The Influence of Topography to the distribution of Ni-laterite deposits of Mangguruuh Area, Sebuku Island, South Kalimantan

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Abstract. One important factor that influences the optimization of the formation of nickel laterite deposits is the slope of a region’s topography. The Mangguruuh area in Sebuku Island in South Kalimantan is composed of ultramafic rocks on a gently flat topography but forms laterite deposits of varying thickness. Based on the exploration data from 33 drilling points and field data acquisition, this study aims to: 1) create topographic slope groups with varying ranges to determine the range most suited to real conditions in the field, 2) determine the laterite thickness, 3) analyze the concentration of Ni and Fe in limonite and saprolite layers, 4) analyze the effect of topographic slope to the laterite thickness. The method used is the measurement of topographic slope in the field with compass and using ArcGIS software applications in preparing the maps, analyzing laterite profiles from the drilling data and sampling rocks and ores. The study performed a laboratory analysis consisting of petrographic analysis and X-ray Fluorescence testing of the elements. The result revealed that the appropriate topographic slope groups in the study area were 0-5%, 5-10%, 10-15% and ≥ 15%. The laterite thickness of > 10m lied on the slope of 0-5% and 5-10% and contains a moderate-high nickel content of 1.2% - > 1.4%. This indicates that laterite nickel enrichment is influenced by topography. While the distribution of iron ore with medium and high levels of concentration (45-50% and > 50%) has commonly occurred in each topographic slope group indicating that topography is less influential on the distribution of iron ore. Earlier research has indicated that effect of topography on different morphologies is clear and many of the studies were conducted on a regional scale, but interestingly in Sebuku area, the topography is gently flat but the thickness and nickel content is varied. So the results of this study can be applied to slightly flat slope areas and therefore needs more detailed mapping.

1. Introduction
Nickel laterite deposits are formed due to further weathering of ultramafic rocks carrying Ni-Silicates, generally in the sub-tropical to tropical regions of the equator. The geological conditions and tectonic patterns of Eastern Indonesia conduct to the formation of potential laterite deposits in eastern Sulawesi
(Sorowako, Pomalaa, Bahodopi), eastern Halmahera (Gebe, Tanjung Buli, Sangaji, Pakal Island), and northern Irian Jaya (Waigeo, Gag , Sentani). On Sebuku Island, South Kalimantan found laterite nickel deposits that have different characteristics from other regions. The laterite deposits have a low nickel content compared to iron content [1]. Laterite iron ore reserves reached 426.5 million tons, which is the largest iron ore reserves in Indonesia.

In addition to protolith and climate, the topography is also an essential factor in the formation of laterite nickel deposits. Laterite nickel can be formed in areas that have moderate reliefs controlled by structure and fracture density [2]. In areas with variate topographic slopes will form laterite deposits with different thicknesses. The thickness of the limonite zone is inversely proportional to the topographic slope which indicates that there is a correlation between the percentage of slope and the thickness of laterite deposits [3] [4]. Sebuku Island has a maximum topographic elevation of 125 m which elongate in the east. The research area is located in the western part, the topography is included in the geomorphology of the terrain with an uneven slope between 2 - 25 meters. On the west coast, there are freshwater swamps which are bordered by mangrove zones up to 500 m.

This research was conducted based on exploration drilling data which was confirmed by field observation data obtained from the Mangguruh Island of Sebuku Island, Kota Baru Regency, South Kalimantan Province. The area is part of the employment contract of PT. Sebuku Iron Lateritic Ores. The main focus of this study was to determine the optimal topographic slope group as a location for the formation of laterite nickel deposits, especially in relatively flat areas.

2. Materials and Method

2.1 Geology of Sebuku Island

Regional Geology of Sebuku Island is in Kotabaru Sheet, Kalimantan, published by the Geological Survey, Indonesia in 2006 [5]. The oldest rock that is Jura-aged is ultramafic consisting of harzburgite, dunite, serpentinite, gabbro, basalt, and serpentinized pyroxenite. In the Late Cretaceous, Pitap Formation is deposited in shallow marine environments, consisting of conglomerate, sandstone, and siltstone interfering, limestone insertion, breccia, claystone, conglomerate, and basalt. In Eocene, the Tanjung Formation was deposited which consisted of a tangle of conglomerates, sandstones, and claystone with shale, coal and limestone inserts. The Tanjung Formation overlaps the Pitap Formation and the Haruyan Formation. The youngest sediment in the study area is Alluvium (Qa) sediment, which is the result of erosion from older rocks whose sedimentation process still continues to the present. The lithology consists of gravel, sand, silt, clay, and mud. These deposits are found as swamp deposits, rivers and beaches. Its spread mainly occupies the plains around the Sebuku Strait.

Figure 1. Regional Gology of Sebuku Island [5].
2.2 Method

The study was conducted in the Mangguruh Region, Sebuku Island, South Kalimantan, is a sub-district located to the east of Laut Island at 3° 24′ 23″ North Latitude and 116° 24′ 21″ Timur East Longitude. The research location can be reached for 10 hours by road from Banjarmasin to Batulicin Ferry Port, crossing to Pulau Laut by ferry for 2 hours to arrive at Tanjung Serdang Port, followed by a trip on the Sea Island to the Pier to then go to Gosong Bay. From Gosong bay use a speedboat crossing to Tanjung Nusantara pier on Sebuku Island for 2 hours (Fig. 2).

![Figure 2. Map of the research area](image)

The research method consists of field observations, slope value analysis, analysis of geochemical data from drilling, and modifying the classification of rays based on geochemical data. Observations in the field are surveys of surface geological mapping through predetermined trajectories, including morphological observations, exposed rock observations, observations of alteration zones, and rock sampling. Measuring the slope using a geological compass, and determining the position on the map by field orientation and using GPS. Samples from the selected field were then prepared in the form of the thin section of rock for petrographic analysis using a polarizing microscope in the Department of Geological Engineering, Hasanuddin University, which aims to determine rock types based on mineral composition and texture and microstructure in rocks.

Physical analysis of rocks is done on 33 core drilling directly at the time of drilling and on the results of the previous drilling. Physical characteristics analysis consists of color, mineral composition, grain size and minerals which aim to determine the profile of laterite deposits consisting of layers of limonite, saprolite, and bedrock. Geochemical analysis using X-ray Fluorosense (XRF) instrument, to analyze oxide compounds contained in nickel laterite deposits oxide compounds using spectrometry methods such as SiO₂, MgO, CaO, Al₂O₃, Ni, Fe and Co.

Slopes can be defined in the form of percentages, comparing height difference to horizontal difference. The topographic analysis used ArcMap software to create slope maps in the study area. Furthermore, to find the slope classification at the surface that corresponds to the thickness of the deposits from the results of the analysis on the borehole, three slope classifications are made, namely: topography with slope 0 - 2°, 2° - 7°, 7° - 15° and ≥15°; 0 - 5°, 5° - 10°, 10° - 15° and ≥ 15°; 0 - 7°, 7° - 14°, 14° - 21° and ≥ 21°.
3. Result and Discussion

3.1 Geomorphogy and Topography
Morphogenesis analysis is the process of natural results of the results of weathering, erosion, and material movement processes. As a result of the denudational process that works on ultramafic rocks continuously, the land surface in the area decreases in height and forms almost flat surface. Based on the morphometric approach, the geomorphology unit in the study area is on low hills with slope forms generally convex to straight, and roughness is quite smooth and uniform. Based on the classification of reliefs can be divided into three units, namely flat topography, surging with sloping and irregular slopes with sloping hills. Flat topography is characterized by a slope of 0 - 2% and a difference in altitude <5 meters. The geomorphological unit is wavy in areas with slopes of 3 - 7% and differences in altitude of 5 - 50 m. While areas with slopes of 8 - 15% include undulating geomorphology units.

![Figure 3. Plain and denudation hill of morphology unit](image)

![Figure 4. Map of slope degree with slope value: A. 0-2, 2-7, 7-15, ≥15; B. 0-5, 5-10, 10-15, ≥15, C. 0-7, 7-14, 14-21, >21](image)

Based on the slope distribution which is measured directly in the study area and compared with topographic maps, three slope percentage distributions can be grouped. The slope classification considers the largest to the smallest slope angle and the density of the slope percentage value. The three classifications with slope percentage values as follows A. 0 – 2%, 2 – 7%, 7 – 15% and >15%; B. 0 – 5%, 5 – 10%, 10 – 15% and >15%; C. 0 – 7%, 7 – 14%, 14 – 21% and > 21% (Fig. 4). The percentage slope of classification A shows that there is an overlap in the range 0 - 2% with 2 - 7%, as
well as 2 - 7\% with 7-15\%. In the B classification overlap between 0 – 5\% and 5 -10\% can be minimized as well as percentage 5 – 10\% with 10 – 15\%, while 10 - 15\% and >15\% the more specific the distribution area. Classification of percentage slope C shows the distribution of 0 – 7\% is very broad compared to the range 7 – 14\%, percentage slope 14 – 21\% and >21\% the smaller the distribution. Based on the classification of the slope, the classification corresponding to the study area is topographic classification B, because it can describe the topographic state in accordance with the study area, supported by the slope data measured directly.

3.2 Research Study Area

Based on lithostratigraphy, the research area is composed of two non-formal rock units namely the Peridotite Unit and Gabbro Unit (Fig. 5).

Figure 5. Geological map of Mangguruh area

3.2.1 Peridotite Unit

Peridotite units occupy 80\% of the research area spread from north to south. The exposed rock can be grouped into four based on the level of serpentinization. The first group is rocks that do not have serpentinization; the second group of rocks that experienced serpentinization was 10-40\%; the third group is peridotite rock whose serpentine level is 41-70\% and the fourth group is serpentinite rock.

The exposed peridotite rocks are characterized by greenish gray, massive textured, phaneritic, composed of olivine and pyroxene minerals. Peridotite under a microscope is called dunite which is composed of olivine (50 - 60\%), pyroxene (20 - 27\%), plagioclase (8 - 10\%) and magnetite minerals (2 - 3\%). The rocks have altered by serpentine mineral by 8\%. Olivine mineral in the form of anhedral measuring 0.2 - 0.9 mm, there are cracks in olivine individuals forming a small portion, and partially replaced by serpentine minerals. Orthopyroxene is brownish green, subhedral in shape; two-cleavage form a 90° and some have been changed by serpentine minerals. This first group rock was found in an amount of at least about 10\% in peridotite units.

The second group of peridotite rocks is exposed to gray, hypocrystalline, composed of olivine and pyroxene minerals. Observations on a thin section of rock are called harzburgite which is composed of augite minerals (35 - 45\%), olivine (20-25\%), hypersthene (10-20\%), plagioclase (5-20\%) and opaque minerals (5-10\%). Serpentine minerals alter the pyroxene and olivine minerals in the fracture, the space between minerals and some individual minerals is completely changed.
The third group is peridotite which is exposed to yellowish gray, hypocrystalline which is composed of pyroxene and olivine minerals and serpentine minerals and quartz veins. Analysis of rocks under a microscope is called lherzolite which is composed of minerals augite (40-50%), olivine (20-25%), and hypersthene (10-25%). The space between minerals is changed by chrysotile serpentine minerals characterized by light brown color, fibrous forming mesh texture, and parallel extension.

The fourth group of peridotite rocks is greenish gray, foliated textured and glassy due to serpentine mineral content. Petrographic analysis showed greenish-brown color, low relief, fibrous shape, partly formed mesh texture, and partly filled veins. There is a subhedral to an anhedral distribution of magnetite minerals and is 0.05 - 0.1 mm in size (Fig. 6).

![Figure 6. Serpentinite under microscope with mesh texture](image)

3.2.2 Gabbro Unit

The exposed gabbro unit has experienced high weathering, and shows reddish color changes. Gabbro rocks at the borehole show a blackish gray to brown. Holocrystalline texture, composed of clinopyroxene minerals (30-50%), labradorite (20-30%) olivine (10-25%) and honblede (10-25%). Minerals form are subhedral to anhedral and 0.5 - 1.6 mm in size.

3.3 Laterite Profile

Data for determining the laterite profile from observations in the field and results of drill hole analysis. Differences in layers of laterite deposits are found in the physical characteristics of color, grain size, and minerals found in each layer, in accordance with the standardization of PT. SILO (Sebuku Iron Lateritic Ores). Observation in the field in outcrops found limonite, saprolite and bedrock layers. The limonite layer is brownish red to yellowish, measuring grains of sand to clay, layer thickness of 1.5 - 2.0 meters. Found minerals goethite, hematite and secondary quartz. Saprolite layer is characterized by greenish brown color deposits, rock fragments of origin are still visible between grains of sand to clay. There are textured boxwork veins, serpentine veins and chalcedony. Saprolite layer thickness between 1.0 - 2.0 m. The bedrock layer is yellowish gray, characterized by massive rocks and partly in the form of large fragments (Fig. 7).

Differences in physical characteristics and grades of Ni and Fe in a borehole are used to determine the layers of nickel laterite deposits. The limonite layer is reddish brown, measuring silt to clay and not solid, there are goethite, hematite and magnetite minerals. Saprolite layer is yellowish brown in color, the size of sand grains to glacial, and there are origin rock fragments of 5.0-10 cm in size, there are garnierite and serpentine minerals. The bedrocks layer is composed of gray peridotite, massive texture and several parts in the form of fragments measuring 5.0-30 cm (Fig. 8).
3.4 The thickness of laterite deposits

The determination of laterite thickness based on the total thickness of the limonite and saprolite layers which are distinguished based on the grade of Ni and Fe. Geochemical analysis is very important in determining the laterite profile, because each layer has a different chemical element. Elemental analysis is carried out qualitatively and quantitatively. Qualitative analysis was conducted to analyze the types of elements contained in the deposits and quantitative analysis was carried out to determine...
the concentration of elements in the borehole results. Classification of Ni and Fe elements in laterite profiles in the study area was divided into three, namely low, moderate and high (Table 1).

| Element | grade (%) |
|---------|-----------|
| Ni      | < 1.2    | 1.2 - 1.4 | > 1.4 |
| Fe      | <45      | 45 - 50   | > 50  |

The results of geochemical analysis of the limonite layer have a high content of Fe, which is > 35% and low Ni elements < 1.2%. Based on the description of the core obtained a minimum thickness of 0.5 meters at the drill point 113 and the maximum thickness is 6.85 meters at the drill point 25. The thickness difference in the limonite layer is caused by various aspects, such as bedrock, rock structure, topography, climate, subsurface water and surface water [3] [4].

In the saprolite layer, the minimum thickness is 1.09 meters at borehole 29 and the maximum thickness is 11.5 meters at the borehole 25. The difference in saprolite thickness is due to the lack of fractures in the bedrock so that the weathering intensity is low. In addition it is also influenced by the sloping topography so that the thickness of the saprolite is thinned because the chance of surface water to seep into the soil is not optimal. Bedrock is a rock that is still fresh and weathering processes are still very small. Observation of peridotite bedrocks in the core, shows blackish green color, holocrystalline crystallinity, phaneritic granularity, equigranular relations, subhedral-anhedral, olivine, and pyroxene forming minerals, and serpentine.

The thickness of laterite in the study area was classified into three, namely thin (< 7.2 meters) medium (7.2 - 10 meters) and thick (> 10 meters). On the map of the relationship between slope and laterite thickness, it can be seen that the thick distribution of sludge is generally at a slope of 0 - 5%, although there is also a slope of 5-10% in the southwest. The spread of the thickness of the precipitate is moderate at a slope of 0-10%. Whereas the thickness of thin deposits is spread in a slope of 10-15%. The development of intensive laterite deposits on gentle slopes in the slope is 0-10%, so the weathering process is relatively the same in the area. Similarly, the absorption of rainwater to the bedrock will be intensive which causes chemical weathering greater than physical weathering.

3.5 Influence of Slope with Lateritic Thickness and Ni and Fe grade

The influence of topography on thickness in the study area can be analyzed from overlays of laterite thickness data and slope maps. The thickness of laterite at slopes of 0 - 5% and 5-10% is generally higher, because the area has a flat topography and also not steep, so that surface water moves slowly and will have enough time to penetrate deeper through rock fractures. This penetration causes the mobile elements to be carried along with the flow of water and eventually accumulates to form thick laterites. In contrast to the slopes of 10-15% and > 15% which are generally thinner, which is caused by a steep topography causing surface water does not have enough penetration time to the surface. So that the weathering process is less than optimal. The slope of the slope has a large influence on the level of weathering and accumulation. However, in some locations the slope is not found thick laterite deposits, it can also be caused by the influence of the structure is not optimal to form fractures in rocks [2]. Protolith also plays a role in the formation of laterite nickel deposits, namely harzburgite [6] peridotite, whereas in the study area it is dominated by lherzolite peridotite.

Nickel distribution data associated with slope, the distribution of nickel with grade values > 1.4% and 1.2% - 1.4%, generally located in topography with slopes of 0 - 5% and 5-10%. In this topography, groundwater does not move quickly so that nickel deposits that are mobile are not displaced. Nickel distribution of slope < 1.2%, generally located in topography which has slopes of 10-15% and > 15%. In these slopes, surface water does not have enough time to penetrate downwards so
that the formation of laterite and nickel is less effective and if penetration occurs to the bedrock, it can cause the nickel element to be carried away by the subsurface water flow which is relatively faster.

Distribution of iron ore levels high to moderate are in all slope values in the study area but generally are at slope percentages of 0-5%, 5-10%, and > 15%. While the distribution of iron ore with low levels is at every percentage slope. So that in the study area shows that the influence of topography on iron ore distribution is not significant. It is also related to high Fe content compared to Ni in thick to thin laterite deposits. Serpentinite rock that is widely distributed in peridotite units is a rock originating from deposits containing high levels of Fe. Petrographic analysis shows that magnetite minerals are scattered and some form veins in serpentine rocks and serpentinized peridotite rocks. Magnetite is a mineral that is responsible for high Fe levels compared to Ni.

In the process of chemical weathering, groundwater rich in CO₂ comes from the air and decomposition of plants decomposes unstable minerals such as olivine and pyroxene in ultra-alkaline rocks, which will produce Mg, Fe, soluble Ni and Si tend to form colloids form very fine silica particles. In solution, Fe is oxidized and settles as ferric hydroxide. Iron deposits are concentrated in the limonite zone. In this zone is dominated by goethite, hematite, magnetite and clay minerals.

Factors that greatly affect the formation and distribution of iron ore are chemical weathering, which break down and dissolve primary minerals. Another factor that is also very supportive is that groundwater will leach minerals to the limit between limonite and saprolite; other factors can be in the form of pH, and topography. Laterite type iron ore is generally found in the peak hills which are relatively sloping or have a slope of less than 10%, making it one of the main factors of iron ore distribution.

Figure 9. The distribution of thickness and grade of Ni-Fe on slope map

4. Conclusion
The results of the study were in the Mangguruh area of Pulau Sebuku sub-district, Kota Baru district, South Kalimantan Province, as follows:
1. The topographic slope of the study area is divided into four (4), namely topography with a large slope of 0-5%, topography with a slope of 5-10%, topography with a slope of 10-15%, and topography with a large slope > 15%.
2. Moderate to high laterite thickness in topography with slopes of 0-5% and 5-10%, while topography with a slope of 10-15% and > 15% has a thickness of thin laterite; this shows that topography is one of the dominant factors affecting the thickness of laterite.
3. Topography is the dominant factor affecting the distribution of nickel in the study area.
4. Distribution of iron ore is dominant in slopes of 0-5%, 5-10%, and > 15%, while low iron ore is at each percentage slope, then topography is an insignificant factor in the distribution of iron ore.

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