

Training and Procedure for the Creation (Digging) of Wells on the Boundou-Waade Bauxite Plateau (Sangaredi), at the Compagnie des Bauxites de Guinee (CBG), with a View to Determining the Physicomechanical Properties (Prefecture of Boke-Administrative Region of Boke-Republic of Guinea)

Soryba Bangoura¹, Daouda Keita², Marie Constance Beavogui³

¹Department of Geological Services, Higher Institute of Mines and Geology of Boké, Boké, Republic of Guinea

²Department of Mining Services, Higher Institute of Mines and Geology of Boké, Boké, Republic of Guinea

³Department of Processing-Metallurgy, Higher Institute of Mines and Geology of Boké, Boké, Republic of Guinea

Email: bigusdakancy@gmail.com

How to cite this paper: Bangoura, S., Keita, D., & Beavogui, M. C. (2026). Training and Procedure for the Creation (Digging) of Wells on the Boundou-Waade Bauxite Plateau (Sangaredi), at the Compagnie des Bauxites de Guinee (CBG), with a View to Determining the Physicomechanical Properties (Prefecture of Boke-Administrative Region of Boke-Republic of Guinea). *Journal of Geoscience and Environment Protection*, 14, 351-372. <https://doi.org/10.4236/gep.2026.144019>

Received: January 29, 2026

Accepted: April 26, 2026

Published: April 29, 2026

Abstract

The Boundou-Waadé deposit is part of the Sangarédi bauxitic plateaus (CBG concession), Boké Prefecture. In light of the different results obtained, it should be noted that there are two genetic types of bauxites on this plateau: *in-situ* or residual lateritic bauxites which are formed by alteration of the source rocks on site and sedimentary lateritic bauxites formed by alteration of sedimentary deposits accumulated in the Paleo-Cogon lake basin during the Middle Miocene of the Sangarédi series. The analysis of the major elements indicates that the more the content of SiO₂ and Fe₂O₃ decreases, the more the content of Al₂O₃ increases. Knowledge in the rock domain involves the determination of a certain number of physico-mechanical characteristics. These can be determined on the one hand by laboratory tests on samples coming either from drilling or from blocks taken *in-situ* and on the other hand by tests carried out *in-situ*, either in trenches or wells. or galleries, or natural terrain. These wells served as means of controlling the various screw and core drilling works which sometimes present some disadvantages. The work carried out made it possible to specify the physico-mechanical characteristics of different litho-genetic



types of bauxites and related rocks from the Boundou-Waadé deposit. To do this, we used approaches and a field campaign that provided us with extensive information on the geological features, followed by determination of the physico-mechanical properties of the bauxite facies encountered.

Keywords

Deposit, Bauxite, Well, Features, Boundou-Waadé

1. Introduction

Man's natural aspiration to know nature, to discover its secrets and to use its riches for his own benefit has always been one of the main factors in culture and civilisation. Man's relationship with the mineral environment can serve as a criterion for his degree of civilisation at a given time, that is to say his level of knowledge of minerals and the way in which they are used and worked. In the case of bauxite, we know that, thanks to certain technological processes, it provides the most widespread metal in the earth's crust, i.e. aluminium. Its ore, bauxite, is very abundant in tropical regions (Mamedov, Chausov et al., 2020; Tchaoussov & Sereдкиn, 2004).

Today, society's needs are growing rapidly in almost every area. Meeting these needs requires more and more raw materials, and more and more engineering work (Esterle & Lajoinie, n.d.).

In addition to its agricultural potential, the Republic of Guinea covers a vast area with various deposits and showings of useful minerals, including bauxite (which accounts for 2/3 of the world's reserves and resources), various deposits of iron, gold, diamonds, etc., and numerous showings of chromium, titanium and construction materials, to name but a few (Figure 1). There are also numerous chromium, titanium and construction materials deposits, to name but a few (Mamedov, Chausov et al., 2020; Well, 2011).

Guinea has the world's largest reserves of bauxite, the ore used to produce aluminium. With a high alumina content, Guinea's bauxite reserves are estimated at over 40 billion tonnes, of which 23 billion tonnes are located in the Boké region (Statista, 2021).

With this in mind, a number of studies have been carried out on this plateau, including some on geology and others on reserve evaluation. Although the facies and mechano-physical properties of the bauxites were studied during the geological studies, it has to be said that the data from all these studies has not been compiled (Samozvantsev, & Diallo, 1976, Zainudeen, Mohammed, Nyamful, Adotey, & Osae, 2023).

The aim of this work is to drill the wells and study the physical-mechanical properties of the rocks encountered, i.e. to determine the density of the unworked rock and the specimens, the expansion coefficient and the strength (Keita

& Diané, 2024, Moussa, Konaté, & Fanta, 2011).

These data are necessary above all for the correct evaluation of reserves, on the one hand, and for the development of the conditions for the exploitation of the deposit, on the other.

We therefore planned to carry out the following work:

- Deepen knowledge of the geological make-up of the study area;
- Allude to the different bauxitic facies of the Boundou-Waadé plateau;
- Determine the physico-mechanical properties of the rocks and ores; and
- Organise research work and interpretation of results.

In order to obtain conclusive results, we used various methods, including bibliographical research, field work and studies related to the physico-mechanical properties of the bauxites encountered in the study area (Sidibé & Yalcin, 2019; Moussa, Konaté, & Fanta, 2011).

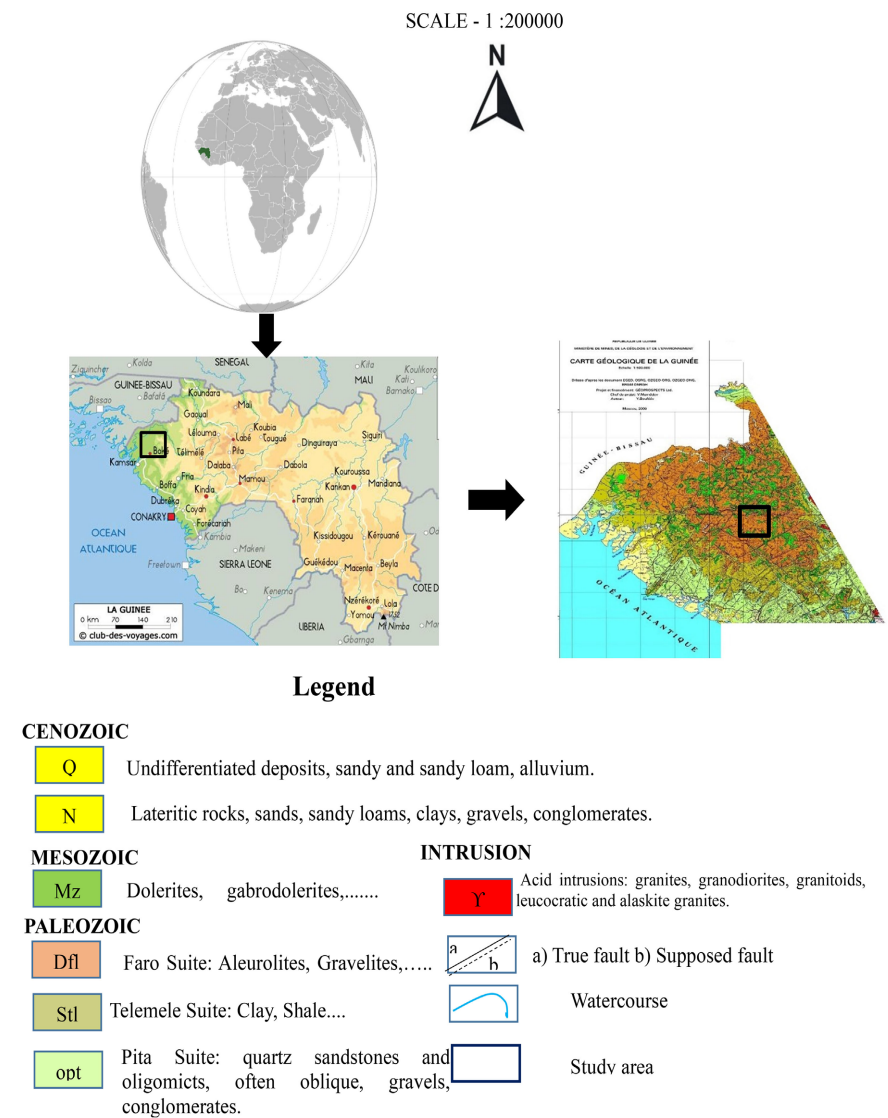


Figure 1. Geological map of the study area (Mamedov et al., 2020).

2. Material and Methods

2.1. Geographic-Geological Situation of the Study Area

According to the study region belonging to the Boké prefecture is located between $10^{\circ}30'$ and $11^{\circ}45'$ north latitude, $13^{\circ}45'$ and 15° west longitude, and covers an area of 11,453 km². It is located in the north-west of the Republic of Guinea and is administratively bounded to the east and north-east by the prefectures of Téliélé and Gaoual, to the west by the Atlantic Ocean, to the south by the prefecture of Boffa and to the north by the Republic of Guinea Bissau (**Figure 2**) (Sadjo, Touré et al., 2015; Marcel & Malm, 1984). This region is characterised by three (3) main distinct topographical zones:

- the coastal zone
- the hilly zone
- the plateau zone.

The relief is more rugged towards the eastern part of the prefecture (Fouta Djalon Mandingo) than towards the coast, where it is much less pronounced, with altitudes varying from 30 to 100 m (Seliverstov, 1970; Soumah, 2009).

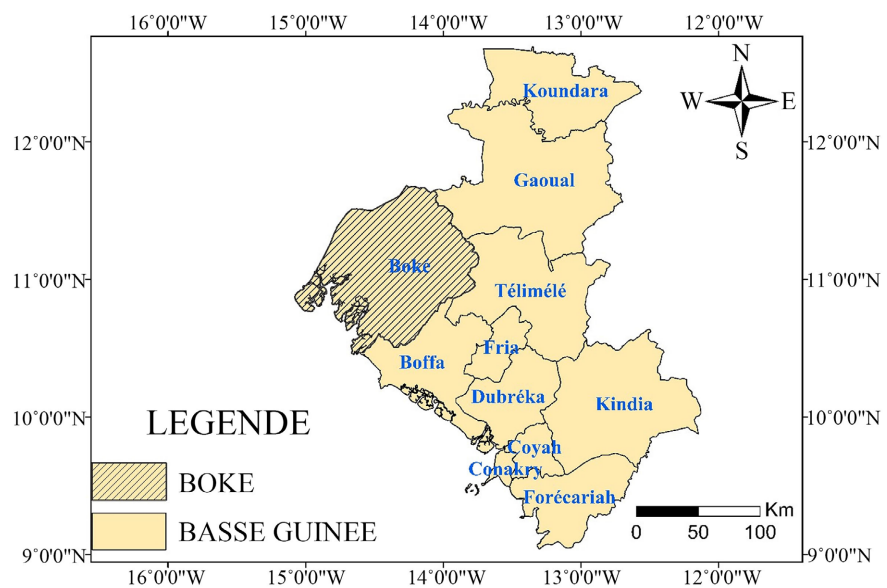


Figure 2. Location map of boké prefecture.

2.2. Geological Context

According to (Sadjo, Touré et al., 2015; Mamedov, Tchaoussov et al., 2004), the history of geological studies in the region cannot be separated from that of the national territory in general and the Guinean coast in particular, of which it is an integral part. In 1920, the Compagnie des Bauxites du Midi became interested in Boké bauxite. According to (Bogatyrev, Zhukov et al., 2009; Hayet & Ouzadid, 2016); from 1948-1956, the Compagnie française des bauxites du Midi undertook new research and prospecting work, following which major bauxite deposits were discovered, including the Sangarédi deposit.

In 1963, a new agreement was signed between the Republic of Guinea and HALCO MINING (Harvey Aluminium Company) for the exploitation of Boké's bauxites. This agreement provided for the creation of a company called C.B. G (Compagnie des Bauxites de Guinée) and a project to build an alumina plant in due course (Mamedov, Tokarlikov et al., 1998). With the setting up of an Organisme de Recherche Géologique (ORG), our study region has undergone various geological surveys.

The geological survey was carried out at a scale of 1:200,000, and studies were carried out in part on each sheet. It should be noted that a number of missions with different objectives have carried out studies in the Boké region, including the Compagnie Générale des Minéraux Atomiques (COGEMA) looking for uranium, and since 1998 the CBG, through GEOPROSPECTS, has been undertaking research and prospecting campaigns on the plateaux located in the Halco Mining concession to increase its bauxite potential. With this in mind, the bauxite deposits of Boundou-Waadé, N'Dangara, Bidikoun, Silidara, Parawi, Thiapikhouré and other plateaux were prospected (Seliverstov, 1970; Mamedov & Makarova, 2020).

✓ **Bauxitic facies of the Boundou-Waadé plateau:**

The Boundou-Waadé deposit has two genetic types. The distinguishing factors at a glance are facies, texture and structure.

This type of bauxite is formed as a result of the alteration of source rocks in situ. Paleozoic sedimentary Paleozoic sedimentary source rocks are the Devonian Faro 1 and Faro 2 aleuro-argillites and the Mesozoic dolerite intrusions. The proportion of *in-situ* bauxitic facies in the CBG area is 75% of total reserves. *In-situ* lateritic bauxites formed at the expense of massive Devonian Faro argillites, which could be corneanised to varying degrees. The main lateritic bauxite facies encountered are structural and brecciated (Zainudeen, Mohammed, Nyamful, Adotey, & Osae, 2023).

Sedimentary lateritic bauxites were formed by alteration of the sedimentary deposits accumulated in the Paleo-Kogon lake basin during the Middle Miocene. The proportion of sedimentary lateritic bauxites at the Sangarédi locality (concession-CBG) is 22% of total reserves. The main facies of sedimentary lateritic bauxites are gravelly bauxites (Mamedov, Tokarlikov et al., 1998).

✓ **Geological make-up of the region**

The study area contains Paleozoic (Ordovician, Silurian, Devonian) and Cenozoic (Paleogene, Neogene and Quaternary) formations. The Mesozoic is only represented by basic intrusions (dolerites).

-Paleozoic (Pz)

Ordovician-Pita suite (Opt)

According to Moussa, Konaté, & Fanta (2011), Mohamed Lamine (2015), the Ordovician deposits were first named in 1970 and located mainly in the south-western part and are generally represented by fine quartz sandstones sometimes feldspathic with intercalation of aleurolites. These formations lie unconformably on older formations (conglomerates) and are overlain by Silurian formations.

The deposits are up to 300 m thick and no fossils have been found in them to date.

Silurian-Telimélé suite (Stl)

These are widely developed to the west and south-west of our study area as well as in the Cogon-Tinguilinta interfluve. They are generally represented by finely bedded mudstones, compact mudstones, aleurolites and quartz sandstones. Their thickness varies between 200 and 300 m. These deposits are made up of the remains of Graptolites, fossils that are characteristic of the Silurian period. These deposits are consistent with Ordovician deposits (Sidibé & Yalcin, 2019).

Devonian-Suite Faro (Dfr)

- Studies by Diallo et al (2010) have shown that Devonian deposits are found in the central and eastern parts of the region, where they are underlain by the argillites and aleurolites of the Témimélé suite. The Devonian has been established on the basis of isolated outcrops and is as follows:
- A lower part, made up of quartz sandstone with brachiopod footprints. A middle section, formed by alternating grey aleurolites in thin plates, brown aleurolites, argillites and iron lenses containing numerous brachiopod footprints.
- An upper part, represented by finely stratified quartz sandstones. With a thickness varying between 300 and 320 m. They have been attributed to the Devonian because of the presence of Devonian-age brachiopod remains and their stratigraphic concordance with the Silurian layers of the Témimélé suite (Seliverstov, 1970).

- Cenozoic (Cz) Paleogene (P):

It is represented by marine formations and weathering crust. These deposits outcrop to the south of the study area in the coastal plain around the town of Kolaboui. They consist of bedded clays, topped by quartz sands containing coal debris and pyrite nodules. These formations are 27 m thick. The lateritic alteration crusts are derived from the alteration of argillites and dolerites (Statista, 2021).

-Neogen (N):

According to Mamedov, Tokarlikov et al. (1998), the Neogene was observed all along the Cogon valley, precisely in the Sangarédi area. They lie on alteration crusts that are related to the Paleogene denudation surfaces and are less widespread. These formations include, from bottom to top: light-grey pisolites resting on clays, gravelites and gibbsitic pebbles. The apparent thickness of these formations exceeds 30 m.

Quaternary (Q):

According to the work of Seliverstov (1970), these deposits are developed in the coastal plain and in the river valleys. A distinction is made between the marine and continental formations of the Middle-Upper Quaternary, the Upper-Recent Quaternary and contemporary deposits.

Upper Middle Quaternary deposits (QII-QIII):

Represented by marine and fluvial facies widespread in the Cogon and Tinguilinta valleys. The first terrace is made up of marine deposits; in the delta area of the Cogon, fine-grained sandy silts and quartz sands are found. It is 3 to 5 metres thick. Fluvial deposits are represented by the alluvium of the first terrace (Well, 2011);

Late Quaternary deposits (QIII-QIV):

They are located in the valleys of small rivers and are represented by sandy silts, sands and pebbles from the flood plains and the first terrace. The thickness of these deposits varies from 2 to 5 metres. These geological formations are supplemented by useful minerals (Mamedov, Tokarlikov et al., 1998).

✓ Useful minerals

The study area contains deposits of useful metalliferous minerals, some of which were discovered by the Compagnie des Bauxites de Midi and the C.B.G. These useful minerals are classified into two (2) groups (Mamedov & Makarova, 2020).

- Metalliferous useful minerals:

There are also useful minerals represented by aluminium, iron, copper, lead, nickel, cobalt and molybdenum, most of which are scattered throughout the study area. For example, we have the bauxite plateaux of Sangarédi, Boundou-Waadé, Parawi, N'Dangara, Sillidara, Bidikoun, etc.

- Useful non-metalliferous minerals:

These are represented by building materials which are very widespread thanks to the large extension of magmatic rocks, loose deposits and alteration crust formations. These include sands, gravels, clays and dolerites (Beauvais, 1991).

✓ Economic minerals

The minerals of economic interest for bauxite extraction are:

- Gibbsite: $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$;
- Diaspore: $\text{AlO}(\text{OH})$;
- Boehmite: $\text{AlO}(\text{OH})$, (Sylla, 2008).

Bauxite is the main aluminium ore. Aluminium's malleability and ductility make it easy to machine. It is used in the aerospace, automotive, packaging, domestic equipment, architecture and steel industries, etc.

Its properties include resistance to tension and atmospheric action, and it is a good conductor of heat and electricity, with a melting point of 658°C . It is difficult to find a branch of industry that can do without aluminium

(<https://www.universalis.fr/encyclopedie/bauxites/genese-des-bauxites/> (accessed September 8, 2023).

Thanks to its incomparable properties, aluminium can be found today, in the form of alloys, in a great many industrial applications (Table 1). In plain sight, or transparently, aluminium is omnipresent and contributes to our modern way of life (<https://geology.com/minerals/bauxite.shtml> (accessed September 10, 2023).

Table 1. Some properties of aluminium.

Melting point	660 °C
Crystal structure	FCC
Density	2700 (kg/m ³)
Thermal conductivity	237 (W/mK °C)
Coefficient of linear expansion (20 °C, pure Al)	23.1 × 10 ⁻⁶ (K ⁻¹)
Electrical resistivity	0.0265 (μΩ·m)
Mechanical properties (20 °C, pure Al)	660 °C
Rm	70 - 80 (MPa)
Re	10 - 20 (MPa)
A%	50% - 60%
E	70,000 (MPa)

✓ Materials (equipment) used

They are enormous, including: one 1) compressor; two 2) pick hammers equipped with a sinking or grooving chisel (**Figure 3**); four 4) sinking foils; one (1) weighing more than 100 kg; three 3) buckets and many others.

Compressor: designed to increase the pressure of a gas by reducing its volume (**Figure 4**).

Cable winch: this mechanical device controls the winding and unwinding of any type of rope (cable, chain, rope carrying or pulling a load) (**Figure 5**).

**Figure 3.** Jackhammer.**Figure 4.** Compressor.



Figure 5. Cable winch.

3. Result

3.1. Geographical Context of the Boundou-Waadé Plateau

The Boundou-Waadé deposit is part of the Sangarédi bauxite plateau, located approximately 7 km north-west of the Sangarédi mine. In fact, this plateau has the same studies as the N'Dangara plateau. These two plateaus are bounded by the following geographical coordinates:

- 11°02'24"N-11°06'00"N
- 13°47'05"W-13°55'10"W (Figure 2)

They are bordered to the north by the Thiapikhouré river, to the south by the Laafou river, to the east by the Pora river and to the west by the Sangarédi-Balandougou road. The Boundou-Waadé river separates these two bauxite plateaus. The BOKE-SANGAREDI trunk road crosses the entire length of the Boundou-Waadé bauxite plateau.

3.2. Sinking the Exploratory Well

To carry out this work satisfactorily, human and material resources were used.

One (1) Geologist (team leader): principal supervisor and person in charge of the work, responsible for the organisation, monitoring of sinking and sampling work, control and safety of personnel at all levels. He identifies the samples and describes the fronts. They measure well dimensions, label, wax and weigh samples.

Well diggers: carry out shaft sinking, channel sampling and sampling in the shaft, continuously monitor sinking from the surface.

Two (2) Shovelers: carry out sample hauling, sample quartering and weighing.

One (1) Compressor mechanic: Responsible for the condition of the machines and tools: compressor, jackhammers, cable winch, metal ladder, etc.

The importance of wells is above all to provide rigorous and objective information on the quality, geology and physical-mechanical properties of the industrial and genetic types of bauxite in a given deposit. Shafts also serve as a means of monitoring the various screw and core drilling operations, which have a num-

ber of disadvantages, including the following:

✓ **The screw survey:**

- Loss of samples when the ground is fractured.
- The dilution or concentration of the ore in the samples
- The incorporation of materials torn from the walls of the borehole

✓ **The core survey:**

- Loss of the fine part due to the use of water as a washing liquid.
- Overestimation of quality, by leaching of silica during drilling and sawing of cores.
- The loss of samples following the drilling regime (axial thrust, rotation speed, washing liquid flow rate), in the transition zones; bauxite-laterite, laterite-clay.

3.3. Shaft Sinking Steps

The sinking work begins by stripping the area and taking the dimensions of the well (120 cm along the length and 100 cm in width), using a rectangular piece of wood designed for this purpose. In the context of two (2) boreholes (screw and core), this wood is arranged so that one of the walls on the long side of the well coincides with the screw and core boreholes.

When it is a single borehole (screw or core), the length of the well is oriented in the North-South direction so that the long side coincides with the walls of the controlled borehole.

When the direction of the well is defined, a rope is installed for the start of sinking (**Figure 6(a)**).

The material extracted from each advancement is brought to the surface by the bucket and placed on a board to be crushed and weighed;

✓ Paraffinized and non-paraffinized samples are taken every 20 cm of advancement;

- After sinking one meter of the well, various measurements are carried out:
- 10 vertical measurements of each wall
- 10 horizontal measurements
- 10 interval floor measurements
- 10 measurements from the roof of the interval (on the string); a total of 120 measurements per interval.
- These measurements are used to determine the volume of the ore in the massif and to control the verticality of the well (**Figure 6(d)**). The sinking was accompanied by the taking of a whole series of samples (**Figures 6(c)-(e)**).

1) Large sample on each 0.5 m of shaft sinking weighing approximately 15 - 20 kg.

2) Two groove samples on each 0.5 m of shaft sinking weighing approximately 3 kg each. The large sample best reflects the chemical composition of the excavated interval.

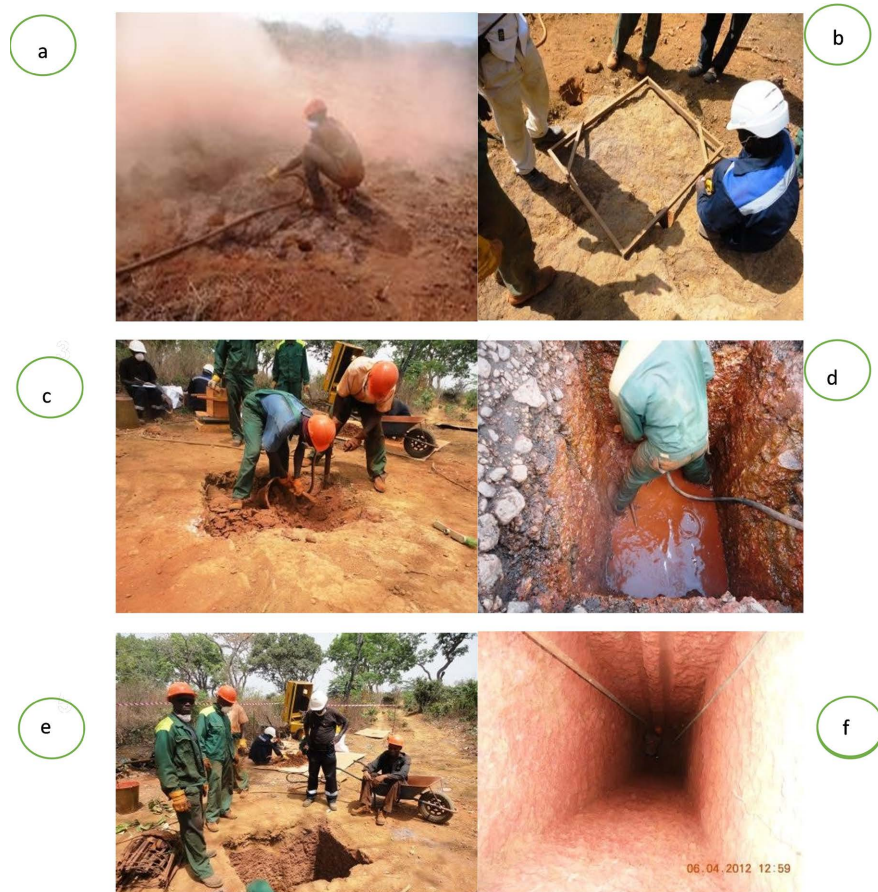


Figure 6. Steps of sinking. (a) Blowing; (b) Tracing; (c) Start of sinking; (d) (e) Evolution of well sinking and (f) Well completed.

3.4. Groove Driving

Grooving is only carried out after measurements of the walls of the well. For this purpose, when the two boreholes are more than 50 cm from each other, a groove is made near each borehole, otherwise a groove is made between them (**Figure 7(e)**). When the mass of samples from the dark interval is completely collected on the surface of the well and the wall measurements taken, the bottom of the well is completely covered with a tarpaulin. From the start of the interval the groove is dug on the indicated front with dimensions: 5/10 cm, to the bottom of the well following a vertical line.

If for sinking a well it is the hammer with a pointed blade which is recommended for its good performance, grooving is rather appropriate with a hammer with a blade flattened at the end. Since there must be more than one groove, the work is done successively one after the other, ensuring that the samples from one groove are completely on the surface before those from the second or third groove.

The main objective of channel sampling is to control the quality of screw or core drilling. To do this, the well was set up so as to have the drilling trace on the walls.

At a distance of 10 - 20 cm from the trace of the survey, a metric sample was taken using the jackhammer from the groove having a width of 10 cm and a depth of 5 cm. All the material thus obtained (approximately 5 - 7 kg) was crushed, mixed and divided into two identical samples at the groove of approximately 3 kg each (Figure 7(b)). The collected samples were wrapped in plastics and transported to the sampling section (Figure 7(d)).

Delimitation of groove samples: 10 cm wide, 5 cm deep and 1 m long (on the dark interval)

Quarting after mixing the groove sample which checks the results of the borings before taking 3 or 5 kg

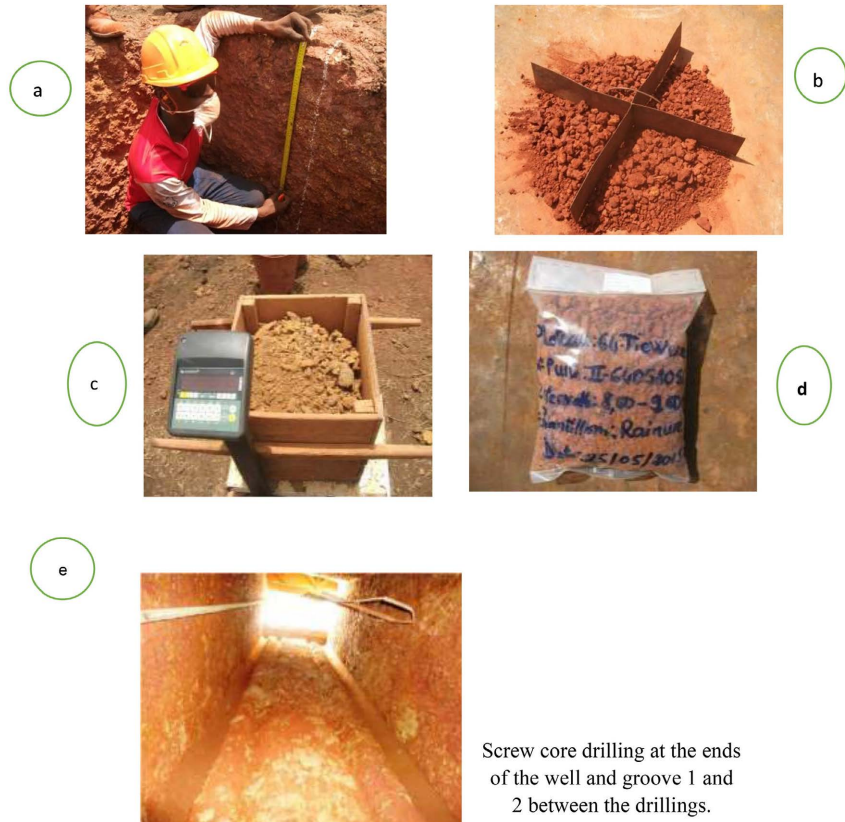


Figure 7. (a) (b) and (d) Groove sampling; (c) Weighing of the sample; (e) Walls of the well with screw borings, core drilling and the 2 grooves.

3.5. Safety Devices

Shaft sinking is a dangerous activity, and compliance with health and safety standards remains a primary concern.

- The land around the well, within a radius of 1 m, must be free of any object, even small ones, and work instruments.
- Staff must wear safety equipment; helmet, safety shoes, gloves, respirator and safety belt attached to the winch cable.
- The descent into the well and the ascent are only possible using the ladder or special mountaineer equipment.
- During the descent or ascent, two people must be at the winch.
- The well digger must be supervised by a person during sinking.

- Personnel must constantly check the condition of the winch cable and ladder.
- When the well shows traces of gas, it must be aerated by the compressor. The hose must be fixed at the bottom of the well, when the hammer is stopped.
- When raising the buckets to the surface, the fall prevention safety hook must be activated. The well digger currently in the well must stand on the opposite side of the winch.
- The compressor must be constantly monitored and kept at a regulatory distance and position, depending on the working conditions and wind direction.
- Staff must have a pharmacy kit.

When sinking shafts, it is strictly forbidden to:

- Descend into the well in the absence of at least two supervisors on the surface.
- Descend into the well using the winch cable. Ascending by the winch is only possible in exceptional cases by activating the fall prevention safety hook.
- Go down or back up from the well without a ladder or winch, leaning on the walls.
- Go down or up and work in the well without a safety belt attached to the winch.
- Lower or raise the jackhammer using the hose.
- Raise the bucket without having activated the safety fall arrest hook.
- Drop stones or any other object into the well.
- Be in pairs in the well.
- Being in the well during rain.
- Working in the well with the faulty winch or compressor.
- Work in the well in the presence of traces of gas without forced ventilation.

3.6. Safety Measures after Sinking

After the well sinking work, it is recommended to (see **Figure 8**):

- Completely cover the well with a 150/150 cm slab designed for this purpose.
- Inform the surrounding villages of the presence of the well and the related danger.
- Fence the well with a plate bearing the words “DANGER”.
- Make drains for runoff around the well.



(a)



(b)

Figure 8. (a) Excavation nearing completion; (b) Excavation completed and closed with a concrete slab.

3.7. Determination of Density

The hammer samples are initially taken out to be weighed, then placed in an oven at a temperature of 105°C for 8 hours. After drying, the samples are weighed again, when a sample is large, an analytical portion of 100 - 200 g is taken and weighed before being paraffinized. This paraffining aims to block all the pores of the sample during the new weighing in water.

3.8. Determination of the Density of Rocks in an Undisturbed State

The most reliable and accurate method for determining density is determination in the undisturbed state. For this, wells measuring 1 × 1.2 m in section were dug. At the same time as the well was being dug, detailed documentation was carried out during which the cavernousness and cracking of the rocks were assessed. The vertical continuity of the well and compliance with the dimensions of the cross section were checked.

The rock taken at each interval of one meter of sinking was weighed after being placed in boxes specially made for this purpose. The empty space of the rock in the undisturbed state was measured as follows: each wall of the well was measured vertically ten (10) times and horizontally five (5) times. The bottom of the well and the start of the interval were also measured ten (10) times in each direction. From these measurements, we evaluated the average width in one direction and in the other, also the average height. From these data we obtained the volume of the rock in an undisturbed state.

The ratio between the weight of the extracted rock (P) and the volume of the rock in an undisturbed state (V) provides the value of the density (d) of the bauxites under conditions of natural water content: $d = P/V$. This method is very precise, because it allows all cavities, caverns and cracks open in the rock to be taken into account. In addition, since the measurements are carried out several times, this makes it possible to take into account the hollows and protrusions which may be found on the walls of the well.

3.9. Calculation of the Density of Undisturbed Dry Rock

The calculation of the dry rock density is based on the density values of the undisturbed rock in its natural state and the average water content, as determined from samples taken from this undisturbed rock. The dry rock density (D) is determined according to the formula:

$$D = (d/(W + 100\%)) \times 100\%$$

where:

D is the density of the undisturbed rock evaluated for dry rock;

d is the density with the natural water content;

W is the average water content coefficient for the corresponding samples, %.

3.10. Determination of the Expansion Coefficient

During the sinking of the shafts, all the rock removed was measured using measuring boxes to determine the volume of the rock in the disturbed state. Thanks to these measurements and in parallel with the determination of the density, the coefficient of expansion was determined for the case of sinking wells with a jackhammer (Figure 4)

$$K = V_2/V_1$$

where:

V_1 is the volume of the undisturbed rock;

V_2 : is the volume of the rock removed from the well and measured using the measuring box;

K: is the expansion coefficient.

3.11. Results of Determining the Expansion Coefficient

When sinking wells, in parallel with determining the density of the bauxites and the overlying and underlying rocks, we determine the expansion coefficient. When digging the wells using the jackhammer, as a rule, the size of the fragments does not exceed 100 mm, which is close to the size of the fragments of the CBG crusher in Kamsar. Thus, these data can be used to approximately calculate the expansion coefficient of the ore during crushing. Table 2 gives the expansion coefficient for the different litho-genetic types of bauxites and related rocks.

Table 2. Expansion coefficient for the different litho-genetic types of bauxites.

No.	Litho-genetic type	Expansion coefficient Kf	Cavernosity, %
1	Apodoleritic bauxite	1.48	5 - 7
2	Gelled apodoleritic bauxite	1.45	2 - 4
3	Weakly apodoleritic bauxite	1.52	4 - 6
4	Jelly	1.46	5 - 7
5	Sangarédi gravelly bauxite	1.46	1 - 2
6	Sangarédi gravel-gresoid bauxite	1.49	5 - 7
7	Gelled structural bauxites	1.30	14 - 16

The studies carried out show that the expansion coefficient hardly depends on the litho-genetic type of the bauxites and their composition. The average values of this coefficient vary for different types of bauxites. These changes fall in the range of 1.45 to 1.53, averaging 1.46 - 1.49. The coefficient of expansion of rocks decreases remarkably (up to 1.36) only in the laterites of the transition zone, which are characterized by high cavernosity (14% - 16%) (see table) and by the presence of cavities.

In summary, for the bauxites deposits on the Boundou-Waadé plateau, the coefficient of expansion ranges from 1.46 to 1.49.

3.12. Determination of Sample Density

To determine the density of samples, it is necessary to determine the mass (weight) of the sample in a dry state (P0) and its volume (V). The density of irregularly shaped porous samples is determined by weighing the paraffinized samples in water (Figures 9(a)-(c)). According to this method, the rock sample was weighed three (3) times to determine:

P0—the mass of the sample in a dry state, g;

P1—the mass of the paraffinized sample, g;

P3—the mass of the sample paraffinized in water, g.

The density of the sample is determined in the following order.

1) The mass of the paraffin film (P4), is determined according to the formula

$$P4 = P1 - P0$$

2) The volume (VP·P) of the paraffin film is determined according to the formula:

$$VP \cdot P = P4 / 0.93$$

where 0.93 is the density of paraffin g/cm³.

3). The density (ρ) of the sample is determined according to the formula:

$$\rho = P1 / [(P1 - P3) - VP \cdot P]$$

Among the 203 samples whose density was determined, 191 (samples) were sent to Kamsar for chemical analysis according to the standards in force at the CBG. This was necessary to see the relationship between the density and chemical composition of the bauxites and related rocks (Figures 9(a)-(c)).



Figure 9. Paraffinized and non-paraffinized samples: (a)-(c) Freshly collected samples.

3.13. Study of the Physico-Mechanical Resistance of Bauxites in Monoliths

To study the physico-mechanical properties, we took, during the sinking of the

wells, monoliths of the main litho-genetic types of bauxites and related rocks. The studies were carried out at the “construction materials laboratory” of the University of Conakry (Republic of Guinea). The laboratory carried out the following tests on the monoliths:

- The tensile strength (in cutting);
- Shock resistance;
- Triturability;
- Hardness.

3.14. Determination of Impact Resistance

The impact resistance of the sample is the result of the joint action of shock and wear. This test was carried out on a Los Angeles installation according to the NF P18-573 method “determination of the Los Angeles coefficient”.

According to this method, the rock crushed up to the fraction of 10 - 25 mm and weighing $m_0 = 4840$ g was put into a drum along with the rock. After closing the lid, a rotation program was applied (30 to 35 rpm), number of rotations 500.

Once the drum stops, the rock is removed and sifted with a 1.6 mm sieve. The 1.6 mm N reject was washed, dried at a temperature of 105°C and weighed. The Los Angeles (LA) coefficient was determined according to the formula:

$$LA = [(m_0 - m_1)/m_0] \times 100\%$$

where: m_0 —initial weighing mass 4840 r; m_1 —mass of refuse on the sieve after crushing.

3.15. Determination of Triturability

The triturability of the samples (resistance to trituration) was determined using the “DEVAL” installation, according to the NF P18-577 method. For this, the sample weighing 7000 g was washed and dried at a temperature of 105°C. After that the sample was sieved in order to obtain a proportion between the fractions: +25 - +40 mm - 4200 g and +40 - +50 mm - 2800 g.

The sample thus prepared was placed in the cylinder of the DEVAL installation and the installation was programmed at 10,000 revolutions at a speed of 30 revolutions/minute. Then the crushed material is extracted from the installation and sieved with a diameter of 1.6 mm. The material remaining on the sieve is always weighed in order to obtain the DEVAL coefficient (DH) calculated according to the following formula:

$$DH = [(m_0 - m_1)/m_0] \times 100\%$$

where: m_0 is the initial weighing, g; m_1 is the mass of the screening refusal (+1.6 mm) after crushing.

3.16. Determination of Hardness

The hardness of the samples was determined by comparing the hardness of the samples with those of the reference samples according to the Mohs scale.

3.17. Results of the Determination of Triturability and Impact Resistance

Resistance to impact and wear is an important technical characteristic for the technological treatment of rocks in the case where this treatment involves operations aimed at crushing the ore (grinding, crushing). Here, energy expenditure is directly linked to impact resistance (viscosity), resistance to crushing, and crushing of the ore.

The analysis of these characteristics specific to various litho-genetic types of bauxites indicates their resemblance, because the values of the impact resistance (Los-Angeles), samples of all the litho-genetic types vary between 33% and 38%, and the triturability (Deval) oscillates between 17% - 21%. At the same time, certain remarks can be made regarding the values located within these limits. Thus, the two characteristics indicated above, the bauxites formed at the expense of the series

Sangarédi are more easily grindable (crushing or crushing) than the other types. On the other hand, apodoleritic bauxites are a little stronger than other types.

Generally speaking, for bauxite from the Boundou-Waadé deposit, the following values can be used: impact resistance 34% and crushing resistance 19%; based on results obtained from the N'Dangara deposit.

Table 3. Physico-mechanical characteristics of the main lithogenetic types of bauxites and associated rocks.

No.	Physico-mechanical characteristics	Litho-genetic types of bauxites:			Ferruginous laterites	
		Lateritic sedimentary	Lateritic in situ deriving from aleuro-argillite from Devonian	Apodoleritics	Roof	Floor
1	Density of the reworked rock t/m ³	1.93	2.07	2.04	2.36 (spéc.)	1.72
2	Water content, %	5.9	4.5	5.3	4.9	14.5
3.1	Absorption capacity, %	9.6	7.4	9.6	3.0	11.4
3.2		17.8	15.4	18.8	6.3	21.2
4	by mass by volume	97	161	94	170	56
5	Resistance to	46	34	48	40	28
6	compression, kgf/cm ²	21.1	17.0	17.1	32.9	24.4
7	Tensile strength; kgf/cm ²	38.2	30.9	34.6	13.7	30.8
8	Triturability, %	5.8	6.5	5.8	H/O	14.7
9	Impact resistance, %	24	23	31	8	23
10	Cavernosity, %	1.46	1.49	1.48	1.53	1.30

The hardness of the bauxites from the Boundou-Waadé deposit is, generally speaking, higher than that of the bauxites from the N'Dangara deposit (5.7 versus 3.8). It is clear that the hardness of bauxites is inversely proportional to their crushability. Thus, bauxites with a hardness ranging between 3.5 and 5 are char-

acterised by high triturbability (21% - 25%) at the Boundou-Waadé deposit and belong to this group of bauxites formed from the Sangarédi series and the ferruginous laterites of the transition zone. Bauxites with a hardness of 6.0 - 6.5 have low triturbability—15% - 19% (at the Boundou-Waadé deposit, this group is represented by apodoleritic bauxites (**Table 3**) and bauxites formed from aleuro-argillites).

The information collected makes it possible to highlight the following particularities and distinctive characteristics of various litho-genetic types of bauxites:

- 1) The bauxites formed at the expense of deposits of the Sangaredis series have a minimum density and minimum strength characteristics;
- 2) Bauxites formed at the expense of aleuro-argillites have a maximum density in an undisturbed state characterized by high cavernosity. This is explained by the fact that they are attached to the lower parts of the profile, where the cavernosity increases regularly. Structural bauxites are characterized by high mechanical strength (**Table 3**) while the cavernosity increased with depth, which caused a decrease in density and a decrease in the expansion coefficient as well as other changes. This trend is generally confirmed by the results obtained on the Boundou-Waadé deposit. However, as noted above, the Boundou-Waadé deposit is characterized by lower cavernosity values, and especially less contrasting than those of the N'Dangara deposit.

4. Discussions

The present study provides a comprehensive characterization of the physico-mechanical properties of the different litho-genetic types of bauxites and associated rocks of the Boundou-Waadé plateau, based on exploratory well sinking. The use of wells constitutes a particularly reliable approach, as it allows direct observation of the geological structures, accurate sampling under near *in-situ* conditions, and precise determination of volumetric and mechanical parameters, in contrast to conventional screw and core drilling methods.

The determination of density in the undisturbed state represents one of the major strengths of this work. Unlike laboratory-based density measurements on remoulded or fragmented samples, the well-sinking method integrates the effects of natural cavernosity, fractures and voids. This approach has been highlighted by several authors as essential for realistic reserve estimation and mining design in lateritic bauxite deposits (Mamedov et al., 2004; Keita & Diane, 2024).

The use of paraffinized samples further ensures the preservation of natural moisture content and pore structure, thereby reducing experimental bias linked to drying or water loss. Similar procedures have been successfully applied in other West African bauxite provinces, notably in Sangarédi and Kindia, confirming the methodological robustness of the present study.

The results clearly show that density, cavernosity and mechanical strength vary primarily as a function of the litho-genetic type of bauxite. Bauxites derived from the Sangarédi sedimentary series exhibit lower density and lower mechanical re-

sistance, which can be attributed to their higher degree of alteration, granular texture and reduced cementation. This behaviour is consistent with observations reported by Sidibé and Yalcin (2019) and Zainudeen et al. (2023) for sedimentary lateritic bauxites in similar tropical environments.

Conversely, apodoleritic bauxites and those derived from Devonian aleuro-argillites show higher density and strength values. These bauxites are generally located in the lower parts of the weathering profile, where compaction and partial preservation of the parent rock fabric result in higher mechanical cohesion. However, despite their higher density, these facies may present significant cavernosity, particularly at depth, which locally reduces the expansion coefficient and affects bulk density estimates.

Overall, the physico-mechanical characteristics of the Boundou-Waadé bauxites are broadly consistent with those reported for the N'Dangara deposit, although the latter displays more pronounced contrasts in cavernosity and density. The relatively homogeneous properties observed at Boundou-Waadé suggest more uniform mining and processing conditions, which is advantageous for large-scale exploitation.

5. Conclusion

It is undeniable today that the ever-increasing development of the world depends very heavily on the exploitation of useful minerals. However, these minerals must be searched for and found and then extracted from the ground or subsoil. It is on the basis of our observations and research of the different elements in the field that we were able to approach and treat the different aspects of this problem. The main objective of channel sampling is to control the quality of screw or core drilling. To do this, the well was set up so as to have the trace of the drilling on the walls. When the two boreholes are more than 50 m from each other, a groove is made near each borehole, otherwise a groove is made between them.

The wells also serve as means of controlling the various screw and core drilling works, which sometimes present some disadvantages. The work carried out made it possible to specify the physico-mechanical characteristics of different litho-genetic types of bauxites and related rocks from the Boundou-Waadé deposit and to compare them with the results of studies carried out on the N'Dangara bauxitic deposit. The main factor determining the physico-mechanical particularities of the bauxites widespread on Boundou-Waadé is their belonging to a concrete litho-genetic type. Since the litho-genetic types of bauxites and related rocks can be distinguished visually and thus mapped, allowed us to calculate the average values of the physico-mechanical parameters.

The importance of wells is above all to provide rigorous and objective information on the quality, geology and physico-mechanical properties of the industrial and genetic types of bauxites in a given deposit. The sinking work begins by stripping the area and taking the dimensions of the well (120 cm along the length and 100 cm in width), using a rectangular piece of wood designed for this purpose.

Finally, we must remember that sinking wells is a dangerous activity, and compliance with health and safety standards remains a primary concern.

Acknowledgements

I would like to express my sincere thanks to the people of good will who contributed to the production of this document. I solemnly thank Dr. Hassane Thioye for his guidance and advice in writing scientific documents of this kind, despite his many duties. Also to Dr. Daouda Keita, on duty at the Institut Supérieur des Mines et Géologie de Boké, for his moral and material support in producing a clear work; and to Dr. Marie Constance Beavogui, also on duty at the Institut Supérieur des Mines et Géologie de Boké, for the amendments made to the translation and editorial form.

Funding

The research that led to these results was funded by the General Management of the Institute Superior des Mines et Geology de Boké and the Centre Emergent Mines et Society.

Conflicts of Interest

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

References

- Beauvais, A. (1991). *Paleoclimates and Dynamics of an Armored Landscape of the Central African Republic: Morphology, Petrology and Geochemistry*. Doctoral Thesis.
- Bogatyrev, B. A., & Zhukov, V. V. (2009). Bauxite Provinces of the World. *Geology of Ore Deposits*, 51, 339-355. <https://doi.org/10.1134/s1075701509050018>
- Esterle, M., & Lajoinie, J. P. (n.d.). Encyclopædia Universalis [WWW Document]. *Universalis*. <https://www.universalis.fr/encyclopedie/bauxites/>
- Hayet, L. D., & Ouzadid, S. (2016). *Study of the Physico-Mechanical Properties and Durability of Self-Compacting Mortar Based on Fired Brick Aggregates*. Faculty of Science and Technology.
- Keita, O., & Diane, M. (2024). A Model of Physico-Mechanical Characterization of Sangaredi Bauxites and Related Rocks Taking into Account Their Litho-Genetic Type. *Journal of Minerals and Materials Characterization and Engineering*, 12, 281-298. <https://doi.org/10.4236/jmmce.2024.126018>
- Mamedov, V. I., Chausov, A. A., Okonov, E. A., Makarova, M. A., & Boeva, N. M. (2020). The World's Largest Fouta Djallon-Mandingo Bauxite Province (West Africa): Part I. Background. *Geology of Ore Deposits*, 62, 163-176. <https://doi.org/10.1134/s1075701520020026>
- Mamedov, V. I., Tokarlikov, V., Seredkin, M., & Chaplyguine, O. (1998). *Results of the First Phase of Exploration on the Territory of the HALCO Concession*. Geoconsult Ltd.
- Mamedov, V., & Makarova, L. (2020). *Ministry of Mines and Geology, Mining Potential (WWW Document)*. Higher Institute of Mines and Geology of Boké.

- Mamedov, V., Tchaousov, A., & Seredkin, M. (2004). *Report and Conclusion on the Physico-Mechanical Characteristics of Bauxites and Related Rocks of the Boundou-Waadé Deposit*. Higher Institute of Mines and Geology of Boké.
- Marcel, P., & Malm, J. (1984). *Determination of Density by the CBG Core Cutting Method*. Higher Institute of Mines and Geology of Boké.
- Mohamed Lamine, D. (2015). *Scouring Prospecting Project for the Eastern Deposit of the Boundou Waadé Plateau. CBG Dealership*. Higher Institute of Mines and Geology of Boké.
- Moussa, C., Konaté, S., & Fanta, M. (2011). *Geology and Exploitation Prospecting Project of the Bauxitic Deposit of N'Dangara North-West Bowal 10 Concession CBG*. Higher Institute of Mines and Geology of Boké.
- Sadjo, D., Touré, E. M., & Diallo, S. (2015). *Studies of Litho-Genetic Types and Related Rocks of the Bauxitic Lateral Cover of Boundou Waadé CBG Concession*. Higher Institute of Mines and Geology of Boké.
- Samozvantsev, V., & Diallo, H. (1976). *Geological Map of the Republic of Guinea at a Scale of 1:200,000. Kandiafara and Koumbia Sheets and Explanatory Notice*. Geological Exploration Society Russian Federation-Geological Research Organization.
- Seliverstov, Y. P. (1970). *Geological Map of the Republic of Guinea at a Scale of 1/200,000*. <https://www.universalis.fr/encyclopedie/bauxites/genese-des-bauxites/>
- Sidibé, M., & Yalcin, M. G. (2019). Petrography, Mineralogy, Geochemistry and Genesis of the Balaya Bauxite Deposits in Kindia Region, Maritime Guinea, West Africa. *Journal of African Earth Sciences*, 149, 348-366. <https://doi.org/10.1016/j.jafrearsci.2018.08.017>
- Soumah, F. (2009). *Geological-Economic Evaluation of the Thiapikouré Bauxitic Deposit at the Preliminary Prospecting Stage. Bowal, CBG Concession*. Higher Institute of Mines and Geology of Boké.
- Statista (2021). *Main Bauxite Producing Countries 2013-2019*. <https://fr.statista.com/statistiques/565292/principaux-pays-de-la-production-mondiale-miniére-de-bauxite>
- Sylla, O. (2008). *Geology and Prospecting Project for the N'Dangara Center Bauxite Deposit (Bowal 10) CBG Concession*. Higher Institute of Mines and Geology of Boké.
- Tchaousov, A., & Seredkin, D. M. (2004). *The Final Report on the Results of the Detailed Prospecting (75 × 75 m) and the Special Studies Carried out on the Boundou-Waadé deposit*. Higher Institute of Mines and Geology of Boké.
- Well, A. H. (2011). *Geology and Detailed Prospecting Project of the Eastern Part of the Bauxitic Deposit of Thiapikhouré Bowal 74 of the Cogon Lingourou Zone*. Higher Institute of Mines and Geology of Boké.
- Zainudeen, N. M., Mohammed, L., Nyamful, A., Adotey, D., & Osae, S. K. (2023). A Comparative Review of the Mineralogical and Chemical Composition of African Major Bauxite Deposits. *Heliyon*, 9, e19070. <https://doi.org/10.1016/j.heliyon.2023.e19070>

Link

<https://geology.com/minerals/bauxite.shtml>

<https://www.universalis.fr/encyclopedie/bauxites/genese-des-bauxites/>