



Islamic Azad University
Mashhad Branch

Comparison of bauxite resources – geo-economical considerations

G. Komlóssy*¹ and W. B. Morrison²

1. *Geo-Kom Geological Exploration Ltd. Vércse u. 23, Budapest – Hungary H-1124*

2. *William B. Morrison and Assoc. 3115 Bayo Vista, Alameda CA – 94501 USA*

Received 25 November 2009; accepted 25 February 2010

Abstract

In order to meet the significantly increased metal demand of the world market, it has been decided to expand the capacity of the existing alumina refineries and to set up new plants (more than 2 Mt/a each). The selection among the bauxite sources is based on previous exploration data, such as: tonnage, grade, mineralogy, etc., the geographical position of the deposit, existing natural and constructed infrastructure and the distance from deep water ports. Environmental and political risks are also investigated. Decision making is a complex task in which the close co-operation of professionals of the bauxite-alumina industry is needed. The authors specify the most determinant factors which are investigated for decision making and call attention to the fact that, in many cases, inconsistent data are compared as if they were equal in value or identical such as:

- the reliability of explorations made for deposits in various countries, and at different times is also different,
- the methods applied in reserve calculation and resource estimate are different,
- the qualitative criteria used for commercial grade ores are different,
- no numeric data are available showing the possible error in reserve calculation
- the terminology used for bauxite categories is also different.

Adequate attention is never given for the further development of possible prospects; their investigation may be neglected in the selection. As a consequence, when different resources are compared, the geological risks (stability in bauxite production) cannot adequately be taken into account. For minimizing the transport costs (either the bauxite supply to the alumina plant or the alumina shipping to the smelter or both) the geographical position of the raw material is one of the most significant economic factors in the value of the deposit. There are several regions in the world which are so rich in bauxite potential (West Africa, edge of the Guyana Shield in Venezuela and Brazil, the Amazon Basin in Brazil, Weipa Gove in Australia, Eastern Ghats in India, etc.) where new deposits should be explored as a function of their geographical position. The landsat interpretation has proved to be an excellent tool for establishing priorities among the options. The authors give a short review and comparison of the most significant regions and deposits focusing their interests on the:

tonnage, grade and mineralogy, further prospects (undiscovered) deposits, infrastructure, distance from mine/deposits to the deep water ports, available alumina content (for a low or a high temperature procedure) for estimating the bauxite consumption per ton of alumina, soluble silica content for estimating the caustic soda consumption per ton of alumina, beneficiation cost in some cases, risk factors (geological, environmental, political and national)

The authors conclude, that in spite of the fact that about 30 - 35 billion tons of bauxite have been registered so far as proved + probable reserves and a further 55 – 60 billion tons can be estimated as possible resources in the world, finding new resources in better geographical locations and their exploration may be advantageous. The new exploration data must be more reliable, as well. The costs of reconnaissance and exploration may be far below the haulage costs.

Keywords: *World bauxite resources, Exploration data reliability and comparability, New bauxite resources, Geographic locations*

1. Introduction

When companies make selection (screening) among the different possible bauxite resources often the value of the various deposits (given in \$) are compared. This valuation can be expressed in the Net Present Value (NPV); Internal Rate of Return (IRR); and/or Payback period.

*Corresponding author.

E-mail address (es): *geokom@ mail.datanet.hu*

The calculation of these values is charged with different risks:

geological (mining) risks, environmental risks and political risks.

Geologists are responsible for the geological risks composed of several elements for which some can only be expressed more or less reliably with numbers (these may be believed to be objective elements); while the others can only be estimated (these are “semi-objective” elements). Both types of elements should be involved in the valuation of a given deposit when

determining an NPV or an IRR. The purely subjective factors such as: political and environmental risks, although very important, are left out of consideration in this paper.

2. Data to be compared

The minimum economic size for new alumina facilities as well as the threshold cost of supporting infrastructure necessitates a tendency towards considering potentially large deposits. It is not uncommon for aluminium companies to be interested in deposits with min. 300 M tons of identified bauxite resources which can be extracted with open pit methods – anything less, and the deposit must be of particularly high quality. Further the ore must be gibbsitic (boehmite+ diaspore content < 5 %) with a low reactive silica content (preferably < 3%).

Past investigation has demonstrated that the following countries are in the first rank in satisfying the above mentioned conditions: Australia, India, Guinea, Brazil and Venezuela while Indonesia, Vietnam, Mali, Ghana and Cameroon are in the second rank.

When comparisons are made between various deposits, even at the screening level, the following main items are investigated:

1. Geographical position:
 - (a) country,
 - (b) location of deposit
2. Status:
 - (a) name of owner
 - (b) free for licences: prospecting and mining ones
3. Infrastructure:
 - (a) deep water port availability,
 - (b) its berthing capacity,
 - (c) distance from the deposit to the port (on road and railway, transport on road to the railway),
 - (d) estimation of the length of the road if construction is needed
 - (e) other haulage systems (e.g. conveyor belt, rope way, etc).
4. Ocean transport, if relevant
5. Geology: grade and tonnage of the bauxite:
 - (a) Resources/reserves in *measured+indicated+inferred* categories,
 - (b) Bauxite potential (hypothetical – speculative),
 - (c) Condition of the resource/reserve estimate (cut off values), estimation methods, conditions of the ore categorisation,
 - (d) method of exploration (pitting, drilling techniques),
 - (e) mineralogy,
6. Mining capacity of operating mines (Mt/a) if relevant:
 - (a) Productivity of a mining unit (t/km²),
 - (b) Ore thickness: average and range (m),

(c) Overburden thickness: average and range (m) and type,

(d) Stripping ratio (m³/t)

(e) Mining method, blasting: yes or no,

(f) Estimated mining loss and dilution,

(g) Mining costs per ton of bauxite (Capex and Opex)

7. Bauxite beneficiation (if relevant) recovery in % and costs per ton of bauxite concentrate.

8. Processing: Extractable alumina% → bauxite to alumina: (t/t)

Reactive silica % → soda to alumina (kg/t)

9. The legal status of the deposits is to be registered such as: ownership of mining and/or prospecting licences and delineation of the areas of potential which are worthy and free for prospecting.

3. Inconsistencies in the Geological Data

3-1 Tonnage and grade of bauxite

The available tonnage and the grade of bauxite are probably the most important elements one can consider when comparisons are made. However, the results of bauxite explorations have been realized in different systems (drilling or pitting grids), which have applied different techniques in drilling, analytical methods, etc. over different times. Resource/reserve calculation and resource estimates have also been made with different methods and under different conditions (cut-off values for grade and mine able thickness). As such, the reliability of the information that results must be estimated and evaluated by an experienced bauxite geologist (competent person) before selection is made.

• *Drilling – pitting grid*

From past experience the authors find that, in general, there are no problems with the grids that are applied in laterite bauxite explorations. Categorization of the reserves/resources (see later) are based only on the grid applied. An inconsistency in data occurs due to the fact that as exploration techniques have advanced, the variances of extractable ore thickness (tonnage) have been calculated with greater accuracy. This has occurred with the application of geo-mathematical methods. In the past (before the eighties or the nineties) the main components were not calculated with the same methods, so that such qualifiers such as the possible error are not included. Therefore, when different deposits are compared, it may occur that more exact data are compared (and registered in different statistics) with far less exact data as if they were of equal statistical accuracy and rigor.

• *Drilling and pitting techniques*

The Authors have found that the reliability of the exploration data is highly dependent upon the reliability of the drilling techniques [1]. An extreme example where the results of diamond core drilling (A) are compared with that of reverse circulation (B)

drilling is highlighted in Figure 1.

The figure above shows that both the thickness (tonnage) and the grade of the deposit estimated by prospecting depend significantly upon the drilling technique used during the exploration. It is possible that the range of such possible errors can be expressed in the categorization. However, in many instances such categorization is often neglected (see details in paragraph of Reserve/resource categorization).

Moreover, when data are extracted from different sources for comparison of deposits it may happen that no information is available on the exploration techniques employed for the different deposits. When the possible dilution is taken into account, the core drilling method is correct. Therefore, the theoretical bauxite to alumina (t/t) is 2.42 in case of core drilling

and in case of Edison 2000 it is 2.73. The effect of this inaccuracy, in the case of a 1 Mt/a capacity refinery, with a 6 USD/t bauxite price at the plant and 200 USD/t NaOH makes a difference of about 8-9 million USD/ year.

In this instance the differences in silica content are so high that it can not be explained with dilution; basically the difference must be derived from unsuitable drilling technique used in exploration. According to a rough estimation, again using an alumina refinery of 1 Mt/a capacity, (calculated with 200 USD/kg NaOH price) this error made a difference of as much as 10 million USD /year in 1993. This significant difference plays an important role in the calculation of the NPV of the deposit, again estimated on the basis of bad exploration data

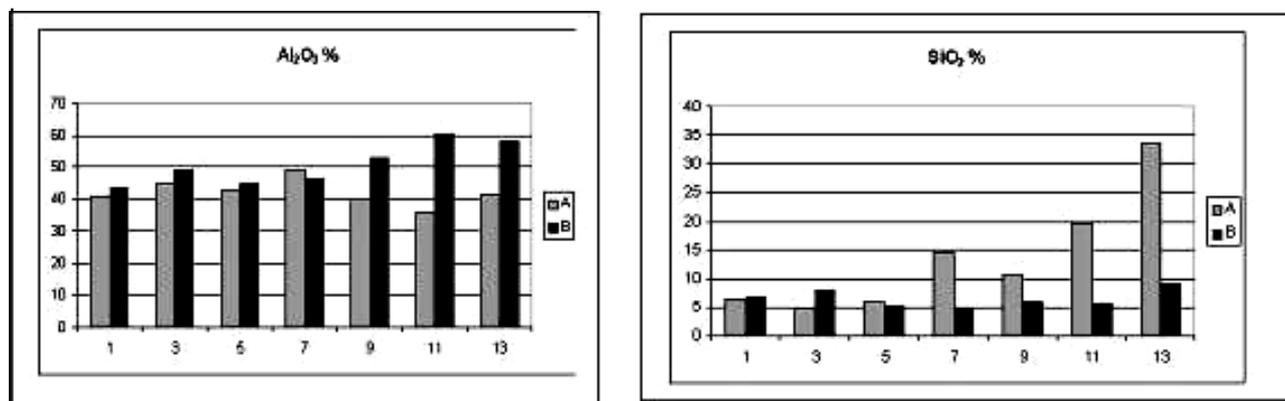


Fig. 1. Results of diamond core drilling (A) compared with that of reverse circulation (B) drilling

Table 1. Another example from an Indian deposit compares core drilling results with an Edison2000 vacuum.

Drilling methods	Al ₂ O ₃ (t) %	Al ₂ O ₃ (av.) %	SiO ₂ % (t)	SiO ₂ % (r)
Core drilling	46.7	44.2	2.65	2.25
Edson 2000 vac.	41.0	38.5	2.65	2.25
Actual mining	43.5	~41	2.6 – 2.7	2.2-2-3

Table 2. A South American example compares exploration with actual mining results

	Tonnage	Al ₂ O ₃ (t) %	Al ₂ O ₃ (av)%	SiO ₂ (t)%	SiO ₂ (r) %
Forecast (exploration)	30.30	59.84	56.06	3.69	3.43
Actual (mining)	28.10	58.55	52.44	5.97	5.55

Table3. Reserve assessment comparison applying different methods in a test area

	R. polygonal			D. Krigged			Current polygonal		
	Mt	Av. Al ₂ O ₃ %	r SiO ₂ %	Mt	Av. Al ₂ O ₃ %	r SiO ₂ %	Mt	Av. Al ₂ O ₃ %	r SiO ₂ %
raw data	63	31.2	1.3	94	30.0	1.4	78	29.9	1.3
expected mining	54	31.2	1.3	63	29.4	1.6	78	30.8	1.6

• **Reserve/resource estimate and terminology**

Almost always in the evaluation of different bauxite resources there are no data in the statistics to characterize the method used in the reserve calculation /resource.

The bauxite deposit was explored in 50m x 50m grid (raw data) and 25m x 25m grid mine development grid (+ dilution and –mining loss determined as expected mining data). Bauxite resources/reserves were classified into “measured resources” and measured reserves. Difference between the *R. polygonal* and *Current polygonal* in tonnage, in case of “expected mining tonnage”, is as much as 44 % which is so high that the error is far beyond that which is permitted to be in *measured*, or even in *indicated* categories.

A very definite inconsistency exists in the very manner in which the content of a deposit is defined. Often statistics on a given deposit report “reserve” as the only category without further explanation. From the seventies the concept of *resources* has been introduced [2] but not everywhere. Further, in different statistical data, the concepts and definitions are confused and not always correctly used. Hence, a geologist making comparisons among various bauxite deposits has to recognise the terms in use and has to adjust them in his assessment for consistency. As it is clearly worded in the JORC code of 1992 [3] as follows:

- “Resource”: is quantified on the basis of geological data and an assumed cut-off grade only. There is an implication that there are reasonable prospects of eventual economic exploitation.
- “Reserve”: it is that part of the resource which, after application of mining factors, results in an estimated tonnage and grade which can be the basis of a viable

project after taking account of all relevant metallurgical, marketing, environmental, legal, social and governmental factors. See Fig. 2.

• **Reserve – resource categorisation**

Ore reserves and resources are classified into categories which express the geological knowledge and confidence levels that can be attributed to both grade and tonnage. The confidence level in the results and classification increases with the progress of the geological activities. There are different classification systems and *when they are applied for bauxite deposits* they can be well suited to each other. Basically, only the names are different as it is shown in the Table 4. Nevertheless, it is worth mentioning that there have been a lot of changes in the definition and determination of each the categories. JORC 2004 shows a significant improvement in this area [3]. While formerly the reserve resources categories were merely established on the basis the drilling/pitting grid space, the importance of the investigation of (1) the reliability of the drilling techniques, (2) sample recoveries, (3) sampling and analytical methods, etc. are emphasized.

Unfortunately, attention to these details is still neglected in practice in many cases, despite their importance. It is very important that the JORC even if it is a “code” is still only a guideline. It is still the responsibility of the geologist to deliver his interpretation. Individual, subjective, judgements are also implemented in categorisation. Therefore, categorisation, by whatever method, can only be accepted as quasi exact and the possible errors of all components (tonnage, grade) in each category still need to be computed with application of geo-mathematical methods

Table 4. Classification Systems for ore resources

Increasing level of knowledge (8)

Stages of knowledge	Reconnaissance		Prospecting	General exploration	Detailed exploration
US before 1976	Possible			Probable	Proven
US after 1976	Undiscovered		Inferred	Demonstrated	
				Indicated	Measured
JORC 2004			Inferred	Indicated	Measured
UN 1996	Undiscovered		Identified		
			Inferred	Indicated	Measured
	Speculated	Hypoth.	Inferred	Indicated	Measured
Soviet	D3 D2	D1	C2	C1	A + B

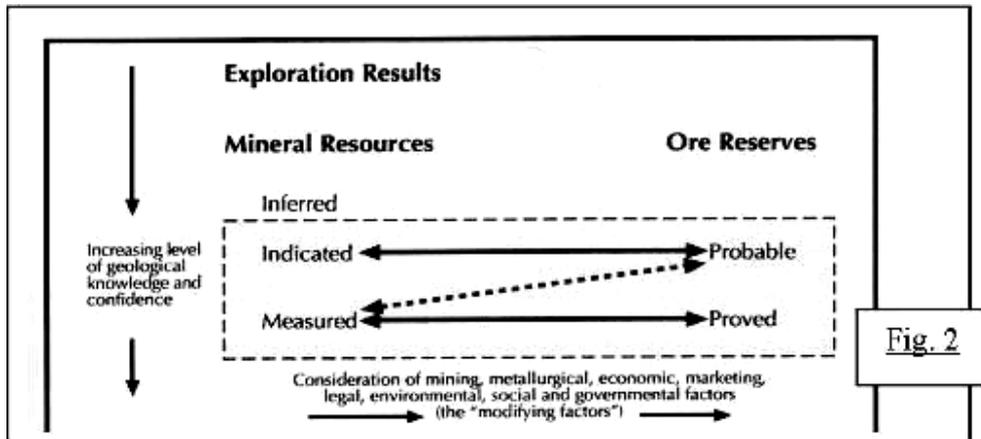


Fig. 2. Relationship between exploration results, mineral resources & ore reserves- JORC Code 2004 [3]

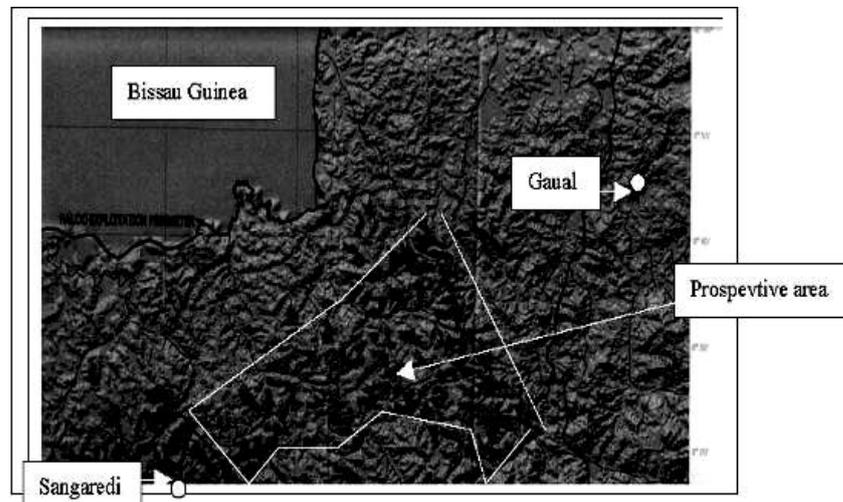


Fig. 3. Detail of a prospective undiscovered area in Guinea

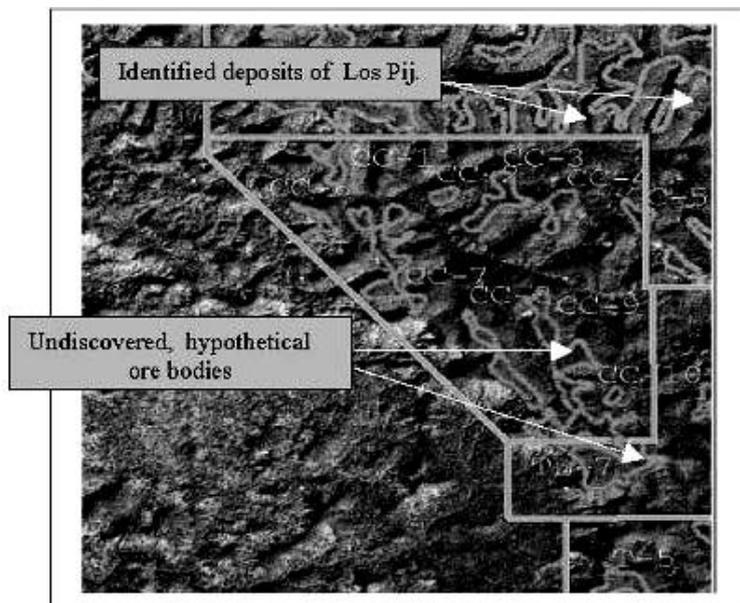


Fig. 4. Example of a prospective undiscovered plateau near Los Pijiguaos (Venezuela) Landsat imagery

Table 5. Selected Competitive Bauxite Resources (Identified) and Further (Unidentified) Prospects

Country	Deposit / Group of deposits	Identified resources (Mt)	Further prospects (Mt)	Date of reference
Australia	Darling Range -	1,000	1,000 – 1,500	1985
	Mt. Sadleback			2006
	Weipa	1,200	4,000	2006
	Gove	220	200	2006
	Ely	780	low grade only	2006
	Total	3,400	5,200 – 5,700	2006
Indonesia	W. Kalimantan	800cc	1,500cc	1984+
Vietnam	Bao Lok-Thau Rai	313cc	760cc	1979+
	Dac Nong	1,200cc	2,500cc	1979+
	Konplong	160cc	200cc	1979+
	Phuoc Long	140cc	200cc	1979+
	Kontum-Pleiku	0	200cc	1979+
Total		1,413cc	3,860cc	
India	East Coast	1.700	100-200	2005
	Others	800	100?	2005
	Ninahin	150	not identified likely: 200 - 500	1975 1983
	Total	270		
	Minim Martap	560 +200?	320	1972+ 1978+ 1982-84+
Cameroon	Fongo Tongo	50	not investigated	
	Total	730	800 – 1,000	
Sierra Leone	Mokanji hills and Gondama	10cc	probably yes, not investigated	1984+
Port Loko	104cc			
Total	114cc			
	Bamako West	105	500-1,000 crude ore	1972+
Beléa	10cc	400		
Faléa	171			
Total	676			
Guinea	Boké Goual District			
	(1) Sinthiourou	220		'96-'06
	(2) GAPCO	1 – 2,000		2002
	(3) Boké NW	0		2006
	Fria District			
	(1) Fria	360	100	2002
	(2) Boké – Fria	0	2,000	2006
(3) S of Fria	0	1,000	2006	
	Kindia District	78	12	2002
Brazil	Trombetas District	850		1990
	Almeirim District	>320		1990
	Paragominas Dist.	2,400		2000
	New explorations	<1,400	>5,000	2005
Venezuela	Los Pijiguaos	320	1,200	2004
	Western rim of Guyana Shield		3,000	
	Total	320	5,200	2004

cc= concentrate + According to our knowledge no new exploration has been done since that time. x = Between Sinthiourou and Goal township (see Fig. 3)

5. Bauxite Supply Opportunities – Country Review

The annual world bauxite production was 142 Mt in 2002 (USGS Mineral Commodity Statistics) which will probably be increased up to minimum 150 Mt in the

near future.

Australia

According to the latest available statistical data (2002) Australia produces as much as 54Mt of bauxite which is 38% of the world production (USGS statistics). Because of the developed infrastructure, political and

economical stability Australia will retain its leading role even if its share in the world production drops as new developments, and expansions have been decided, or are being prepared or have commenced in Guinea, Brazil and also in India. The Ely and Gove deposits are gibbsitic and quite favorable. However, their identified resources and potential tonnage are dwarfed by that of bauxite from the Weipa deposit which can be processed only at high temperature.

Indonesia

Different companies, from time to time, have investigated the possibility of the utilisation of the Indonesian bauxites which were discovered in 1924 and at that time owned by NIBEM -the subsidiary of the Billiton Co. The most important bauxite occurrence (not currently being mined) is in West Kalimantan Island (Borneo). The bauxite bearing complexes are soft lateritic clay from which harder bauxite "fragments" can be washed out; sieving was done at 1.4 mm diameter. Statistical data refer to this grain size. Recovery varies between 35 % and 85 %; the average could be around 55%- 60% [5].

The most important is the Tayan deposit located in the vicinity of the Kapuas River which may serve as a possible transport route (some 150 km) towards the deepwater port at Pontianak. Bauxitic hills (prospecting lease areas) extend over 300km from the north (Tayan) towards the south. Deposits are covered by dense jungle and stand closely together in a swampy, alluvial plain with rivulets and few lakes.

Vietnam

The impression of the Authors is that this country falls out of the international interest, for lack of infrastructure. This evaluation is true but relative. If Vietnam is compared with the prospective and undiscovered territories of Venezuela and Brazil the situation is not so far disadvantageous as it is believed, e.g. the possible utilisation of a slurry pipe haulage system has not yet been investigated. These deposits may not be adequately known in the international statistics; however, they were published by the Vietnamese Govt. in the eighties (30) [6]. The main Vietnamese laterite bauxite deposits are located 170 km (on paved road) from Ho Chi Minh City (formerly Saigon) and extend for 200 – 250 km along the Cambodian border. They were intensively prospected and explored during the eighties by Soviet and Hungarian teams and a number of techno-economical studies were made for the UNIDO (Vienna) on the beneficiation and alumina technology [7]. Utilisation of the ore deposits was investigated by ALCAN [8] and also by PECHINEY (1996?).

The Vietnamese Bauxites are young, soft, earthy soil in which harder bauxite fragments can be found. Bauxite complex can be easily beneficiated by washing and screening carried out at different grain sizes, most frequently >1mm and > 3mm. The ore reserves given in Table 5 and 6 refer to wet concentrate.

India

Total identified bauxite resources in India are estimated as much as 2,300 Mt out of which more than 1,700 Mt are located in the East Coast Region (Orissa and Andhra Pradesh States). The others are found in Central India, West Coast and Gujarat State. The whole country might possess an additional 700-800 Mt of undiscovered resources [9, 10 and 11].

For the international comparison the East Coast (EC) bauxites are taken into account, the others are out of interest in this paper. EC bauxites have low reactive silica (2.6%) and low mono content (<3.0%). The extractable ore thickness is 10-12m in average. Huge resources are concentrated in a small area making the mining effective. In this area, there are a number of plateaux with >100 Mt of bauxites (Ghadamardan, Karlapat, Sijimali-Kutrumali, Baphmali, Panchpatmali, Jeralla). There is only one operating mine and alumina plant located in the heart of the region (Damanjodi), owned by the NALCO. The bauxite price at the plant is one of the cheapest all over the world. Calculating for 1 ton of alumina it must be below 20 USD. Railway line between Visakapatnam (deep water port) and Raipur pass through the region and there are also two important branch lines.

Bauxite deposits are located on the top of the plateaux in between 900m –1,400 m above sea level .and at 600 – 800 m relative heights [9, 11]. Access to the hilltop is difficult. From the Damanjodi mine to the refinery there is a 14 km long conveyor belt providing for haulage.

The hill tops are basically grasslands and uninhabited. The forested hill slopes are under protection. It is also worth mentioning that the areas of Andhra Pradesh deposits (with the exception of the Araku Valley) are recently infected by Naxalites¹

The export of these bauxites is not permitted, but alumina refinery construction, in joint venture with local companies, is supported by the local governments. Mining license has only been granted for NALCO (Damanjodi). For utilization of the others, representing >100 Mt of bauxite, different companies have been formed. The company compositions are continuously changing. There are further prospective areas around the identified deposits.

Ghana

Estimates of the total bauxite reserves/resources of Ghana vary from 300Mt (Pechiney – 1975) up to 780 Mt (Int. Bauxite Association – 1978). Infrastructure of Ghana (access to the bauxite deposits) is relatively favourable.

The bauxite resources of Ghana are:

1. Kibi Mts. and Atewa Range Districts are situated about 80-100km from Accra deep water port connected

¹ Maoist terrorists groups

by paved road. Main rail road leading to Accra can be accessed in 10 – 30km.

2. Nyinahin: distance from the Awaso mine (close to the Nyinahin deposit) and port is 240km by rail. Technological Feasibility Study was made by the Aluterv-FKI (Budapest – Hungary 1978).

The Ghana Bauxite Co (ALCAN) supplies bauxite to Alcan's alumina operation in Canada from Awaso deposit. Production has been expanded to 800,000 t/a

Cameroon

Bauxite deposits can be found in three occurrences as follows:

(1) *Minim – Martap* and

(2) *Ngaoundal* in the Adamaoua Mts. (Northern Territory) and

(3) *Fongo Tongo* (South-West Territory).

Ownership: Société d'Études des Bauxites de Cameroon (SEBACAM) founded in 1970 with 40% participation of the Government, 45% Pechiney, 10% Vereinigte Aluminium Werke and 5% Kaiser Aluminium and Chemical Corp. The prospective areas in the vicinity of Minim–Martap and Ngaoundal occurrences and probably also at Fongo Tongo are free for exploration licence.

Industrial development of the country is paralyzed by poor infrastructure. The “Transcamerounaise” railway line connects Douala (main port) through Yaounde (capital) and Ngaoundere township. Ngaoundal deposits are in the vicinity of the rail track, 802 km from Douala port. Minim – Martap deposits are located about 40 km NW from this rail road. There was no heavy loading capacity of the train in 1982. The same conditions are supposed to prevail up to now. Fongo Tongo can only be accessed on one of the main national paved roads leading from Douala towards Fomban town. The distance between Douala and Fongo Tongo is 250 km. There was a plan for railway construction for bauxite alumina industry connecting Ngaoundal with Kibi Loabé [12]. It is not known whether the construction has been realised.

Explorations were performed in two campaigns, the first between 1958 and 1961 by the Direction des Mines et de la Géologie du Cameroun and the French BRGM and the second one between 1969 and 1972 by SEBACAM and Pechiney-Ugine. Altogether 24 plateaux were discovered at Minim – Martap from which 11 have been explored in detail. At Ngaoundal 3 deposits have been identified at elevations of 1200m-1400m above sea level. Identified + undiscovered resources, estimated by LOTZE, J.(1978), [13] are as much as 1.8 billion tons in Cameroon from which 1 billion tons of bauxite is estimated for the two groups of deposits situated in the Northern Territory [14.]

At Minim – Mamartap measured and indicated reserves are as much as 560 Mt on 11 plateaux and an additional 200 Mt resources are estimated to be available classified into inferred category (SEBACAM inventory

1982 -84). Fongo-Tongo represents 50Mt of bauxite which is below the interests of the companies. Nevertheless, considering its high quality ore (Av. Al₂O₃: 49% and SiO₂(r):1.8%) and favourable geographical position, compared to the two other occurrences, it is a typical case where the investigation of the further prospects of the surroundings is highly advisable because it may be much more valuable than the already explored Minim– Martap.

Sierra Leone

Identified bauxite reserves/resources (owned by the SIEROMCO- an Alusuisse affiliate) are minor compared to the other deposits investigated in this paper. Moreover, the bauxite needs up-grading. With washing and screening the recovery is >50 %. Nevertheless, there are three very important factors which significantly increase the value of these deposits:

(1) Close location to the Atlantic Ocean: 50-70 km From Port Loko deposit with existing road and railway.

(2) In between Port Loko and Mokañji hills a prospective zone is supposed to exist which probably has not yet adequately investigated.

(3) According to our knowledge the further prospects on the Fouta Djallon Range, between the Liberian and Guinea borders, has also not yet investigated.

Bauxite is soft, can be easily treated (no blasting is needed) and it is a tri-hydrate type ore.

Mali

Pre-feasibility study for the bauxite-alumina and aluminium industry sponsored by the UNIDO (Vienna) was made by the ALUTERV-FKI (Budapest – Hungary) in 1972[15]. According to our knowledge neither development nor further explorations have been made since this time. Bauxites in Mali occur on dissected remnants of an old (Cretaceous) peneplain at 600 – 650m above sea level.

Infrastructure is very poor. Bamako West deposit is in the best position located about 100km from Bamako which is connected by railway with Dakar (Senegal) deep water port (1,200) km.

Comparing these deposits with that of Guinea, their value is far below the latter, partly because the ore bodies are more scattered, and because partly their accessibility is more difficult than the Guinea lease areas. Beneficiation tests were also carried out; the volume dropped about by 45%, while the quality did not change significantly. For that reason in the Table 5 the crude resources are listed.

Guinea

Regarding its identified bauxite deposits both in tonnage and grade, its further prospects, and its geographical position, Guinea is the number one bauxite country of the world. This is even though Australia is currently the leading producer - due to its much better infrastructure. Bauxite output of Guinea, in 2002, was 15.7 Mt (USGS Minerals Commodity

Statistics). With this figure Guinea is the second largest bauxite producer of the world.

Accessibility of the bauxitic “*bowals*” located on savannah zone is much easier than that of those in the Amazon Valley and Guyana Shield in South America. On the one hand they are covered by dense jungle, and on the other one the morphology is also favourable. Relative elevations vary between 100m and 200m. Ore concentration is high. Number of ore bodies contain >100 Mt of bauxite. The relatively high mono content (>5%) at some places is a disadvantageous factor; nevertheless, it concentrates in more or less definite layers which can be selectively mined, as at Sangaredi. Available alumina concentration is also not high, typically around 43-45 % (depending on the cut-off used in different resource estimates).

There are 6 bauxite districts as follows: (1) Boké - Gaoual, (2) Fria (3) Kibi (4) Pita Labé (4) Tougué (5) Dabola. (5). The top priority is with the first three bauxite districts where operating mines exist and because of their geographical position, closer distance to transport routes and level of geological knowledge. Rehabilitation of the old railway track, from Dabola to Conakry, would be important for the development of this bauxite district.

In the past years (1998-2002) very successful explorations were carried out, led by Russian professionals on the GAPCO licence area (situated between Sangaredi and Boké townships). A green field alumina refinery has been decided to set up for the huge resources with a capacity about 2 –2.5 Mt/a.

For the Boké-Gaoual deposits the transport route is the existing railway track between Sangaredi and Kamsar deep water port; however, it is hardly believed that it will be able to satisfy the increasing demand. Side rail roads or transport routes, from the ore bodies to the railway track, must be constructed. The other two bauxite districts (Fria and Kibi) have their own haulage system.

In Guinea the bauxite potential, in practice, is not limited. When any selection is made in Guinea there must be only one single aspect; this is the geographical location that is the distance between the existing transport routes leading to Kamsar or Conakry. In this respect the following areas are deemed to be the most important:

- NW of Boké towards the Bissau Guinea border,
- SE from Boké, between the town and Fria licence area.
- South of Fria licence area; this is partly the coastal area.

Investigation of the possibly buried younger penplain surfaces (Surinam analogy) would be advisable.

Prospects established for the Boké – Gaoual and Fria Districts (Table 5) are a very rough estimation (speculative category) made with the aid of landsat

imageries and local geomorphological knowledge.

Brazil

The country is in the focus of interests in the bauxite – alumina – aluminium industrial developments. The main reasons are the abundant resources (identified + undiscovered), easy mining, acceptable quality, tri-hydrate in mineralogy, relatively low mining cost even if the beneficiation is included. Last but not least, the domestic professional knowledge: traditions in mining and alumina industry and a stable government. Method of beneficiation has already been worked out and tried at Trombetas. Disadvantageous factors are the dense tropical rain forest cover and lack of infrastructure in the remote areas. Along the contact of the southern margin of the Guyana Shield and the northern one of the Brazil Shield (geographically called Amazon Valley) is one of the regions where bauxite should be found in the vicinity of the existing natural infrastructure (as it is in the case of the Trombetas deposits with the Trombetas and Amazon Rivers). The following main bauxite districts are distinguished: (1) Trombetas, (2) Almeirim, (3) Paragominas which give more than 95% of the Brazilian resources. Identified resources are recorded as much as 3,200Mt by BOULANGÉ, G. – CARVALHO, A. [16] and 3,600Mt by BÁRDOSY, G. – ALEVA, J.J. G. [14]. The Caracau, Almeirim and Morro de Filipe in the Almeirim District are not included. It is supposed that in the past one and half decades the explored resources have increased considerably. MAMEDOV, V. I. – BOGATYREV, B. [17] estimated as much as 5,000 Mt tons of crude ore. Therefore in Table 5, the latest figure is also listed. The recovery of beneficiation varies between 50%-70%. Beneficiation cost should be below \$2/t of concentrate.

Venezuela.

It is one of the new bauxite producer countries. Los Pijiguaos deposit is a “world class” type. Ore bodies are in high concentration within the Los Pijiguaos mining licence area. Out of this area the productivity is seemingly less. Access to the ore bodies, is difficult. They are also scattered. The whole territory is covered by dense rain forest. The only existing transport route toward the ocean is the Orinico River which can only be used for seven-eight months in a year. Because of the complicated transport system bauxite price can hardly be kept below 60\$ for 1 t of alumina processed at the Puerto Ordaz alumina plant. Investigation of the northern rim of the Guyana Shield in a better geographical position e.g. between the Caura and Caroni Rivers is highly recommended. Disadvantageous factors are compensated by a good quality ore. Political risk is out of question, but while the political climate changes the bauxite geological conditions are stable.

6. Conclusions

1. The confidence level of the reserve/resource estimates (from the reliability of the exploration method and techniques up to the method of calculation) are very different, so that, the geological risks in a possible investment are considerably different which must be expressed in their NPV and IRR.
2. Clarification of the geological risks is one of the fundamental tasks of the responsible geologists which can only be done by a thorough site visit and checking of the original documents of the exploration. These works must be done for all of the deposits which were selected for comparison.
3. For achieving consistent (comparable) data new reserve/resource estimates may be needed for each deposit to be compared, applying the same criteria in estimation.
4. Further prospects of the surrounding areas of relatively small, but good quality bauxites, mainly if they are in a favourable geographical position, are highly recommended.
5. Valuable bauxite deposits: >1,000 Mt, tri-hydrate type, < 3% SiO₂(r), >45% Al₂O₃ (av) are expected still to be discovered in Vietnam, Guinea, Brazil and Venezuela. Indonesia is questionable.

References

- [1] KOMLÓSSY G., 2003, A geologist responsibilities in the aluminium industry. – *Travaux of ICSOBA, XIVth. Int. Symposium. V.30. No.34*, Zagreb Croatia
- [2] US BUREAU OF MINES AND US GEOLOGICAL SURVEY, 1980, Principles of a Resource/Reserve Classification for Minerals. – *Geol. Surv. Circular 831*
- [3] AUSTRALASIAN CODE FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES AND ORE RESERVES – THE JORC CODE (2004).
- [4] KOMLÓSSY, G., UNGER, Z., 2004, Application of remote sensing techniques in bauxite resource estimation - *Travaux of ICSOBA. XVth.Int. Symposium. v.31, No.35*. St. Petersburg - Russia
- [5] RODENBURG, J.K., 1984, Geology, genesis and bauxite reserves of West Kalimantan, Indonesia. – *In Jacob J. El. ed. Bauxite Proc. 1984 Bauxite Symposium. Los Angeles USA AIME, New York*
- [6] UNIDO: Atlas of Mineral Resources of the ESCAP Region Vol. 6. Vietnam – Explicatory brochure – 1990.
- [7] SOLYMÁR, K – KOMLÓSSY, G. FISCHER, F, SINGHOFFER, E. – GOLYÁN, G. – BURDA, A., 1989, Techno-economic study on Tan Rai bauxite deposit, Bien Hoa, Vietnam – UNIDO document.
- [8] ALCAN: Results of Alcan Studies on Vietnam Bauxites 1990-1991 Vol. 1
- [9] NANDI, A.K., 2001, The Indian Bauxite Scenario and Prospects for Export – *Metal Bulletin's 7th. Bauxite and Alumina Seminar*, – Vienna – Austria.
- [10] BOSHKAR, K.G., 2005, Bauxite Exploration in India – Future prospective. – *Proceedings of ICSOBA XVIth Int. Symp.* – Nagpur – India.
- [11] MUKHOPADHYAY, M.K., 2005, Indian Bauxites and their Prospects – An Overview. – *Proceedings of ICSOBA XVIth Int. Symp.* Nagpur – India.
- [12] S'IGMOND, G., 1982 (UNIDO) Plan directeur d'industrialisation pour le Cameroun. – Phase preparatoire. Yaounde Cameroon
- [13] LOTZE, J. 1978, Economic evaluation of World Bauxite resources: in Proc. 4th. Int. Congress of ICSOBA, Athens, v.2, p.493-506
- [14] BÁRDOSSY, GY., G.J.J. ALEVA, 1990, Lateritic bauxites – *Akad. Kiadó – Budapest 1990*
- [15] S'IGMOND, G. - BALKAY, B. - SOLYMÁR, K - MOLNÁR, A., 1974, Bouillon de rapport définitif sur une étude préliminaire de factibilité sur la conversion local des bauxites Malgaches Budapest. Chemokomplex-ALUTERV
- [16] BOULANGÉ, G. – CARVALHO, A. (1989), The genesis and evolution of the Porto Trombetas bauxite deposits in the Amazon Basin, Pará, Brazil. CONG. INT. ICSOBA, v.6, p.115-125
- [17] MAMEDOV, V. I. – LISSOV, J. ROUDASHEVSKI, L., 1988, Rapport sur la résultats de l'étude de la composition chimique et minéralogique de la propriétés technologique des bauxites de gisements Debele et Balandougou