Aluminium for future generation: new bauxite resources identified in Guinea

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Abstract. Guinea in West Africa is home to about 27% of the world's bauxite reserves – aluminium's principal ore. The well-known Sangaredi deposit alone represents other 80% of the Guinean bauxite production, with an annual production of about 14 Mt. Numerous potentially interesting plateaus have been inventoried but they were poorly explored and their resources remain poorly constrained. Two large areas have been explored between 2006 and 2009, one (Batafong) located north of Boke, the other one (Lelouma) located to the west of Labé. The most promising plateaus were first identified by combined gamma-ray spectrometry and GIS automated delineation constrain by pertinent topographic parameters. These plateaus were then explored by systematic Auger and core drilling completed by pits. These works led to the identification of around 1 400Mt of high quality gibbsitic bauxite grading more than 45 % Al_2O_3 and less than 2.6 % SiO_2 with good content of available alumina and low content in reactive silica.

Keywords: gamma-ray spectroscopy; selective GIS extraction, bauxite; gibbsite; Guinea

1 Introduction

If Guinea is only the fifth world bauxite producer with an annual production of about 17.4 Mt (2012), it ranks first in terms of reserves with about 27% (7.4 billion tons) of the world bauxite reserves. Most of the present Guinean production (14 Mt) is ensured by the Sangaredi mine, also known as the Boke mine, owned and operated by the Compagnie des Bauxites de Guinée (CBG). Bauxite is transported by train (135 km) down to the port of Kamsar. Additional production comes from the Débété mine, property of the Compagnie des bauxites de Kindia, and until 2012, some bauxite was mined from the Fria deposits and refined in the Fria Alumina refinery, by Alumina Compagny of Guinea. The Fria operations were stopped in 2012.

In 2006, Mitsubishi Corporation (Japan), entrusted BRGM to design and realise the exploration programme on 24 prospecting permits for bauxite, grouped in 3 blocks, Batafong, Lélouma-North and Lélouma-South, covering and a total area of 11 492 km^2 (Fig. 1). This paper presents the main results of this programme realized from April 2006 to October 2009.

2 Delineation of the prospective plateaus

Most of the country has been prospected for bauxite in the mid-70s during the soviet cooperation, and prospective bowé have been inventoried in a catalogue in 2003 by Dr. V. Mamedov. 67 bauxitic plateaus had been previously identified by the Russian teams within the MC permits. Two of them had been drilled partly at 600 m x 600 m spacing, and 14 others had been tested by limited reconnaissance boreholes.

2.1 Gamma-ray spectrometry

Available gamma-ray spectrometric data (1981-1982 Geosurvey GmbH 1km line spacing geophysical survey), were processed and plotted by BRGM to check whether they may have some correlation with the bauxite distribution. A regular 250 m x 250 m grid on the study area was generated with Total Count (TC), Uranium (U), Potassium (K) and Thorium (Th) count data.

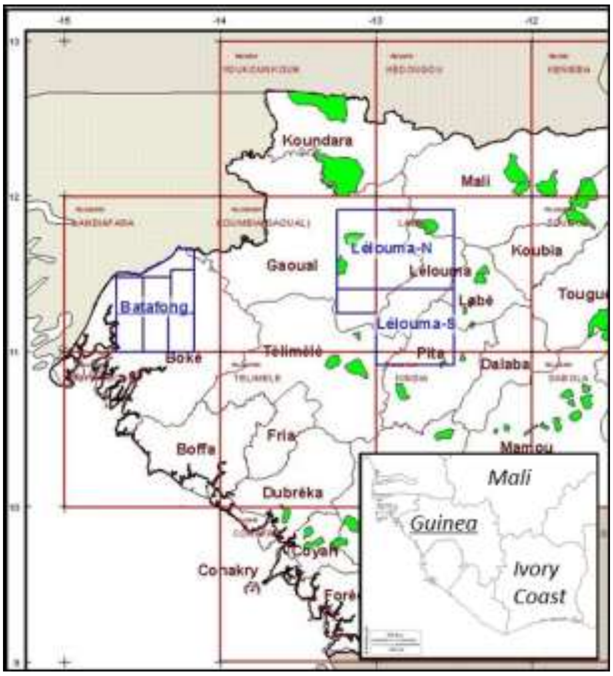

Figure 1. Location of the Batafong, Lelouma-North and Lelouma-South blocks.

A good correlation was observed between the Th/K ratio and the potentially bauxitic plateaus within the limits of the precision of the geophysical data (Fig. 2). High values of Th/K were interpreted as a marker of intense supergene alteration and constitute an interesting guide to rank the prospectivity of the plateaus. Potassium initially present in feldspar and mica was supposed to be leached whereas thorium, mainly hosted by zircon is less mobile.

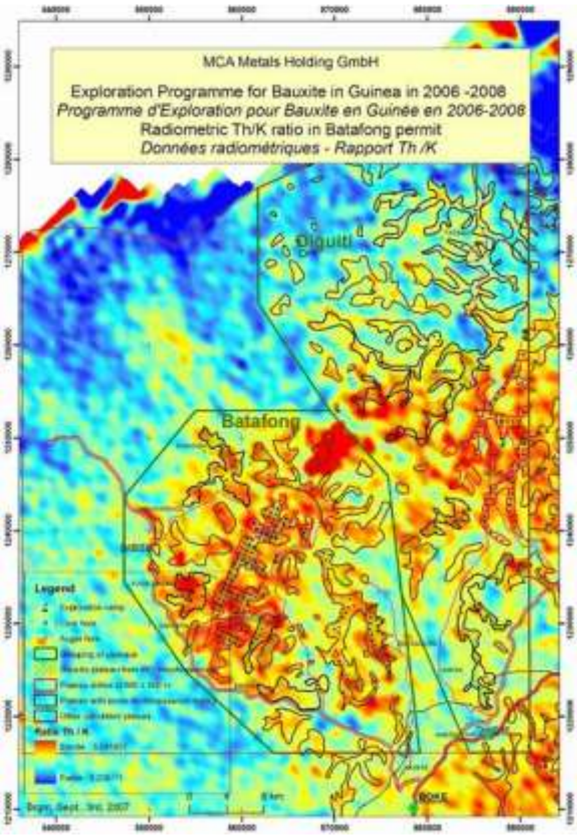

Figure 2. DEM plateaus on Th/K radiometric ratio in Batafong block. Highly weathered plateaus in orange and red (high Th/K ratio), poorly weathered plateaus in (dark to light blue).

2.2 Automatic plateau modelling

Using the digital elevation model (DEM) derived from the SRTM, an automated delineation of topographic plateaus was applied. The principle consists in finding the flat surfaces situated at topographic highs. First the difference of level (the difference between the elevation of the plateau and the interpolated elevation of the low points situated in the hydrographic network) was calculated. Then, the flat areas were drawn from the calculated topographic slopes. The combination of "difference of level > 25 m" and "local slope < 10°" has been retained, after some tests, to define the topographic plateaus in the present study. Such parameters have been described by as highly favourable for bauxite development insuring good drainage conditions for solutions percolating through the weathered lithologies (Bardossy and Aleva 1990).

2.3 Aster images

The ASTER satellite image data covering the 3 blocks have been processed with atmospheric corrections, using ENVI built in routines. Different combinations of Aster bands were tested in order to try to discriminate between bauxitic and barren zones, trying to enhance the specific spectrometric signature of gibbsite (AlO(OH)3). Unfortunately, all attempts to obtain a clear alumina spectral signal were vain. According to Bardossy and Aleva (1990), the spectral signals of aluminium and iron oxides are too similar to allow a clear discrimination.

Compared to the 67 bowé recorded on the Mamedov's map and synthesis, and after the combination of all available data; more than 142 plateaus, gathered into 8 "groups of plateaus" (Batafong, Diguiti, Linsan, Bougoumé, Diountou, Sagalé, Hériko, Timbi–Saran) or as scattered plateaus, were computerised and retained for field work.

3 Geological context

The MCAM permits were mainly situated in the South-Western tip of the Taoudenni sedimentary basin (Late Proterozoic to mainly Palaeozoic sediments), which extends from Central-Eastern Mauritania to Mali to Western Guinea, in the West African craton.

The geology of the area mainly consists of horizontal to subhorizontal mudstones and siltstones of the Mali Suite (Late Proterozoic), sandstones of the Boundou (Cambrian) and Pita (Ordovcian) Suites, mudstones and siltstones of the Télimélé Suite (Silurian) and sandstones and siltstones of the Faro Suite (Devonian) (Brinckmann et Meinhold, 2007). This sequence is locally cut or intruded by Mesozoic (late Triassic to early Jurassic) doleritic laccoliths, sills, and rare dykes. Ages ranging between 201 and 196 Ma have been obtained on doleritic dyke and sills from the Fouta Djalon region (Deckart et al. 1997).

4 Field work and geochemical analysis

The bauxitic potential of the delineated plateaus was evaluated from 3 638 Auger drill holes at a spacing of 600x600m (Phase 1), 300x300 (Phase 2) and 150x150m (Phase 3) mainly in the Batafong block for a cumulated length of 35 332 m (av. depth 9.7m). The representativity of the destructives drill holes was tested by 159 cored drill holes (cumulated length of 1922m) and 19 pits (0.8x1.2m; cumulated length of 134m), also used to determine the density of the material.

A total of 37178 samples have been analyzed for major oxides (Al_2O_3, SiO_2, Fe_2O_3, K_2O, MgO, TiO_2, P_2O_5 + LOI), available alumina and reactive silica at 143 and 235°C. The analyzed bauxite are dominated by gibbsite (Al_2O_3. $3H_2O$) as confirmed by X-ray diffraction tests. Low amounts of boehmite ($Al_2O_3.H_2O$) were observed only in a limited number of samples. The reactive silica content is low ranging between 1.4 and 1.7%.

Only a very limited number of boreholes were also analyzed for traces and rare earth elements. In terms of trace elements, samples are characterized by quite elevated Cr content (455 ppm), V (544 ppm) (both elements being positively correlated) and Zr (av. 838 ppm; positively correlated with Th). The Ga content of tested bauxite is ranging between 40 and 80 ppm with no clear relation with depth.

The total amount of REE is low ranging between 64 and 317 ppm in poorly weathered rocks (bottom of the Auger borehole) and between 92 and 281ppm in highly weathered rocks, dominated by LREE (LREE/HREE ranging between 3 and 10). Two extreme vertical REE distribution in a profile are presented, one showing a REE enrichment (Fig. 3a) in the bauxite-rich part of the profile (), a second one characterized by a clear REE impoverishment (Fig. 3b).

The shapes of the chondrite-normalized REE patterns are quite similar from one borehole to the other, showing a distinct LREE enrichment [$(La/Sm)_n$ ~2.2-5.9] and quite unfractionated HREE [$(Gd/Yb)_n$ ~0.5-1.2] (Fig. 4a, b). All samples are characterized by a low negative Eu anomaly [(Eu/Eu_n) = 0.65 to 0.94] and a positive Ce anomaly [(Ce/Ce_n) = 1.1 to 1.4] that can locally rich 3.6 in some poorly weathered samples (Fig. Xb). The REE shape of fresh doleritic sills from the Fouta Djalon area is quite different with a distinct negative slope for HREE [$(Gd/Yb)_n$ ~1.4-1.6] (Deckart et al. 2005) suggesting that the studied bauxitic samples probably derived from siltstones and mudstones rather than mafic rocks.

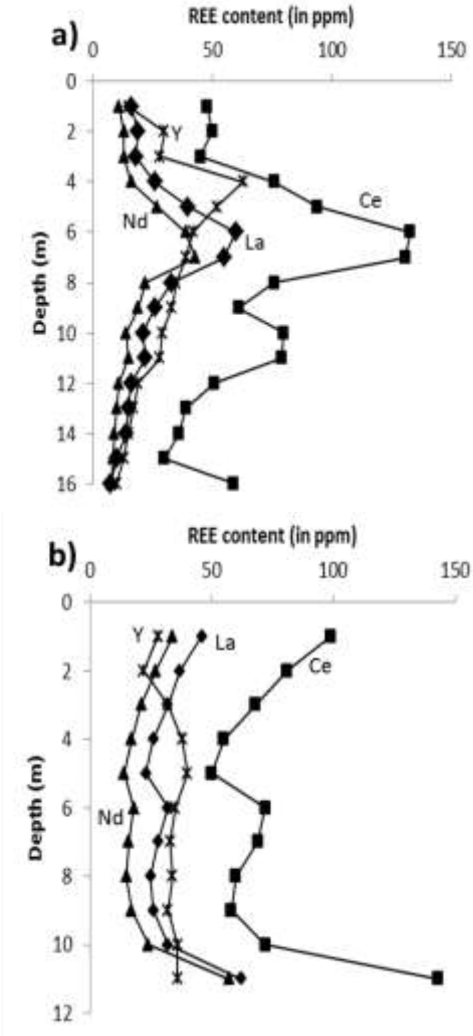

Figure 3. Vertical distribution of REE in two boreholes BO139 (a) and BO190 (b).

All the spectra of a given profile are mainly parallel, bauxite samples being distributed above (Fig. 4a) or below (Fig. 4b) the less weathered samples (saprolite), in accordance with the behavior of REE described above. LREE and HREE are moving the same way during bauxitisation, except in few samples showing a more pronounced HREE depletion (Fig. 4b).

6 Resources

Using a cutoff grade of $Al_2O_3 \geq 40\%$ and $SiO_2 < 10\%$, the following bauxites resources have been identified:

- Lélouma North block: **1 072 Mt** @45.3% Al_2O_3 and 2.3% SiO_2 (87% measured, 13% indicated), with nearly **1 000 Mt** for the sole Bougoumé plateaus;
- Lélouma-South Block: **67 Mt** @43.0%Al_2O_3 and 2.2% SiO_2;
- Batafong Block: **433 Mt** @ 45.5% Al_2O_3 and 2.6% SiO_2 (92% measured and 8% indicated) with **302 Mt** for the sole Batafong plateaus.

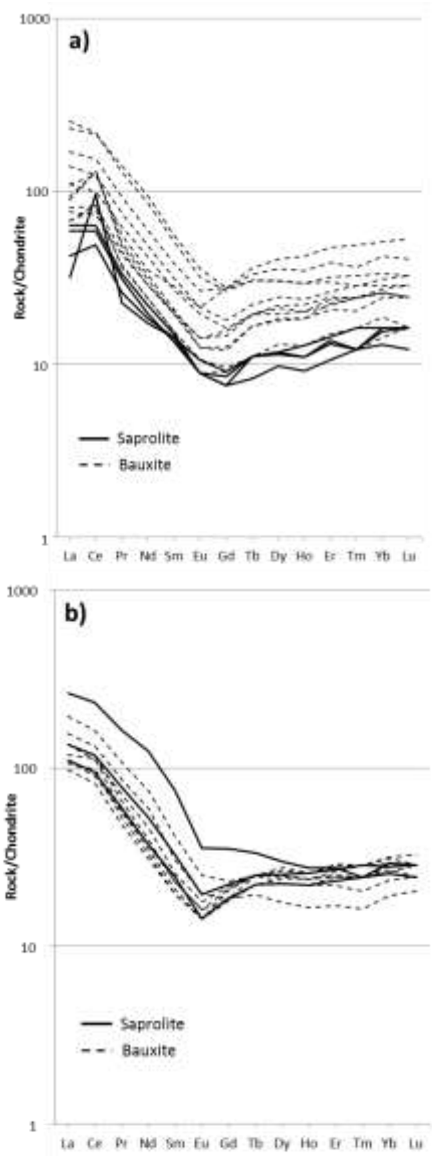

Figure 4. Chondrite normalized REE-patterns for saprolite and bauxite from boreholes BO139 (a) and BO190 (b) (values from McDonough and Sun, 1995).

7 Conclusions

Gamma-ray spectroscopy and more especially the Th/K ratio, and the automatized plateau modelling appear as efficient tools for bowé delineation and potential ranking. Around 1 400Mt of high quality bauxite have been identified on the Batafong and Lelouma blocks. Gibbsite is the main Al-oxide and the content in SiO_2 is low. The available alumina is ≥39% Al_2O_3 and reactive silica (at 145°C) is ≤1.7% SiO_2.

In terms of resources, the Bougoumé plateau (Lélouma-North block) is a world class deposit. Unfortunately, it is located at more than 140km from the Sangaredi railway station and at around 250 km from the port of Kamsar. The Batafong plateau is characterized by lower resources but is only located at less than 50km from the Atlantic coast.

Despite the encouraging results, and for its own geostrategic and economic reasons, MC finally relinquished the permits in 2010. New companies took them immediately over, one in Batafong, the other one in Lélouma. The company working in Batafong carried out some additional drilling for resource extension, some surveys for bauxite evacuation channel (port site), and preliminary economic assessment. The growing Chinese demand for the next five years, the decision of Indonesia to stop in 2014 the exportation of non-transformed bauxite, the evolution of the Guinean mining policy, the ambition of Guinea to increase its production up to 25% of the world demand in the 2020 horizon, the probable start, in 2016, of the Dian Dian project (reserves of 564 Mt of bauxite) are arguments in favor of the future increase of the leader position on the international market, that should help promoting the Batafong resources and perhaps later the Lélouma resources.

Acknowledgements

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