Characteristics and Genesis of Laterite Bauxite in Sompak District and Surrounding Areas, Landak Regency, West Kalimantan

by Tri Winarno

Submission date: 17-Mar-2023 09:39AM (UTC+0700)
Submission ID: 2039025014
File name: IJOG_1st_author.pdf (10.12M)
Word count: 5393
Character count: 29215

INDONESIAN JOURNAL ON GEOSCIENCE
Geological Agency
Ministry of Energy and Mineral Resources

Journal homepage: http://ijog.geologi.esdm.go.id
ISSN 2355-9314, e-ISSN 2355-9306

Characteristics and Genesis of Laterite Bauxite in Sompak District and Surrounding Areas, Landak Regency, West Kalimantan

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Manuscript received: November, 6, 2021; revised: February, 14, 2022;
approved: November, 3, 2022; available online: January, 5, 2023

Abstract - West Kalimantan has very large bauxite resources, reaching 2.07 billion tons, equivalent to 57.32% of the total bauxite resources in Indonesia with bauxite reserves of 0.84 billion tons or equivalent to 66.77% of the total national mineral reserves. The researched area covers Sompak District and surrounding areas, Landak Regency, West Kalimantan. This research aims to determine geological conditions, laterization, and characteristics of laterite bauxite in the studied area. Methods used in this research are geological mapping, lateritic mapping, and petrographic and geochemical analyses. The lithology of the researched area is composed of granodiorite, porphyry quartz diorite, granite, porphyry andesite, porphyry basalt, alluvial, and swamp deposits. Laterite profiles in the researched area generally consist of topsoil, latosol, bauxite, and clay zone. The laterite bauxite derived from granodiorite is classified as a medium grade, laterite bauxite from porphyry quartz diorite is classified as high-grade bauxite, laterite bauxite from andesite porphyry is classified as low-medium grade bauxite, and laterite bauxite from porphyry basalt in the studied area is classified as high grade bauxite. Laterite bauxites in the researched area were formed from weathered parent rocks which were intermediate - alkaline igneous rock.

Keywords: laterite bauxite, laterite profile, igneous rocks, Landak Regency

How to cite this article:
Winarno, T., Ali, R. K., Simangunsong, H., and Almiftahurrizqi, 2023. Characteristics and Genesis of Laterite Bauxite in Sompak District and Surrounding Areas, Landak Regency, West Kalimantan. *Indonesian Journal on Geoscience*, 10 (1), p.37-49. DOI: 10.17014/ijog.10.1.37-49

Introduction

Background

Bauxite which is the basic material for producing aluminum, is named after Les Baux Province, a village where the first deposits were discovered. Bauxite contains hydrated alumina equivalent to as much as 40-60% Al_2O_3, and is free of the other siliceous materials leached out over time (Hocking, 2005). Aluminium (Al) is the most widely distributed metal in the environment occurring naturally in the trivalent state (Al^{+3}) as silicates, oxides, and hydroxides, but may combine with other elements such as chlorine, sulphur, fluorine, and form complexes with organic matter (Igbokwe *et al.*, 2019). Aluminum is a metal that is soft in its pure form, but hard when solid, light, resistant to corrosion, and is a good conductor. This makes aluminum widely used as a raw material in the automotive industry, construction materials, and household appliances (Surdia and Saito, 1992).

Globally, of all the world bauxite deposits, more than 80% are laterite bauxite deposits (Gow and Lozej, 1993; Robb, 2005). According to Bardossy (1982), about 14% of the world bauxite production comes from karst bauxite, 85% comes from laterite bauxite, and the remaining 1% comes from allochthonous (transported) bauxite. West Kalimantan has very large bauxite resources, even the largest in Indonesia, reaching 2.07 billion tons, equivalent to 57.32% of the total bauxite resources in Indonesia with bauxite reserves of 0.84 billion tons or equivalent to 66, 77% of the total national mineral reserves (Pusat Data dan Informasi Energi dan Sumber Daya Mineral, 2016).

Bauxite found in Indonesia is laterite bauxite derived from weathering of rocks rich in feldspar minerals. Bauxite in Indonesia is mostly found in tropical-subtropical areas, which includes Bintan Island (Riau Islands), Kota Pinang (North Sumatra), Bangka Belitung, West Kalimantan, and a small part is found in Central Kalimantan, Southeast Sulawesi, Sumba Island, and Halmahera (Allen and Donnithorne, 2013). In Indonesia, bauxite was first discovered in 1924 in Kijang, Bintan Island, Riau Islands. Bauxite found in Bintan Island has been mined and exported since 1935, and was discontinued in 2013 (P.T. ANTAM Tbk., 2019).

Bauxite in Sompak District, Landak Regency, West Kalimantan, is found in igneous rocks from Mensibau Granodiorite Formation. The lithology in the researched area consists of granodiorite, quartz diorite, biotite-hornblende granite, and tonalite. In comparison, the bauxite around the researched area in Tayan District, Sanggau Regency, West Kalimantan, is found in diorite, quartz monzodiorite, quartz diorite and microdiorite pyroxene (Nugraheni *et al*., 2022).

The main problem of this research is to find the laterite bauxite grade in each lithology.

The classification of laterite bauxite in the researched area uses the standards from P.T. ANTAM Tbk. based on the results of physical observations and the geochemical analysis. Based on the results of physical observations, laterite bauxite can be classified into three grades, which are:

a. Low grade that still contains fresh rock or has a quartz content of > 30%.
b. Medium grade that still shows the original rock texture or contains 10%-30% quartz.
c. High grade that no longer shows the original rock texture and is poor in quartz (< 10%).

The classification of laterite bauxite is also based on the cut off grade (COG) value which is adjusted to the needs of a smelter or company. The cut off grade (COG) Al_2O_3 used by P.T. ANTAM Tbk. is 42%. Based on the cut off grade (COG) of Al_2O_3, laterite bauxites can be classified into two groups, which are:

a. High grade that has > 42% Al_2O_3 content.
b. Low grade that has < 42% Al_2O_3 content.

On the basis of its chemical characteristics, there are several main components in bauxite, those are Al_2O_3, Fe_2O_3, SiO_2, and TiO_2. Other components with very small presence consist of FeO, CaO, MnO, MgO, K_2O, Na_2O, and P_2O_5. Silica (SiO_2) in bauxite can be found in the form of the quartz minerals (free quartz/$TSiO_2$) and kaolinite (reactive quartz/$RSiO_2$) (Valeton, 1972). Bauxite has an economic value and is feasible to mine if it has Al_2O_3 content of not less than 45-50%, a relatively small Fe_2O_3 (not more than 20%), and the total silica (SiO_2) of not more than 3-5% (Valeton, 1972). But it is not the same in all conditions.

The researched area is part of the operation mining permit area of P.T. ANTAM Tbk. which covers Sompak District and its surroundings, Landak Regency, West Kalimantan (Figure 1). The study aims to determine the geological conditions, laterization, characteristics, and the genesis of laterite bauxite in the studied area.

Geological/Stratigraphical Settings

The researched area is included into the geological map of Singkawang Sheet (Figure 2). Based on the geological map of Singkawang Sheet (Suwarna and Langford, 1993), the studied area is composed of two formations, which are:

a. The Mensibau Granodiorite Formation (Klm), comprising granodiorite, quartz diorite, biotite-hornblende granite, and tonalite. This formation has an Early Cretaceous-Late Cretaceous age.

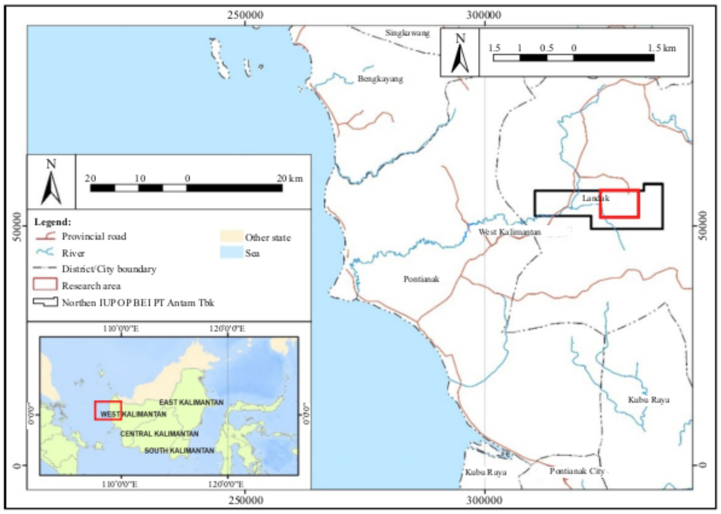

Figure 1. Locality map of researched area (Map source: Geospatial Information Agency, 2018).

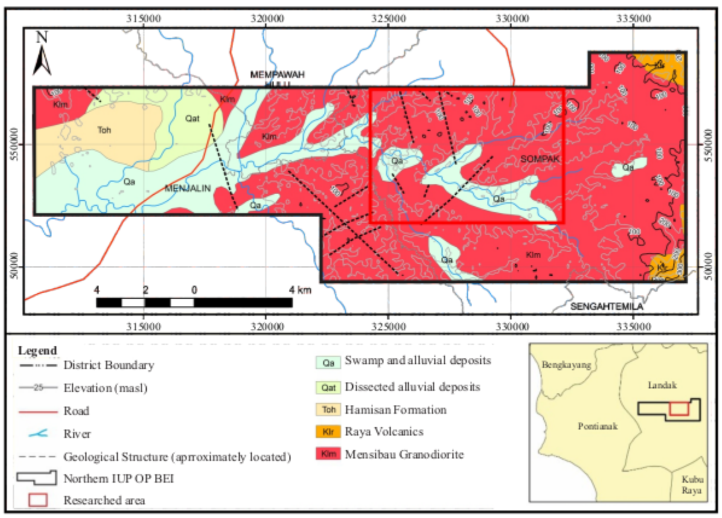

Figure 2. Regional geology map of Singkawang Sheet. The researched area is composed of Mensibau Granodiorite Formation (Klm) and Swamp and Alluvial Deposits (Qa) (after Suwarna and Langford, 1993).

b. Alluvial and Swamp (Qa) deposits that consist of silt, sand, gravel, and plant materials.

The researched area is located in the Southwest Borneo Block (SW Borneo) which is part of the Sunda Shelf (Sundaland). The geological structure in the researched area is controlled by the Mensibau Granodiorite Formation (Klm) which is Singkawang batholith. This formation is thought to have formed as a result of subduction between the South China Sea Proto Plate and the northern part of the Sunda Plain in the Early Cretaceous (Suwarna and Langford, 1993).

A previous study conducted by Ramadhan *et al.* (2014) in the Klenco area, Landak Regency, West Kalimantan, showed that laterite bauxite in the area derived from weathering of Al-rich igneous rock including granodiorite, quartz diorite, and diorite. The study used petrographic and XRF analyses. Thus, it can be hypothesized that the bauxite in the studied area also comes from weathering of Al-rich igneous rocks from the Mensibau Granodiorite Formation.

Methods and Materials

Methods

The methods used in this research are geological mapping, laterite mapping, petrographic analysis, and XRF (X-Ray Fluorescence) analysis.

Geological mapping was carried out to determine the type of lithology in the researched area. During the geological mapping, parent rock samples were taken for petrographic and XRF analyses.

Laterite mapping was performed to identify the laterite profile of the researched area, including laterite soil (latosol), ferricrete, bauxite, and clay zone. In the laterite mapping, laterite samples were also taken, especially bauxite samples and latosol samples for physical and XRF analyses.

Petrographic analysis was conducted to determine the rock description optically. Thin section samples were prepared to identify mineralogical and petrographical characteristics under a polarizing microscope. The rock samples from the researched area were cut and polished to make thin sections. The petrographic analysis was carried out at the Laboratory of Paleontology, Remote Sensing and Optical Geology, at the Geological Engineering Department, Universitas Diponegoro.

The geochemical analysis was executed by using XRF analysis to study the major oxides and trace elements along with their concentrations in the rock deposits using spectrometric methods. Currently, XRF is the most common method of analysis used in the determination of major elements and trace elements on rock samples. It is versatile and can analyze up to eighty elements over a wide range of sensitivities, detecting concentrations from 100% down to a few parts per million (Rollinson, 2014). The results of this analysis were geochemical data comprising the percentages of $TSiO_2$, $RSiO_2$, Al_2O_3, Fe_2O_3, and TiO_2.

Materials

Twelve rock samples were used for petrographic analysis to determine the rock types, and twenty-three laterite samples for the study of physical and XRF analysis of bauxite.

Result and Analysis

Stratigraphy

Based on the field observation, the researched area is composed of intermediate-basic igneous rocks, (from oldest to youngest respectively) they are granodiorite, porphyry quartz diorite, granite, porphyry andesite, and porphyry basalt (Travis, 1955) as well as alluvial and swamp deposits (Figure 3).

Granodiorite

The granodiorite unit covers about 55% of the researched area. From the observation of its physical properties, the rock is white to light grey and has a massive structure (Figure 4). The rock shows phaneritic texture, holocrystalline, subhedral- euhedral crystal form and coarse grain. Based on petrographic observation, the thin section of the rock consists of quartz (25%), plagioclase (andesine, An_{39}) (35%), orthoclase (5%), biotite (20%), and opaque minerals (10%) (Figure 5).

Porphyry Quartz Diorite

The porphyry quartz diorite unit covers about 15% of the researched area. From the observation of its physical properties, the rock is dark grey to black and has a massive structure (Figure 6). The rock shows porphyrytic texture, holocrystalline, subhedral- euhedral crystal form and coarse grain. Based on petrographic observation, the thin section of the rock comprises of quartz (15%), plagioclase (andesine, An_{44}) (50%), biotite (30%), and opaque minerals (5%) (Figure 7).

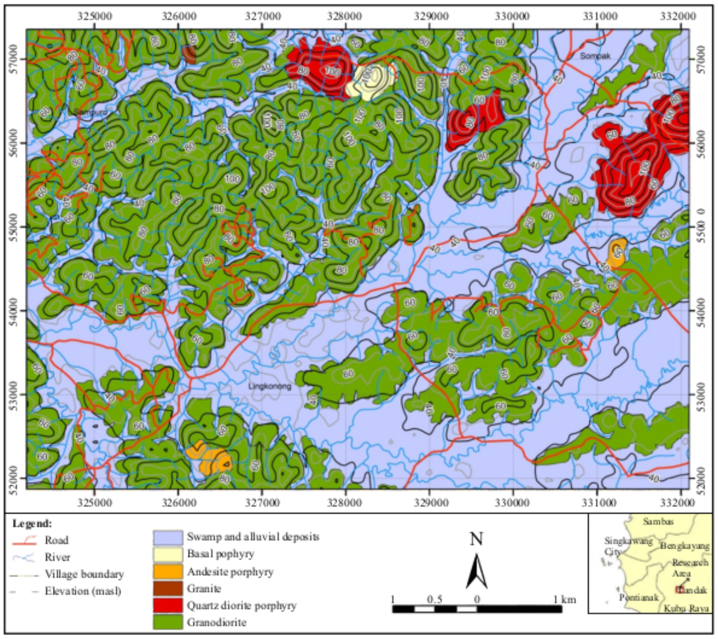

Figure 3. Geological map of the researched area.

Figure 4. (a, b) Outcrops of granodiorite in the researched area; (c) Hand specimen of granodiorite in the researched area.

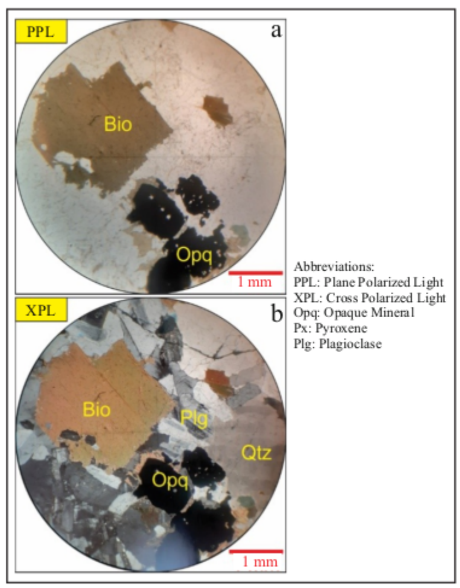

Figure 5. Photomicrographs of thin section of granodiorite, (a) in plane polarized plane and (b) in cross polarized plane.

Granite

The granite unit covers about 2% of the researched area. From the observation of its physical properties, the rock is pink and has a massive structure. The rock shows phaneritic texture,

Figure 6. (a) Outcrop of porphyry quartz diorite in the researched area; (b, c) Hand specimen of porphyry quartz diorite in the researched area.

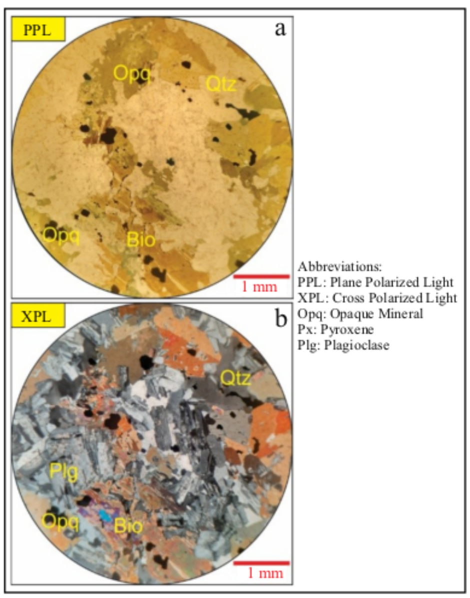

Figure 7. Photomicrographs of thin section of quartz diorite. (a) in plane polarized plane and (b) in cross polarized plane.

holocrystalline, subhedral-euhedral crystal form and coarse grain (Figure 8). Based on petrographic observation, the thin section of the rock is composed of orthoclase (25%), plagioclase (albite, An_6) (15%), quartz (50%), and biotite (10%) (Figure 9).

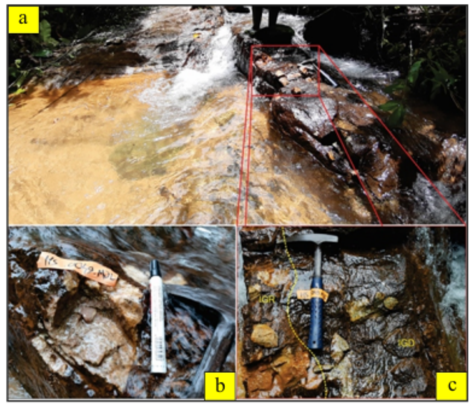

Figure 8. (a, b) Outcrop of granite in the researched area; (c) Contact of granite (IGR) and granodiorite (IGD) in the researched area.

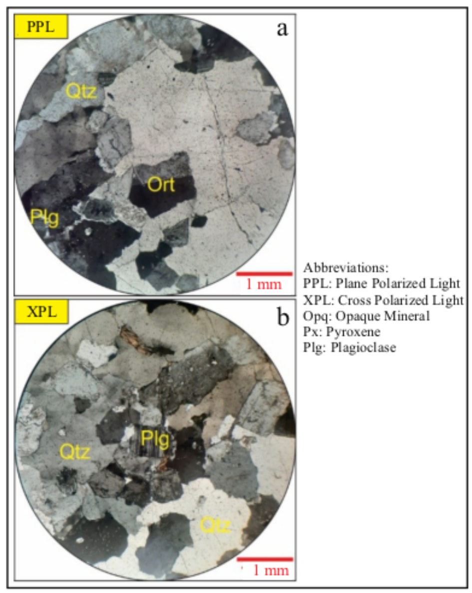

Figure 9. Photomicrograph of thin section of granite. (a) in plane polarized plane and (b) in cross polarized plane.

Porphyry Andesite

The porphyry andesite unit covers about 8% of the researched area. From the observation of its physical properties, the rock is dark grey and has a massive structure (Figure 10). The rock shows porphyritic texture, hypocrystalline, subhedral to euhedral crystal form. In a thin incision, it can also be clearly seen that the boundary

Figure 10. (a) Outcrop of porphyry andesite in the researched area; (b, c) Hand specimen of porphyry andesite in the researched area.

between the minerals (phenocrysts) is quite firm, which varies from subhedral to euhedral. Based on petrographic observation, the thin section of the rock consists of plagioclase (andesine, An_{42}) (25%), orthoclase (2%), hornblende (15%), opaque minerals (3%), and groundmass (55%) (Figure 11).

Porphyry Basalt

The porphyry basalt unit covers about 5% of the researched area. From the observation of its physical properties, the rock is black and has a massive structure (Figure 12). The rock shows porphyritic texture, hypocrystalline. Based on petrographic observation, the thin section of the rock consists of plagioclase (labradorite, An_{54}) (55%), clinopyroxene (20%), opaque minerals (5%), and groundmass (20%) (Figure 13).

Alluvial and Swamp Deposits

The alluvial and swamp deposits unit cover about 15% of the researched area. In general, alluvial and swamp deposits are composed of an accumulation of clay - sand material, rock fragments of gravel-pebble size as a result of the weathered rocks in the studied area (Figure 14).

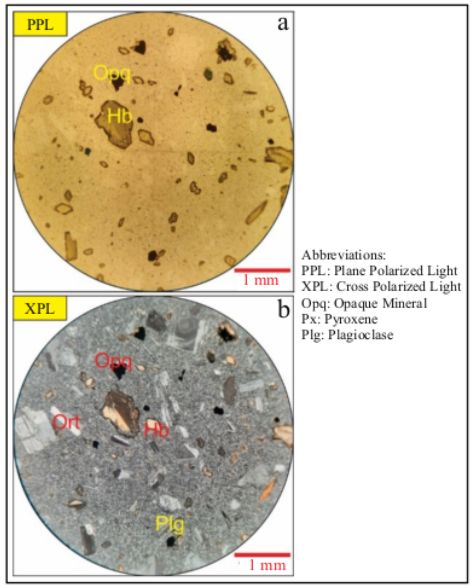

Figure 11. Photomicrographs of thin section of porphyry andesite; (a) in plane polarized plane; and (b) in cross polarized plane.

Characteristics of Laterite Bauxite

Based on the results of laterite mapping, the laterite bauxites in the researched area were found in the parent rock of granodiorite, porphyry quartz diorite, porphyry andesite, and porphyry basalt. The distribution of laterite bauxite in the researched area is shown in Figure 15.

Figure 12. (a, c) Outcrop of porphyry basalt in the researched area; (b) Hand specimen of porphyry basalt in the researched area.

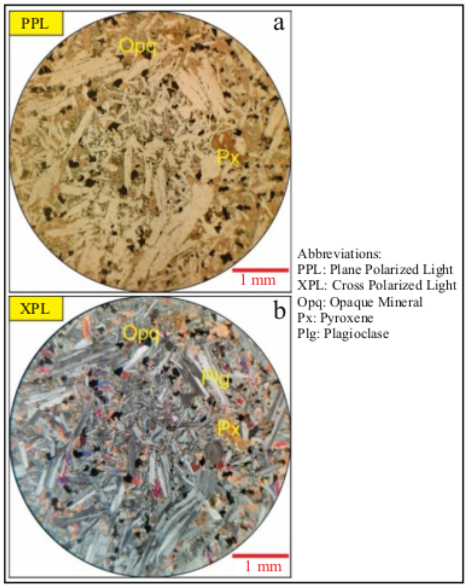

Figure 13. Photomicrographs of thin section of porphyry basalt; (a) in plane polarized plane and (b) in cross polarized plane.

Figure 14. Outcrop of alluvial deposits in the researched area.

Laterite bauxite from granodiorite

Laterite bauxite from granodiorite parent rock still shows the original rock texture due to laterization process that has not occurred optimally (Figure 16). The laterite profiles that can be observed are lateritic soil (latosol), iron layer (ferricrete), bauxite (ore), and horizon or clay layer (kong).

Latosols which occur from granodiorite parent rock generally have a bright colour ranging from yellowish brown to light brown, and generally still contain abundant quartz minerals.

Beneath the latosol, there is generally a relatively thin layer of iron (ferricrete) with the thickness between 1-5 cm. Ferricrete often becomes the boundary between latosol and bauxite (ore). Ferricrete generally has dark brown, reddish brown to red colour, composed of accumulated iron oxides (goethite, hematite).

Beneath the ferricrete, there can be found the bauxite zone. Laterite bauxite from granodiorite origin rocks generally has a light brown to reddish colours, and still contains resistant minerals from original rock, especially quartz. In general, laterite bauxite from granodiorite parent rocks still contains 10 to 30% quartz. In addition, there are also iron oxides (FeOx) such as goethite, hematite, and other clay minerals.

At the bottom of the laterite profile, there is a clay zone (kong) which is the final stage of laterization. This zone is composed of clay material (kaolinite) and is often found abundance of quartz mineral accumulation. The clay (kong) zone of these laterites usually has a pale yellow to white colour.

Based on the XRF analysis, bauxite from granodiorite has a relatively high SiO_2 content (21.88% - 56.59% $TSiO_2$/free quartz and 2.58% - 5.43% $RSiO_2$/ reactive quartz), small Fe_2O_3 content (3.99% - 8.96%), alumina/Al_2O_3 (23.96% - 46.51%), and TiO_2 (0.24% - 0.38%) (Table 1). Based on the characteristics of the bauxite, in general, laterite bauxite from granodiorite is classified as medium grade.

Laterite bauxite from porphyry quartz diorite

The laterite profiles from porphyry quartz diorite parent rock that can be observed are lateritic soil (latosol), iron layer (ferricrete), bauxite (ore), and horizon or clay layer (kong).

Latosols which occur from porphyry quartz diorite parent rock generally have relatively darker colour, from dark brown to reddish brown. In contrast to granodiorite laterite, ferricrete is quite difficult to find in this laterite. The ferricrete occurs as concretions which are accumulations of iron residues.

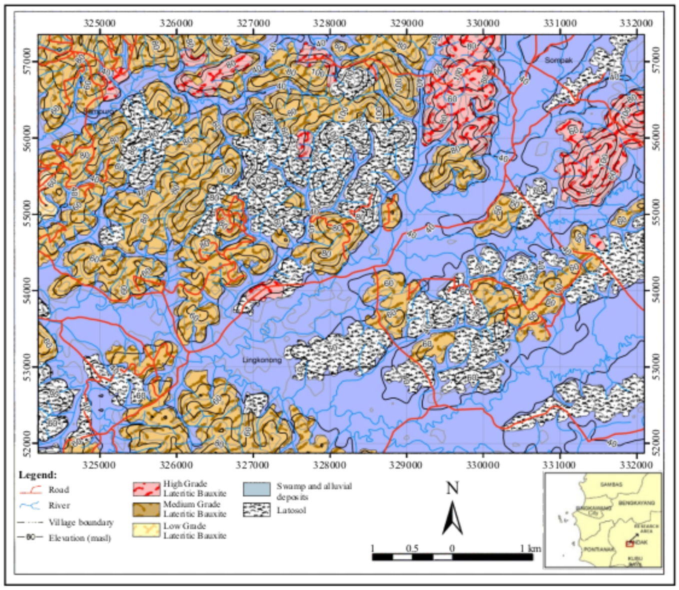

Figure 15. Distribution of laterite bauxite in the researched area.

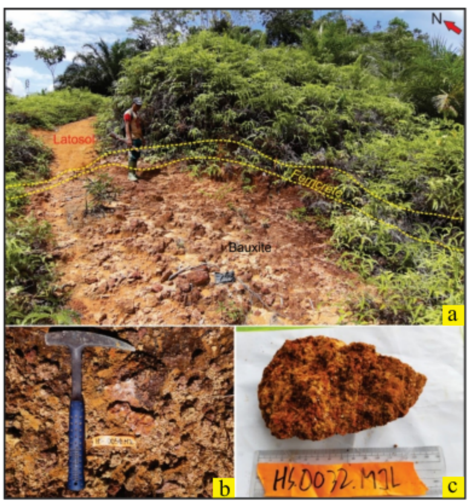

Figure 16. (a) Laterite profile; (b) Outcrop of bauxite zone; and (c) hand specimen of bauxite from granodiorite in the researched area.

In general, the bauxite does not show the original rock texture. The bauxite from diorite quartz porphyry has a light brown to reddish colour (Figure 17), and in general still contains small amounts (< 10%) of quartz (SiO_2).

After the bauxite zone, a clay horizon (kong) can be found as the final result of the laterization process. This zone has a yellowish-brown colour, and generally still contains quartz, but with a relatively fine size.

Based on XRF analysis, bauxite from porphyry quartz diorite contains relatively low $TSiO_2$ (10.85% - 30.92%) and $RSiO_2$ (3.253% - 8.14%), relatively high Fe_2O_3 (5.68% - 14.77%), high alumina (Al_2O_3) (32.2% - 2, 84%), and TiO_2 (0.5% - 1.03%) (Table 1). On the basis of bauxite characteristics, laterite bauxite from porphyry quartz diorite is classified as high grade bauxite.

Table 1. XRF Analysis of Laterite Bauxite of Each Parent Rock

Parent rock	Grade (%)				
	$TSiO_2$	$RSiO_2$	Al_2O_3	Fe_2O_3	TiO_2
Granodiorite	21.88-56.59	2.58-5.43	3.99- 8.96	23.96-46.51	0.24-0.38
Porphyry quartz diorite	10.85-30.92	3.23-8.14	5.68-14.77	32.2-52.84	0.5-1.03
Porphyry andesite	32.65	3.46	6.31	38.99	0.46
Porphyry basalt	16.26-17.96	2.19-3.84	11.1-15.76	40.98-45.5	0.81-1.11

Figure 17. (a) Laterite profile; (b) Outcrop of bauxite zone; and (c) Hand specimen of bauxite from quartz diorite in the researched area.

Laterite bauxite from porphyry andesite

Laterization in porphyry andesite does not occur optimally. Based on field observation, the lateritic soil (latosol) and bauxite concretions are very difficult to find in the researched area. The laterite profiles from porphyry andesite that can be found in the researched area are latosol and laterite bauxite. Bauxite from porphyry andesite has reddish-brown colour, less quartz content (< 10%), but rich in iron oxides (Figure 18).

Based on the XRF analysis, laterite bauxite from porphyry andesite contains $TSiO_2$ (32.65%) and $RSiO_2$ (3.46%), relatively low Fe_2O_3 (6.31%), relatively low Al_2O_3 (38.99%) and TiO_2 (0.46%) (Table 1). Elicited from the characteristics of the bauxite, laterite bauxite from andesite porphyry is classified as low-medium grade bauxite.

Laterite bauxite from porphyry basalt

The laterite profiles found in porphyry basalt are latosol and laterite bauxite. Latosol generally has dark brown colour, and sometimes can still be found the presence of quartz (< 10%). Bauxite from porphyry basalt has dark brown to reddish-brown colour (Figure 19), less quartz content but rich in iron oxides (goethite, hematite) as a result of the oxidation of iron-containing minerals (Fe) which are abundant in porphyry basalt.

On the basis of the XRF analysis, laterite bauxite from porphyry basalt has a relatively low SiO_2 content compared to bauxite from other origin rocks (16.26% - 17.96% $TSiO_2$ and 2.19% - 3.84% $RSiO_2$), high Fe_2O_3 content (11.1% - 15.76%), high alumina (Al_2O_3) content (40.98% - 45.5%), and TiO_2 (0.81% - 1.11%) (Table 1). Assumed from the characteristics of the bauxite, laterite bauxite from porphyry basalt in the studied area is classified as high grade bauxite.

Genesis of Laterite Bauxite

Laterite bauxites in the researched area were formed from weathering of parent rocks which were intermediate-alkaline igneous rock. There are five parent rock units in the researched area, from the oldest to the youngest, namely granodiorite, porphyry quartz diorite, granite, porphyry andesite, and porphyry basalt. All

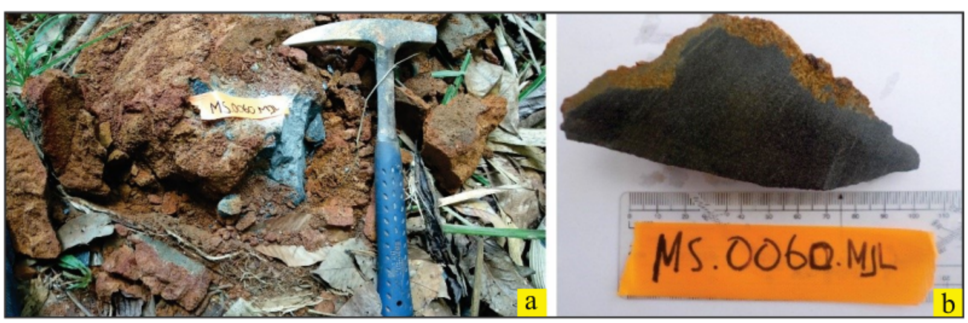

Figure 18. (a) Outcrop of bauxite zone and (b) hand specimen of bauxite.

Figure 19. (a) Laterite profile; (b) Outcrop of bauxite zone; and (c) Hand specimen of bauxite from porphyry basalt in the researched area.

parent rocks in the researched area are aluminosilicate (Al_2SiO_5) rocks, which are rich in feldspar minerals as the main mineral carrier of aluminum (Al) in rocks.

From the laterite mapping, not all parent rocks in the studied area were laterized optimally and produced economic laterite bauxite. The formation of laterite bauxite in the researched area occurs in four parent rocks, they are: granodiorite, porphyry quartz diorite, porphyry andesite, and porphyry basalt. Laterite bauxite with granite origin is not found in the researched area. This is interpreted mainly due to the steep topography of the area with granite parent rock. The steep topography caused vertical erosion to work more dominantly, so that laterization did not run optimally. Thus, making it difficult to find granite laterite outcrops in the researched area.

The various parent rocks continuously underwent weathering process (laterization) for a long time, until finally formed laterite bauxite in the researched area. The weathering process on the parent rocks then produced laterite zones. In general, there are four different laterite zones in the researched area, from top to bottom, comprising top soil, lateritic soil (latosol), ore (bauxite), and clay zone (kong) (Figure 20). The first horizon

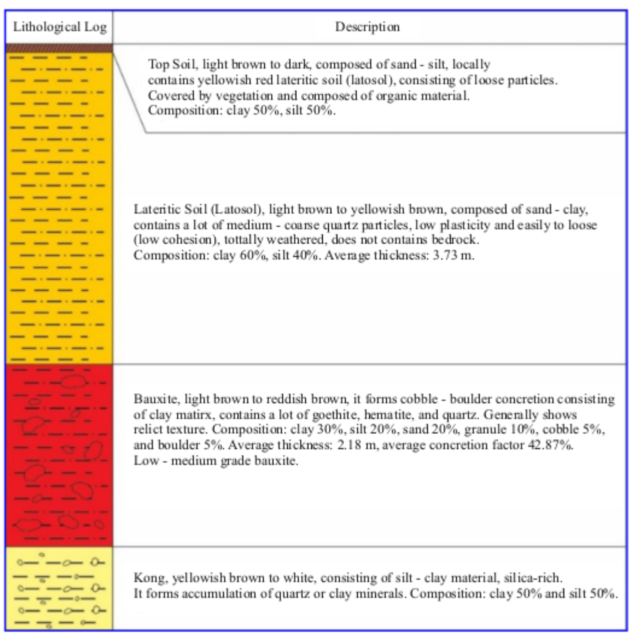

Figure 20. Laterite profile in the researched area.

which is the top layer is top soil. The top soil is a soil horizon that is rich in nutrients and organic matter, and is a zone covered by vegetation.

Beneath the top soil, there is laterite soil (latosol) which generally has a yellowish, brownish, to reddish colour. Latosol is a zone that is rich in silica, as a result of the hydrolysis process of silicate minerals in the parent rocks. This soil is formed because all the nutrients from the alkaline and alkaline earth groups, and also some Si elements have been leached. The hydrolysis reaction causes the release of the Si element from the feldspar, resulting in a reaction for the formation of clay minerals (kaolinite). Kaolinite is also associated with free Si, iron oxide, and aluminum (Al), which are the main constituents of this zone.

Beneath the latosol, generally there is a layer of iron (ferricrete) which is rich in iron oxide minerals. This zone is often found as the boundary between the latosol zone and the ore (bauxite) zone. The oxidation and hydration reactions that occur from iron oxide minerals, are generally in the form of goethite and hematite, and are associated with silica and aluminum. In the studied area, the ferricrete zone can be found in the form of concretions (nodular) or hard layers.

Beneath the ferricrete, there is a layer where the aluminum (Al) content will reach its maximum. This zone is an accumulation zone of bauxite-forming mineral concretion (gibbsite, boehmite, diaspore), with various thickness as a result of the enrichment of aluminum (Al) residues. Bauxite is formed as a result of the separation between aluminum (Al) and silica. The separation of aluminum and silica occurs in two stages. The first stage is the process of forming kaolinite ($Al_2(OH)_4Si_2O_5$) from weathering of feldspar. If kaolinite undergoes hydrolysis again which results in the loss of silica (desilication), there will be the formation of aluminum hydroxide minerals, namely gibbsite ($Al[OH]_3$). This aluminum hydroxide mineral (gibsite) is associated with iron oxide minerals (goethite, hematite) and clay minerals (kaolinite) to form an ore zone (bauxite).

Beneath the ore (bauxite) zone, there is another zone rich in silica (Si) in the form of a layer of clay (kaolinite) as the final stage of laterization known as clay zone (kong). This zone was formed due to the relatively slow water circulation, so that dissolved silica in the early stages of diagenesis will undergo a resilication reaction in the aluminum hydroxide mineral (gibsite), forming a layer of clay (kaolinite) which is rich in silica (Si). The kong zone is usually formed below the permanent groundwater table. In rock bodies that are submerged by groundwater, poor water circulation causes disruption of the leaching or desilication process, so that the dominant reaction is the formation of clay minerals (kaolinite) which is the main material in the clay zone (kong) layer.

Conclusions

The lithology in the researched area is composed of granodiorite, porphyry quartz diorite, granite, porphyry andesite, porphyry basalt, as well as alluvial and swamp deposits. The formation of laterite bauxite in the researched area occurs in four parent rocks: granodiorite, porphyry quartz diorite, porphyry andesite, and porphyry basalt. There are four different laterite zones in the researched area, from top to bottom: top soil, lateritic soil (latosol), ore (bauxite), and clay zone (kong). The laterite bauxite from granodiorite is classified as medium grade, laterite bauxite from porphyry quartz diorite is classified as high grade bauxite, laterite bauxite from andesite porphyry is classified as low-medium grade bauxite, and laterite bauxite from porphyry basalt in the researched area is classified as high grade bauxite.

Acknowledgments

The authors wish to thank Universitas Diponegoro, especially to Faculty of Engineering that has supported the research fund. The authors also thank the support of P.T. ANTAM Tbk. Unit Geomin, IUP OP BEI Utara for allowing the authors to get the data.

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