

Mineralogical and Geochemical Characterization of the Paranas Karst Bauxite Deposit, Samar Island, Philippines

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<https://doi.org/10.71659/icsoba2024-bx001>

Abstract

Bauxite is a residual soil resulting from intense tropical weathering of rocks rich in aluminium oxide. It is the most important source of aluminium and is recently tapped as potential source of rare earth elements (REEs). The Philippines holds substantial bauxite deposits on Samar Island, which were declared as bauxite mining reservation sites by Presidential Proclamation in 1977. Of these reservation sites, the Paranas bauxite deposit being developed by Alumina Mining Philippines Inc., is in the most advanced stage of exploration, with numerous test pit and drill core data available. This study aims to describe the mineralogical and geochemical characteristics of the Paranas bauxites.

The bauxites in Paranas are recognized by their orange-brown clayey soil, with minor disseminations coarse black manganese particles. X-ray diffraction analysis have shown the major mineral components to be gibbsite, boehmite, goethite, lepidocrocite, cristobalite, and anatase. This study identified two types of bauxite within the area: lateritic bauxite and karst bauxite. The former arising from in situ weathering of mafic sedimentary rocks, and the latter originating from the weathering of basalts and their subsequent deposition in limestone cavities in karst landscapes. The karst bauxites, found in the southwestern area, contain higher aluminium content (>35 wt %) than the lateritic bauxites located in the northwest. The Paranas bauxites are characterized by high levels of Fe₂O₃, SiO₂, and P₂O₅. Furthermore, REE concentrations reach up to 700 ppm in the karst bauxites. The ongoing study on mineral chemistry intends to map out the elemental distribution across different soil and mineral phases within these deposits, further advancing our knowledge of this essential geological resource.

Keywords: Paranas Bauxite, Mineralogy, Geochemical characteristics, Philippines

1. Introduction

Bauxites are clay-like sediments formed due to the weathering of rocks rich in alumino-silicate minerals. They are the major ore of aluminum, consisting primarily of the crystalline alumina minerals gibbsite, boehmite and diasporite [1]. Recent studies have also identified the potential of bauxite for extracting rare earth elements (REE) and other minor elements like vanadium, scandium, gallium, lithium, and molybdenum [2,3]. In selected countries, producing REE as a by-product of large-scale aluminum production from bauxite is seen as a cost-effective solution that results in a smaller environmental footprint [4].

In the Philippines, the majority of bauxite deposits are located on Samar Island (Figure 1), which was designated as a bauxite mining reservation by a 1977 Presidential Proclamation. Among the

areas identified for bauxite extraction on Samar, the deposit in Paranas managed by Alumina Mining Philippines Inc. is the most advanced in terms of exploration with numerous historical drill data available. This study focuses on the mineralogical and geochemical characteristics of the Paranas bauxite deposit. The results of this study will hopefully contribute to the evaluation of its potential for REE by-product extraction.

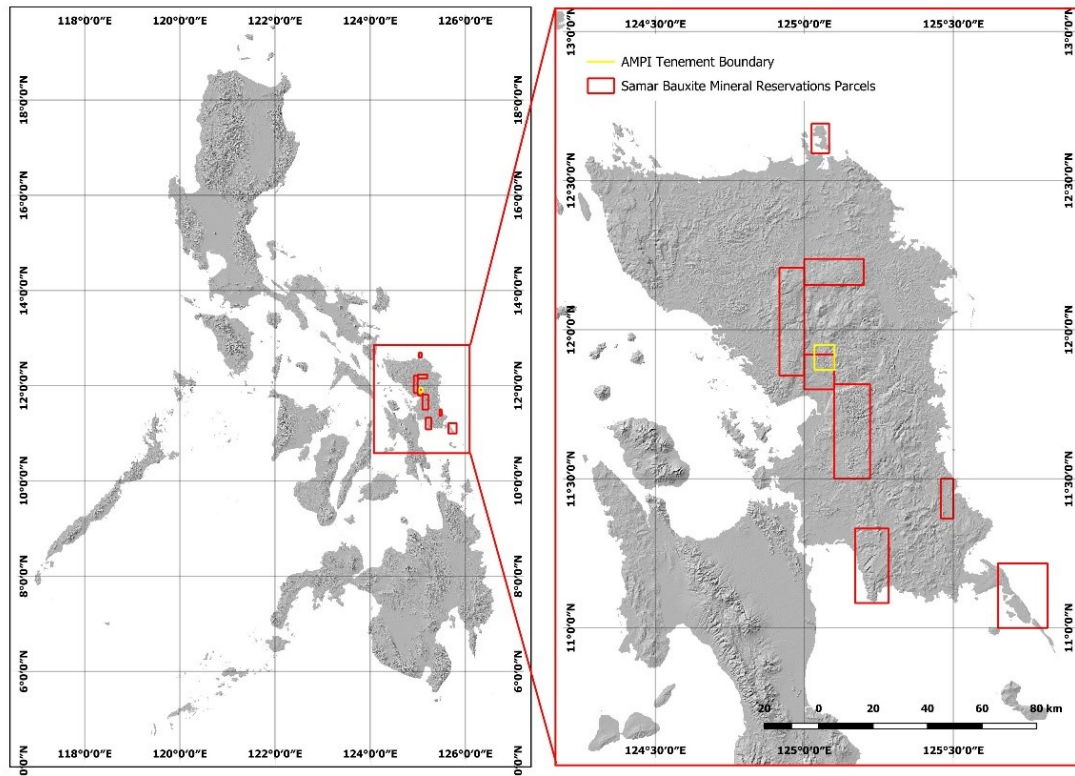


Figure 1. Map showing the tenement boundary of Alumina Mining Philippines Inc. (yellow) in Samar Island, Philippines where the Paranas bauxite deposit is located.

2. Geologic Setting

Samar Island is located in the central portion of the Philippines, bounded by the west-dipping subduction of the Philippine Sea Plate (PSP) beneath the Philippine Mobile Belt (PMB). In the western portion of Samar Island, the sinistral Philippine Fault Zone (PFZ) can be seen transecting the island of Leyte [5]. The basement rocks in the island are the Jurassic to Paleogene ophiolitic rocks that originated from the subduction of the proto-Philippine Sea Plate along the eastern margin of the Philippines [6]. Overlying the ophiolitic units are arc-derived clastic rocks and carbonates [7].

In the study area of Paranas, the oldest rocks consist of Late Cretaceous basaltic pillow lavas as well as blocky and amygdaloidal lava flows. Overlying these igneous rocks are Late Cretaceous interbedded sandstones, calcareous mudstones, and orthoconglomerates. These gently dipping clastic units are primarily composed of volcanic and mineral fragments, along with an abundance of shell fragments. Middle Miocene limestone units overlie the Late Cretaceous sedimentary rocks. The limestone is marly and contains abundant fossils of bivalve shell fragments, benthic foraminifera and other bioclasts cemented by sparry calcite. The limestone served as an ideal depositional site for the weathered products of the nearby aluminium-rich volcanic and clastic units [8].

3. Bauxite Characteristics

Two types of bauxite deposits were identified in Paranas, Samar: lateritic and karst. The lateritic bauxite occurs as red-brown soil with medium-grained rock and mineral fragments of manganese, quartz, and clay particles. It is found in areas with higher elevation (300-400 masl) in Paranas, unconformably overlying the interbedded sandstone-siltstone sequences. On the other hand, the karst bauxite in Paranas occurs between the peaks of karst hills, with limestone serving as the bedrock of the deposit. These deposits are found in sinkhole basins at lower elevations (<200 masl), with profiles reaching depths of up to 14 meters. Karst bauxites are characterized by massive, homogenous orange-brown clay soil with few coarse-grained manganese nodules, especially in the upper portion of the soil profile. There are no significant changes in appearance with depth. Of the two bauxite types, the lateritic bauxite contains relatively lower aluminium grades (<35% Al_2O_3) compared to karst bauxites. In this paper, we focus on the data on karst bauxites in the study area.

Based on aluminium oxide content, the karst bauxites were classified as low grade (< 44 wt.% Al_2O_3), medium grade (44-47 wt.% Al_2O_3), and high grade (> 47 wt.% Al_2O_3). Data from X-ray fluorescence analysis show no significant variability in major oxide composition within the first four meters of the test pit soil profiles (Table 1). In addition to aluminium oxide, bauxite also contains elevated concentrations of Fe_2O_3 , SiO_2 , and P_2O_5 . In terms of rare earth element concentration, low-grade bauxite has an average total REE+Sc+Y of 328 ppm, while medium grade bauxite has an average of 469 ppm. The high-grade bauxite has the highest REE concentration of 722 ppm.



Figure 2. Field occurrence of the bauxite in Paranas, Samar, Philippines.

Minerals identified from X-ray diffraction analyses show that the karst bauxite is mainly composed of gibbsite ($\text{Al}(\text{OH})_3$), boehmite ($\text{AlO}(\text{OH})$), goethite ($\text{FeO}(\text{OH})$), lepidocrocite (γ - $\text{FeO}(\text{OH})$), cristobalite (SiO_2), and anatase (TiO_2) [9]. Automated mineral chemistry analysis of karst bauxite soils reveals that over 98 wt.% of the soil is AlOFe with minor $\text{Fe}(\text{Al})\text{O}$, but the exact mineralogy could not be detected due to the amorphous nature of the soils. Trace amount

of crystalline phases identified are quartz, anatase, ilmenite, and ulvospinel. Further analyses are ongoing to map out the elemental distribution across different phases within these deposits.

Table 1. Major oxide composition of the karst bauxite from representative low grade (T1LG), medium grade (T2MG), and high grade (T4HG) test pit samples.

Sample name	Al ₂ O ₃ (wt.%)	Fe ₂ O ₃ (wt.%)	SiO ₂ (wt.%)	TiO ₂ (wt.%)	MnO (wt.%)	P ₂ O ₅ (wt.%)	MgO (wt.%)	CaO (wt.%)	Na ₂ O (wt.%)	K ₂ O (wt.%)
T1LG (0-1m)	37.59	22.01	18.52	1.82	0.17	0.4	0.44	0.17	0.01	0.005
T1LG (1-2m)	34.95	20.73	24.14	1.72	0.27	0.47	0.53	0.18	0.011	0.036
T1LG (2-3m)	38.51	22.82	14.71	1.86	0.23	0.52	0.40	0.19	0.01	0
T1LG (3-4m)	36.29	21.43	21.52	1.77	0.14	0.42	0.49	0.17	0.01	0.021
T2MG (0-1m)	44.18	23.92	2.47	2.0	0.54	0.46	0.26	0.19	0.003	0
T2MG (1-2m)	45.41	24.55	1.77	2.08	0.49	0.42	0.23	0.17	0.002	0
T2MG (2-3m)	45.55	25.67	1.25	2.17	0.27	0.4	0.22	0.16	0	0
T2MG (3-4m)	45.35	25.32	1.07	2.13	0.29	0.35	0.22	0.14	0.001	0
T4HG (0-1m)	47.04	22.55	3.16	2.30	0.53	2.28	0.25	0.47	0.012	0
T4HG (1-2m)	47.53	22.78	2.75	2.34	0.55	2.28	0.23	0.46	0.01	0
T4HG (2-3m)	47.38	23.15	3.02	2.34	0.38	2.12	0.23	0.42	0.009	0
T4HG (3-4m)	47.58	23.13	3.63	3.63	0.32	2.05	0.24	0.41	0.01	0

4. Conclusions

The bauxite deposit in Paranas is associated with interbedded clastic sequences and limestone hills in the area. The bauxite is classified into lower grade lateritic bauxite in the higher elevations and karst bauxite located in the depressions between the karst hills. The karst bauxite is further classified into low grade, medium grade, and high grade based on the aluminium content. Aside from the dominance of Al₂O₃, there is also elevated concentrations of Fe₂O₃, SiO₂ and P₂O₅. The medium grade and high grade karst bauxite contain an average of 46.25 % Al₂O₃ and 2.39 % SiO₂, respectively, suggesting potential for commercial mining, particularly when compared to the typical grade of Guinean bauxite, which averages 45 % Al₂O₃ and 3 % SiO₂.

Rare earth element content of the high-grade bauxite are up to 700 ppm. Further analysis is underway to identify the specific mineral phases associated with REE enrichment. Current metallurgical studies aim to evaluate methods for commercially extracting these REEs, thereby enhancing the overall value of the deposit.

There is no major variability in the geochemical content within the first four meters of the various bauxite profiles. Predominant minerals in the Paranas bauxite include aluminum hydroxides (boehmite and gibbsite), iron oxides (goethite and lepidocrocite), silica (cristobalite), and titanium oxides (anatase). Future mineralogical investigations will focus on quantifying gibbsite and

boehmite, while analytical studies will assess the total organic content of the deposit. These efforts aim to further characterize the Paranas bauxite and confirm its commercial potential.

5. References

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