Remote Sensing of Nickel Laterite Deposits with Landsat-8 in Indara Block, Halmahera Region

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***Abstract*—Exploration activities must be focused and efficient to optimize the use of available resources in identifying prospective areas. Remote sensing plays a crucial role in achieving this goal. Understanding the genesis of nickel laterite formation and utilizing Landsat-8 imagery are essential for exploration in the Indara Block. The band ratio method is used to process Landsat-8 imagery, and the results help assess the potential for laterization in the research area. Image interpretation guides field checks to validate our interpretation. This study evaluates the effectiveness and abilities of Landsat-8 in nickel laterite exploration, aiming to provide breakthroughs in other regions and act as a reference for future research.**

***Keywords*—exploration, remote sensing, regional exploration, nickel laterite, Landsat-8, geology**

I. Introduction

The research area called Block Indara, which is administratively located in Central and East Halmahera Regency, is shown at Fig. 1. The ongoing exploration stages in this block are regional exploration aimed at searching for and discovering potential nickel laterization that is not yet known.

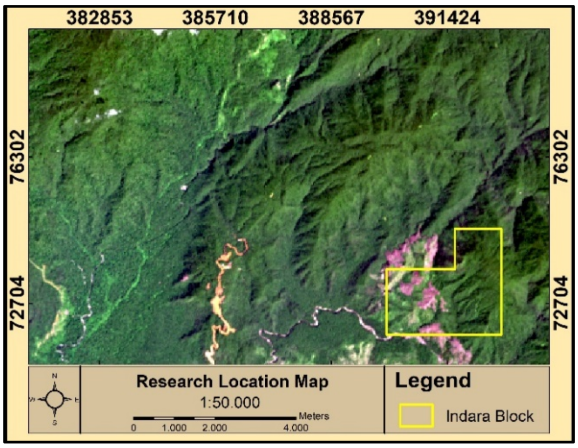

Fig. 1. Research location map and its surroundings, Landsat-8.

Understanding the regional geology is a key factor that must be understood in exploration activities in an area. In the development of nickel laterite exploration, a morphological approach was employed to deepen the analysis and interpret the presence of nickel laterization. The author believes that these common methods are insufficient for effectively interpreting nickel laterization. Therefore, a remhave ote sensing method using Landsat-8 imagery has been developed as a complementary approach to previous techniques, while also assessing the effectiveness of this method, which will be detailed in this study.

A. *Regional Geology*

Regional geological information for the research area was obtained from Geologic Map of the Ternate Quadrangle, North Maluku [1] as shown at Fig. 2. Halmahera is known for its extensive distribution of ultramafic rocks, providing numerous location options for nickel laterite exploration. It is also not uncommon for regional information to be very different locally, so that exploration targets may not be possible to form in that area.

B. *Nickel Laterite*

Nickel laterite deposits are formed through the weathering of ultramafic rocks that contain Ni-silicate. These source rocks typically have a nickel content ranging from 0.2% to 0.4% [2]. Additionally, the topography of an area significantly influences nickel formation; in gentle topography, water moves slowly, allowing it to penetrate deeper into the fractures or pores of the rock compared to steeper terrains [3]. The formation of nickel laterite depends on the interaction between geological factors (such as the original rocks and morphology) and environmental factors (such as climate) [4, 5]. Nickel laterization results in a profile, known as the nickel laterite profile, which, in general, will be formed in the research area as shown at Fig. 3.

On the surface, a layer of limonite will form with >55% Fe_2O_3 and no visible remnants of ultramafic rock textures are still present. A number of grains (Quartz, Serpentinite alteration fragments, manganese oxide) are found in a

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matrix dominated by iron oxide [6]. The materials in this limonite zone that are clay-sized range from 50–70%, while the proportion of sand and coarse sand sizes range from 30–50%. The weathered material that is sand and coarse sand-sized looks rather hard and is estimated to be iron oxides [2].

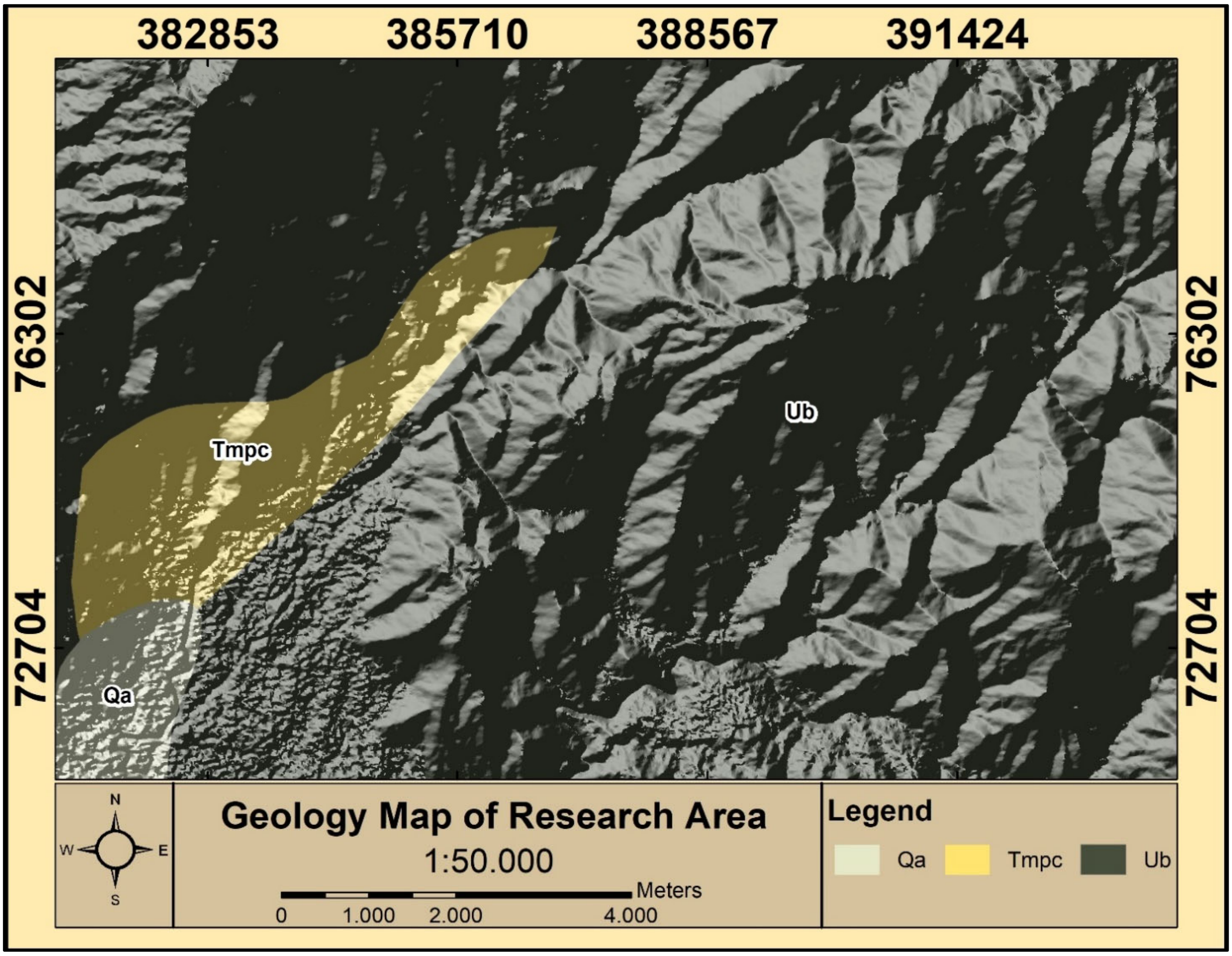

Fig. 2. Digitize geologic map of the ternate quadrangle, North Maluku [1].

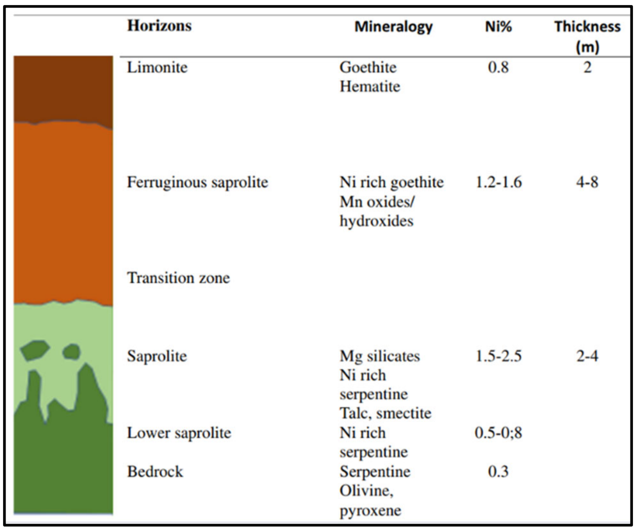

Fig. 3. The Weda Bay profile [6].

II. Data and Methode

A. Data

The secondary data used consist of Landsat-8/OLI Level 1T images with minimal cloud cover. The image was obtained from the U.S. Geological Survey Earth Resources Observation and Science Center (USGS-EROS; http://earthexplorer.usgs.gov/) and was obtained in January 2020.

B. Band Ratio Methode

The interpretation of Landsat-8 imagery, utilizing the available bands, is presented in Table I. The band ratio method enhances contrast between hues by dividing the highest and lowest brightness values in the reflectance curve, after correcting for atmospheric conditions. This method is particularly useful for highlighting specific hues or materials that may not be visible in the raw bands. Band ratio transformation is effective for the qualitative detection of hydrothermal alteration minerals [7, 8]

TABLE I. PERFORMANCE CHARACTERISTICS LANDSAT-8/ OLI [9]

Satellite/ sensor	Subsystem	Band name	Band number	Spectral range (um)	Spatial resolution	Spectral resolution	Radiometric resolution	Swath width
Landsat -8/ OLI	VNIR	Coastal aerosol	1	0.43–0.45	30 m	9 bands	16-bits	185 km
		Blue	2	0.45–0.51				
		Green	3	0.53–0.59				
		Red	4	0.64–0.67				
		Near Infrared	5	0.85–0.88				
	SWIR	Shortwave Infrared 1	6	1.57–1.65				
		Shortwave Infrared 2	7	2.11–2.29				
	VNIR	Panchromatic	8	0.50–0.68	15 m			
		Cirrus	9	1.36–1.38	30 m			

C. *Field Check*

A field check is conducted to gather primary data and validate the interpretation results, allowing for an assessment of how effectively remote sensing can guide exploration targets. The results of the field check include observation points, documentation of outcrops, and descriptions of lithology.

III. RESULT

A. *Regional Geology*

Based on the Geologic Map of The Ternate Quadrangle, North Maluku [1], the entire research area consists of Ultramafic Complex (Ub), as shown at Fig. 4. The geological conditions in this area are highly favorable for the formation of nickel laterite due to the abundance of ultramafic rocks.

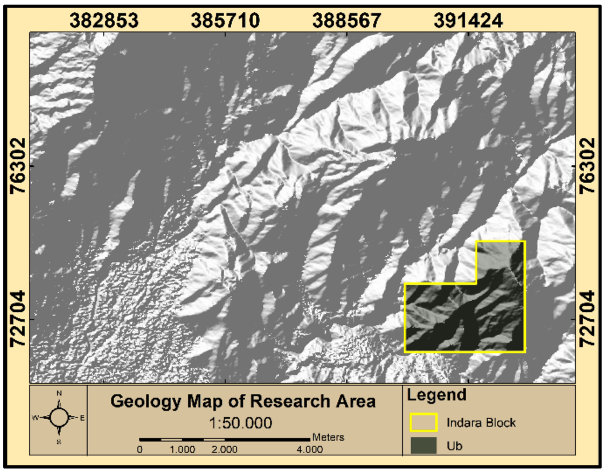

Fig. 4. Geology map of research area from geologic map of the ternate quadrangle, North Maluku [1].

B. *Remote Sensing Interpretation*

Landsat-8 imagery is used to identify iron oxide on the surface of the research area. The limonite layer is characterized by a high iron oxide content. High values in the 4/2 band ratio are effective for detecting charge transfer absorption associated with ferric iron oxides in the blue spectrum region [9]. High values in the 4/2 band ratio were observed in the research area, highlighted at Fig. 5.

The combination of Sabin's ratio, typically used for lithology mapping and hydrothermal alteration, with an RGB composite facilitates easier observation. Sabin's ratio employs band ratios B6/B5, B6/B7, and B4/B2 in RGB [10]. The results for the research area are shown at Fig. 6. In the Sabin's Ratio results, the accumulation of iron oxide is represented by the color blue, providing a clearer and more detailed interpretation of iron oxide in the research area and its surroundings.

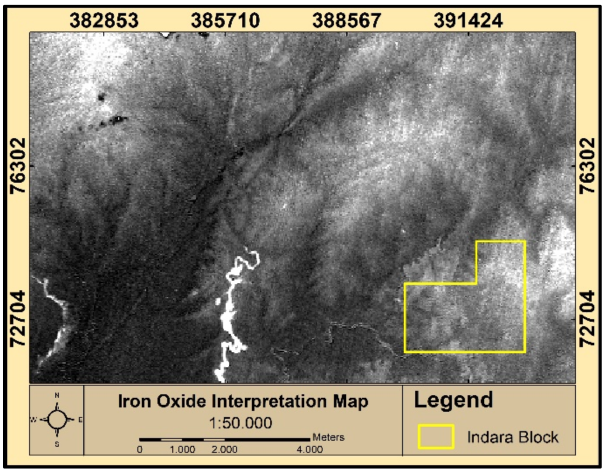

Fig. 5. Iron oxide interpretation map in monochrome.

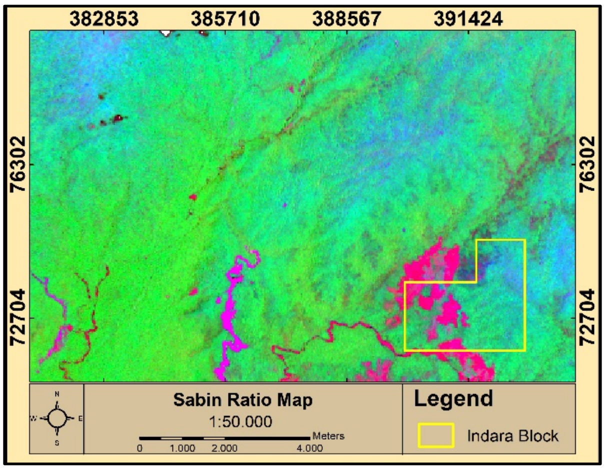

Fig. 6. Sabin's ration map in RGB.

C. Field Check

Based on the results of the interpretation of iron oxide, the research area has a significant concentration of iron oxide in the northern part. Therefore, the researchers are confident that nickel laterite soil will be found in this area. Field checks are focused on accessing the northern part of the Indara Block and taking photographs at several observation points. The observation points and the appearance of the nickel laterite soil identified are shown at Fig. 7. This soil is formed from Dunite rocks, which display an abundance of Olivine minerals (80%) as shown at hand specimens, shown at Fig. 8. The appearance of the nickel laterite soil found closely resembles the top layer of nickel laterite profiles in general, which consists of limonite, as shown at Fig. 3.

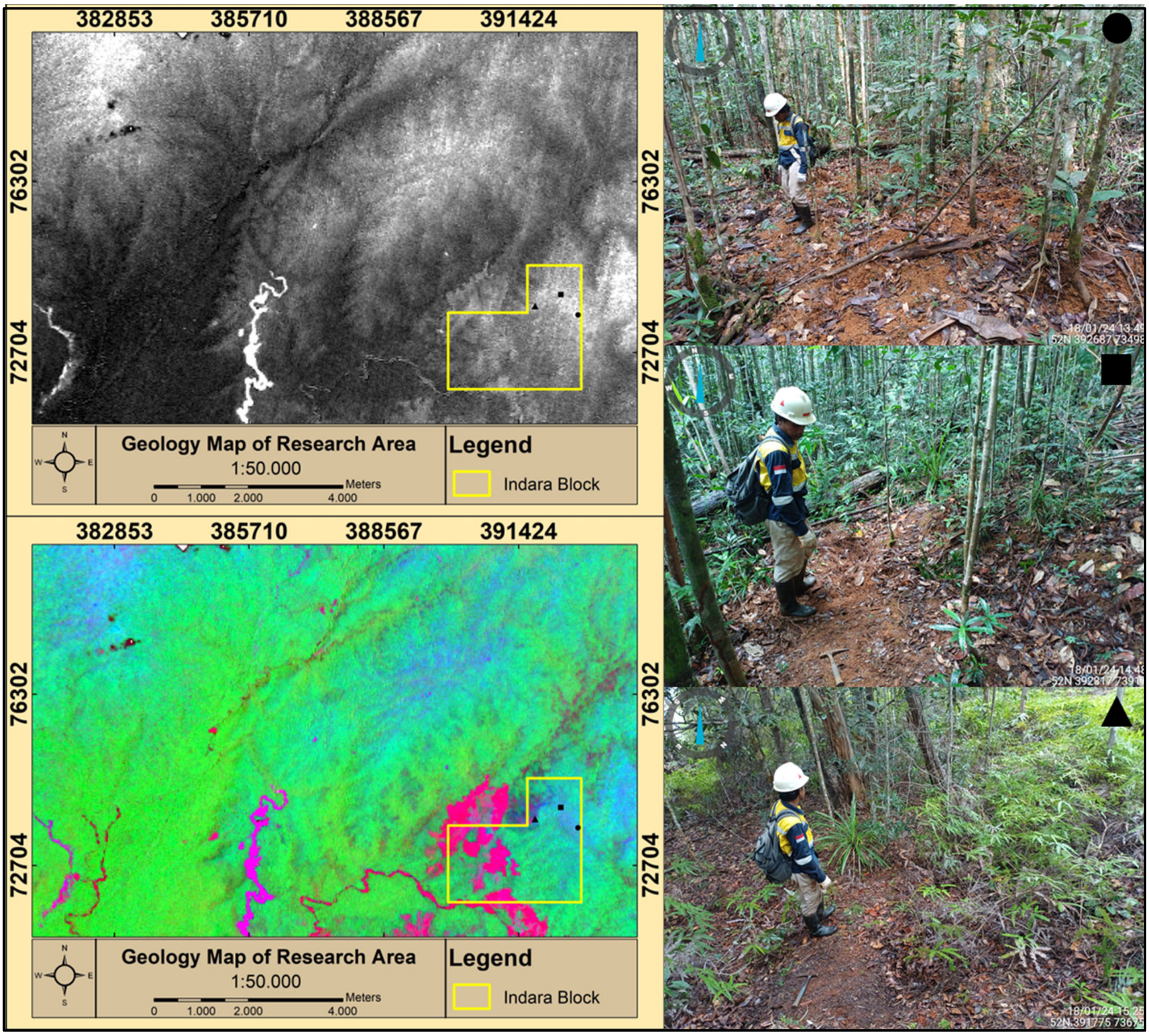

Fig. 7. Preview of field check base on remote sensing interpretation (Ultramafic Laterization).

Fig. 8. Hand speciment of dunite in Nickle Laterite Soil Zone.

On Fig. 9 shows the appearance of the observation point, which the author believes represents the laterization of un-ultramafic rocks. The soil was formed by the weathering of Gabbro, with minerals predominantly composed of Plagioclase, as observed in the hand specimens shown at Fig. 10. There is a visible difference in the color of the soil produced by the weathering of the source rock. This field check validates the distribution of nickel laterite soil, which closely resembles the interpretation of iron oxide in Landsat-8 imagery. This aligns with the author's expectations, indicating that the application of remote sensing can provide valuable insights and enhance the effectiveness of nickel laterite exploration in the Indara Block.

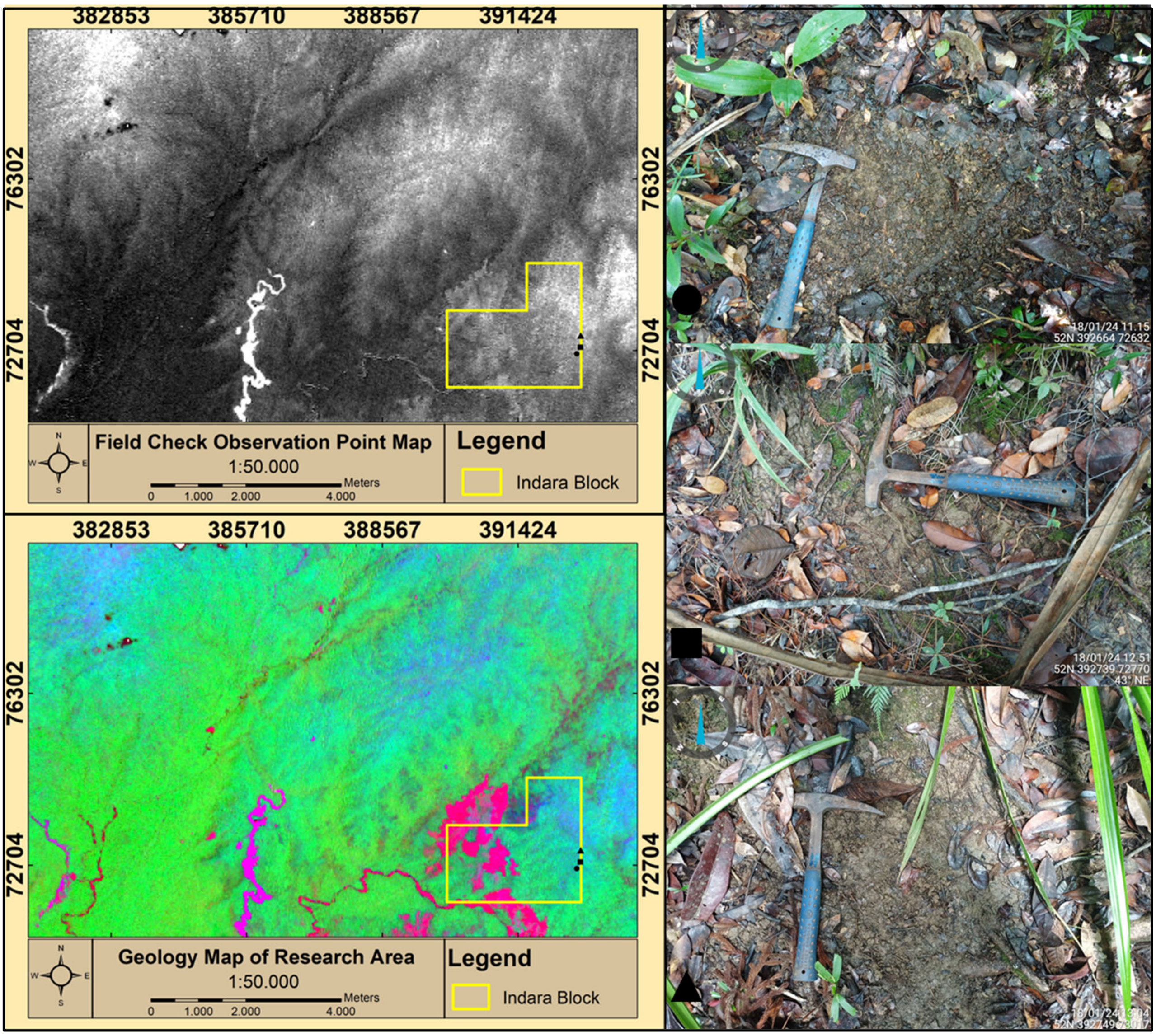

Fig. 9. Preview of field check base on remote sensing interpretation (Un-ultramafic Laterization).

Fig. 10. Hand speciment of Gabbro in Un-ultramafic Laterite Soil Zone.

III. Conclusion

Based on the overall results of the research in the Indara Block, the following conclusions can be drawn:

- The remote sensing method is a key approach for achieving effective and efficient exploration.
- Landsat-8 imagery can effectively interpret the presence of iron oxide targets, even in very dense vegetation, as seen in the Indara Block.
- Areas with high iron oxide concentrations in the Indara Block are associated with nickel laterite soil resulting from the weathering of ultramafic rocks.
- Understanding regional geology, the genesis of nickel laterite, and the application of remote sensing methods are essential for identifying locations with potential for nickel laterization.

Conflict of Interest

The authors stated that the entire study supports regional exploration activities in the IUP of PT Halmahera Sukses Mineral at the Halteng Site. This study is part of the internal research and development efforts of the Department of Geology and Exploration at PT Halmahera Sukses Mineral, Site Halteng.

Author Contributions

We would like to thank Mr. Ludovicus Damardika Jasaputra, the main author, for his efforts in conducting literature studies on image processing and compiling the findings. We also extend our gratitude to Mr. Hendra Setiawan and Ms. Heppy Chintya Padaga for their work in data analysis and for enhancing the writing. Finally, we thank Mr. Christophorus Enggar Suryo and Mr. Joni Djakun for their time and energy in conducting fieldwork in the Indara Block. All authors had approved the final version.

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Ludovicus Damardika Jasaputra was born in Sleman on August 21, 1999. He earned a Bachelor of Engineering in Geological Engineering from Universitas Pembangunan Nasional "Veteran" Yogyakarta in 2021. During his studies, he developed a solid foundation in geological principles, participating in various projects that enhanced his practical skills.

Currently, he works as an Exploration Geologist at PT. Halmahera Sukses Mineral, located in Halmahera Tengah. In this role, he is involved in mineral exploration and geological mapping, utilizing modern techniques to assess and manage natural resources. Previously, Ludovicus gained valuable experience through internships and fieldwork, contributing to several geological projects that refined his expertise and prepared him for his current position.

His research interests include mineral exploration, geological mapping, and sustainable resource management, reflecting his commitment to responsible practices in the field. Ludovicus aims to make significant contributions to geological science and resource management in his career.

Hendra Setiawan was born in Takengon, January 17, 1994. He earned a Bachelor's degree in Geological Engineering from Universitas Pembangunan Nasional "Veteran" Yogyakarta in 2017. Throughout his studies, he developed a strong foundation in geological principles, with a particular focus on structural geology and physical geology.

Currently, Hendra works as an Exploration Geologist at PT. Halmahera Sukses Mineral, where he applies his expertise in exploratory drilling to assess mineral resources. His role involves conducting geological surveys, analyzing drilling data, and collaborating with multidisciplinary teams to ensure successful exploration projects. Hendra is passionate about advancing his knowledge in physical geology, constantly seeking to deepen his understanding of geological processes and their implications for resource management.

In addition to his professional pursuits, Hendra has a keen interest in sports. He has a passion for football, which he played during his university years. He also served as the captain of the soccer team in the Geology and Exploration Department at PT. Halmahera Sukses Mineral, where he fostered teamwork and camaraderie among his peers..

Christophorus Enggar Suryo Born in Surakarta on November 3, 1995, graduated with a Bachelor's degree in Geological Engineering on March 21, 2019. During his time in university, he gained valuable organizational experiences and achieved recognition in various university, national, and international events.

With over four years of professional experience, he began his career as a Geoscientist at Indogeo Social Enterprise from August 2019 to February 2020. During the same period, he also participated in a mapping project focused on limestone reserves as an Exploration Geologist and Geophysicist. Following that, he served as a Management Trainee Field Assistant at PT. KLK Agriservindo from April 2020 to October 2020.

His journey continued at PT. Geo Gea Mineralindo (GGM), where he worked as a Grade Control Exploration Geologist (field mapping) and Foreman Production from February 2021 to January 2022. He then took on the role of Exploration Site Coordinator and Wellsite Geologist at GGM from January to April 2022, before becoming a Field Geologist at PT. Aulia Prima Perkasa from April to October 2022. Most recently, he worked as a Project Geologist at PT WITA from October 2022 to February 2023. Currently, Christophorus serves as the Regional Mapping Supervisor at PT. Halmahera Sukses Mineral (HSM), where he continues to develop his skills and contribute to the field.

Heppy Chintya Padaga was born in Poso on January 3, 1997. In 2019, she earned a Bachelor's degree in Geological Engineering from Universitas Pembangunan Nasional "Veteran" Yogyakarta.

Currently, she works as a Database Geologist at PT. Halmahera Sukses Mineral, where she plays a crucial role in managing geological data. Since her graduation, Heppy has been actively involved in nickel exploration projects, contributing her skills to ensure the success of these initiatives.

With a strong interest in mineral exploration, database management, data analysis, and quality assurance/quality control (QAQC) in exploration, she brings valuable expertise and a passionate approach to her work in the field of geology. Heppy is dedicated to enhancing data integrity and supporting effective decision-making processes within her team.

Joni Djakun was born in Gorontalo on January 8, 1996. He graduated with a Bachelor's degree in Geological Engineering from Universitas Negeri Gorontalo in 2020.

Joni has a strong interest in mineral exploration and has been actively involved in exploration activities since his graduation. He particularly enjoys fieldwork, where he can engage directly with geological surveys and data collection. Currently, he works as a Exploration Geologist at PT Halmahera Sukses Mineral, where he applies his knowledge and skills to contribute to successful exploration projects. His passion for geology drives him to continuously expand his expertise in the field.