Madagascar bauxite as an alternative source

Yves Occello
Managing Partner, Amber Development, L'isle sur la Sorgue, France
Corresponding author: yves.occello@amber-development.com

Abstract

From Farafangana to Manantenina on the east coast of Madagascar Island an extensive exploration was carried out during the 1960's and in the early 1970's. One of the objectives of that campaign was to evaluate the bauxite resources and reserves of the Manantenina area where some extensive exploration, drilling and testing were conducted from 1967 to 1973. This deposit is now covered by exploitation permits and is an interesting option to supply China and eventually the Middle East. Holes and pits totaling 18 350 m. were drilled in such area. The Manantenina deposit is made up of gibbsite nodules within a clay and sand rich matrix. Recent studies undertaken have been based on such previous extensive exploration work and resource evaluations. Different scenarios were evaluated, based on bauxite mining and recovery percentages and on the basis of both crude and washed ore options. The current preferred option is washed bauxite for export. The key numbers are 200 Mt - 41 % available alumina - 1.3 % reactive silica. Location very close to the sea is a significant advantage. Furthermore, it is very easy deposit to mine: No overburden, no forest to clear, and 3 - 6 m thickness on average.

Keywords: Madagascar bauxite; % of available alumina in bauxite; washed bauxite.

1. Why to look at Madagascar bauxite deposit?

China's fast growing alumina production and its declining availability for bauxite of acceptable quality induce an increasing need of imported bauxite. (Figure 1)

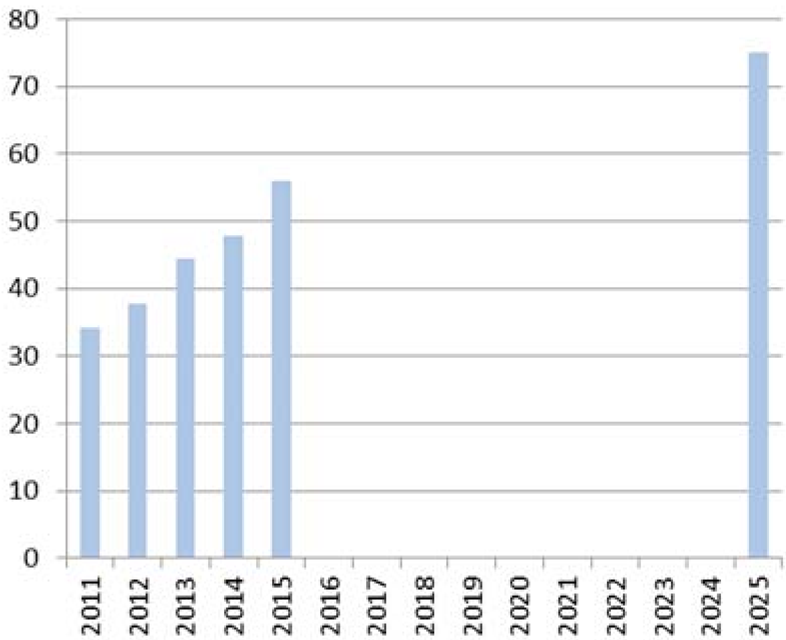

Figure 1. China alumina output (Mtpa) – 2025 average forecasts.

This is why a significant production capacity of low temperature refineries has been developed in Shandong province on gibbsitic bauxite. Supplying sources exist: Australia, India, Malaysia, etc. However, some of those sources could be only temporary. Others, as Guinea, Vietnam, Laos, etc., are promising, but there are infrastructure problems, inducing a certain period of time to be implemented. Madagascar bauxite has some advantages. It is located at a reasonable distance from China. It can also supply the Atlantic zone with its gibbsitic bauxite for the non-integrated refineries. (Figure 2)

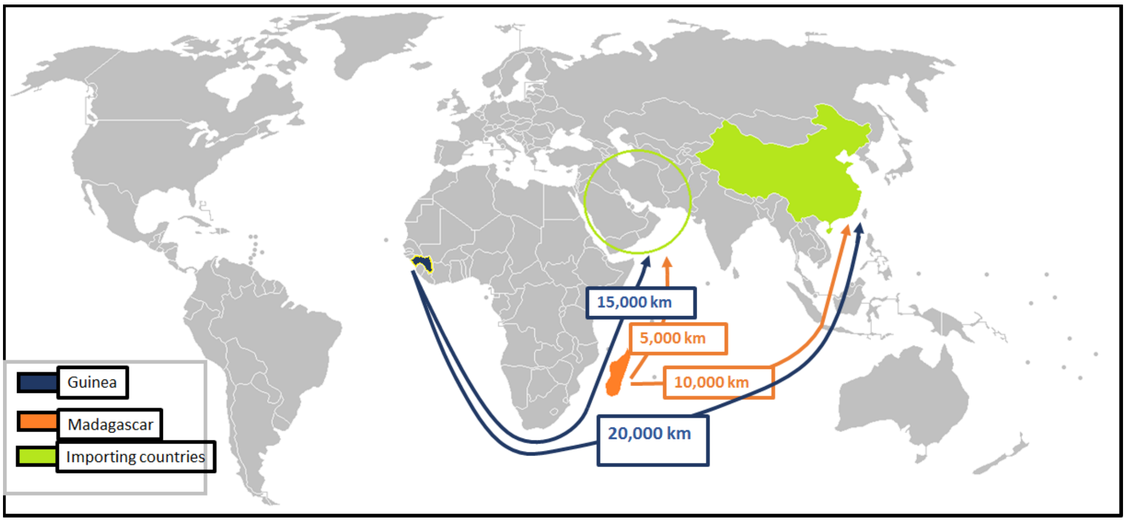

Figure 2. Guinea – Madagascar comparison.

Furthermore, the deposit is very close to the coast and the quality of the washed bauxite (see paragraph 3.1.4) can compete with the other mentioned bauxites. This deposit can rapidly be exploited, so it must be considered.

2. History

Bauxite was first discovered in Madagascar in the late 1940s. It was identified four generic types of bauxite deposits in the island (Figure 3). Bauxite exploration took place, in Madagascar, in the mid-1950s to early 1970s. It was quickly focused on the south-east coast, which was found to contain the most significant resources on the island. This area was considered by various state agencies and mineral companies, including Péchiney and Alusuisse. Between 1967 and 1973, Péchiney carried out an in-depth investigation of the Manantenina deposit, including washing tests on 25 large representative batches (each weighing between 1000 and 1 500 tonnes); Several industrial projects were defined, including (i) the production and export of up to 5 Mt/y of bauxite from a new wharf on the Manantenina coast and, alternatively (ii) the production of up to 1.5 Mt/y of alumina from a new plant in the Fort-Dauphin area. No industrial partner was found and this and other bauxite/alumina projects were definitively abandoned by Péchiney in 1973.

3. Bauxite potential

Typical plateau-type deposits are found along the strongly eroded remnants of the high peneplain in the northern half of the island (1 500 m and higher). Bauxite occurrences are often ferruginous, and the resources of individual plateaux – known as Tampoketsa – are generally small, with the exception of the Ankaizina group of deposits, which were explored by Péchiney in the early 1970s. They are estimated to contain a total of ca. 55 Mt washed bauxite at about 41 % average Al_2O_3. The other Tampoketsa typically contain no more than a few hundreds of thousands of tonnes of low-quality, iron-rich according to an exploration made in 1966. Significant bauxite resources occur along the south-east coast, between Fort-Dauphin (now

Figure 3: Location map, showing main bauxite occurrences in Madagascar.

Tolanaro) and Vangaindrano, and particularly in the Manantenina area. Bauxite occurs as bauxitised leptynites, as hard-rock along the low-lying coastal peneplain (60 m), and as reworked bauxitic nodules in the continental Neogen series. The Manantenina bauxite deposits were extensively explored by Péchiney in the 1960s and early 1970s; they contain an estimated 165 Mt at 39.6 to 39.9 % average Al_2O_3 (Péchiney, 1973). North of Manantenina, significant bauxite resources were recognized by Péchiney on their Faranfagana license. Bauxite occurs mostly as a duriscrust on basalts (up to 98 Mt washed bauxite at about 37 % average Al_2O_3). In addition, a lesser quantity of bauxite is found on crystalline basement (up to 14 Mt washed bauxite at 35 % average Al_2O_3).

Bauxite exploration in Madagascar quickly focused on the south-east coast, which was found to contain the most significant resources on the island. Péchiney's activities were focused north of Fort Dauphin on the Manantenina district, and, to a lesser extent, the Vangaindrano-Farafangana district.

3.1 Manantenina deposit

3.1.1 General geology

The Manantenina district extends between the coast and the Anosy Mountains. There is first a narrow coastal plain, where the Precambrian basement is covered by Tertiary and Quaternary sands. Behind the beach, wind-blown sand dunes up to 20 m high occur. Flat-topped abrasion plateaux follow, having a general 30 m top level. A second abrasion plateau level occurs behind them at an average height of 60 m above MSL. The plateaux are formed of cordierite gneiss; the bauxite occurs on top of them. This double strip of plateaux is at 3 - 15 km distance from the seashore. (Figure 4)

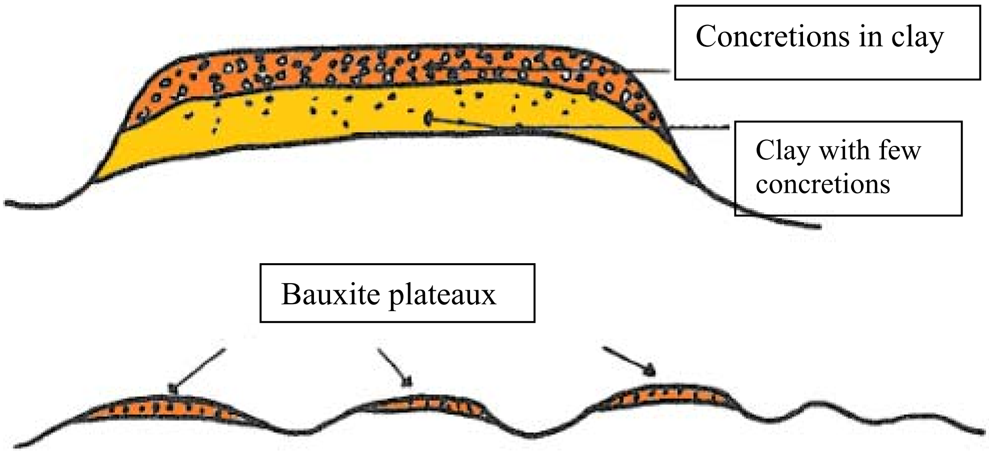

Figure 4. Plateaux typical profile.

3.1.2. Bauxite profile

- soil: 0 – 1 m thick; brown to grey, rich in humus and roots. Grain size is finer than in the bauxite horizon.
- duricrust: none,
- bauxite horizon: 1 - 15 m, generally 3 - 4 m thick; red, yellow, rarely pink and white withunweathered rock debris; consists essentially of 1 - 20 cm gibbsite nodules embedded in a kaolinite and quartz-rich material.
- saprolite: 10 - 20 m thick; pink, yellow, whitish in color, soft, earthy with sandy-clayey consistency; does not contain gibbsite nodules.
- parent rock: cordierite gneiss, more or less weathered. The fresh rock contains about 20 % Al_2O_3, it is hard and compact. There is a gradual transition from the gneiss into the saprolite.

3.1.3. Mineralogy

The grade of the bauxite horizon proved to be rather regular and uniform over the plateau surfaces. Quantitative X-ray diffraction and thermogravimetric investigations showed that gibbsite is the main alumina mineral. The gibbsite crystals are 30 - 40 µm in size. Less than 1 % of boehmite and diaspore has been regularly detected in the bauxite. All reactive silica is bound to kaolinite. The non-reactive silica is in relict minerals, mainly quartz, having grain size of 50 to 2 500 µm; sillimanite and a little disthene. Goethite is the prevailing iron mineral, accompanied by less hematite. Both minerals contain isomorphous Al substitutions. Anatase, rutile and residual ilmenite are the titanium minerals. (Table 1)

Table 1. Mineralogy.

Size fraction after crushing		Pit 210 B			Pit 210 B 4	
at 10 mm and washing	10-2 mm	2 - I,60 mm	1,6 - 1 mm	10 - 2 mm	2 – 1,6 mm	1,6 – 1 mm
Gibbsite	73.6	67.5	55.4	82.3	81.9	79
Hematite	11.2	15.9	21.1	10.8	10.7	10.5
Quartz	7.4	9.6	17.8	1.8	2.6	6.3
Kaolinite	3.6	3.9	3	1.5	2.2	1.4
Rutile, Anastase	1.1	1	0.8	2.9	1.9	1.8
Sillimanite	2.4	1.8	1.4	-	-	-
Zircon	-	-	-	0.2	0.2	0.3
Total	99.3	99.7	99.5	99.5	99.5	99.3

		Pit 210 B			Pit 210 B 4	
	10-2 mm	2 - I,60 mm	1,6 - 1 mm	10 - 2 mm	2 – 1,6 mm	1,6 – 1 mm
Al2O3 available	44.9	29.2	32.4	53	52.7	48.5

3.1.4. Resources and Reserves

Several estimates are available from archives, going back to the early 60 s.
Based on the 18 350 meters drilling campaigns and on the parameters below:

- Recovery: ratio of dry beneficiated bauxite over wet crude bauxite;
- Main cut-off values: T. Al_2O_3 > 30 %; T. SiO_2 < 5 %;
- Secondary cut-off values: thickness > 1 m; overburden to ore ratio (in thickness) > 1;
- Density: 1.75 g/cm³.

Four zones were defined and "exploitable reserves" were calculated (Rouiller 1973 [1]) and are mentioned in Tab X. These reserves are not considered as JORC reserves. (Table 2)

Table 2. Manantenina "reserves".

Area	Beneficiated bauxite (Mt)	Recovery (%)	R. SiO_2	Av. Al_2O_3
Z. Sud	34	35.9	1.4	39.4
Z. Centre	52.4	35.5	1.5	38.9
Z. Nord	79.6	35.3	1.4	40.6
Ex. Nord	50	35	1	41
Total	**216**	**35.4**	**1.3**	**40.1**

3.1.5 Beneficiation tests

30 kt were processed in the washing pilot plant and the capacity was 200 t/h. The results are summarized in Table 3.

Table 3. Washing pilot plant results.

	Crude bauxite		Beneficiated bauxite	
Recovery	**Av. Al2O3**	**R. SiO2**	**Av. Al2O3**	**R. SiO2**
35.10%	32.5	1.98	42.2	1.09

Figure 5.1. Washing pilot unit.

Figure 5.2. Washed bauxite production.

4. Processability

After chemical and mineralogical analysis, the processability conditions of the Manantenina bauxite have been defined. The tests have been done in a Pechiney French pilot plant. (Table 4)

Table 4. Bauxite for Bayer Pilot tests.

	LOI	Tot. SiO2	Tot. Al2O3	Fe2O3	TiO2	R. SiO2	Av. Al2O3	Quartz
Shipment#1	21.71	11.05	45.55	14	1.5	1.5	42.8	12.55
Shipment#2	23.3	18.3	42.4	14.4	1.6	2.03	39.6	16.22
Shipment#3	23.75	18.43	43.16	13	1.56	2	39.8	16.43
Shipment#4	22.8	19.95	42.66	12.75	1.45	2.7	39.3	17.27

A first campaign of successive cycles on 300 t of bauxite and a second on 200 t have been achieved in order to optimize some parameters. As expected, it as been demonstrated that the gibbsitic bauxite digested at 145 °C can produce a good quality alumina with good performance (Table 5).

Table 5: Alumina quality produced by pilot plant.

Cycle #	Composition	(%)	
	Si	Fe	Na2O
16	0.0122	0.0117	0.4
17	0.011	0.0093	0.368
18	0.0098	0.0045	0.372
19	0.0064	0.009	0.296
20	0.0091	0.0045	0.332
21	0.01	0.0054	0.348
22	0.0083	0.0036	0.34
23	0.0082	0.0059	0.36

A refinery was designed based on washed bauxite with the washed bauxite in Table 6:

Table 6. Bauxite for refinery project.

Available Alumina	40 %
Reactive Silica	1.8 0%
Quartz	24 %
Moisture	12 %

The power station design includes backpressure turbines for power production, (Table 7).

Table 7. Refinery main parameters.

Refinery Production	1.65 Mtpa
Wet Bauxite (feed to Bayer Plant)	2.9 t/t
Bauxite Moisture	12 %
Availabilty factor	97 %
Caustic Soda (NaOH)	55 kg/t
Burnt Lime (100%CaO)	13 kg/t
Steam 5 bar	1.1 t/
Steam 12 bar	0.5 t/t

5. Conclusion

The Manantenina deposit has been extensively studied. Its bauxite does not present any particular difficulty in its treatment by the Bayer process. The construction of a alumina refinery on the island looks unlikely in the medium term. However, the washed bauxite can be an interesting source of gibbsitic bauxite for Shandong refineries or non-integrated plants in the Atlantic area.

6. References

1. Roullier, J.P. (1970 - 1973)
2. Bárdossy, G. & Aleva, G. J. J., 1990. Lateritic bauxites. Developments in Economic Geology, 27.Elsevier.
3. Komlóssy,G 2013. Global Bauxite Resources. Metal Bulletin 2013.
4. Carboni, V. 2005 Bauxite Potential of Madagascar.