Drilling Data and Geological Information

2D inversion was performed using Winglink software. Inversion was performed by creating an estimation model of the phase and period curves. The fit between the model created and the phase and period curves was made using the Bostick and Occam models.

Figure 5 shows a 2D cross-section of Line 01 with the distribution of several drill points. Distribution of Garnierite found around points LY03 and LY04. Point LY03 is at an altitude of 20 m above mean sea level (msl), with an alleged nickel mineralization zone (supergene enrichment) located at a depth of 10 m above msl to 40 m below msl. The estimated depth of Molasa Sulawesi at point LY03 is 10 m. The range of resistivity values for the alleged nickel mineralization zone at point LY03 is 11 to 21 Ohm m. Drill point DHB16 confirms the presence of a 0.35 m thick limonite layer from a depth of 7.30 m to 7.65 m. Point LY04 is at an altitude of 40 m above msl, with an alleged nickel mineralization zone (supergene enrichment) located at a depth of 30 m above msl to 10 m above msl. The range of resistivity values for the alleged nickel mineralization zone at point LY03 is 11 to 21 Ohm m. The alleged depth of Molasa Sulawesi at point LY03 is 10 m. Low resistivity anomaly contrast is found at point LY02.Figure 6 shows the 2D cross section of Line 02 with the distribution of several drill points. The distribution of Garnierite found around points LY06, LY07 and LY08. Point LY06 is at an altitude of 30 m above msl, with an alleged nickel mineralization zone (supergene enrichment) located at a depth of 17 m above msl to 5 m above msl. Drill point DHB15 confirms the presence of an 8.5 m thick limonite layer at a depth of 22 m to 30.5 m. The estimated depth of Molasa Sulawesi at point LY06 is 15 m. The supergene enrichment zone is a zone where natural processes occur that concentrate valuable metals near the earth's surface, making ore deposits more economical. In nickel exploration, the supergene enrichment zone is generally found in slope areas and is passed by local structures.

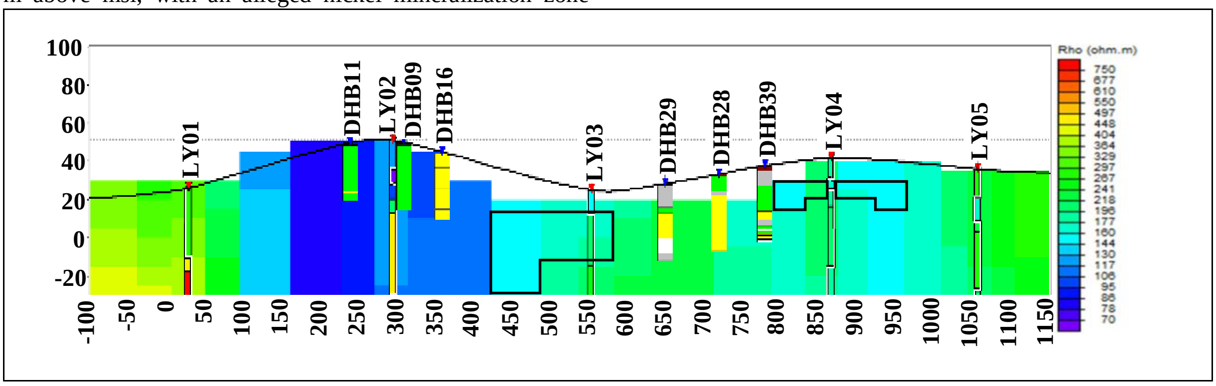

Fig 5. 2D Cross Section of Line 01 and Drill Points

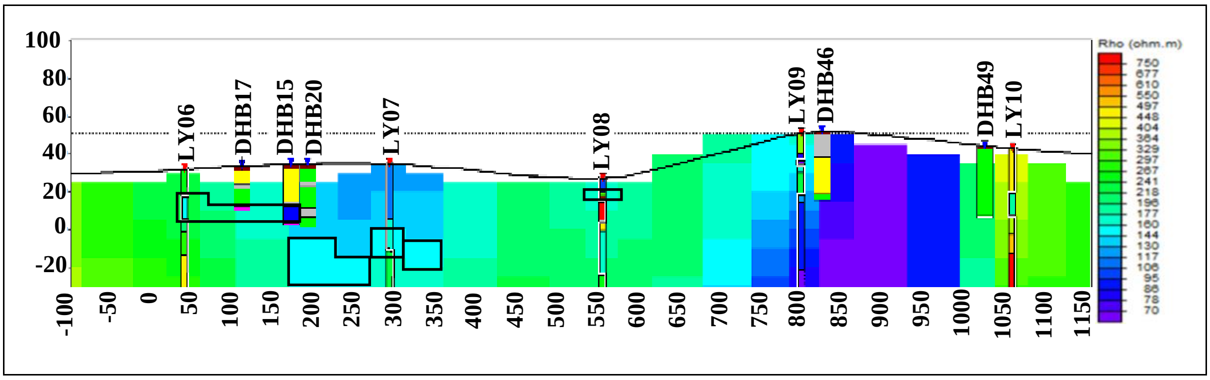

Fig 6. 2D Cross Section of Line 02 and Drill Points

Point LY07 is at an altitude of 30 m above msl, with an estimated nickel mineralization zone (supergene enrichment) located at a depth of 10 m above msl to 20 m below msl. The estimated depth of the Sulawesi Molasa at point LY03 is 20 m. Point LY08 is at an altitude of 30 m above msl, with an estimated nickel mineralization zone (supergene enrichment) located at a depth of 20 m above msl to 15 m above msl. The estimated depth of the Sulawesi Molasa at point LY03 is 10 m. The presence of the Sulawesi Molasa in the South Konawe area affects nickel deposits that are formed due to reduced water intrusion that plays an active role in the weathering process. Water intrusion will dissolve the minerals that have been deposited. Transport to a deeper place in the supergene enrichment zone. The nickel content when deposited in this zone will increase and during that time a cumulative enrichment process occurs.

6. Conclusion

Based on the analysis conducted, it can be concluded that coherence of AMT data in Area, Laeya District, South Konawe Regency based on magnitude curve and pseudo resistivity phase after XPR selection process experienced significant improvement in data quality at all points such as at point LY02 from coherence of 49.09% to 78.32%. Nickel mineralization zone based on 2D cross-section data of AMT resistivity and Drilling data in Area Laeya District, South Konawe Regency shows the distribution of nickel enrichment areas which are qualitatively marked with light blue color with resistivity values of 11 to 21 Ohm m located at points LY03, LY04, LY06, LY07 and LY08. Drilling data shows the presence of limonite layers such as at drill points DHB15 and DHB16. The presence of Sulawesi Molasa which is a feature of nickel deposits in the South Konawe area is also detected in the 2D cross-section.

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