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A TECHNO-ECONOMIC BAUXITE CLASSIFICATION SCHEME AND ITS IMPLICATIONS*

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INTRODUCTION

It is well known that bauxite deposits differ widely in their geological associations, content of aluminium ore minerals and gangue minerals. These latter determine the technology used and equipment sizing on the red side of the Bayer plants which can efficiently process the bauxite. They also have plant capital cost and product marketing implications for bauxite producers. Because the impact of these differences on alumina production costs was negligible before the seventies, bauxite mining expanded to different regions.

The 1973 crisis resulted in a major discontinuity in the growth pattern of the world demand for metals (Tilton, 1985, p. 13). In other words, from the viewpoint of the Western World aluminium industry the average annual growth in demand for primary aluminium decreased sharply after 1984 from almost 10% between 1955 through to 1971 to under 2% after 1980. It is significant that the technical efforts during the high growth period involved increasing plant capacity and production through economies of scale (Perry and Russell, 1982, p. 176). The post-1973 control of cost was made more difficult as a result of major direct increases in costs, prime rate and the cost of bauxite (Perry and Russell, 1982, pp. 176-179) against the background of decreasing consumption growth rates of the metal. These changes had a profound effect on the costs of various items manufactured from aluminium versus alternative new materials such as polymers, ceramics and composites. The result has been a loss of some markets, suggesting that the basic production costs of aluminium and other metals may no longer be competitive and consequently for aluminium the consumption levels as against unit costs of bauxite, energy and the capital costs of facilities need to be re-evaluated to ensure viability.

The objectives of this paper are firstly, to review the bauxite classification scheme developed, secondly, to investigate its implications for the relative valuation of bauxite from different areas, and thirdly, to indicate its bearing on the prognosis for the preferred development and exploitation rates of deposits, and areas where research and development work on bauxite processing is critical for some developing countries in order to at least maintain the competitiveness of their bauxite with respect to bauxite from alternative mines and perhaps even more important to facilitate the competitiveness of aluminium in this present stage of the industry.

BACKGROUND

In recent years there has been increased emphasis on the development of a standardised, definitive, broadly applicable resources classification system to facilitate uniform co-ordinated mineral resources estimates. A joint U.S. Bureau of Mines - U.S. Geological Survey work group produced a modification of the scheme proposed by Blondel and Lasky (1956) and McKelvey (1974), (USGS, 1976). The aluminium situation is however complicated by the fact that unlike other metals, resources estimates are reported in tonnes of bauxite rather than on a metal basis even though it was well recognised that the conversion factor for tonnes bauxite to tonnes aluminium varied between 3.5 and 9.2. Thus, when we simply add bauxite resources estimates and exclude the grade of the crude ore, the final number obtained for the world is really a ball park estimate. Because metal grade alumina is the smelter grade ore, it is desirable that aluminium ore estimates should either be expressed on an aluminium or alumina basis in order to improve the accuracy of the compilation. In addition, the relationship between different bauxites and specific Bayer plant is critical in the evaluation of the market for bauxite resources.

APPROACH

The approach involves firstly the use of a techno-economic bauxite classification scheme based primarily on the distinction between lateritic and karstic bauxites, that is the associated rock type which, as shown by Bardossy and White (1979) and Bardossy et al (1978) is the important determinant of particle size distribution. The relative concentration of the aluminium ore minerals (gibbsite, boehmite, and diaspore) determine the second sub-division. The levels of gangue minerals (using the iron content as the approximate estimate of them) is the third parameter used (Hill and Robson, 1981, p. 19; Hill and Ostojic, 1984, p. 35). The bauxite type is then used as the basis for obtaining an estimate of the aluminium (or alumina) content of the bauxites. It is also used as the basis for determining a system of bonuses and penalties to adjust for differences between a particular bauxite (Hill, Ostojic and Robson, 1983).

THE CLASSIFICATION SCHEME

The proposed bauxite classification scheme attempts to relate bauxite characteristics and Bayer technology (Hill and Robson, 1981, p. 19; Hill and Ostojic, 1984, p. 35). The marked differences in the mud separation characteristics of the lateritic and Mediterranean karstic bauxites as against the Jamaica types have been demonstrated by Solymar et al (1978, p. 62) and confirmed by Strahl (1982, p. 196) and Geppert (1981, pp. 159-160). Medelovici et al (1979), Fey and Dixon (1981), Grubbs et al (1980, 1981) and Grubbs (1982) have provided the mineralogical and geological basis for this distinction in that the mud separation characteristics reflect the effects of different sets of particle size distributions, which are largely determined by the differing levels of substitution of aluminium for iron in the goethite crystal lattice.

Table 1 outlines the scheme. The names which are proposed for the bauxite type are mainly the traditional ones used in the industry, but modifying numbers are used for the Mediterranean and Jamaica bauxites. Where new names are necessary the name of one of the mines which produce this bauxite is used.

Table 1: Classification of Bauxite Types by Major Mines

BAUXITE TYPE	CRITICAL MINERALS	COUNTRY	MINES/OCCURRENCES
A. Lateritic			
(i) Iron Oxide (<10%)			
(a) Guyana	Gibbsite (<3% boehmite)	Brazil	Pocos de Caldas Trombetas
		Guinea	Sangaredi (upper)
		Guyana	Linden, Ituni, Kwakwani
		Sierra Leone	Mokanji, Port Loko
		Suriname	Moengo, Lelydorp Onverdacht
(b) Weipa	Gibbsite + boehmite (5-20%)	Australia	Weipa
		Guinea	Sangaredi (lower)
		India	Gujarat States (Kutch Peninsular)
(ii) Iron Oxides (>10%)			
(a) Kindia	Gibbsite (<3% boehmite)	Australia	Jarrahdale, Del Park, Worsley, Gove, Huntley
		Brazil	Saramenha, Paragominas Pocos de Caldas
		Costa Rica	El General
		Ghana	Kibi, Nyinahm
		Guinea	Fria-Kimbo, Dabola, kindia
		Guyana	Pakaraima Mt.
		India	Orissa, Andhra Pradesh Belgaum
		Indonesia	Bintan Island
		Suriname	Bakhuis Mt.
		Venezuela	Los Pijiguaos
(b) Ghana	Gibbsite + boehmite (5-20%)	Ghana	Awaso
		India	Phutkepahar, E. Madhya Pradesh
		Australia	Mitchell Plateau
B. Karstic			
Iron Oxide (>10%)			
(i) Jamaica-1	Gibbsite (<3% boehmite)	Dom. Rep.	Pedernales (LTD)
		Jamaica	Williamsfield Schwallenburgh Dry Harbour Mt. Lydford
(ii) Jamaica-2	Gibbsite + boehmite (5-20%)	Dom. Rep.	Pedernales (HTD)
		Haiti	Rochelois Plateau
		Jamaica	Essex Valley, Mocho Lydford
(iii) Jamaica-3	Gibbsite + boehmite (5-20%) + aluminian goethite (>20%)	Jamaica	Magotty
(iv) Mediterranean-1	Gibbsite + boehmite (≤50%)	Yugoslavia	Obrovac
(v) Mediterranean-2	Boehmite (>50%) + gibbsite	France	Provence, Languedoc
		Hungary	Halimba, Padragkut Nyirad, Nagytarkany Eszkaszentgyorgy, Gant
		Yugoslavia	Vlasenica, Niksic Jajce, Mostar, Obrovac
(vi) Mediterranean-3	Diaspore (>10%) and boehmite	Greece	Parnassus
		Romania	Padurea Craulin
		China	Kwinin
		U.S.S.R.	Arkaluk
		Yugoslavia	Kosovo

(Modified from Hill and Robson 1981, p. 19)

Karstic Versus Lateritic Bauxites

The first question to be examined is the validity of this basic sub-division of bauxite. Bardossy and co-workers (1978) have shown that lateritic bauxites are, on the whole, coarser grained and more densely packed than the karstic bauxites. The younger lateritic bauxites have particle sizes usually ranging from 0.5 to 30 μm and many, such as the Eastern Ghat deposit of India are coarser, and these usually have porosities exceeding 30 percent. They also showed that deposits which have not been subjected to significant diagenesis are usually finer grained with sizes ranging between 0.5 to 10 μm and decreasing porosity, reflecting increasing cementation by iron and aluminium minerals. On the other hand, the younger karstic bauxites such as those of the Maré and Samar Islands in the Pacific Ocean are extremely fine grained, ranging between 0.05 to 0.40 μm and average particle sizes of approximately 0.2 μm, porosities of 60-70 percent and moisture levels of over 30 percent. The Manchester Plateau deposits in Jamaica range in particle size between 0.05 and 0.5 μm, with a median value of 0.2 μm. In practice, the bauxite usually consists of sub-rounded globules of 2 to 25 μm diameter. The Mediterranean karstic bauxites are somewhat coarser grained than the younger karst bauxites and range in size between 0.2 and 5 μm. Porosities are usually between 15-30 percent where the tectonism is strong. The size differences are reported to be due to the influence of the carbonate ions (Bardossy and White, 1979).

Lateritic Bauxites

The genetic relationship between the high iron, that is, the plateau type and the low iron coastal type is illustrated by Figure 1. Of course, the parent rock also has an effect on the iron content as discussed by Gordon et al (1958, Figure 33). Grubb (1973) has also discussed the genetic relationship between the high level or upland deposits and the low-level type deposits. The former are the highly gibbsitic bauxites and have undergone only minor diageneses. Thus, we see that among the deposits, which are currently exploited, the relationship between the high and low iron deposits is a significant one although the division is not sharp.

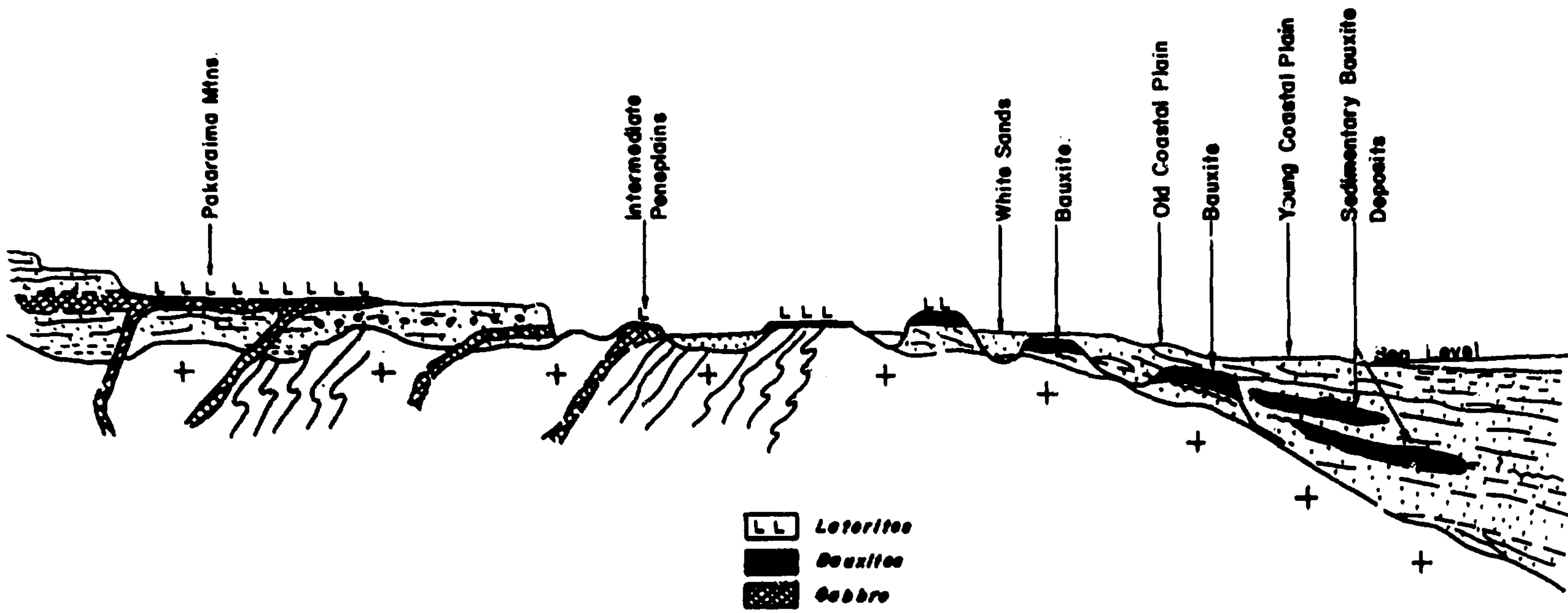
Karstic Bauxites

Two families of karstic bauxites are recognisable. They are the Jamaica types, which are usually soft and earthy, but more compact varieties such as those consisting of cemented pisolites are minor occurrences. On the other hand, the usually compact Mediterranean bauxites have porosites varying from 15-30 per cent for the bauxite of Halimba in Hungary and that of Obrovac in Yugoslavia, to 1-4 per cent for those in Megara in Greece, and Slovenia in Yugoslavia reflecting the effects of different levels of tectonism (Bardossy et al, 1978). Figure 2 illustrates the idealised relationships of the bauxite deposition in Outer Dinarides, which we believe is typical of the Mediterranean bauxite region.

The syngenetic and diagenetic changes in Jamaican bauxites are described by Hill (1977) as causing the development of three basic types of this bauxite. These are, firstly, the Jamaica-1 type which is gibbsitic, usually contains 1 to 2 per cent and invariably less than 3 per cent alumina in boehmite. Hematite is the predominant iron mineral but there may be some aluminous goethite present which usually has no more than 5 mole per cent aluminium substitution for iron. The Jamaica-2 type usually has between 5 and 20 per cent boehmite, hematite and aluminous goethite. The latter usually has a range of substitution of aluminium for iron in its structure (Grubbs, 1982, pp 52-58). The third group also usually has 5 to 20 per cent boehmite present but the usual value is nearer the upper limit and aluminous goethite with about 25 mole per cent substitution is the dominant iron minerals.

Figure 3 illustrates the method of development of the deposits by a mechanism involving the development and coalescence of a series of vertical cylindrical solution pipes occurring at points of weakness in the horizontal limestone strata. The insoluble residue is efficiently trapped on a filter of limestone powder near the bottom of the pipes. However, once the bauxite is formed, subsequent erosion and redeposition of some deposits occur. Figure 4 demonstrates the block faulting relationships which resulted in diagenetic reactions. This mechanism is the predominant bauxitization process in Jamaica. Bardossy (1982a) has pointed out that the bauxite region of Ihurkut, Hungary, the deposits are characterised by features similar to Jamaica deposits. The Jamaica bauxites are mainly pocket infillings. This contrasts with the other Mediterranean bauxite deposits which are essentially transported laterite on to a karst surface.

FIG. 1 GENERALISED GEOLOGICAL SETTING OF BAUXITES AND LATERITES ON SHIELD AREAS AND ASSOCIATED SEDIMENTS



(Not to scale) MODIFIED FROM BLEACKLEY 1964 p.8a

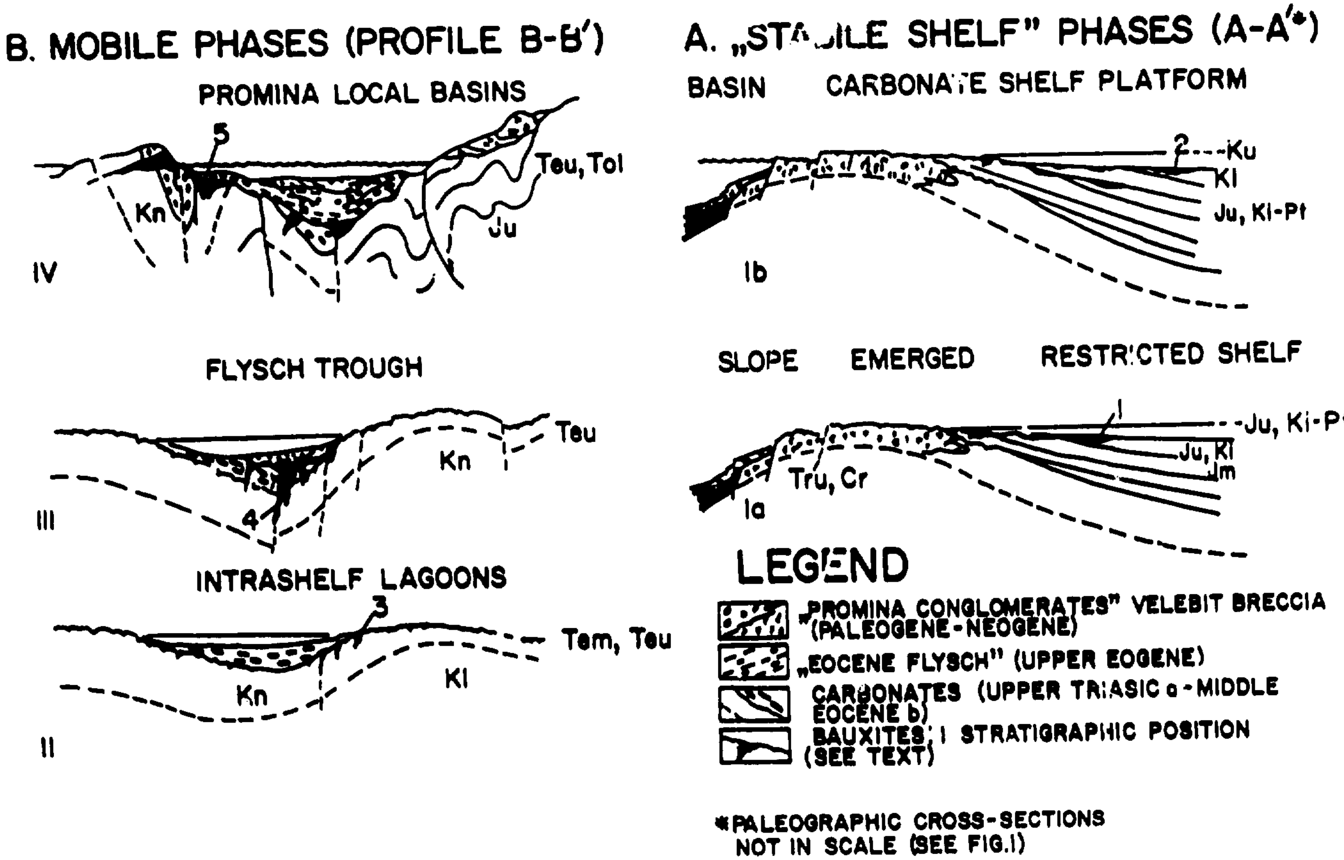


Fig. 2. Phases of bauxite deposition in Outer Dinarides.
Paleogeographic profiles

SOURCE : GRANDIC, 1979 p.59

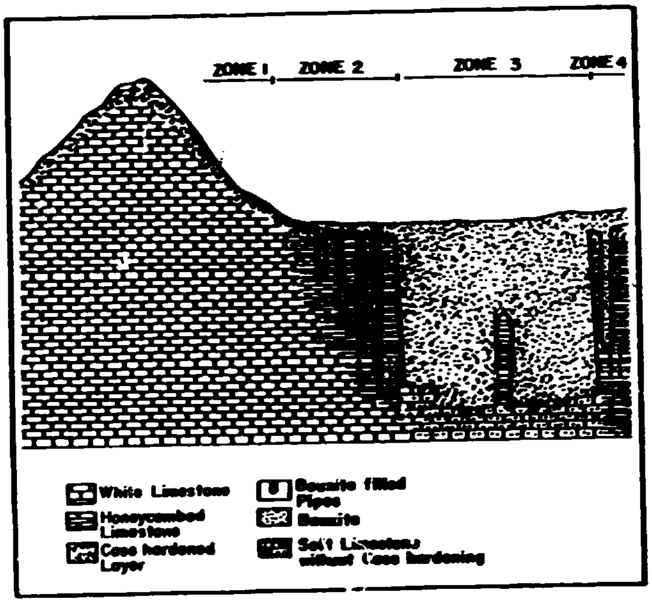
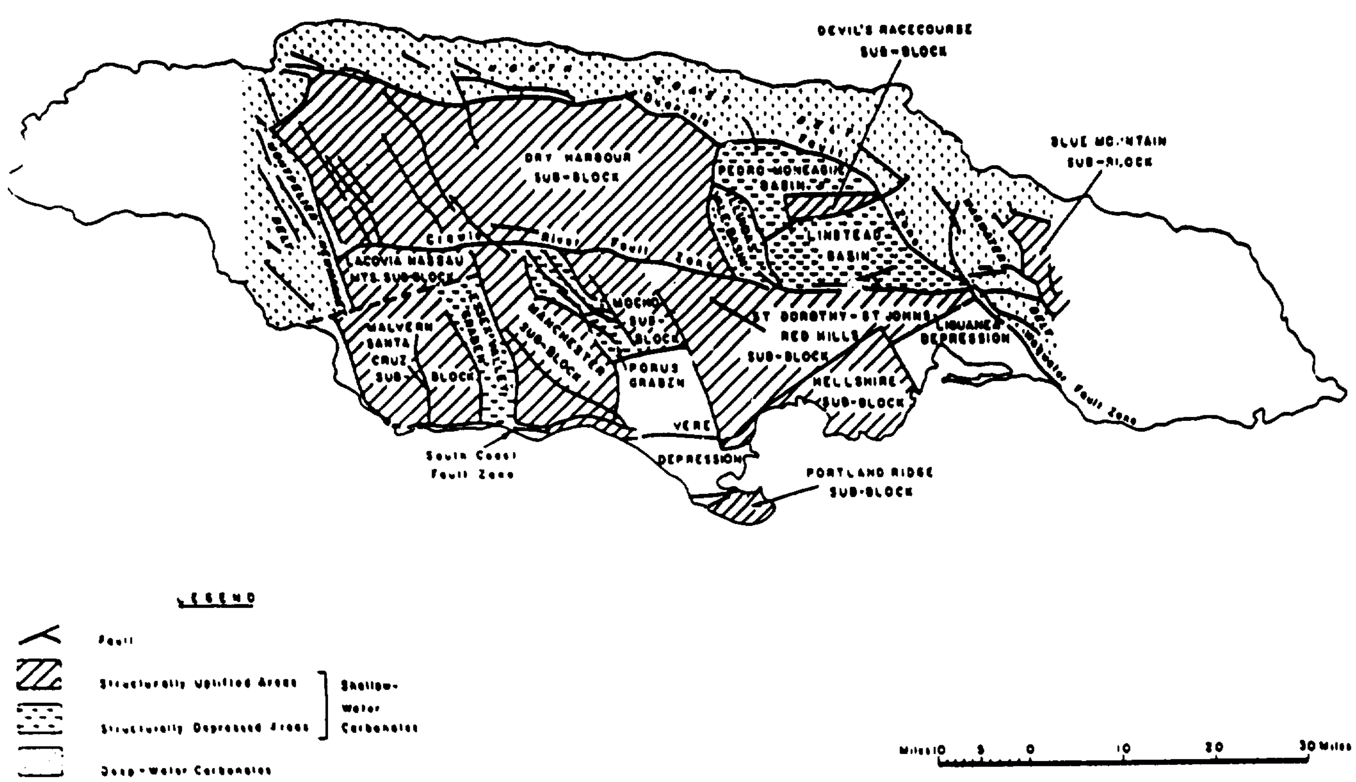


Fig. 3 Idealized cross section showing the zones associated with Bauxite deposits in Jamaica.

SOURCE : HILL, GOLDSMITH & TERRIER, 1979

Figure 4: TECTONIC SUBDIVISIONS OF THE CLARENDON BLOCK



IMPLICATIONS OF CLASSIFICATION SCHEME

Bauxite Resource Development

Table 2 gives a revised estimate of world bauxite resources by bauxite type on an alumina basis. Of these only the developed economic resources are considered in this context as estimates of the presently undeveloped and sub-economic deposits are subject to large variance.

Table 2: Summary of World Bauxite Resources by Types
(million tonnes alumina basis)

Bauxite Types	Developed Economic Resources		Undeveloped and Sub-Economic Resources	
	demonstrated	inferred	demonstrated	inferred
Lateritic				
Guyana	1800	5	40	
Weipa	810			
Kindia	1000	1000	4500	28000
Ghana	60	140	800	1600
TOTAL LATERITIC	3670	1145	5340	29600
Karstic				
Jamaica 1&2	650	2	225	20
Jamaica 3	80		25	
Mediterranean 1&2	510		25	6500
Mediterranean 3	600			700
TOTAL KARSTIC	1840	2	275	7230
TOTAL	5510	1147	5615	36800

(Revised from Hill and Ostojic, 1984, p. 30)

The dominance of the developed economic bauxite resources by Guyana and Kindia types of bauxite is evident. These are followed in abundance by Weipa type. It is noteworthy however that most of the Jamaica types in the developed bauxite resources occur in Jamaica, and that the diasporic Mediterranean-3 type is now approximately of the same abundance as the other Mediterranean types. Most of the Mediterranean-3 type occur in Greece, Yugoslavia, the Soviet Union, China and Vietnam.

The Relative Valuation of Bauxites

Table 3 summarises the parameters used for the commercial assessment of bauxites from the principal mines grouped according to bauxite types and the differences between these parameters. The comparisons are made against the background of the metallurgical characteristics of the bauxite types. It is this relationship which our bauxite classification scheme seeks to correlate. However, the values of the parameters measured vary not only between but also within types because of differences in assay methodologies. This indicates the need to designate a Primary Reference Bauxite and in addition secondary reference bauxites for each type. It is suggested that because the capital costs of Bayer plants are dependent on bauxite type, and are lowest for Guyana type bauxite, this type of bauxite is a logical choice as a primary reference bauxite.

Table 3: Comparable Alumina and Silica Values for Bauxite Exported

TYPE	COUNTRY	MINE	Method	ALUMINA					SILICA			
				Total		Extractable			Reactive			
				Diff.	Total	>230 °C	180°-230 °C	<150 °C	Total	>230 °C	180°-230 °C	<150 °C
Guyana	Guyana	Linden/	Alcan	C	-	-		M	M	-	-	M
		Ituni(U)	Alcan	C	-	-		M	M	-	-	M
		Kwakani	Alcoa	C	-	-		M	M	-	-	M
	Suriname	Moengo	Alcoa	C	-	-		M	M	-	-	M
		Lelydorp	Alcoa	C	-	-		M	M	-	-	M
		Onverdacht	Alcoa	C	-	-		M	M	-	-	M
	Guinea	Sangaredi (U)	Alcoa	C	-	-		M	M	-	-	M
	S. Leone	Mokanji	Alusuisse									
	Brazil	Trombetas	Alcan	C	-	-		M	M	-	-	M
Weipa	Guinea	Sangaredi (L)	Alcan	C	-	-		M	M	-	-	-
	Australia	Weipa	RACC	C	M		C	C	M		C	M[a]
Kindia	Australia	Gove	Jap.		M			M	M			M[a]
	Guinea	Kindia										
	Indonesia	Bintan Is.	Jap.	-	M			M	M			M[a]
Ghana	Ghana	Awaso	BACO	C	-	-	-		M	-	-	-
Jamaica-1	Jamaica	Dry Harbour Mt.	JBI		M	-	M[b]	M	M	-	-	M
Jamaica-2	Dom. Rep.	Pedernales	Alcoa	C	-		M	M	M	-	-	-
	Haiti	Rochelois	Reynolds	C	M	-	-	-	M	-	-	-
	Jamaica	Lydford	JBI	C	M		M[b]	M	M	-	-	M
Medit.-2	Yugoslavia	Niksic	PUK	-	M		C				C	
		Vlasenica	PUK	-	M		C				C	
		B. Krupa	PUK	-	M		C				C	
Medit.-3	Yugoslavia	Kosovo	PUK		M	C[c]				C		
	Greece	Parnasse	PUK		M	C[c]				C		

Source: Hill, Robson and Ostojic 1983, p. 298 C = calculated; M = measured

Table 4 gives the proposed specifications of the Guyana type Primary Reference Bauxite.

Table 4: Some Parameters for Guyana Type Primary Reference Bauxite

Parameters			Values
Alumina -	Difference		56.3%*
	Total		55.6%
	Available	>230°C	51.6%
	Available	<150°C	50.0%*
Silica -	Total		4.0%*
	Reactive	<150°C	3.2%
B/A Factor			2.04%
M/A Factor			0.50%
Organics			0.10%
Moisture			5± 1%
LOI			30.5%

*Usually reported parameters. The others may be measured or calculated.

The values given in Table 4 were selected because they closely approximate specifications of Guyana type bauxites which are predominantly traded internationally. However, under normal commercial conditions, comparison of the appropriate alumina and silica values of the bauxite is really all that are necessary to characterise bauxites of any one type. On the other hand, where bauxites of different types are to be compared, this should be based on comparison with primary and relevant secondary reference bauxite.

A system of bonuses and penalties is necessary to quantitatively adjust for the differences in the costs of beneficiation of different bauxites to alumina. Table 1 identifies ten basic types of bauxite, eight of which are currently traded internationally. The following ratios or factors i.e. bauxite/alumina (B/A); soda/alumina (S/A); mud/alumina (M/A) and organic/alumina (C/A) affect alumina production costs. These ratios should preferably be calculated from assays and metallurgical tests done according to standard procedures. However, if a lower level of accuracy is acceptable they may be calculated from assay data as described by Hill and Ostojic (1983, pp 295-299).

The moisture level of the bauxite as shipped affects the contribution of shipping costs to alumina costs. The associated bonuses and penalties are determined for each bauxite as outlined by Hill, Ostojic and Robson (1983). Figure 5 illustrates the relative differences in bauxite values, firstly on an alumina basis (the value of which in a particular market is assumed to be fixed at any particular time). Secondly, these relative bauxite values are divided by the appropriate bauxite/alumina conversion factor to convert the values to a bauxite basis.

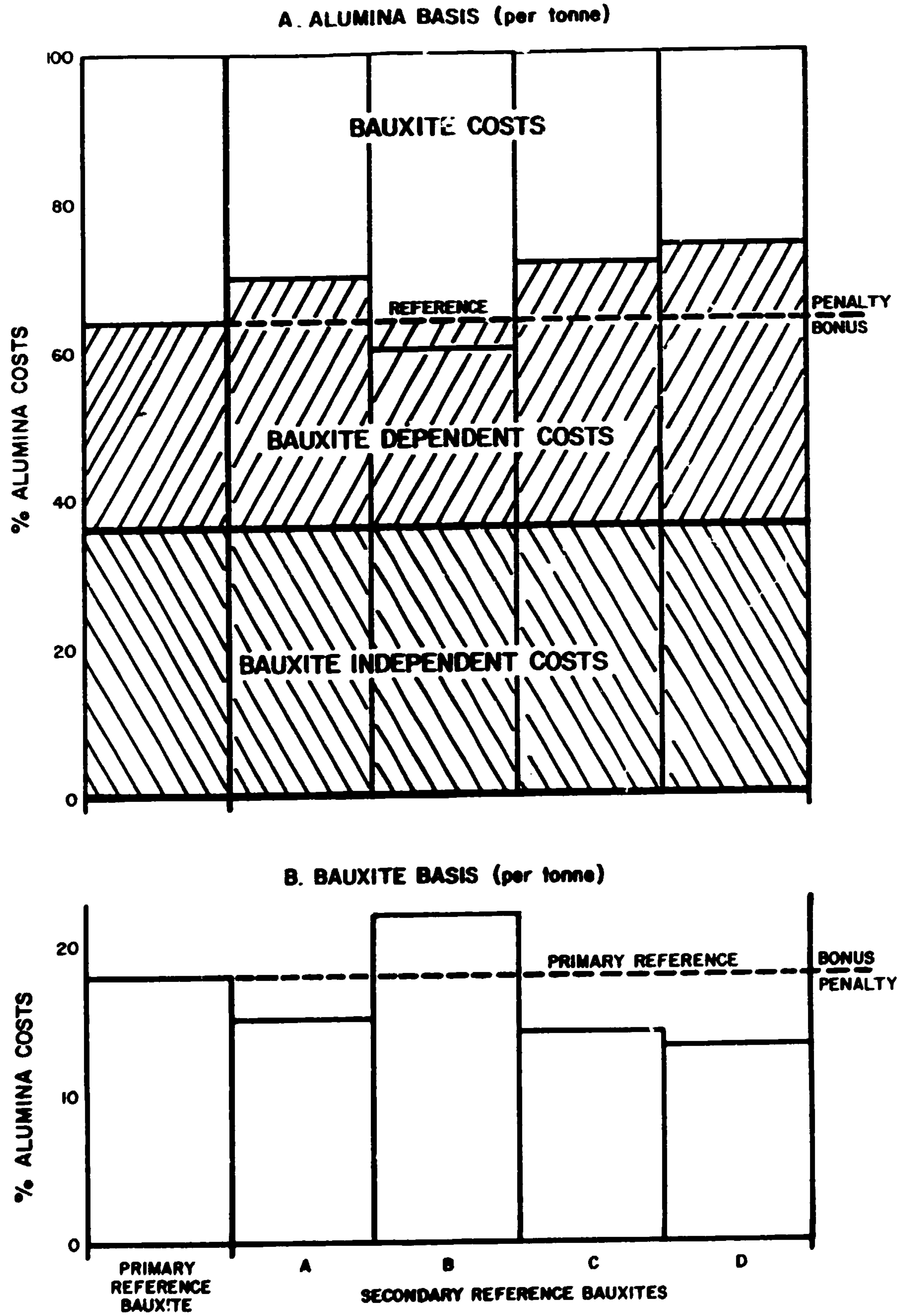


Figure 5 RELATIVE VALUES OF BAUXITES

(Source: Hill, Robson and Ostojic, 1983, p. 294)

DISCUSSION

The bauxite classification scheme put forward here takes into account particle size distribution, the degree of compaction of the bauxite, and its chemical and mineralogical composition. These reflect parent rock, diagenesis and other geochemical processes to which the deposit has been subjected. These parameters are important input factors affecting the technological modifications which are necessary for the efficient Bayer extraction of the alumina. We have, however, given secondary importance to the silica content of the bauxites, because each of the types identified has different silica content with the cut-off point for exploitation being mainly determined by techno-economic considerations, including the availability of alternative bauxite supplies. This is demonstrated by the Fria-Kimbo deposit in Guinea, where digestion at 105^{o}C and atmospheric pressure is necessary in order to avoid the fine-grained quartz reacting with the Bayer liquor. Similarly, the Darling Ranges deposits in Western Australia contain 37 per cent total alumina and 24 per cent total silica but are economic because the extractable alumina content by digestion at 143^{o}C and at a pressure of 242 kPa is 30 per cent while only 1.5 per cent of the silica reacts. Under these conditions, 3.4 tonnes of bauxite and the disposal of two tonnes of residue (mostly as sand size material) are necessary for the production of one tonne of alumina (Sibly and Buckett, 1981, p. 130). Further, our opinion is that if for each deposit the silica content is treated as a secondary variable and the cut-off grade progressively increased with time the economic bauxite resources of many bauxite producing countries will be increased. This has been demonstrated by the increasing economic bauxite resources of Hungary and Yugoslavia (Hill and Ostojic, 1984).

The proposed bauxite classification scheme provides a basis on which we can differentiate bauxite dependent costs in Bayer alumina production costs from the bauxite independent costs. The impact of capital related charges is perhaps the most important of these and explains the present preference for the lower costs low temperature Bayer plants.

The justification for including fuel usage with the bauxite independent charges are firstly, that the variations in energy consumption for different European Bayer plants have far greater dependence on engineering decisions than on the bauxite processes (Juhasz, 1978), and secondly the process heat requirements of high temperature versus low temperature Bayer digestion are in principle the same (Cundiff, 1974). In the case of electrical energy, pumps are usually the principal consumers (Fritschy and Brown, 1983; Lang et al, 1981). In practice, the difference in capital costs to attain the same level of fuel efficiency is the critical factor.

The abundance of the lateritic bauxites as against the karstic bauxite undoubtedly reflects geological factors such as the relative global abundance of other rock types compared to limestone and the geochemistry of the weathering environment. On the other hand, the abundance of Guyana type bauxite in developed economic bauxite resources reflects the preference to prospect and develop this type of bauxite. Further, the locations of the new bauxite finds required major capital investments for their development and so necessitate higher production levels for economic viability. However, in the existing environment of uncertain industrial growth rate and high capital costs, the implementation of new mega-projects, particularly in the metals area, is unlikely for this decade and perhaps this century. Consequently, the expansion of existing major viable projects by de-bottlenecking is likely to be the preferred avenue for growth. The present cost advantages of producing metal grade alumina from Guyana type bauxite is a distinct asset. The Kindia type is however the most abundant and will be the long-term raw material for the industry. However, cognizance must be taken of the possibility of cost reduction in the different stages by changes in mining processing methods and other arrangements.

Because the Guyana type bauxite from Arkansas, Guyana and Suriname has until recently been the principal feedstock for North American Bayer plants much of their research and development work was directed at this type, and this effort has continued today because of the importance of the Trombetas Mine in Brazil. On the other hand, the high quality Weipa type bauxite, particularly from the Sangaredi Mine in Guinea and Weipa in Australia, is becoming increasingly important for the European industry as most of the European mines are now in their old age (Hill and Ostojic, 1984, p. 636). However, the higher shipping costs from Australia to Europe as compared to Guinea and higher silica content of the bauxite from Weipa will continue to give a cost advantage to the Sangaredi Mines in Guinea. This is however partly offset by the fact that the highly sorted particle size distribution of Weipa bauxite requires that Bayer plants have to construct dust trapping facilities at their ports and expand their crusher facilities in order to switch from Weipa to Sangaredi bauxite.

A significant fact however is the urgent need to revitalise the use of Jamaica types of bauxite which is now only produced in Jamaica. The initial development of this bauxite required the development of the sedimentation and decantation technology for economic mud separation. This innovation was enhanced by the development of the use of synthetic flocculants in mud washing and separation and recently dry mud stacking. Today, high pressure decantation of the slurry is in the development stage and has promise of increasing the competitiveness of Jamaica bauxites. It is significant that much of the work has been done in Jamaica and gives reality to hopes for the transfer of technology in this important industry. This is as it should be and strongly indicates that every effort should be made by Jamaica to be an example to other bauxite producing countries to foster and promote the development of technology appropriate to these bauxite resources in order to maintain the competitiveness of their part of the aluminium industry.

The need to produce not only aluminium but iron and other metals from bauxite is also important. Here the Jamaica-3 bauxite type with its highly substitute aluminium goethite content offers an opportunity to so modify Bayer technology that the plants might produce both metal grade alumina and iron ore (magnetite). This would have the added benefit of being a true solution to the present red mud storage problem, in that the mud produced per tonne of bauxite processed would be reduced from being approximately equal to the alumina produced to about twenty per cent of the alumina produced. An added bonus would be a reduction in soda loss.

However, the important task for all of us in the industry at this time is, firstly, to increase the competitiveness of aluminium not only with respect to other metals but perhaps even more important to alternative materials such as polymers, ceramics and composites. This means the bauxite producers should join with the others in the aluminium industry to reduce aluminium production costs as the basis for increasing the competitiveness of this metal. Here the rationale of the proposed system for the relative valuation of bauxites has implications for producers. Secondly for the long term, but starting now, we must develop and implement policies to create local and regional markets for aluminium thereby becoming not simply producers of raw materials, but consumers of finished products from aluminium. It is important to realise that when we speak of the maturation of the aluminium industry we are really concerned with the industry in North America, Europe and Japan and are ignoring the potential for developing the markets in the countries where the industry is in its infancy. The need for aluminium companies to again give priority to product development was recently stressed by Parry (1983, pp. 2-3). These are the challenges which we face as we approach the close of the first century of our aluminium industry.

CONCLUSIONS

The basic conclusion is that the proposed techno-economic bauxite classification scheme can be the basis for defining a Primary Reference Bauxite, supported by identified secondary reference bauxites and a system of bonuses and penalties which will make Bayer plants which are designed to efficiently process a particular type of bauxite, indifferent to the mine from which the bauxite comes. Another factor is the current higher capital costs of plants processing the non-gibbsitic bauxites. Consequently, the developed economic bauxite resources are now dominated by Guyana and Kindia type bauxites. In addition, because it is unlikely that new mega-projects will be implemented by the end of the decade and possibly the century, it is strongly recommended that research and development work aimed at improving Bayer technology and lowering aluminium production cost be given priority in order to improve the competitiveness of the metal particularly in regions where the industry is in its infancy. Finally, the proposed bauxite classification scheme has the advantage of highlighting the compatibility of a particular bauxite with specific Bayer plants for marketing purposes.

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