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Geological and Geochemical Studies of the Bauxite Deposits of Kolia (Prefecture of Boffa) - Administrative Region of Boke-Guinea

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ABSTRACT

The Kolia bauxite plateau, located in the northern and northeastern parts of the Boffa prefecture, is particularly interesting to the Republic of Guinea. The aim of this study is to carry out geological studies of the formations encountered and to determine the content of chemical elements. The bauxite plateaus in the study area, which revealed the presence of gelomorphic, conglomeratic and stratiform facies, are Cenozoic in age. The fieldwork carried out enabled us to take and analyze thirty (30) bauxite samples with alumina contents ranging from 30 to over 50%. The study area therefore contains deposits that have probably undergone several stages of alteration, including lateritisation, erosion and reworking, before finally giving rise to relatively late in situ bauxitisation. These chemical analyses, carried out at the Kamsar laboratory, enabled us to specify that the samples found are bauxitic (ferritic bauxites) resulting from lateritisation; further on, bauxites with high alumina content are found in sectors resulting from aleurolites and schists. Future research on these different Kolia bauxite blocks should focus on the NE part of the Boffa region.

INTRODUCTION

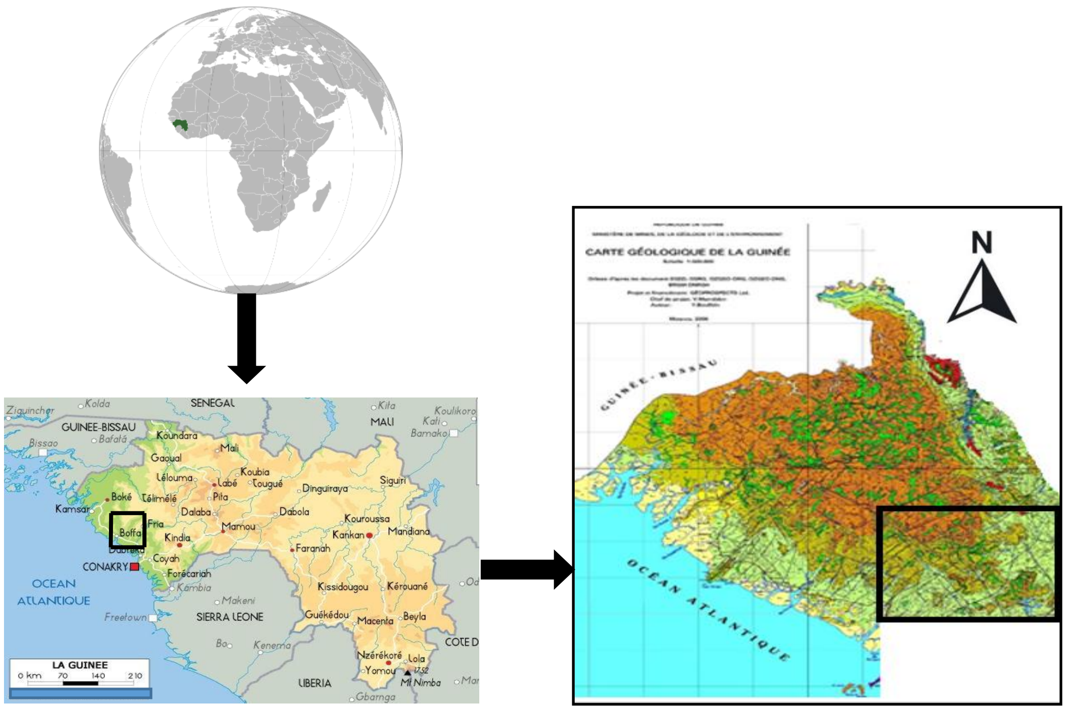
Originally, the term bauxite referred to a group of aluminous and ferruginous rocks similar to those discovered in the Baux region. Aluminum, the main chemical element in bauxite, only exists on earth in combination with oxygen, obviously in silicates [I]. Bauxites are one of the main minerals of supergene origin, i.e. formed under surface conditions. The concentration of alumina results from the transformation of silicates initially contained in eruptive rocks or sedimentary rocks into hydroxides, gibbsite, boéhmite, diaspore, oxide and corundum [2]-[4].

After the Second World War, as a result of the world industry's growing need for aluminum, research and prospecting for bauxite was relaunched in various countries around the world, including Guinea [5].

Guinean bauxite production has been on an upward curve since 2015, with a number of mining companies contributing to this rise, including **CBG**, **SMB**, **CBK**, **SPIC**, etc. From 2017 to today, the country has become China's leading supplier of bauxite (40% of Chinese imports), ahead of Australia. The Republic of Guinea has a large reserve of mineral resources, of which bauxite is the most exploited [6].

For this reason, the country needs to make the most of its subsoil resources in order to take full advantage of them and boost economic growth. For the above-mentioned reasons, the current research work involves studying the various features (tectonic, geomorphological, lithological, stratigraphic, etc.) and indications of mineralization (mineral outcrops, vertical zonation, geochemical, etc.) in this region with the aim of defining prospective zones and guiding mining exploration work. This will enable a reliable assessment of bauxite reserves and resources for the country's future needs [7]-[10].

Aluminum is used in the aerospace, automotive, electrical and construction industries, etc. The development of powerful lateritic crusts in Guinea (and neighboring countries) confirms that the intermittently humid tropical climate is the main factor in the transformation of rocks leading to the formation of bauxite deposits [8]. These bauxites resulting from sedimentary and magmatic rocks are, on the whole, products of the accumulation of lateritic bauxite deposits transformed by processes of dislocation, oxidation and, subsequently, giving rise to an alteration profile. However, the main regional factor is the manifestation of tectonic movements [11].



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Legend

CENOZOIQUE

Q	Dépôts non différenciés, sableux et limons sableux, alluvionnaires.
N	Roches latéritiques, sables, limons sableux, argiles, graviers, conglomérats.

MESOZOIQUE

Mz	Dolérites, gabrodolérites,…….

PALEOZOIQUE

Dfl	Suite Faro : aleurolites, gravélites,…..
Stl	Suite Télémélé : argilites,
opt	Suite Pita : grès quartziques et oligomictes souvent oblique, graviers, conglomérats.

INTRUSION

γ	Intrusions acides : granites, granodiorites, granitoides, granites leucocrates et alaskites.
a b	a) Faille vraie b) Faille
	Cours d'eau
	Zone d'études

Fig 1: Schéma de disposition de la Zone d'études; Mamédov et al., (1996) ; B. Soryba et al., (2022)

MATERIALS AND METHODS

Geographic and geological location of the main Kolia bauxite blocks

The Kolia bauxite blocks are located approximately 25km from the urban district of Boffa in the northern and north-eastern parts of the Boffa Prefecture (Kolia CR). These bauxite blocks reveal a number of features similar to the Sangarédi bauxite deposits in terms of stratigraphy, tectonics, magmatism, geomorphology, hydrogeology and lithology (fig. 1). This region has two (2) bauxite blocks:

- **Boffa Nord:** Straddling the Boffa and Télémélé prefectures, this block contains four (4) drilled bauxite plateaus with reserves estimated at over 2.5 billion tonnes and;

- **Boffa Sud:** Located entirely in the Boffa prefecture, it contains ten (10) drilled bauxite plateaus with an estimated reserve of over 2.3 billion tonnes [12].

Generally speaking, the vegetation in our study area is arid on the Télémélé side, dense and bushy along the watercourses and in the form of islands in places.

Hypotheses on the genesis of the Kolia bauxite deposits

Lateritic bauxites are the result of chemical alteration, aided by physical alteration of pre-existing rocks in a dry, humid tropical climate. This alteration depends in particular on the climate, the nature of the rocks, the geomorphology, etc….., leading to the formation of the crusts of which;

- The alumino-ferruginous alteration crust;

- The clayey (lateritic) alteration crust [13].

During the formation of these crusts, the factors that favor their establishment are: internal and external factors. Internal factors relate to the mineralogical and chemical composition of the rocks subjected to alteration and the ionic potential [15].

The external factors are climate, morphology, hydrogeology, pH and Eh.

As pointed out above, there are two (2) possible hypotheses for the genesis of the bauxite deposits in the study region, and these hypotheses have been widely discussed by researchers on various geological survey missions throughout the country (Dabola Boffa-Kandiafara, Télémélé, etc….), [14] The mission to the Télémélé sheet (led by the Soviets) started from the classical theory, which states that the genesis of the bauxite deposits of the Boffa-Kandiafara sheet is lateritic; the rocks of the lateritic horizons on which these bauxites are formed have a doleritic structure (these bauxitic deposits are apo-doleritic) and, secondly, the bauxitic deposits at Boké and Boffa have exceptionally altered products that are described as laterite [16].

Based on an examination of the geological map (Fig. 1), borehole data and geological profiles, a number of facts merit particular attention:

- The aleuro-pelite clays form the lower level of the lateritic horizon considered as the doleritic horizon.;
- The middle level is represented by the formation of non-industrial ferruginous bauxites.;
- The upper level is represented by industrial aluminous bauxites.;
- Most of the basic rock intrusions recognized in the region and drilled beneath these formations have weakly altered characteristics. Les études géologiques ont prouvé que the Kolia bauxite deposits are formed from argillites, schists and dolerites. These formations, which are considered to be bedrocks, generally have a smooth appearance, and the presence of original structures in some bauxite samples led us to conclude that they are source rocks for these bauxites [16]-[18].

During our stay in Boffa, we were able to observe these source rocks on the slopes of elevations and in the beds of streams in the localities of Bondy, Karagbakou, Yogon, Falaba and Madina.

On the basis of extrapolation, we can see that the rocks found at Boffa have features in common with those found at Sangarédi, exposed to the same climatic conditions and with a favorable topography.

Sample processing

Sample processing involves preparing samples for chemical analysis. The aim of this stage is to obtain an analytical sample with a small mass (100 to 200g) and a final diameter equal to 600μ.

This treatment will include the following operations::

- Crushing or grinding to reduce the size of the fragments.
- Sieving to check the degree of crushing.

Sample analysis

Processed samples are subjected to chemical analysis to determine alumina and silica content, and possibly iron, titanium and water content (loss on ignition).

There are also other methods for determining the oxides and elements associated with bauxite

The purpose of determining the loss on ignition (LOI) of samples is to select samples containing metal and those with no mineralization.

It is carried out using the thermogravimetric analyzer method (TGA-701) to determine the loss on ignition on bauxite samples already pulverized to 100µ [18].

Description of key stages

Carry out the following steps to start up the system:

- Turn the ignition switch on the right-hand side of the Thermogravimetry

Analyzer (TGA) to the "ON" position

- Press the "ON" button on the screen.
- - Finally, press the "ON" button on the computer's central processing unit.
- - Open the TGA 701 software by double-clicking on the "TGA 701" icon.
- Open the dialog box for scheduling analyses by clicking on the "F5 Analyzer" button when it is activated, or on the "F3 Connexion" button, so that the name of the sample is displayed [17].

NB: Modify the identifications if necessary.

- Place the clean crucibles on the table, the number of which corresponds to the number of samples programmed. The crucibles must be placed evenly on the table and in order.

- Start taking the crucibles by pressing the green button on the TGA 701 or by clicking on the green LED flashing on the screen; the TGA closes.

- Once the tare is complete, the TGA opens and moves into the loading position, presenting the crucible to be loaded first, which is always raised above the others.

- Load the crucible with a quantity of samples weighing between 2.5g and 4.99g.

- Press the green button on the TGA or click on the green light on the screen: The TGA closes and opens again, presenting the next crucible.

- Repeat the same operation until the end of the programmed crucibles.

After these various operations, the moisture is completely removed from the sample, followed by loss of mass (LOM) at 1000oC, which changes the color of the sample. Cooling begins when the temperature drops to 800oC, the TGA lid opens and cooling continues with ventilation [18].

- Record the results according to current practice.

- Wait for the end of cooling to recover the residue from the calcined samples. The analysis is complete and the TGA will be available for further analysis when the temperature drops to 33^{o}C.

- **Principle of treatment**

The sample used for this method must be pulverized at -100 mesh and must be calcined beforehand (refer to laboratory method 001-95, determination of mass loss by thermogravimetry). If the time between calcination and preparation exceeds two (2) hours, the sample must be dried at 105oC for two (2) hours, cooled in the desiccator before being weighed [17]-[18].

A previously calcined bauxite sample is melted with a fluxing mixture of lithium meta-borate and tetra-borate to obtain a homogeneous glass bead. The bead is irradiated by an X-ray source that excites the atoms of the elements, which in turn produce characteristic radiation. The intensities of these rays are then converted into concentrations using calibration curves for the individual elements. The analytical results thus obtained are the respective oxide contents of the calcined sample. They are then converted to the content of the uncalcined base during transfer to the database, using the previously determined mass loss [18].

RESULTS

Our study of the Kolia bauxite deposits enabled us to determine:

- the geological formations stratigraphically
- traversed and their associated ages;
- The bauxitic facies encountered and the determination of the various oxide grades found in this bauxite.

In addition, the following geological features were identified:

- **Stratigraphic features**: In general, these deposits are made up of different geological formations:

- **Silurian formations**: Deposits from this suite are less widespread in our region and form the summits of a few hillocks and ranges in and around Cap-Verga.

- The Télémélé suite is stratigraphically concordant with the sandstones of the fifth sub-suite and dips gently below the Devonian sandstones of the Faro suite. The genesis of certain bauxite deposits linked to Silurian formations (shales) in the Tamita CR is no less significant.

- The Télémélé Suite is represented by argillites and iron ore in the form of small inclusions, which is more widespread in the Tougnifili RC [8].

- **The Devonian formations suite faro**

○ (Dfr): the Devonian formations of the Faro Suite are represented by the black argillites; the shales surmounted by the cuirassic formations in places at Madina ;

- **Neogene (N ?) formations**: These formations are thought to be represented by the weathering crust in the study area, giving rise to conglomeratic and gravelly bauxites,

- **Quaternary formations (QIII -QIV)**

On these plateaux, the complex of these deposits is developed in the major beds of the contemporary watercourses (Fatala and its tributaries) which follow the orientation of the secondary faults. These formations are represented by gravel, alluvial clay and sand, Tectonic features.

- Tectonics played an important role on this bauxite plateau, which explains the rugged relief. A layer of cover formed in the Bowé synéclise, to which the deposits are linked, characterizes the area of the deposits [1]. The region is tectonically affected at the present time, resulting in the existence of a mosaic of tectonic blocks that are relatively uplifted in relation to one another and intense fissuring developed in the villages of Bondy, Wondéty, Farenya, etc.

- **Magmatic features: etc.....**

- Generally speaking, all the Kolia bauxite deposits are marked by trap magmatism. Basic magma enters the earth's crust through deep fissures following tectonic reactivation of the area. This tectonic movement is linked to the formation of basic rocks represented by dolerites of Mesozoic age in the form of dykes and sills.

- **Geomorphological features**

The main geomorphological features of this region boil down to a relatively low altitude (100 to 300 m) with a sufficient difference in level between the various peaks in relation to the rivers that drain them. The various summits are affected by a system of tectonic faults that define the existence of different water surfaces.

The plateau is deeply incised by the valleys of the main watercourses, and in a way represents the witness mounds of the denudation surface that favored the formation of the best lateritic bauxites.

- Hydrogeological features

From a hydrogeological point of view, the deposits are waterlogged due to their morphology, porosity and the presence of numerous fissures and cavities. The groundwater "storage" layers are essentially made up of lenses of laterite in places, while the clays form the impermeable wall. Hydrogeological conditions are largely regulated by the presence of the Fatal River and its tributaries.

-Chemical and mineralogical composition of bauxites from Kolia (Boffa):

- Chemical composition

Chemical analysis carried out at the Kamsar laboratory using the XRF method in September 2021 on thirty (30) samples from the Kolia bauxite plateaus revealed the presence of a number of chemical components that can be classified into two (2) types, namely:

- Les composants majeurs constitués de : AL_2O_3, TiO_2, Fe_2O_3 et SiO_2.
- Les composants mineurs et en traces constitués de : CaO, ZnO, MgO, MnO, K_2O, P_2O_5, ZrO_2, V_2O_5 , Cr_2O_3 et SrO. (voir tableau ci-dessous)

- Mineralogical composition

Based on the results of previous mineralogical analysis, the following minerals are found in all the deposits: gibbsite or hydrargilite Al2O3 (OH)3, boéhmite or monohydrargilite Al2O3(H2O), hematite (Fe2O3) and/or goethite (HFeO2); anatase and/or rutile (TiO2); kaolinite [Al4(Si4O10) (OH) 8].

NB: The six (6) boreholes drilled in the study area not only provided us with thirty (30) bauxite samples but also enabled us to determine the chronological succession of the geological formations crossed over a distance of twenty-six (26) km, known as the stratigraphic log of the bauxite horizons (fig.2).

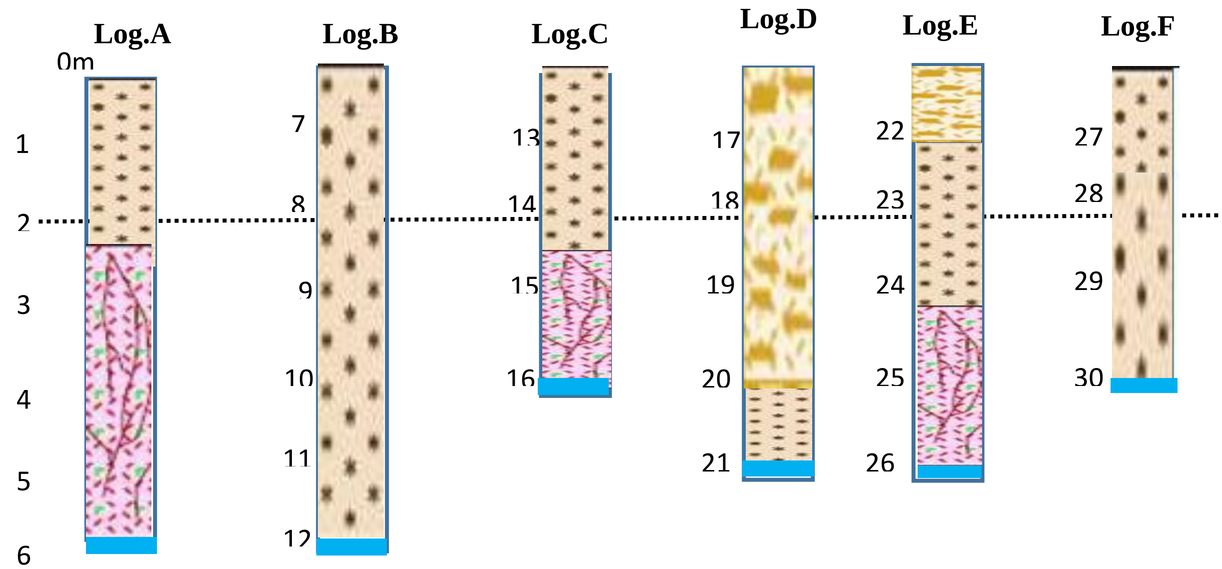


Fig. 2: Stratigraphic log of bauxite horizons and position of samples collected from boreholes A-B-C-D-E and F.

LEGENDE

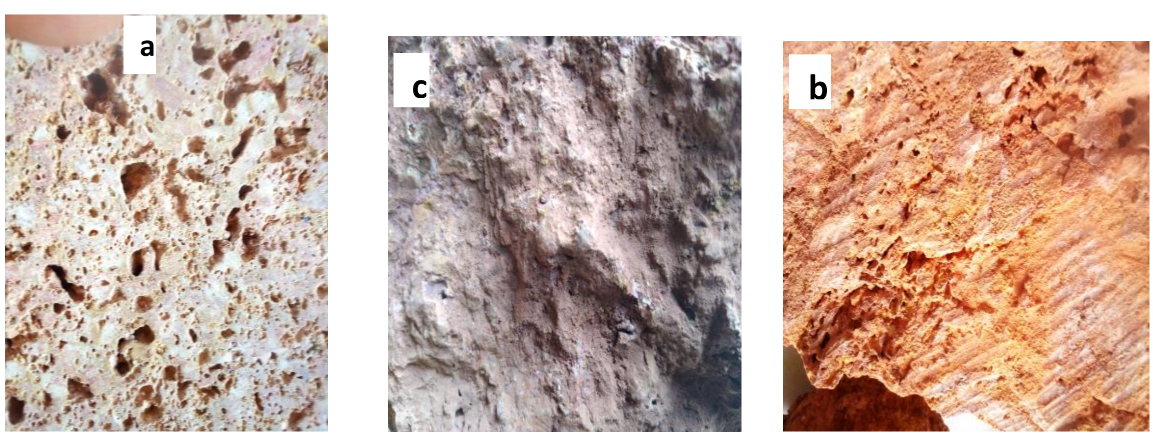
Sol végétal

Bauxite Stratiforme, gris jaune.

Bauxite conglomératique

Argile de base

Bauxite gélomorphe, maron Noir.



Bauxite Gélomorphe

Bauxite Stratiforme

Bauxite conglomératique

Grade table for bauxite samples from Kolia in September 2021.

SOND	N°	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	P_2O_5	K_2O	CaO	V_2O_5	MnO	ZrO_2	MgO	ZnO	Cr_2O_3	SrO
S1	A1	1.42	52.62	1.86	12.90	0.20	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
	A2	2.32	45.10	2.63	20.45	0.02	0.00	0.00	0.10	0.00	0.00	0.01	0.00	0.00	0.00
	A3	1.32	47.40	2.10	21.12	0.10	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
	A4	2.23	40.60	2.53	24.15	0.10	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
	A5	0.95	49.00	2.16	18.23	0.01	0.00	0.00	0.01	0.10	0.00	0.01	0.00	0.01	0.00
	A6	2.06	55.40	2.40	10.63	0.20	0.01	0.00	0.10	0.00	0.02	0.01	0.01	0.00	0.00
S2	B1	2.00	50.10	2.62	14.05	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00
	B2	1.38	48.40	2.24	22.36	0.01	0.00	0.00	0.03	0.01	0.00	0.00	0.01	0.00	0.00
	B3	2.26	47.00	2.43	24.06	0.02	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.01
	B4	1.21	48.40	2.22	23.91	0.10	0.00	0.00	0.12	0.01	0.01	0.00	0.00	0.00	0.01
	B5	2.06	51.00	1.96	12.09	0.20	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01
	B6	2.53	48.20	2.10	18.05	0.20	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00
S3	C1	0.96	46.23	1.65	12.02	0.03	0.00	0.01	0.10	0.01	0.00	0.00	0.01	0.01	0.00
	C2	0.18	44.00	1.52	14.01	0.30	0.01	0.00	0.12	0.10	0.02	0.00	0.00	0.00	0.00
	C3	4.00	43.06	1.26	17.45	0.10	0.00	0.01	0.00	0.10	0.01	0.00	0.01	0.00	0.00
	C4	2,42	58,18	3,49	10,82	0.33	0.00	0.00	0.12	0.01	0.1O	0.00	0.01	0.01	0.00
S4	D1	1,05	48,04	2,45	14,09	0.15	0.00	*0.01*	0.10	0.01	0.00	0.00	0.01	0.00	0.00
	D2	3,37	46,04	3,00	9,15	0.10	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.01
	D3	4.30	52.00	2.00	18.10	0.03	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00
	D4	3.00	46.32	2.62	18.45	0.32	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.01	0.00
	D5	4.23	38.70	2.00	23.35	0.06	0.00	0.00	0.05	0.10	0.02	0.00	0.01	0.01	0.00
S5	E1	4.60	40.56	2.03	14.23	0.20	0.00	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.00
	E2	3.36	49.20	2.36	16.04	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
	E3	5.02	38.92	2.54	24.65	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
	E4	0.63	51.23	2.15	12.27	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01
	E5	4.23	42.16	2.69	20.63	0.20	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00
S6	F1	3.63	54.40	1.36.	10.08	0.20	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F2	4.00	39.21	3.69	18.02	0.10	0.01	0.01	0.00	0.10	0.00	0.00	0.00	0.00	0.00
	F3	1.75	42.65	2.68	15.30	0.10	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00
	F4	2.90	48.10	2.13	22.10	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.00

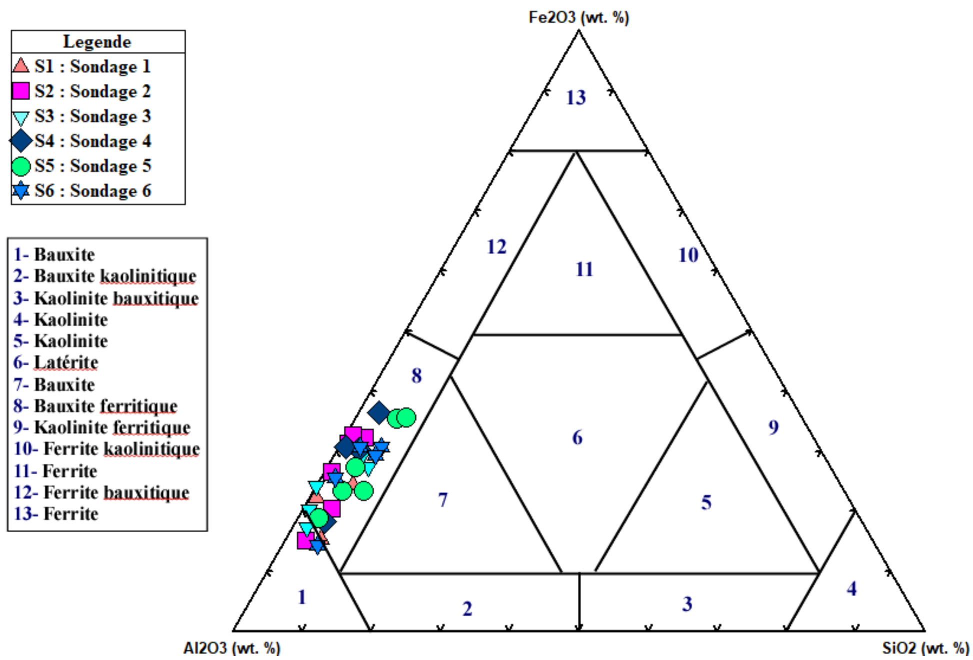


Fig. 3: SCHELMANN (1986) triangular diagram. At this level, the degree of lateralization of the bauxites shows us that most of the Log-A-B-C-D-E and F samples are strongly bauxitic and only slightly ferritic. This model can be assimilated with the leaching of Silica and Iron followed by a residual enrichment of alumina during chemical lateritization.

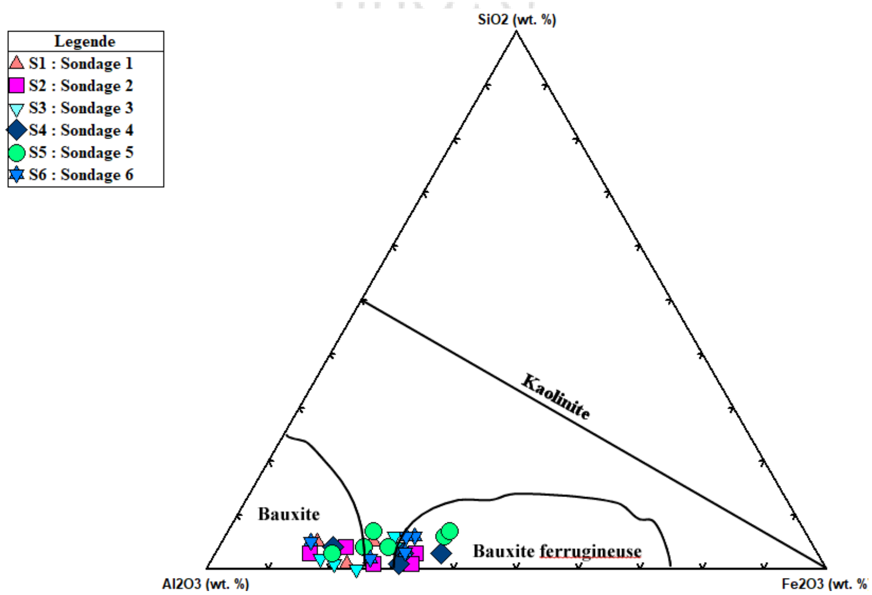


Fig. 4: Triangular diagram between Al2O3 -Fe2O3 and SiO2 from BEAUVAIS et al (1996). In this diagram, the bauxitisation process forms three (3) distinct zones: a bauxite zone, a

ferruginous bauxite zone and an intermediate zone. Kaolinite occupies half of the triangle, i.e. from Fe2O3 to SiO2, passing through the center.

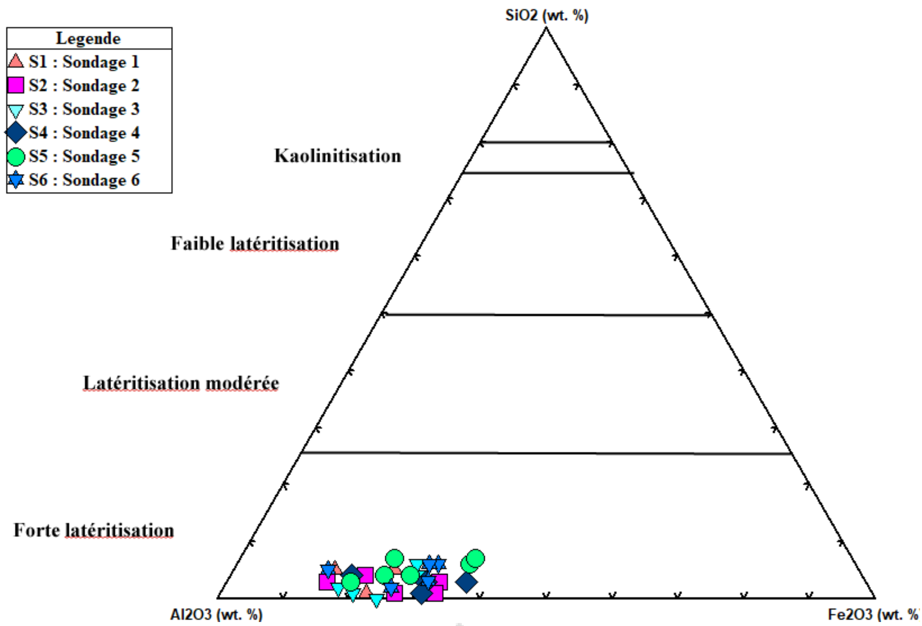


Fig. 5: Triangular diagram between Al2O3-Fe2O3 and SiO2 from BOULANGE et al (1996)

All the Log.A-B-C-D-E and F bauxite samples are found in the high bauxitization grid on the one hand and in the ferruginous bauxite on the other. These Al2O3-SiO2 and Fe2O3 triangular variation diagrams are commonly used to show the degree of lateritisation, mineral control and classification of bauxite.

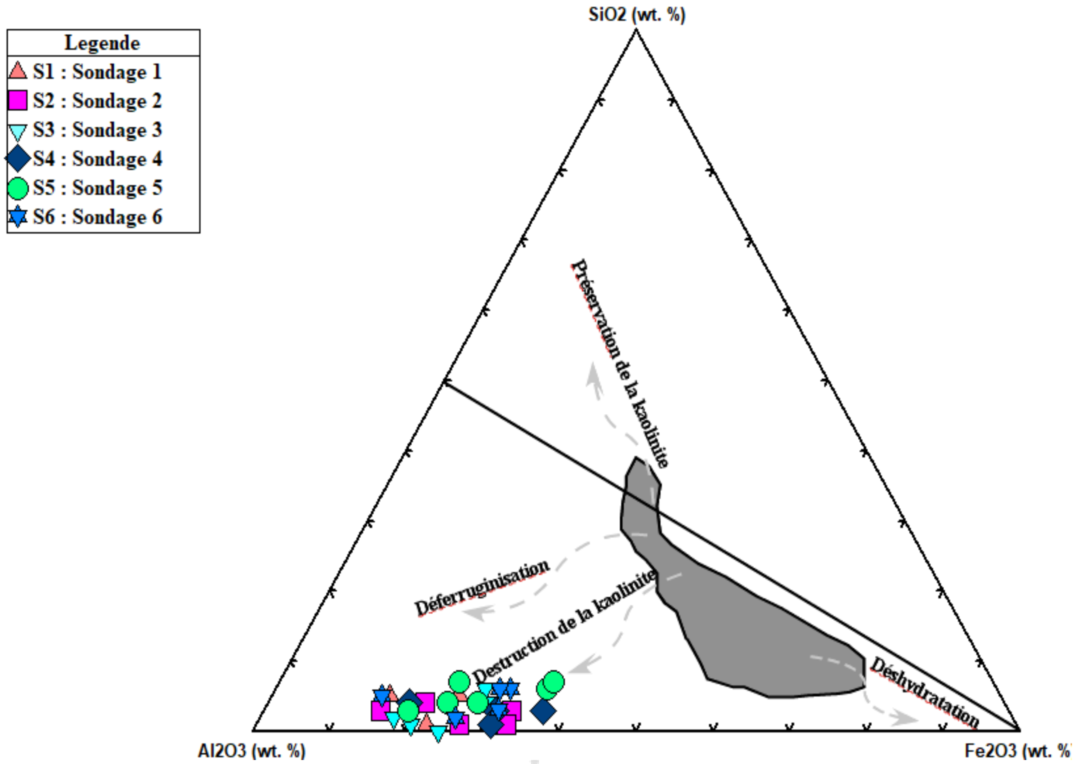


Fig. 6: Triangular diagram between Al2O3-SiO2 and Fe2O3, after BEAUVAIS (1991) and TARDY (1997)

The correlation diagram between SiO and Fe2O3 as a function of Al2O3 for the different boreholes shows Kaolinite preservation (top), deferrugination, Kaolinite destruction (bottom) and dehydration.

DISCUSSION

With regard to the bauxitic facies at Kolia, which vary between conglomeratic, stratiform and geomorphic in all the deposits, the presence of several grains represented by angular fragments of hematite-goethite shows us that the bauxite in the horizons currently in place are derived from the erosion and re-sedimentation of older bauxites and perhaps also from the eroded hard crusts formed on the platform of the exposed open-cast armor [13]-[14]-[8].

However, where armor is rich in aluminous elements, it generally has an aluminum hydroxide-rich rim, suggesting some degree of in situ alteration following the reworking of the old bauxite-hard crust. Note that geochemical trends between Al2O3 and TiO2 suggest significant leaching of silica and concentration of more immobile elements such as Al, Fe and Ti that occurred after re-sedimentation of the ancient bauxites in the Kolia area [24].

Similarly, in the case study of the bauxites in the study area, the deposits probably underwent a multi-stage evolution on the Boffa side that involved lateralization, erosion and reworking to ultimately give rise to relatively later in situ bauxitisation [8]-[14].

Kolia bauxites have a similar Al2O3 content to other bauxite deposits in the surrounding concessions. The notable exceptions are the Madina bauxite plateaux (Tamita CR), where the Fe2O3 content varies from 10 to over 20%, while the Silica content reaches 10% in the sandstone bauxites (Tamita CR) due to the presence of feldspathic sandstones [14].

The two (2) Kolia bauxite plateaus have similar grades, with the exception of a few samples from the Bondy plateau, which have a lower Fe2O3 content than the Madina bauxite plateau. In short, we can see that during the bauxitisation process, major, minor and trace elements are always fractionated in this area [14]-[25].

CONCLUSION

A certain number of physico-climatic, biological and geomorphological conditions must be met for bauxite to form and concentrate. In other words, the parent rocks are subjected to the action of weathering agents, resulting in the formation of weathering products which, given favorable climatic conditions, give rise to bauxite deposits. The major components of bauxite are gibbsite and boéhmite, while diaspore is the minor component.

On the basis of textural and structural observations, we can conclude that Kolia bauxites are derived from aerolites, dolerites and schists. These bauxites were formed by redeposition from the accumulation of already altered products. Generally speaking, the geochemical process of dismantling lateritic bauxites is the product of the destruction of kaolinite, favored by the hot, humid tropical climate. This geochemical analysis enabled us to identify fourteen (14) oxides, divided into two (2) elements (minor and major), and the samples found are bauxites resulting from lateralization.

In the context of this study, the degree of Schellmann bauxitisation shows that most of the samples from the log. A.B.C.D.E and F, are strongly bauxitic and only slightly ferritic. This model can be assimilated with the leaching of silica and iron followed by a residual enrichment of alumina during chemical lateralization (fig.3). In the Beauvais diagram, the bauxitisation process has three (3) distinct zones: bauxite zone, ferruginous bauxite zone and intermediate zone (fig.4). Finally, with the Boulangé diagram, the bauxite samples are found in the strong bauxitisation grid on the one hand and in the ferruginous bauxite on the other (fig.5). These triangular variation diagrams are commonly used to show the degree of lateralization, mineral control and classification of bauxite. Chemical analyses carried out at the Kamsar laboratory have shown that bauxites with high alumina content occur in the sectors resulting from the Madina schists (Tamita Regional Council) and the Bondy dolerites and schists (Kolia Regional Council).

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