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RESEARCH ARTICLE

Influence of Laterite Bedrock on Ni Content in Langgikima District, North Konawe Regency, Southeast Sulawesi, Indonesia

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Abstract

This study investigates the influence of bedrock on nickel (Ni) content in laterite deposits in the Lameruru Region, Langgikima District, North Konawe Regency, Southeast Sulawesi Province, Indonesia. The research area is dominated by ultramafic rocks, which are potential sources of laterite nickel. The study employs literature review, field surveys for lithological data collection and representative sampling, petrographic analysis to determine mineral composition and rock types, and geochemical analysis using X-Ray Fluorescence (XRF) to determine nickel content in the rocks. The results show that the bedrock in the study area consists of harzburgite and olivine pyroxenite. Harzburgite, occupying approximately 72.72% of the area, is composed of 54-78% olivine, 15-45% orthopyroxene, 6% clinopyroxene, and accessory minerals, while olivine pyroxenite, occupying about 27.28% of the area, is composed of 27% olivine, 49% orthopyroxene, 17% serpentine, and 7% spinel. Geochemical analysis reveals that harzburgite has higher Ni content (0.10-0.16%) compared to olivine pyroxenite (0.03-0.10%). The distribution of Ni in the bedrock and saprolite is directly proportional, with higher Ni content in harzburgite in both zones. The study concludes that the type of bedrock greatly influences the nickel content in laterite deposits, with harzburgite having a higher Ni content due to its higher percentage of olivine minerals, which are the main hosts of nickel in ultramafic rocks.

Keywords: Bedrock, Nickel, Nickel Laterite, North Konawe

1. Introduction

Indonesia is fundamentally a country rich in natural resources, especially minerals, which are non-renewable resources. One important example of these natural resources is minerals. Nickel, as one of the earth's economically valuable mineral resources, needs to be discovered to meet the needs of the industrial sector. In its pure form, nickel is soft and has rust-resistant properties, but when combined with iron, chromium, and other metals, it can form hard stainless steel. The combination of nickel, chromium, and iron produces stainless steel that is widely used in kitchenware, home and building ornaments, as well as industrial components (Ahmad, 2001; Kuligowski and Halperin, 1992).

Sulawesi Island and the small surrounding islands have unique and complex geological and geomorphological conditions. This is closely related to tectonic dynamics, as the area lies at the intersection of three active global plates. As a result, the geology of Sulawesi and its surrounding areas is extremely complex (Jaya et al., 2024; Nugraha and Hall, 2022; Martono et al., 2022; Maulana et al., 2015; Surono, 2013b). Collision occurs among the three plates (triple junction), which include the Indo-Australian plate, the Pacific Ocean plate, and the Eurasian plate. The Indo-Australian plate moves relatively northward, the Pacific Ocean plate moves relatively westward, and the Eurasian plate is relatively stationary (Hall, 2012). As a result of the collision activity of these plates, Sulawesi Island and the surrounding smaller islands possess high geological complexity, attracting earth scientists to conduct research (Sidarto, 2013).

The stratigraphy of the Southeast Arm of Sulawesi Island consists of three groups: the Metamorphic Rock Complex as the Continental Fragment, the Ophiolite Complex, and the Sulawesi Molasse. (Sidarto, 2013), can be seen at Fig. 1. The name East Sulawesi Ophiolite Belt was given by Simandjuntak et al. (1993) for the mafic and ultramafic rocks as well as their overlying pelagic sediments. The ultramafic rocks consist of harzburgite, dunite, wehrlite, lherzolite, websterite, serpentinite, and pyroxenite, which serve as host rocks for the occurrence of laterite nickel deposits. Generally, these ultramafic rocks have undergone intense serpentinization (Syahrul et al., 2025; Jaya et al., 2024).

Research on bedrock in laterite nickel deposits in Sulawesi has been extensively conducted using various methods and has successfully identified the types of bedrock that host laterite nickel, based on the mineral composition of the rocks. Several examples of studies that have been conducted include geochemical constraints on the mobilization of Ni and critical metals in laterite deposits (Ito et al., 2021) and the influence of bedrock and geomorphology on lateritization and the distribution of ni and fe levels in laterite nickel deposits (Hasria et al., 2021). These research has shown that bedrock is the main factor in the formation of laterite nickel deposits but didnt include its spatial influence based on their correlation.

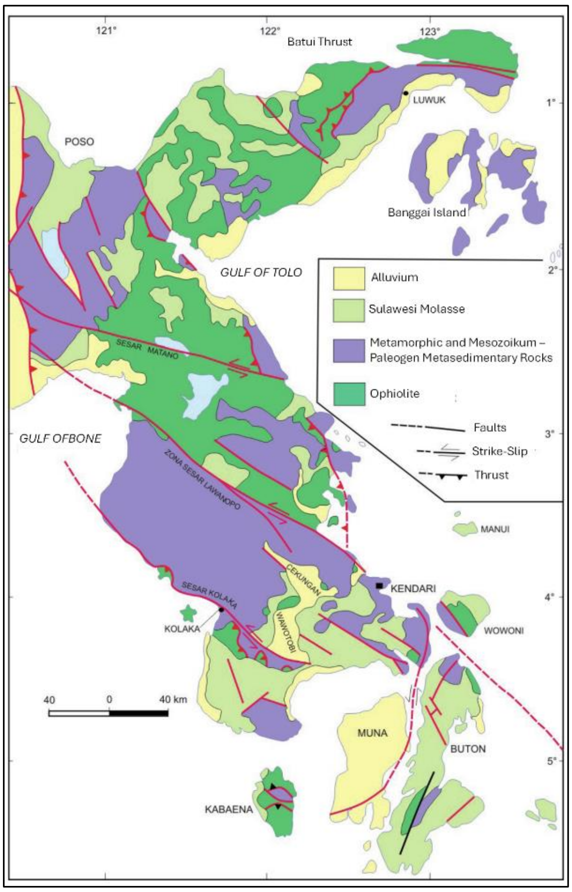

Fig. 1 Geological Map of the Southeast Arm of Sulawesi (modified from Surono, 2013a).

The research area is located in North Konawe, Southeast Sulawesi (Fig. 2), which is dominated by ultramafic rocks and is one of the regions with potential as a source of laterite nickel (Ni). The study focuses on the influence of the various bedrock on the lateritic nickel content.

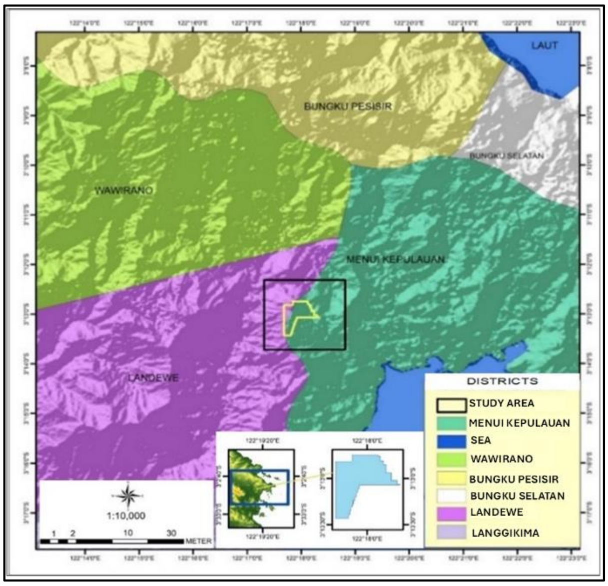

Fig. 2 Administrative Map of The Research Areas.

2. Methodology

Field activities were carried out by observing the morphology and collecting several representative ultramafic rock samples. These samples were analyzed using petrographic and XRF geochemical methods. Petrographic analysis was conducted using a polarizing microscope to identify the rock's characteristics, including mineralogy, texture, and the optical properties of its minerals. The petrographic analysis began with preparing rock samples into thin sections with a thickness of about 0.03 mm, mounted on a microscope slide glass. This analysis produces a microscopic description of the mineral sections. Sample preparation and analysis were conducted at the Optical Mineralogy and Petrography Laboratory, UPN Veteran Yogyakarta. Geochemical analysis using the XRF (X-Ray Fluorescence) method was performed to analyze the major chemical composition and the concentration of elements present in the ultramafic rock samples. XRF preparation and analysis were conducted at PT. Jakarta Anugerah Mandiri Laboratory, North Konawe. A synthesis of the results from both analyses will then be conducted to determine the influence of bedrock on the nickel content in laterite nickel deposits.

3. 3. Results

3.1 Morphology

The research area is located in Lameruru Village, Langgikima Subdistrict. The research was conducted in a production area covering 25 hectares and situated at an elevation of 400–500 meters above sea level. Descriptively, based on the classification (Van Zuidam, 1985), the relationship between absolute elevation and the morphography of the research area falls into the hilly morphology unit. Geomorphological conditions were analyzed using topographic maps and direct field observations, resulting in a slope map based on the Digital Elevation Model (DEM) according to the classification (Van Zuidam, 1985). The slope map and the boreholes can be seen in Fig. 3.

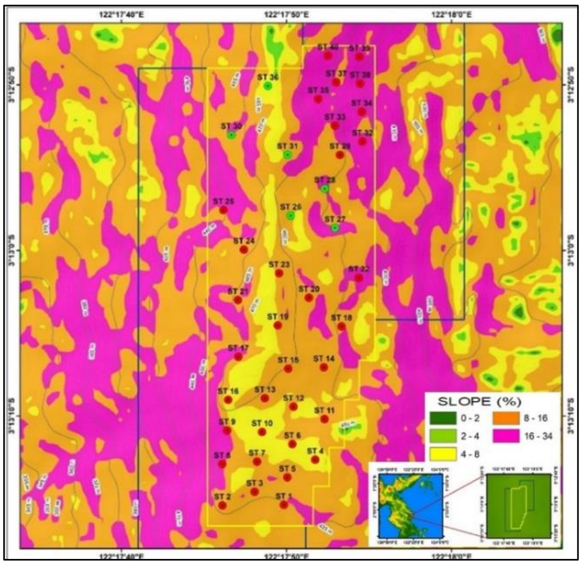

Fig. 3 Slope Map of The Reseacrh Areas (the red dots represent harzburgite boreholes, and the green dots represent olivine pyroxenite boreholes).

Based on the results of the slope analysis, in general, the study area consists of several morphological units, including the gently sloping hill with a slope percentage of 7-15%, the steep hill with a slope percentage of 15-30%, and the steep to very steep hill with a slope percentage of 30-70% (Van Zuidam, 1985). The geomorphological units in the study area can be seen in Fig. 4.

Fig. 4 Geomorphology of the study area, (A) Sloping hill morphology, (B) Steep hill morphology, and (C) Steep-very steep hill morphology.

3.2 Bedrocks

Observation and sampling of ultramafic igneous rocks in the study area were conducted in the bedrock zone, with a total of forty (40) samples collected. The observation and sampling of these rocks were carried out to determine the types of rocks and the mineralogy of the constituent rocks present in the study area. The results of petrographic analysis show that the rocks forming the bedrock of the laterite deposits in the study area are harzburgite and olivine pyroxenite (Fig. 5).

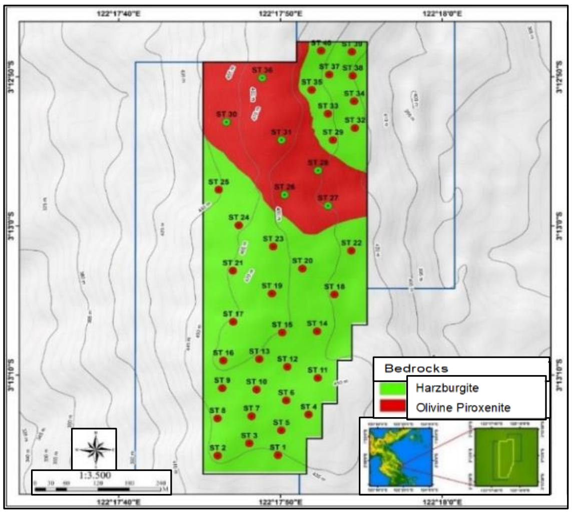

Fig. 5 Bedrock Zones (the red dots represent harzburgite boreholes, and the green dots represent olivine pyroxenite boreholes).

3.2.1 Harzburgite

Harzburgite (Fig. 6) in the study area has physical characteristics of weathered color that is dark brown and fresh color that is yellowish green. Under microscopic analysis of samples ST 5, 17, 25, and 39, the rock slides appear yellow; holocrystalline crystallinity; medium to fine phaneritic granularity; anhedral to subhedral crystal shapes, crystal sizes ranging from 0.1-2 mm; hypidiomorphic equigranular texture; composed of 54-78% olivine, 15-45% orthopyroxene, 6% clinopyroxene, and accessory minerals including spinel, serpentine, and talc. Based on its mineralogy, this rock is classified as harzburgite (Streckeisen, 1976). This rock occupies approximately 72.72% and is evenly distributed from south to north at the research site, which covers an area of 18.14 hectares.

3.2.2 Olivine Piroxenite

The olivine piroxenite (Fig. 7) in the study area has a weathered dark brown color and a fresh dark green color. Under microscopic observation of sample ST-31, the thin section of this rock appears yellowish-brown; holocrystalline crystallinity; medium-fine phaneritic texture; anhedral to euhedral crystal shapes; crystal sizes ranging from 0.1-2 mm; hypidiomorphic equigranular relationship; composed of 27% olivine, 49% orthopyroxene, 17% serpentine, and 7% spinel. Based on its mineralogy, this rock is classified as an olivine pyroxenite according to Streckeisen (1976). This rock occupies about 27.28% and is evenly distributed from east to northwest in the study area, covering an area of 6.86 hectares.

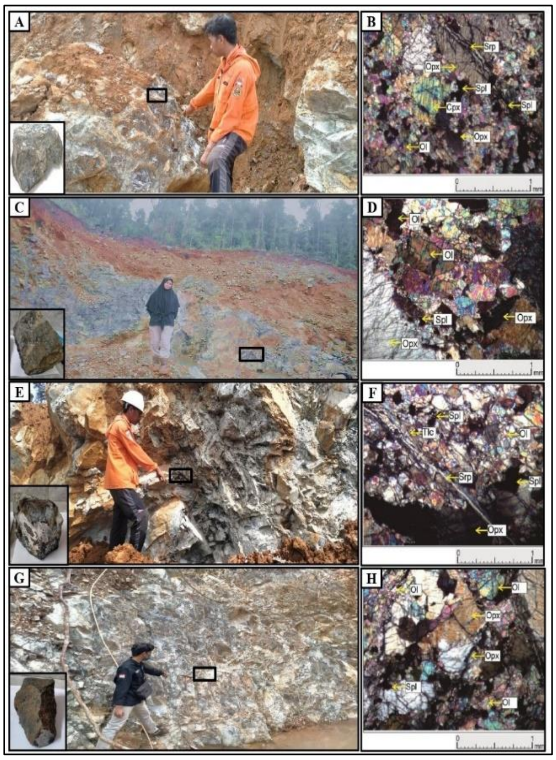

Fig. 6 (A), (C), (E), (G): Borehole outcrops of ST 5, 17, 25, 39. (B), (D), (F), (H): Microphotography of ST 5, 17, 25, and 39 borehole on cross nicol.

Fig. 7 (A): Borehole outcrop of ST 31. (B): Microphotography of ST 31 borehole on cross nicol.

3.3 Distribution of Nickel Content (Ni)

The geochemistry analysis using XRF was conducted in two zones, namely the bedrock and saprolite. Based on the results of the XRF analysis (Table 1), Ni in the bedrock can be divided into two categories: Ni concentrations with a percentage of 0.03-0.10% are categorized as low concentrations and are marked with a red color symbol, while Ni concentrations with a percentage of 0.10-0.16% are categorized as high concentrations and are marked with a blue color symbol (Fig. 8). Ni in saprolite rock is also divided into two categories. Ni concentrations with a percentage of 1.35-1.60% are categorized as low concentrations and are marked with a red color symbol, while Ni concentrations with a percentage of 1.60-2.12% are categorized as high concentrations and are marked with a blue color symbol (Fig. 9).

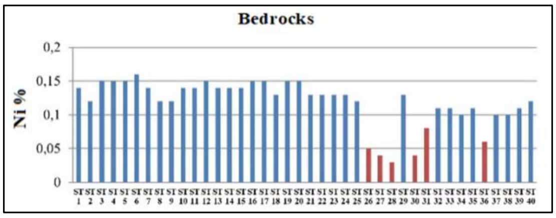

Fig. 8 Ni on bedrocks

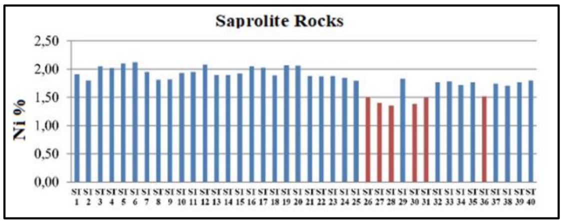

Fig. 9 Ni on saprolite rocks

Table 1. Ni based on XRF Analysis

Sampel ID	Litologi	Ni (%) Bedrocks	Ni (%) Saprolit Rock
ST 1	Harsburgit	0.14	1.91
ST 2	Harsburgit	0.12	1.8
ST 3	Harsburgit	0.17	2.05
ST 4	Harsburgit	0.15	2.02
ST 5	Harsburgit	0.15	2.1
ST 6	Harsburgit	0.15	1.94
ST 7	Harsburgit	0.14	1.95
ST 8	Harsburgit	0.12	1.81
ST 9	Harsburgit	0.13	1.92
ST 10	Harsburgit	0.14	1.93
ST 11	Harsburgit	0.14	1.95
ST 12	Harsburgit	0.14	1.91
ST 13	Harsburgit	0.14	1.9
ST 14	Harsburgit	0.14	1.9
ST 15	Harsburgit	0.14	1.9
ST 16	Harsburgit	0.15	2.05
ST 17	Harsburgit	0.15	2.03
ST 18	Harsburgit	0.14	1.9
ST 19	Harsburgit	0.15	2.07
ST 20	Harsburgit	0.15	2.06
ST 21	Harsburgit	0.13	1.88
ST 22	Harsburgit	0.13	1.87
ST 23	Harsburgit	0.13	1.88
ST 24	Harsburgit	0.13	1.8
ST 25	Harsburgit	0.12	1.79
ST 26	Olivin-Ortopiroksenit	0.05	1.5
ST 27	Olivin-Ortopiroksenit	0.04	1.4
ST 28	Olivin-Ortopiroksenit	0.03	1.35
ST 29	Harsburgit	0.13	1.83
ST 30	Olivin-Ortopiroksenit	0.04	1.38
ST 31	Olivin-Ortopiroksenit	0.08	1.5
ST 32	Harsburgit	0.11	1.77
ST 33	Harsburgit	0.11	1.78
ST 34	Harsburgit	0.11	1.72
ST 35	Harsburgit	0.11	1.77
ST 36	Olivin-Ortopiroksenit	0.06	1.52
ST 37	Harsburgit	0.1	1.74
ST 38	Harsburgit	0.1	1.71
ST 39	Harsburgit	0.1	1.72
ST 40	Harsburgit	0.12	1.8

To obtain a distribution map of Ni, interpolation of Ni at each sampling point was carried out using ArcGIS. The interpolation used to determine the distribution of Ni is IDW (Inverse Distance Weighting), an interpolation technique that takes into account spatial relationships (distance) and is a linear combination or weighted average of the surrounding data points (Lu and Wong, 2008). The IDW method is used to estimate a value at unsampled locations in the study area based on surrounding data (Shepard, 1968). The distribution of Ni can be seen in Fig. 10.

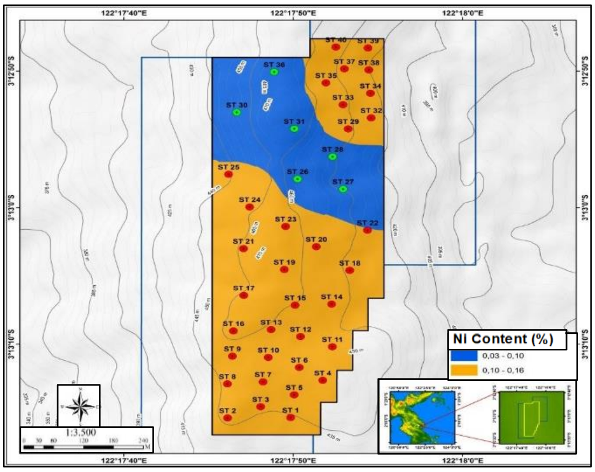

Fig. 10 Distribution of Ni

4. Correlation of Bedrock and Ni Content

Harzburgite and olivine orthopyroxenite are types of ultramafic rocks that serve as the bedrock forming laterite nickel deposits in the study area. The primary nickel-bearing minerals are olivine and pyroxene, while serpentine is a secondary mineral that can also carry nickel, although its content depends on the origin of the primary mineral. The role of olivine minerals in the bedrock affecting the percentage of Ni can be seen in Table 2**.**

Table 2. Correlation of Ni (%), olivine (%), and bedrock

Sample ID	Bedrock	Olivine (%)	Ni (%)
ST-5	Harsburgit	72%	0.15
ST-17	Harsburgit	70%	0.15
ST-25	Harsburgit	59%	0.12
ST-31	Olivin Ortopiroksenit	27%	0.08
ST-39	Harsburgit	50%	0.11

The table above shows that harzburgite rocks have an olivine mineral percentage of around 50% - 72% and produce a high Ni content, 0.11-0.15, while olivine orthopyroxenite rocks have an olivine mineral percentage of around 27% and produce a lower Ni content. Correlation between mineralogy and Ni content in peridotite has shown by Herzberg et al. (2016) that Ni content will increase in olivine-rich peridotite. One of the factors in the formation of laterite nickel deposits is the presence of ultramafic bedrock (Butt and Cluzel, 2013; Freyssinet et al., 2005). Nickel enrichment in ultramafic rocks depends on the olivine content (Golightly, 1981; Gleeson et al., 2004) because olivine is the main magmatic mineral that hosts nickel. The nickel (Ni) content is influenced by several factors, including:

a. Rock origin: The nickel content in olivine can originate from the parent rock. Peridotite rocks, which contain a lot of olivine minerals, have a higher nickel content than other rocks (Olfindo et al., 2020; Beinlich et al., 2018; Kierczak et al., 2021).

b. Magma content: The nickel content in olivine can also depend on the nickel content in the magma where the olivine forms. Magma rich in nickel tends to produce olivine with a higher nickel content (Barnes et al., 2023).

c. Metamorphic processes: The metamorphism of rocks containing olivine will affect the chemical composition of the olivine. Metamorphic processes may involve changes in temperature, pressure, and chemical composition, all of which can affect the nickel concentration in olivine (Clarke et al., 2020).

d. Serpentinization process: The serpentinization process can influence the nickel content in olivine. Serpentinization can increase the solubility of nickel in hydrothermal solutions, which in turn can affect the redistribution of nickel within the mineral (De Obeso and Kelemen, 2020; Scholten et al., 2018) . The nickel levels in peridotite and pyroxenite rocks have different percentages, as shown in Fig. 11.

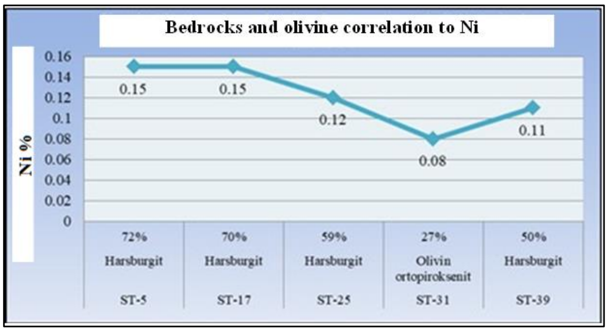

Fig. 11 Correlation of bedrock and olivine to nickel contents

Based on the results of the correlation between bedrock and Ni content as shown in Figure 14, it can be seen that harzburgite rock has a high Ni content with a value of 0.16%, while olivine orthopyroxenite rock has a lower Ni content with a value of 0.08%. This is in accordance with the statement by Ahmad (2009) which states that the average nickel content in fresh ultramafic rocks that have not undergone serpentinization is 0.16% for peridotite and 0.08% for pyroxenite. The relationship between Ni levels in bedrock and saprolite rock can be seen in Fig. 12.

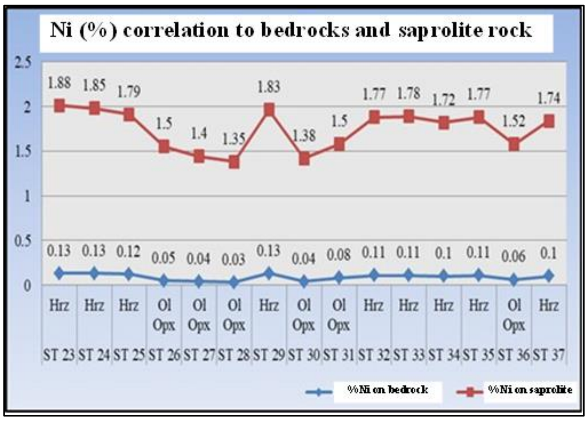

Fig. 12 Correlation of Ni (%) to bedrocks and saprolite rock

Based on the correlation results of Ni content, it shows that the Ni values in bedrock and saprolite rock are interrelated and directly proportional, where the Ni in harzburgite rock has high values in both the bedrock and the saprolite rock. The same also applies to olivine orthopyroxenite rock, where the Ni in olivine orthopyroxenite is lower than that in harzburgite, both in the bedrock and in the saprolite rock.

In general, the relationship between bedrock and Ni can be observed by overlaying the Ni distribution map of the bedrock onto the rock distribution map (Fig. 13). Harzburgite rocks are associated with high Ni and are distributed from the south to the north of the study area, while the olivine orthopyroxenite bedrock is associated with lower Ni and is distributed from the east to the northwest of the study area.

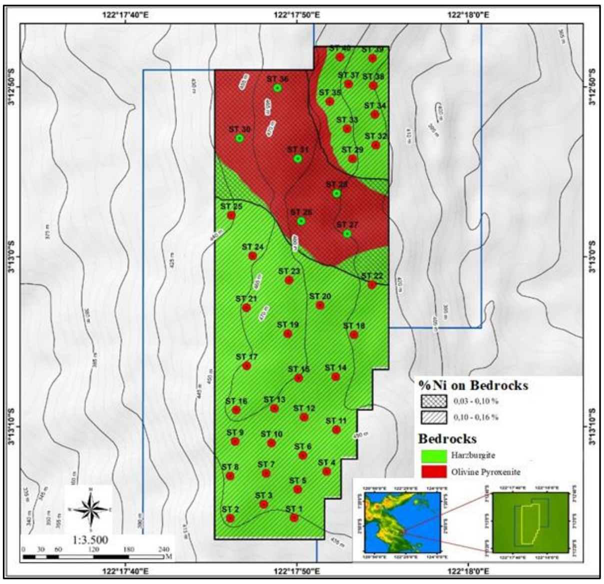

Fig. 13 Distribution of Ni (%) overlayed with bedrocks

5. The Influence of Bedrock on Ni Content

The type of bedrock greatly influences the nickel content in laterite (Hasria et al., 2024). The percentage of mafic minerals (olivine, orthopyroxene, and clinopyroxene) in the bedrock will result in different levels of Ni elements. Harzburgite and olivine-orthopyroxenite are ultramafic rocks that constitute the bedrock in the study area. The Ni content in harzburgite is higher compared to olivine-orthopyroxenite, because peridotite bedrock contains more olivine minerals, which will form garnierite; this mineral is the highest carrier of Ni elements. On the other hand, pyroxenite bedrock generally contains more pyroxene minerals than olivine minerals.

6. Conclusion

Based on the results of research on the influence of bedrock on Nickel concentration, it can be concluded as follows:

1. The lithology developed in the research area consists of ultramafic rocks composed of harzburgite-type peridotite and olivine orthopyroxenite-type pyroxenite, which are made up of olivine, orthopyroxenite, and clinopyroxenite.
2. The distribution of the Ni element in the bedrock shows that a Ni content of 0.03% represents the lowest value in the study area, while a Ni content of 0.16% represents the highest value in the study area. Ni content with a percentage of 0.03 – 0.10% is associated with harzburgite rocks, distributed from east to northwest and occupies about 26.0% of the study area, which covers 6.52 hectares. Meanwhile, Ni

content with a percentage of 0.10 – 0.16% is associated with olivine orthopyroxenite rocks, distributed from south to north and occupies about 73.96% of the study area, which covers 18.48 hectares.
3. The type of bedrock greatly influences the nickel content in laterite, which varies according to the percentage of mafic minerals (olivine, orthopyroxene, and clinopyroxene); different bedrock types will result in different Ni element contents. Harzburgite and olivine orthopyroxenite are ultramafic rocks that form the bedrock in the research area. The Ni content in harzburgite is higher than that in olivine orthopyroxenite. Based on the amount of olivine on bedrock in research area, harzburgite is the best as Ni source for laterite mining.

Acknowledgments

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