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# Analysis of Bauxite by X-Ray Fluorescence: Mineralogical Study of the Boffa Deposits

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## Abstract

This study investigates the chemical and mineralogical composition of bauxite samples from five operating sites in Boffa, Guinea, aiming to assess their quality and suitability for alumina production using the Bayer process. The researchers employed X-ray fluorescence (XRF) to determine elemental composition after calcination and fusion with lithium borates. The results indicate that the Boffa bauxites are high in alumina (34.28% - 54.02% $Al_2O_3$) and low in silica (0.98% - 7.29% $SiO_2$), suggesting high quality and economic viability.

## Keywords

X-Ray Fluorescence, Boffa, Bauxite, Mineralogy, B-Quant

## 1. Introduction

Guinea has the world's largest reserves of bauxite, the ore used to produce aluminum, and its subsoil contains more than a third of these. These reserves are mainly located in the following regions: Lower Guinea (Boké, Kindia, Fria, Boffa), Middle Guinea, in the Fouta-Djalon massif (Tougué, Pita, Mali, Mamou, Dalaba) and Upper Guinea (Dinguiraye, Dabola, Siguiri). With a high alumina content, Guinean reserves are estimated at more than 40 billion tons, including 25 billion concentrated in the province of Boké [1].

### Study Area

The prefecture of Boffa, where the samples were taken, is an administrative subdivision of the province of Boké. It covers an area of 6003 km$^2$ and is 150 km from Conakry. Boffa had 211,063 inhabitants in 2018, according to the National Institute of Statistics. Located along the Atlantic Ocean on the Conakry-Boké axis, it is crossed by the Fatala River. Eight (8) sub-prefectures make up it: Koba, Lisso, Kolia, Mankounta, Tougnifily, Doujrou, Tamita and Boffa Centre. It is bordered to the north by the prefectures of Boké and Télémélé, to the east by the prefecture of Fria, to the south by the prefecture of Dubréka and to the west by the Atlantic Ocean.

For several years, this locality rich in bauxite has experienced an unprecedented mining boom and is home to many mining companies, including: Alufer, China Power Investment, TBEA, Chalco Mining, Axis Minéral, and Eurasian.

Eleven (11) mining companies hold exploration and exploitation permits there. Four (4) companies have already set up in (5) five rural communes including: Bel Air Mining in Doupourou and Tougnifily, which began production in 2018; Chalco in Tamita. China State Power Corporation (SPIC), ex-CPI, in Doupourou and Koliah, and Eurasian on the ore transport corridor in Lisso and Tamita whose ore quay is in Kokaya in Tamita [2].

From a technical and economic point of view, the quality of bauxites depends essentially on their alumina ($Al_2O_3$) and silica ($SiO_2$) content. The more alumina and the less silica bauxite contain, the greater their economic and industrial values [3]. The $Al_2O_3$ content, a criterion for the quality and economic value of bauxite, directly influences the yield of the BAYER process, the main industrial approach for extracting alumina from bauxite; gibbsite and diaspore ores are more interesting than boehmite ores in terms of processing cost [4].

The composition of the bauxite, the level of impurities in the liquor and the optimal consumption of caustic soda determines the efficiency of the refinery. Thus, precise analyses of the $Al_2O_3$ content, its mineralogical form, and the impurities of the bauxite are essential for the evaluation of the deposits, which optimizes the exploitation of the mine and the management of the refinery. The lack of scientific data on bauxite indices makes their valorization difficult [5] [6]. The present work aims at the chemical and mineralogical study of samples of bauxite materials from Boffa.

Nowadays, there are several analytical methods for determining the quality of bauxite. In the methodology section, we will briefly present those implemented in this study.

This study provides valuable baseline information on the chemical and mineralogical composition of these bauxites, which is essential for resource evaluation, process optimization, and economic development decisions. The study contributes to a better understanding of bauxite resources in Guinea, which is crucial given the country's substantial reserves and global importance in aluminum production.

## 2. Methodology

### 2.1. Analytical Methods

#### 2.1.1. Collection, Preparation of Samples and Materials

The samples were taken from five (5) operating sites on bauxite stocks formed after blasting or the use of "surface mining".

These samples were prepared in the laboratory by crushing, quartering, drying, grinding, pulverizing, homogenizing, and distributing them into polyethylene and codified bottles.

Materieals: personal protective equipment, plastic bags, markers, shovels, common laboratory materials, reagents (lithium bromide LiBr, lithium tetraborate and metaborate 35% $Li_2B_4O_7$ - 65% $LiBO_2$).

### 2.1.2. Chemical Analyses

**1) X-ray fluorescence**

**Principle: Fused cast-bead method**

- Calcination of a test portion (5g) of the sample at 1000˚C in a thermogravimetric oven and determination of the loss on ignition (LOI) as a percentage of the mass loss, corresponding to the volatile elements (water + organic matter).
- Fusion of a portion of the calcined sample (1g) with a suitable flux, lithium meta and tetraborate ($Li_2B_4O_7$) to destroy its mineralogical and particulate composition.
- Casting of the molten mixture in the form of a vitrified bead which is introduced into an X-ray fluorescence spectrometer.
- Irradiation of beads with X-rays and measurement of the fluorescent (secondary) X-ray intensities of the required elements present in the bead and determination of the chemical composition of the sample by reference to calibration curves previously established based on beads produced from pure reagents and/or reference materials, prepared in a manner analogous to the samples or certified reference materials. The concentration of the element is proportional to the intensity of the radiation [5].

**2) Phase estimation by B-Quant**

**Principle**

B-Quant is an expert system that, from regression lines and hypotheses based on knowledge of the behavior of bauxite elements in the BAYER process, established ratios and XRF analysis results, estimates the mineralogical phases [5]. Its results have been validated by comparison with those of wet chemistry and diffractometry (mineralogy).

For all these methods, the results of the standards that accompany the unknown samples, compared to the certified values for each element, ensure that the analysis processes of our samples are under control.

This equipment was used to produce the analysis results:

- Sample preparation: test bases, ovens, jaw crusher, risk crusher divider, broom pulverizer, rotary homogenizer, distributor, sieve set.
- LOM: thermogravimetric ovens (TGA), computer and specific software.
- Glass beads: fluxers, computer and specific software.
- Spectrometer: XPW 2404 X-ray spectrometer, computer, specific software.
- B-Quant: B-Quant software version 98, from Alcan computer, database.

**Results and Discussion**

Table 1 shows the X-ray fluorescence test results of the bauxite samples. Loss

**Table 1.** Results of XRF analyses based on nature.

| ID | DATE | HEURE | MINUTE | LOI | $SiO_2$ | $TiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | ALDIFF | $P_2O_5$ | $K_2O$ | CaO | $V_2O_5$ | MnO | $ZrO_2$ | $Cr_2O_3$ | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 240527020 | 27-May-24 | 14 | 39 | 20.27 | 0.98 | 1.78 | 42.03 | 34.28 | 34.95 | 0.23 | 0.01 | 0.05 | 0.13 | 0.02 | 0.05 | 0.09 | 99.90 |
| 240527021 | 27-May-24 | 14 | 40 | 21.21 | 1.93 | 2.15 | 36.88 | 37.28 | 37.83 | 0.11 | 0.02 | 0.02 | 0.11 | 0.01 | 0.08 | 0.09 | 99.89 |
| 240527022 | 27-May-24 | 14 | 41 | 27.13 | 1.05 | 2.32 | 18.76 | 50.32 | 50.75 | 0.09 | 0.01 | 0.01 | 0.10 | 0.01 | 0.07 | 0.08 | 99.95 |
| 240527023 | 27-May-24 | 14 | 41 | 23.35 | 1.23 | 2.04 | 31.52 | 41.35 | 41.86 | 0.13 | 0.01 | 0.02 | 0.12 | 0.02 | 0.06 | 0.09 | 99.94 |
| 240527024 | 27-May-24 | 14 | 42 | 22.08 | 5.15 | 2.81 | 30.83 | 38.58 | 39.14 | 0.19 | 0.01 | 0.02 | 0.13 | 0.03 | 0.06 | 0.05 | 99.92 |
| 240527025 | 27-May-24 | 14 | 43 | 25.56 | 3.25 | 2.49 | 20.78 | 47.46 | 47.92 | 0.13 | 0.01 | 0.01 | 0.09 | 0.01 | 0.05 | 0.09 | 99.93 |
| 240527026 | 27-May-24 | 14 | 43 | 24.95 | 3.45 | 2.32 | 22.66 | 46.14 | 46.62 | 0.15 | 0.01 | 0.04 | 0.08 | 0.01 | 0.04 | 0.06 | 99.91 |
| 240527027 | 27-May-24 | 14 | 44 | 24.54 | 3.32 | 2.46 | 23.69 | 45.53 | 45.99 | 0.14 | 0.01 | 0.02 | 0.09 | 0.02 | 0.04 | 0.06 | 99.92 |
| 240527028 | 27-May-24 | 14 | 45 | 24.85 | 2.61 | 2.69 | 23.60 | 45.79 | 46.25 | 0.12 | 0.01 | 0.04 | 0.08 | 0.02 | 0.05 | 0.06 | 99.92 |
| 240527029 | 27-May-24 | 14 | 45 | 24.97 | 3.59 | 2.47 | 20.84 | 47.67 | 48.14 | 0.15 | 0.01 | 0.05 | 0.07 | 0.01 | 0.04 | 0.05 | 99.91 |
| 240527030 | 27-May-24 | 14 | 46 | 28.03 | 1.45 | 2.61 | 14.93 | 52.59 | 52.98 | 0.08 | 0.03 | 0.02 | 0.08 | 0.03 | 0.04 | 0.05 | 99.94 |
| 240527031 | 27-May-24 | 14 | 47 | 18.65 | 6.42 | 1.71 | 42.38 | 30.12 | 30.85 | 0.18 | 0.02 | 0.02 | 0.15 | 0.06 | 0.04 | 0.21 | 99.96 |
| 240527032 | 27-May-24 | 14 | 47 | 24.02 | 2.44 | 2.07 | 28.67 | 42.25 | 42.80 | 0.12 | 0.01 | 0.01 | 0.11 | 0.02 | 0.05 | 0.14 | 99.92 |
| 240527033 | 27-May-24 | 14 | 48 | 23.01 | 2.57 | 2.02 | 31.09 | 40.71 | 41.31 | 0.13 | 0.01 | 0.02 | 0.11 | 0.04 | 0.05 | 0.15 | 99.91 |
| 240527034 | 27-May-24 | 14 | 49 | 21.49 | 1.31 | 2.28 | 38.47 | 35.84 | 36.45 | 0.15 | 0.01 | 0.03 | 0.11 | 0.04 | 0.08 | 0.09 | 99.91 |
| 240527035 | 27-May-24 | 14 | 49 | 27.13 | 1.60 | 2.30 | 17.66 | 50.88 | 51.31 | 0.10 | 0.02 | 0.02 | 0.08 | 0.03 | 0.06 | 0.07 | 99.94 |
| 240527036 | 27-May-24 | 14 | 50 | 24.22 | 1.86 | 2.24 | 26.67 | 44.53 | 45.01 | 0.14 | 0.01 | 0.01 | 0.08 | 0.02 | 0.07 | 0.09 | 99.94 |
| 240527037 | 27-May-24 | 14 | 51 | 24.66 | 1.21 | 2.13 | 28.01 | 43.44 | 43.98 | 0.14 | 0.01 | 0.01 | 0.10 | 0.04 | 0.06 | 0.12 | 99.95 |
| 240527038S | 27-May-24 | 14 | 51 | 25.66 | 1.90 | 3.04 | 19.54 | 49.25 | 49.86 | 0.17 | 0.02 | 0.02 | 0.12 | 0.02 | 0.06 | 0.10 | 99.91 |
| 240527039 | 27-May-24 | 14 | 53 | 19.96 | 0.98 | 1.61 | 41.88 | 34.84 | 35.58 | 0.19 | 0.00 | 0.03 | 0.14 | 0.03 | 0.07 | 0.14 | 99.87 |
| 240527040 | 27-May-24 | 14 | 53 | 17.13 | 2.40 | 1.42 | 52.12 | 26.07 | 26.93 | 0.18 | 0.04 | 0.01 | 0.18 | 0.03 | 0.09 | 0.22 | 99.89 |
| 240527041 | 27-May-24 | 14 | 54 | 21.80 | 1.91 | 2.46 | 34.60 | 38.64 | 39.24 | 0.10 | 0.01 | 0.03 | 0.14 | 0.04 | 0.06 | 0.14 | 99.91 |
| 240527042 | 27-May-24 | 14 | 55 | 25.56 | 1.45 | 2.50 | 23.34 | 46.70 | 47.15 | 0.09 | 0.01 | 0.02 | 0.10 | 0.03 | 0.04 | 0.12 | 99.96 |
| 240527043 | 27-May-24 | 14 | 55 | 20.94 | 1.34 | 2.70 | 38.95 | 35.41 | 36.08 | 0.17 | 0.00 | 0.01 | 0.12 | 0.09 | 0.05 | 0.14 | 99.91 |
| 240527044 | 27-May-24 | 14 | 56 | 24.06 | 2.43 | 2.69 | 25.60 | 44.72 | 45.22 | 0.09 | 0.01 | 0.02 | 0.13 | 0.04 | 0.05 | 0.11 | 99.94 |
| 240527045 | 27-May-24 | 14 | 57 | 20.53 | 1.25 | 1.98 | 38.96 | 36.80 | 37.28 | 0.11 | 0.01 | 0.01 | 0.10 | 0.03 | 0.05 | 0.10 | 99.93 |
| 240527046 | 27-May-24 | 14 | 57 | 24.54 | 2.07 | 2.91 | 25.72 | 44.21 | 44.76 | 0.10 | 0.01 | 0.02 | 0.15 | 0.04 | 0.04 | 0.14 | 99.95 |
| 240527047 | 27-May-24 | 14 | 58 | 24.23 | 7.21 | 2.13 | 21.21 | 44.70 | 45.23 | 0.11 | 0.10 | 0.01 | 0.08 | 0.03 | 0.04 | 0.08 | 99.93 |
| 240527048 | 27-May-24 | 14 | 59 | 26.08 | 5.41 | 2.25 | 17.56 | 48.18 | 48.71 | 0.09 | 0.13 | 0.01 | 0.07 | 0.02 | 0.05 | 0.07 | 99.92 |
| 240527049 | 27-May-24 | 14 | 59 | 26.17 | 5.49 | 2.13 | 17.48 | 48.25 | 48.74 | 0.09 | 0.12 | 0.01 | 0.07 | 0.02 | 0.04 | 0.07 | 99.93 |
| 240527050 | 27-May-24 | 15 | 00 | 24.69 | 5.88 | 2.26 | 21.96 | 44.61 | 45.21 | 0.12 | 0.16 | 0.02 | 0.08 | 0.02 | 0.04 | 0.08 | 99.92 |
| 240527051 | 27-May-24 | 15 | 01 | 23.73 | 7.29 | 2.07 | 22.34 | 43.92 | 44.56 | 0.12 | 0.21 | 0.02 | 0.08 | 0.01 | 0.04 | 0.07 | 99.90 |
| 240527052 | 27-May-24 | 15 | 01 | 25.30 | 3.74 | 2.01 | 23.20 | 45.23 | 45.75 | 0.13 | 0.09 | 0.01 | 0.08 | 0.01 | 0.05 | 0.09 | 99.94 |
| 240527053 | 27-May-24 | 15 | 02 | 28.85 | 0.86 | 2.75 | 14.23 | 52.98 | 53.31 | 0.08 | 0.01 | 0.01 | 0.09 | 0.01 | 0.04 | 0.06 | 99.96 |
| 240527054 | 27-May-24 | 15 | 03 | 25.00 | 4.39 | 2.13 | 22.26 | 45.80 | 46.22 | 0.10 | 0.01 | 0.01 | 0.10 | 0.01 | 0.05 | 0.08 | 99.94 |
| 240527055 | 27-May-24 | 15 | 03 | 27.54 | 1.53 | 2.11 | 17.98 | 50.47 | 50.85 | 0.08 | 0.01 | 0.02 | 0.08 | 0.01 | 0.03 | 0.06 | 99.92 |
| 240527056 | 27-May-24 | 15 | 04 | 26.66 | 2.21 | 2.05 | 17.96 | 50.71 | 51.12 | 0.09 | 0.01 | 0.01 | 0.09 | 0.01 | 0.04 | 0.09 | 99.92 |
| 240527057S | 27-May-24 | 15 | 05 | 25.72 | 1.86 | 3.03 | 19.50 | 49.30 | 49.89 | 0.17 | 0.02 | 0.02 | 0.12 | 0.02 | 0.06 | 0.10 | 99.92 |
| 240527058 | 27-May-24 | 14 | 52 | 28.17 | 2.08 | 2.63 | 12.77 | 54.02 | 54.35 | 0.07 | 0.03 | 0.02 | 0.08 | 0.01 | 0.04 | 0.06 | 99.96 |

Table 2. B-Quant.

| ID | DATE | HEURE | MINUTE | LOI | AL-143 | AL-235 | Mono |
|---|---|---|---|---|---|---|---|
| 240527020 | 27-May-24 | 14 | 39 | 20.27 | | | |
| 240527021 | 27-May-24 | 14 | 40 | 21.21 | | | |
| 240527022 | 27-May-24 | 14 | 41 | 27.13 | 45.51 | 48.74 | 3.23 |
| 240527023 | 27-May-24 | 14 | 41 | 23.35 | | | |
| 240527024 | 27-May-24 | 14 | 42 | 22.08 | | | |
| 240527025 | 27-May-24 | 14 | 43 | 25.56 | 41.41 | 44.24 | 2.83 |
| 240527026 | 27-May-24 | 14 | 43 | 24.95 | 39.93 | 42.83 | 2.89 |
| 240527027 | 27-May-24 | 14 | 44 | 24.54 | 38.82 | 42.24 | 3.42 |
| 240527028 | 27-May-24 | 14 | 45 | 24.85 | 39.83 | 43.07 | 3.23 |
| 240527029 | 27-May-24 | 14 | 45 | 24.97 | 39.83 | 44.29 | 4.45 |
| 240527030 | 27-May-24 | 14 | 46 | 28.03 | 48.01 | 50.93 | 2.92 |
| 240527031 | 27-May-24 | 14 | 47 | 18.65 | | | |
| 240527032 | 27-May-24 | 14 | 47 | 24.02 | 37.81 | 39.39 | 1.58 |
| 240527033 | 27-May-24 | 14 | 48 | 23.01 | | | |
| 240527034 | 27-May-24 | 14 | 49 | 21.49 | | | |
| 240527035 | 27-May-24 | 14 | 49 | 27.13 | 45.62 | 49.03 | 3.41 |
| 240527036 | 27-May-24 | 14 | 50 | 24.22 | 38.21 | 42.06 | 3.85 |
| 240527037 | 27-May-24 | 14 | 51 | 24.66 | 39.41 | 41.25 | 1.84 |
| 240527039 | 27-May-24 | 14 | 53 | 19.96 | | | |
| 240527040 | 27-May-24 | 14 | 53 | 17.13 | | | |
| 240527041 | 27-May-24 | 14 | 54 | 21.80 | | | |
| 240527042 | 27-May-24 | 14 | 55 | 25.56 | 41.61 | 44.67 | 3.06 |
| 240527043 | 27-May-24 | 14 | 55 | 20.94 | | | |
| 240527044 | 27-May-24 | 14 | 56 | 24.06 | 37.81 | 41.97 | 4.16 |
| 240527045 | 27-May-24 | 14 | 57 | 20.53 | | | |
| 240527046 | 27-May-24 | 14 | 57 | 24.54 | 39.01 | 41.55 | 2.54 |
| 240527047 | 27-May-24 | 14 | 58 | 24.23 | 38.31 | 39.13 | 0.82 |
| 240527048 | 27-May-24 | 14 | 59 | 26.08 | 43.61 | 44.06 | 0.45 |
| 240527049 | 27-May-24 | 14 | 59 | 26.17 | 43.81 | 44.12 | 0.31 |
| 240527050 | 27-May-24 | 15 | 00 | 24.69 | 39.42 | 40.04 | 0.62 |
| 240527051 | 27-May-24 | 15 | 01 | 23.73 | 37.01 | 37.90 | 0.89 |
| 240527052 | 27-May-24 | 15 | 01 | 25.30 | 41.11 | 41.80 | 0.69 |
| 240527053 | 27-May-24 | 15 | 02 | 28.85 | 50.01 | 51.56 | 1.55 |
| 240527054 | 27-May-24 | 15 | 03 | 25.00 | 40.01 | 41.78 | 1.77 |
| 240527055 | 27-May-24 | 15 | 03 | 27.54 | 46.61 | 48.54 | 1.93 |
| 240527056 | 27-May-24 | 15 | 04 | 26.66 | 44.20 | 48.34 | 4.14 |
| 240527058 | 27-May-24 | 14 | 52 | 28.17 | 48.41 | 52.10 | 3.69 |

on ignition (LOM) indicates the rate of volatile matter including organic matter. In these samples, LOM rates are high, we recommend that these plants do stripping to remove organic matter followed by leaching by rainwater.

Trace elements and minor oxides are in acceptable proportions ($P_2O_5$, MnO, CaO, $V_2O_5$, $TiO_2$, $K_2O$, $ZrO_2$, $Cr_2O_3$).

On the other hand, iron oxide $Fe_2O_3$ is high. It is correlated with total alumina, varying in the opposite direction, which predicts a significant volume of residues (sludge and sand). The correlation between $Fe_2O_3$ and $Al_2O_3$ in bauxite analyzed by XRF results from both geochemical (formation processes and mineralogy) and analytical (matrix effects and sizing) factors. A negative correlation is often observed but may vary depending on the type of bauxite and analytical conditions.

Table 2 of the phase analysis by B-Quant (version 98) shows that:

- 12 samples out of 37 do not meet the analysis criteria; their mineralogical composition has not been estimated, given that the operating conditions of B-Quant are not met. At 42% as a cut-off grade. Precise mapping by geologists allows the correct delimitation of the exploitation zone. With a cut-off grade of 34% (Al2O3) only one hole is out of specification.
- For the other twenty-five (25) samples, the bauxite is essentially gibbsitic. Iron, in the form of goethite, is dominant.
- For Titanium, anatase is the dominant form. Unfortunately, combined silica has not been estimated. It is deduced by difference: Combined $SiO_2$ = Total $SiO_2$ – Quartz.

## 3. Conclusion

The government has an interest in imposing a cut-off grade of 40% for export and 34% for local refineries. Boffa bauxites have specific characteristics in terms of mineralogical composition and impurity content. It is therefore recommended to use local reference samples for the calibration of the XRF apparatus, to consider, the geochemical particularities of the region. In addition, adequate sample preparation, including calcination and fusion with an appropriate flux, is essential to minimize matrix effects and obtain accurate results. The determination of the alumina ($Al_2O_3$) content in bauxites, particularly those from the Boffa region in Guinea, is essential to assess their quality and industrial potential. X-ray fluorescence (XRF) analysis is a commonly used method for this determination due to its speed, accuracy and cost.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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