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TECHNOLOGY ADAPTATION AND EMPLOYMENT IN THE BAUXITE/ALUMINA INDUSTRY OF JAMAICA

by

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FOREWORD

This working paper is the second in a series on alternative mineral processing technologies in the Third World prepared within the framework of the World Employment Programme.

The major objective of the study is to present an exhaustive analysis of the Jamaican bauxite/alumina industry, identifying the technological adaptations that have taken place as well as the scope for further adaptations which will lead to increased employment. More specifically, the following issues are explored:

i) the importance of the bauxite/alumina industry to the Jamaican economy, as well as the place of Jamaica in the world aluminium industry;

ii) the techniques of production used in Jamaica to mine bauxite and convert it to alumina with special reference to the importance of energy cost and availability;

iii) employment generation and the impact of scale of operations on unit costs;

iv) opportunities for expansion of the local industry and increased national control via regional and international cooperation in joint ventures; and

v) possibilities to increase local linkages and foster greater knowledge of the industry through the creation of specialist institutions.

The study finds that although the bauxite/alumina industry accounts for a very small percentage of employment in Jamaica, it is of vital importance to the economy due to its earning of foreign exchange and its contribution to Government revenue. At the same time, the absence of indigenous energy resources has increasingly made the Jamaican industry less competitive compared to those of countries which have both the mineral and energy resources (e.g. Australia and Brazil). Additionally, the United States, traditionally the largest market for the Jamaican industry, has been losing its importance as a producer of aluminium, due in part to higher energy costs.

The menu of available mining and refining technologies is well known and the trend is towards larger and more capital-intensive ones. However findings of the study suggest that the options for technological adaptations may be limited within the Jamaican industry, where the growth potential is also meagre. The scope for expansion of the industry seems, however, greater if regional and international collaboration can take place. This will permit "marriage" of complementary natural resources for mutual benefit.

As regards increased linkages within the local industry, the study identifies financing as the major obstacle to the production of caustic soda (an input) or the construction of a sheet-rolling mill. Finally, the study identifies concrete benefits which have been derived from the establishment of institutions such as the Jamaica Bauxite Institute (JBI) which had the specific objective of increasing local knowledge of the overall aluminium industry regarding both technological and economic aspects. This has enabled Jamaica to bargain on a more equal basis with the multinational enterprises.

The major implications of the study for policy-makers and future researchers are:

i) the increased energy cost has limited the options for energy-deficient countries in the exploitation of natural resources;

ii) the chance of further development of the local industry may lie in increasing economic and technological knowledge which will help implement regional collaboration projects and improve the industry's ability to bargain with multinationals; and

iii) the implementation of regional projects can be hindered by a variety of obstacles ranging from the difficulty of obtaining financing to the uncertainty of political factors.

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CHAPTER 1

INTRODUCTION

1.1 Organization of Study

The study comprises seven chapters. In this, the Introduction, the context of the study is established. First, we present the definitions of "technology" and "technology adaptation" which determine the areas chosen for analysis.. The chapter analyses the importance of the bauxite/alumina industry and the impact of increasing energy prices on the Jamaican economy. There is also a brief discussion of the level of unemployment which obtains in the country.

Chapter II establishes the role of Jamaica in the world aluminium industry. Data and analysis are provided on the growth and decline of the Jamaican component of the industry over its thirty-year existence. In Chapter III, there is a detailed review of the main techniques of production used in the world industry for processing and smelting of alumina. In order to provide a total profile for the industry, a similar discussion of various mining techniques is presented in an Appendix.

Chapter IV discusses the techniques used in bauxite mining and processing in Jamaica and then considers the general issue of scale in the industry. Next it analyses specifically employment and income generation, size of operation and production costs for the Jamaican industry.

In Chapter V, the question of the option for the development and expansion of the industry through increased regional and international cooperation is considered. The importance of this option must be seen in the light of the country's deficiency in factors such as energy and a large domestic market. Chapter VI considers another option for expanding the local industry - that of increasing local linkages

* The authors wish to express their thanks to the various organisations which made data available for the study. Special thanks are due to the Jamaica Bauxite Institute. They also thank Mrs. Kathleen Miles who typed various versions of this report.

both backward and forward. Finally, Chapter VII discusses the impact which the creation of local institutions has had on the industry to date.

1.2 Definition and Orientation

Given what seems to be an infinite number of interpretations to the word "technology", it is useful to begin by establishing as clearly as possible the meaning implied in this study. Girvan (1979) provides a definition which captures the essence of that which we wish the word to convey. It is

> "Technology ... (is) the knowledge, skills, methods and procedures associated with the production and utilisation of goods and services in a given society." Girvan (1979, p.1)

The discussion in Girvan proceeds to make the critical distinction between the embodiment of technology, and technology itself. The embodiment of technology is materialised in designs, specifications, formulations, operating instructions, machinery, equipment, buildings, systems and other tangible forms. However, the acquisition of the embodiment of a technology in the form of plants, equipment and process formulation is not equivalent to possessing the technology needed to repair and maintain the facilities or to modify systems to suit, and respond to particular local conditions.

In the specific sense of the bauxite/alumina industry, the embodiment of the industry's technology can be easily acquired by any country in the form of physical entities such as mining equipment and alumina plants. However, for a country to be able to claim to have mastered the technology of the aluminium industry the requirements are much more extensive. In addition, it entails acquisition of detailed knowledge of the world industry, of the major factors which change the nature of demand for aluminium and the factors affecting investment decisions.

This broad definition of technology provides the context within which we consider the term "adaptation". For this definition, we appeal to UNIDO (1980, pp. 15). It is as follows:

> "Adaptation is the process of matching alien technologies to local factor endowments, social customs and values and national development objectives". (Our emphasis)

The two definitions combine to delineate the scope within which this study interprets "technology adaptation" within the Jamaican bauxite/alumina industry. The term is not restricted solely to modifying the techniques used in mining and refining the ore. Rather, more generally, it also applies to the extent to which Jamaica is able to increase national knowledge of the operations of the world aluminium industry as well as of those of the local component. Furthermore, and perhaps most important, technology adaptation implies the ability to anticipate future changes in the world industry and devise strategies to either neutralise possible negative repercussions, or to capitalise on opportunities.

The suggested definition of adaptation makes specific reference to "local factor endowments" and "national development objectives". More generally, it should speak of "factor endowments and deficiencies", as adaptations are influenced as much by the factors in which a country is deficient, as much as by those with which it is endowed. In the case of Jamaica, any possible future developments in the bauxite/alumina industry must be considered with reference to the importance of bauxite/alumina to the economy, to the absence of any indigenous energy sources, the shortage of foreign exchange and the high level of unemployment in the labour force.

1.3 Importance of Bauxite/Alumina Industry to Jamaican Economy

Jamaica's economy is structurally dependent on external trade. The major sectors of the economy (e.g. manufacturing) are either dependent on imported raw materials or are geared to produce for external markets (e.g. bauxite/alumina, sugar, bananas). Given the economy's dependence on imports, the sectors which earn foreign exchange hold positions of particular importance. This importance is increased by the now chronic deficit on balance of trade. See Table 1.1.

TABLE 1.1: Jamaica: Merchandise Trade - 1978-81 (US$m)

Year	Exports	Imports	Balance Visible Trade
1978	738.1	864.7	-126.6
1979	814.7	1002.8	-188.1
1980	959.3	1172.6	-213.3
1981	970.4	1467.2	-496.8

Source: Economic and Social Survey, various editions

The importance of the bauxite/alumina industry can be derived from a disaggregation of the total value of exports by SITC. Table 1.2 shows that Crude Materials (Bauxite/Alumina) accounted for over 70% of the value of visible exports for the '79-81 period, reaching as high as 78.6% in 1981. The next most important category was food (sugar, bananas etc.) but in 1981, the value of bauxite/alumina was over eight times that of food. In fact, the combination of bauxite/alumina and the food exports accounted for 85% or over of total exports in each of the three years. This serves to illustrate the relative insignificance of the manufacturing sector as an export earner for the Jamaican economy.

TABLE 1.2: Jamaica: Exports by SITC Categories (1979-81)

SITC Categories	1979 US$m	1979 %	1980 US$m	1980 %	1981 US$m	1981 %
0 Food	109.5	13.4	99.2	10.3	92.4	9.6
1 Beverages and Tobacco	26.7	3.3	29.4	3.1	32.7	3.4
2 Crude Materials (Bauxite/Alumina)	583.3	71.6	736.1	76.8	762.2	78.6
3. Mineral Fuels	34.0	4.2	19.1	2.0	16.9	1.7
4 Animal and Vegetable Oils & Fats	0.3	-	0.1	-	-	-
5 Chemicals	16.0	2.0	15.0	1.6	15.9	1.6
6 Manufactured Goods	16.0	2.0	14.8	1.5	14.8	1.5
7 Machinery	11.8	1.4	25.1	2.6	13.1	1.3
8 Misc. Manufactures	17.2	2.1	20.0	2.1	22.2	2.3
9 Misc. Commodities	0.2	-	0.5	-	-	-
	814.7	100.0	959.3	100.0	970.4	100.0

Source: Derived from Economic and Social Survey - various editions

The bauxite/alumina industry is of importance to the Jamaican economy in areas other than being the most important foreign exchange earner. It is a significant contributor to the financing of Government operations. This is effected by means of annual transfers to Central Government from the Capital Development Fund (CDF) which was established in 1974 to invest the earnings from the then newly-introduced bauxite levy. Although the use of this money for recurrent expenditures violates the rationale for the establishment of the CDF, the fact is that these "transfers" accounted for 22%, 16.7% and 19.3% of the Government's revenue for the fiscal years 1979/80, 1980/81 and 1981/82, respectively.

The industry is not a significant employer of labour. The total labour force was approximately 6,000 when the industry was at peak production. However, the fortunes of other sectors, with greater impact on employment, are influenced to a great extent by the state of the industry, as a result of their need for imported raw materials.

1.4 Energy and the Jamaican Economy

We have made reference to the dependence of the Jamaican economy on imports. Nowhere is this dependence more apparent than with regard to energy where over 98% of the country's commercial energy requirements are imported. This dependence on imported energy is not only the result of absence of local resources but also to the fact that during the era of cheap oil supplies, consumption climbed rapidly, rising from 6.184 million barrels in oil equivalent (MBOE) in 1961 to 19.839 MBOE in 1973.

Arthur (1980) provides a useful discussion of the impact of the oil price increases on the energy intensive techniques which characterise domestic production. Jamaica, like most other energy-deficient countries, adjusted to the wave of price increases by a process of recession. Over the 1974-80 period, there was continuous decline in real output. This decline can be directly related to a compression of petroleum consumption from a peak of nearly 20 MBOE in 1973 to 15.37 MBOE in 1980.

1.4.1 Impact of Energy Prices on Balance of Payments

Rising oil prices have retarded the growth of the Jamaican economy by requiring an increasing proportion of export earnings to be spent on purchasing energy. Conversely, it has implied the diversion of foreign exchange resources away from being allocated for the importation of investment goods. The energy crisis has compounded the country's

foreign debt situation and the combination of debt and oil payments accounts for nearly a half of the country's foreign exchange cash expenditure in 1979, 58.8% in 1980 and 58.5% in 1981. It is of significance that the expenditure on non-oil imports actually decreased in current dollars between 1979 and 1981. This implies an even more serious reduction in the real level of imports over the period.

TABLE 1.3: Foreign Exchange Cash Expenditure - 1979-81

(US)$m.

	1979		1980		1981	
	$	%	$	%	$	%
Debts and Lines of Credit	335.2	32.3	318.2	30.4	504.1	37.0
Oil*	176.1	17.0	255.0	24.4	293.1	21.5
Non-Oil Imports	401.4	38.7	357.2	34.1	398.1	29.2
Other Payments	124.3	12.0	115.9	11.1	168.6	12.3

*excludes purchases by bauxite/alumina companies

Source: Bank of Jamaica Statistics.

1.5 Jamaica's Unemployment Situation

No serious discussion of the main socio-economic characteristics of Jamaica can avoid consideration of the issue of the level of unemployment. Hence foreign-exchange earning and employment-creating capabilities are perhaps the two most important factors by which investment decisions are evaluated. In terms of investments by the State itself, the consideration is not solely in terms of the specific investment decision being analysed. Also of importance is the comparison with another project (or projects) the implementation of which would be precluded if the one being presently contemplated is

approved. As will be seen in Chapter V, such a comparison was a constant obstacle, but obviously not the only one, to a final commitment to a major investment in a new alumina plant.

In Table 1.4, the unemployment picture for the period 1976-1981 is displayed. It shows that between 1976 and 1981, the level of unemployment has increased from 22.4% to roughly 26% in 1981. However, what is of greater significance is that the absolute number of unemployed has increased from 197,800 to 262,500 in the same period. This implies that not only is the backlog of unemployed untouched but not enough jobs are being created annually to take care of new entrants to the labour force.

TABLE 1.4: Jamaica: Level of Unemployment 1976-81

Year	Total Labour force '000 persons	Unemployed Labour force '000 persons	% of Total
1976	883.6	197.8	22.4
1977	910.0	220.2	24.2
1978	939.0	230.5	24.5
1979	953.6	264.7	27.8
1980	991.2	270.8	27.3
1981	1014.9	262.5	25.9

Source: Department of Statistics

The full extent of the problem is not understood until one looks at the data on the main streams of emigration. Table 1.5 provides the details. It shows that over the nine year period 1972-1980, a total of over 190,000 Jamaicans emigrated to the U.S.A., Canada and the U.K. Although this emigration must have implied the loss of some skilled members of the labour force, it also meant that others who would have contributed to the pool of the unemployed also migrated. Hence, were it not for migration, the present level of unemployment would have been greater.

TABLE 1.5: Main Streams of Jamaican Migration - 1972-80

Destination	1972	1973	1974	1975	1976	1977	1978	1979	1980
U.S.A.	13,427	9,963	12,408	11,076	9,026	11,501	19,265	19,714	17,874
Canada	3,092	9,363	11,286	8,211	7,282	6,291	3,858	3,213	3,161
U.K.	1,630	1,872	1,397	1,394	1,198	1,029	766	737	649
TOTAL	18,139	21,198	25,091	20,681	17,506	18,821	23,889	23,669	21,684

Source: Economic and Social Survey, 1981.

CHAPTER II

JAMAICA'S PLACE IN THE WORLD ALUMINIUM INDUSTRY

2.1 Introduction

For over thirty years Jamaica has had an important place in the world aluminium industry. The country's role in the industry began shortly after the end of World War II. It resulted to a large extent from its identification as an alternative or supplementary source of ore for the North American refineries and smelters, because of the sinking and harassment during the war of bauxite ships plying between the Guianas (the traditional suppliers) and the U.S. Davis (1980, 1981) provides a detailed analysis of the factors surrounding the development of the industry in Jamaica.

The growth of Jamaica's importance in the world's aluminium is inextricably tied to the emergence of North America, particularly the U.S.A., as a major producer and consumer of primary aluminium. The impact of World War II on the growth of the North American industry can be seen by the fact that in 1939, North America accounted for about 35% of world primary aluminium production. By 1943, this figure had increased to 66% of world production. Western Europe's share, by contrast, had fallen from 60% of world production in 1938 to 23% in 1943.

The stimulus to the growth of the North American industry did not end with the war. In the immediate post-war period, the industrial capacity of several European countries had been so devastated that they were unable to produce enough to meet their requirements. As a consequence, they had to rely on North America to supplement local

production. For example, in 1947, while production in the U.K. amounted to 29,400 tonnes, consumption of crude aluminium was 161,000 tonnes. The deficit was made up largely by imports from Canada.

2.1.1 <u>The Role of the TNC's</u>

The growth of the Jamaican industry must be analysed within the context of the involvement of the major aluminium TNCs. They first entered Jamaica in the early 1950s. There are presently five TNCs operating in the Jamaican industry, including four of the six major aluminium TNCs. Kaiser and Reynolds export dried bauxite, ALCAN ships only alumina, processed at its two plants, located at Ewarton and Kirkvine, while ALCOA also ships alumina,processed at its Halse Hall plant. The fifth company, ALPART is a consortium of Kaiser, Reynolds and Anaconda and exports alumina.

A sixth TNC, Revere, built an alumina plant and started production in 1971 but ceased activities in 1975 as a result of a combination of factors, the chief of which was the uneconomic size of the plant. Table 2.1 provides summary information on the companies in operation in Jamaica.

TABLE 2.1: JAMAICA: BAUXITE ALUMINA OPERATIONS BY TNCs (1978)

Company	Ownership (percentage)		Mine site	Alumina plant site date	Annual capacity ('000 metric tonnes) Alumina	Bauxite
1. JAMALCAN	ALCAN	93%	Russell Place	Kirkvine, 1952 (Mandeville, Manchester)	562	2,687
	JAMAICAN GOVT.	7%	Schwallemburg	Ewarton, 1959 (St. Catherine)	558	
2. JAMALCO	ALCOA	94%	Breadnut Valley	Halse Hall, 1972 (Clarendon)	550	1,270
	JAMAICA GOVT.	6%				
3. ALPART	ANACONDA	27%	Essex Valley	Nain 1970 (St. Elizabeth	1,130	3,117
	REYNOLDS	36.5%				
	KAISER	36.5%				
4. KAISER BAUXITE	KAISER	49%	Water Valley	—	-	4,200
	JAMAICA GOVT.	51%				
5. REYNOLDS	REYNOLDS	49%	Lydford	—	-	3,100
	JAMAICA GOVT.	51%				
6. REVERE[a]	REVERE COPPER & BRASS INCORP.		Magotty	Magotty, 1971	(200)	(500)
				TOTAL (excluding REVERE)	2,800	14,374

[a]Production ceased in 1975.

Source: Adapted from Policies and Negotiations with Transnational Corporations in the Bauxite Industry of Jamaica, Economic Commission of Latin America, 1982.

2.2 Expansion of World Aluminium Industry, 1950-1980

The stable growth and expansion of the market economies of North America and Western Europe in the 1950s and 1960s generated rapid expansion of the world aluminium industry. The availability, during this period, of capital resources at low interest rates and cheap energy supplies, was a positive factor for the industry which is highly capital-intensive and one of the largest per unit consumers of electrical energy.

At the beginning of the 1950s primary aluminium production in the market economies (North America, Western Europe, Africa and Japan) stood at 1,269,700 tonnes and grew to 3,551,100 by 1960 - an average annual increase of 18%. In the centrally-planned economies, the rapid rate of economic development after 1945 also brought about an even more dramatic percentage increase in production of the metal. In 1950 production stood at 201,000 tonnes and moved by 1960 to 911,450, an average annual increase of 35%.

Tables 2.2 and 2.3 provide data on world primary aluminium production for the period 1950-80. The data show that primary aluminium production increased at a rapid rate in the 1950s and 1960s and at much reduced rate in the 1970s. This reduction in the rate of expansion of the industry was common to both Western and Eastern bloc countries.

TABLE 2.2 World Aluminium Production - 1950-80

('000 tonnes)	-1950	1960	1970	1980
1. Market Economies	1,269.7	3,551,0	8,069.7	2,778.5
2. Planned Economies	201.0	911.4	2,246.1	3,285.9
3. Total World	1,470.7	4,462.4	10,315.8	16,064.4

Source: Metal Statistics, 1980.

TABLE 2.3: Average Annual Growth Rates in World Primary Aluminium Production, 1950s, 60s and 70s

	1950s	1960s	1970s
1. Market Economies	18%	13%	5.9%
2. Planned Economies	35%	14.6%	4.6%
3. Total World	20%	13.1%	5.6%

2.3 World Bauxite Production: 1955-80

Table 2.4 provides data on World and Jamaican bauxite production for the period 1955-80.

TABLE 2.4: Bauxite Production 1955-1980: Jamaica and World '000 tonnes

	1955	1960	1970	1974	1975	1980
Jamaica	2,688	5,835	12,010	15,166	11,380	11,978
World	17,984	27,620	66,797	83,935	77,045	91,338

Source: Metal Statistics, various issues and JBI Fact Sheets on Jamaica's Bauxite Production.

The table shows that bauxite production in Jamaica increased by an annual average rate of 23% in the period 1955-60 compared to 10.7% in world production. In the period 1960-70 Jamaica's production increased by an annual average rate of 10.3% whilst world production increased by 12%. In the decade of the 1970s world production continued to expand but at a greatly reduced rate averaging about 5.3% per annum. On the other hand Jamaica's annual production rose by an annual average rate of 7.1% up to 1974 but registered absolute declines thereafter to end up with a zero growth for the decade.

In Table 2.5, data are provided on world and Jamaican bauxite production for the period 1970-1981. It shows that Jamaica's production peaked in 1974 at 15.2 million tonnes and suffered a severe decline in 1975, reflecting the effects of the impact of the 1974-75 recession in the market economies. The fall in demand for bauxite is shown in the decline in world production from 83.9 million tonnes in 1974 to 77 million tonnes in 1975. Table 2.5 shows too that Jamaica's share of world production declined from a high of 21% in 1970 to roughly 13% in the 1979-81 period.

TABLE 2.5: Bauxite Production 1970-81
Jamaica and World — '000 tonnes

Year	World	Jamaica	% of World
1970	60,162	12,010	21.0
1971	66,797	12,440	18.6
1972	70,806	12,539	17.7
1973	74,866	13,646	18.2
1974	83,935	15,166	18.1
1975	77,045	11,380	14.8
1976	80,492	10,296	12.8
1977	85,224	11,434	13.4
1978	84,369	11,736	13.9
1979	88,009	11,505	13.1
1980	91,338	11,978	13.1
1981	87,796	11,606	13.2

2.4 Alumina Production 1966-1978

Over the fifteen year period 1966-1978, world alumina production increased from 14.8 million tons to 30.8 million tons. During the same period, Jamaica's production increased from 0.8 million tons to 2.1 million tons, reflecting both an increase in bauxite production and an increase in refining capacity, as is indicated in Table 2.1. Table 2.6 provides details on Jamaica's share of world production for the period. The country's share of alumina production reached its peak in 1974 (10.1%) corresponding to the greatest year of bauxite and alumina output.

TABLE 2.6: Alumina Production, 1966-1978: Jamaica and World

('000 tons)

Year	World	Jamaica	% of World
1966	14,784	804	5.4
1968	17,306	923	5.3
1970	20,683	1,689	8.2
1972	23,601	2,136	9.1
1974	28,553	2,871	10.1
1976	26,855	1,627	6.1
1977	30,053	2,046	6.8
1978	30,845	2,142	6.9

Source: Transnational Corporation in the Bauxite/Aluminium Industry, UNCTC.

2.4.2 Jamaican Alumina Exports

Table 2.7 shows that the USA, Canada and Western Europe are the major markets for Jamaican alumina accounting for 94% in 1970, 87% in 1974, 89% in 1978, 82% in 1980 and 80% in 1981. Within this grouping Western Europe's share has increased from 34% in 1970 to 47.5% in 1974, to 54.5% in 1980, and declined to 44.7% in 1982. Canada's share declined from 17% in 1970 to 6% in 1974 and remained at that level up to 1980. It increased to 36% in 1981 then declined to 25% in 1982. The USA market accounted for 44% of Jamaica's alumina shipments in 1970 but declined to 33% by 1974 and further declined to 21% by 1980, increased to 27% in 1981 but declined to 12.5%, the lowest level, by 1982.

These figures clearly indicate that in absolute terms Jamaica's bauxite and alumina exports to USA and Western Europe have fallen from the peak levels of 1974. However, the greatest decline has taken place in the U.S.A. market. Western Europe is the largest market with Canada second. The Latin American market has shown a steady increase during the late 1970s, largely due to the Government contract with the Venezuelan State Company VENALUM. Table 2.8 provides data on the growth of primary aluminium consumption in Jamaica's major markets for bauxite and alumina.

TABLE 2.7: Jamaica: Alumina Shipments (000 metric tons)

Countries of Destination	1970	1974	1978	1980	1981
U.S.A.	748	953	610	495	693
% increase (decrease)		27	(36)	(19)	40
Canada	285	178	280	157	422
% increase (decrease)		(37)	57	(44)	169
Latin America	6	40	88	56	171
% increase (decrease)		567	120	(36)	205
Western Europe	576	1,353	1,011	1,286	915
% increase (decrease)		135	(18)	27	(29)
Africa	79	119	87	186	315
% increase (decrease)		51	(27)	114	69
Eastern Europe	19	203	62	179	32
% increase (decrease)		968	(69)	189	(82)
	1,713	2,846	2,138	2,359	2,548

Source: Jamaica Bauxite Institute

TABLE 2.8: Primary Aluminium Consumption in Selected Markets

(000 metric tons)	1970	1974	1978	1980
U.S.A.	3,488	5,128	4,978	4,473
% increase (decrease)		47	(3)	(10)
Canada	220	358	339	292
% increase (decrease)		63	(5)	(141)
Western Europe	2,606	3,390	3,553	3,853
% increase (decrease)		30	5	8
Latin America	201	396	487	603
% increase (decrease)		97	23	24
Eastern Europe	2,092	2,763	3,302	3,309
% increase (decrease)		32	19	0

Source: Metal Statistics 1980.

The data in Tables 2.7 and 2.8 clearly demonstrate that in the period 1970-80, Western Europe, Latin America and Eastern Europe have shown the fastest growth rates for primary aluminium consumption and that these regions also represent the areas of relative growth for Jamaica's alumina exports.

2.5 Market Constraints Limiting Growth of Jamaican Industry

The factors leading to the decline of the Jamaican industry in the post 1974 period are several. The main one is the declining importance of the U.S. market which is by far the most important for the Jamaican industry. However, there are other factors including

(i) Expansion of bauxite and alumina production in Guinea, Australia, Brazil as a result of decisions by the major trans-national corporations to diversify the source of their supplies of these commodities;

(ii) Lack of indigenous energy resources in Jamaica;

(iii) The impact of the Jamaican Bauxite Levy relative to the taxation policies of other bauxite-producing countries.

2.5.1 Declining Importance of USA Market

At the start of the 1970s the USA produced 3.607 million metric tons of aluminium or 35% of world production; by the end of the decade it produced 4.653 million metric tons or 29% of world production. During the same period, Western Europe increased its share of world production from just under 20% to 23%. In terms of consumption, the U.S. share of the world total declined from 35% in 1970 to 29% in 1980. The relative decline in the U.S. aluminium industry is reflected in the stagnation of the market for bauxite. Between 1974 and 1980, there

was a reduction of imports from all countries, except Guiana (high quality bauxite) and Brazil. Table 2.9 provides the data.

TABLE 2.9: US Imports of Bauxite by Country ('000 short tons)

Country	1970	1974	1978	1980
	Year			
Australia	263	82	21	-
Brazil	-	-	-	856
Dominican Republic	1,019	1,333	692	623
Guinea	567	1,870	3,706	4,531
Guyana	355	839	462	645
Haiti	691	656	648	498
Suriname	3,274	3,256	2,489	1,509
Jamaica	8,403	8,698	7,106	6,773
Total	14,572	16,734	15,124	15,435

Source: US Bureau of Mines

As regards the decline of US consumption, a number of factors have been identified as being responsible for the declining position of the USA in the production and consumption of aluminium. These factors are:

a) the Energy Crisis of the 1970s;

b) the maturity of the USA economy and the more rapid economic expansion in Western Europe, Japan and USSR;

c) the location of integrated bauxite, alumina and smelter facilities in Australia and Brazil.

2.5.1.1 Energy Crisis of the 1970s

The oil price shocks of 1973 and 1979 posed severe difficulties for the US economy because of the increasing reliance on imported oil. Furthermore most large-scale U.S. hydro-power sources are already developed and the scope for new growth is extremely limited. Hence, the once remarkably cheap energy supplies from the Bonneville Power Administration and the Tennessee Valley Authority have become very expensive. This tight supply/demand energy position is likely to continue to exert upward pressures on energy costs whilst the environmental problems associated with the development of nuclear energy will continue to depress supply.

2.5.1.2 Maturity of US economy and rapid expansion of W. Europe, Japan and Eastern European economies

In the 1970s the US economy expanded at a much slower rate than the economies of Japan, W. Europe, and Eastern Europe. Table 2.10 provides data on the growth rates of GNP per capita.

TABLE 2.10: Growth of GNP per Capita for Selected Regions

%

Country Group	1955-70	1970-80
United States	2.0	2.1
W. Europe	4.1	2.4
Japan	9.2	4.2
E. Europe	5.8	2.8
World	3.1	1.9

Source: 1982 World Development Report.

The difference in growth rates are partly due to higher level of development of the US economy vis-a-vis Western Europe etc. and therefore the reduced scope for further expansion.

2.5.1.3 Location of integrated bauxite, alumina and aluminium smelter facilities in Brazil and Australia

As a consequence of the energy crisis described in 2.5.1.1 above and the resulting tightness of energy supply/demand balance in the U.S., increased efforts, in the 1970s, were focussed on developing integrated facilities in bauxite-producing countries with adequate supplies of energy. In particular the coal and natural gas resources of Australia and the hydroelectric potential of Brazil have made these two countries into attractive locations for new facilities. In the period, Australia recorded 50% in its aluminium production while Brazil recorded a spectacular 400% increase with further large scale expansions under implementation and planned for the near future.

2.5.2 Expansion of production in Australia, Brazil and Guinea

The rapid development of the industry in these three countries is perhaps the single most important factor responsible for the decline of the Jamaican industry. In the 1960s the large transnational corporations which undertook the major investments in the industry opted for a broadening of their supply sources and production locations based on the existence of rapidly expanding markets for finished products in Europe and Japan and also the availability of large supplies of coal and natural gas in Australia, and in the case of Guinea the availability of high grade bauxite. Table 2.11 shows the growth of the bauxite industry in these countries.

TABLE 2.11: Bauxite Production in Selected Countries 1970-80

('000 tonnes)

Australia	9,256	14,437	19,995	24,084	24,293	27,178
Guinea	2,490	2,600	7,600	11,316	11,648	13,311
Brazil	510	765	858	998	1,131	4,152
Jamaica	12,010	12,539	15,166	10,296	11,736	11,978
World	60,162	70,806	83,935	80,492	84,369	91,338

The data show the rapid expansion of production in Australia with an increase of roughly 200%, and over 400% in Guinea and 700% in Brazil in the period 1970-80, whereas total World production increased by only 53% in the same period.

2.5.3 Lack of Indigenous Energy Resources

Jamaica's energy needs are met by the importation of fuel oil from Venezuela and Trinidad and Tobago. The island is 97% dependent on imported oil as the source of energy as it possesses no supplies of its own. Small hydro-power schemes and development of identified peat resources are the only possible sources of indigenous energy supplies in the future.

The further expansion of the bauxite and alumina industry is seriously impaired by the lack of energy resources as energy costs now represent the most significant cost item in the production of alumina in Jamaica, increasing by 144% between 1974 and 1981. Table 2.12 indicates the magnitude of this problem which has become more significant in recent times.

TABLE 2.12: Average Fuel Cost per Tonne of Alumina Production in Jamaica 1974-81

Year	(US$)
1974	34.4
1976	34.8
1978	37.1
1979	50.7
1980	74.4
1981	83.9

The options open to Jamaica are, in reality quite limited. There is the possibility of progressively reducing dependence on imported oil. Estimates prepared by the Government's Energy Division project that if an all-out effort is made, the share of power generated from oil could be reduced from the present 92% to 55% in the year 2000. However, the bulk of the substitution would be accounted for by coal which would also be imported. At best, local energy sources (peat, hydro, bagasse) developed to the fullest capacity would only account for approximately 15% of total demand by the year 2,000. Furthermore, power supplied from hydro and bagasse would be subject to seasonal fluctuations.

It is clear, therefore, that the Jamaican bauxite/alumina industry will be dependent on imported fuels even in the medium to long term. The realistic choice is between continued use of oil and conversion of generating units for use of coal. One company has carried out extensive analysis of the costs associated with conversion of its generating units and coal is by far the more economic choice. However, the major problem to be solved is the financing of capital costs of conversion.

There is, however, one remaining area in which savings on energy costs can be made in the bauxite/aluminium industry. This is in increasing the efficiency of energy utilization. If we focus on the three alumina companies, the average fuel oil usage per tonne of alumina was 3.32 barrels in 1980, with a range of 2.53 to 4.53 barrels. The average improved to 3.17 per tonne in 1981 as a result of conservation efforts. The State's Energy Division has set the companies a long-term target of 2 barrels per tonne but the companies feel that 2.5 barrels per tonne is a more realistic objective.

2.5.4 Jamaican Bauxite Levy relative to Taxation Policies of other Bauxite Producing Countries

The bauxite production levy imposed by the Jamaican Government in 1974 resulted in a significant increase in government revenues from the industry as well as the foreign exchange earnings. Other major bauxite producer countries also introduced new tax measures including export taxes, as in the case of Brazil and Guinea, withholding taxes on dividends and interest payments and royalties as in Australia and production levy in the case of Guyana.

By the late 1970s it was generally agreed that the Jamaican levy represented the highest tax rate on bauxite among IBA countries. Although the higher Jamaican levy is partially offset by certain clear advantages in the form of the lower mining costs, and lower transportation costs to the North American market, it is clear that it accounted in some measure for the reduced attraction of Jamaica as a source of bauxite and alumina.

In the 1979 negotiations between the Government of Jamaica and the TNCs operating locally, an agreement was reached which reduced the base rate of the levy, in relation to minimum production levels.

CHAPTER III

THE PRODUCTION TECHNIQUES USED IN THE ALUMINIUM INDUSTRY

3.1 Introduction

The techniques utilized in the aluminium industry are related to: (i) bauxite mining, transportation and handling; (ii) bauxite processing into alumina by the Bayer process; (iii) the reduction of alumina into primary aluminium by the Hall-Heroult process; (iv) the alloying and shaping of the primary aluminium into various forms - i.e. semi-fabrication; and (v) fabrication of aluminium into various end uses, such as beverage cans, pots and pans, roofing and siding materials for building, etc.

Integral to the whole production process are various inputs, such as: naturally-occurring aluminous source materials, mainly bauxite; caustic soda for extracting alumina from bauxite; energy at all stages but principally at the smelting stage; carbon and aluminium fluoride in the smelting process; and various alloying materials, such as magnesium and silicon.

In the following sections of this chapter, we discuss the techniques used in the major stages, from bauxite processing through to semi-fabrication in the world industry. For completeness a discussion of the techniques used in mining operations is presented in an Appendix.

3.2 Alumina Processing

The basic process by which alumina is extracted from bauxite was invented by Dr. Karl Josef Bayer, and patented by him in 1888.

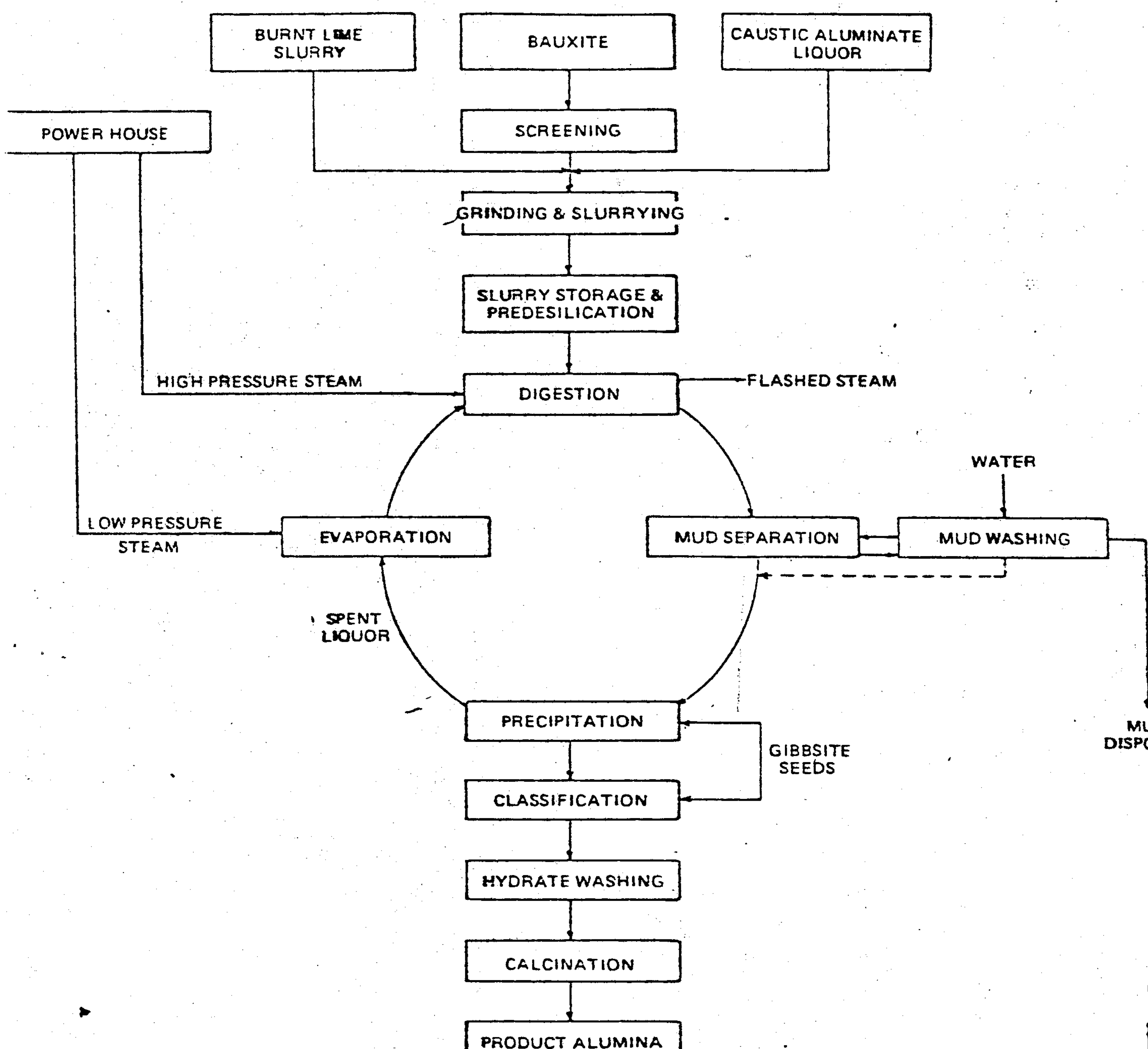
While serving as a manufacturing chemist in Russia he filed two patents for the production of alumina. The first of these (1888) described a process for the precipitation of hydrate of alumina by seeding from an aluminate-lye - a departure from the Deville-Pechiney carbon dioxide precipitation process. The second of Bayer's patents (1894) claimed a process for digesting bauxite with the aluminate-lye concentrated from the previous cycle rather than extracting alumina by the Deville-Pechiney calcination of bauxite with sodium carbonate.

These two discoveries constitute the Bayer process used to this day for 95% of the world production of alumina.

The process (shown schematically in Fig. 3.1) is essentially as follows:

1. Bauxite is digested with caustic soda solution under pressure.
2. The alumina is extracted in the form of soluble sodium aluminate which leaves behind most of the impurities, largely iron oxide titania and silica as insoluble residues.
3. The clear filtered sodium aluminate soluble is diluted, cooled and a 'seed' of alumina trihydrate is added. The sodium aluminate solution hydrolyses on the surface of the seed to form crystalline trihydrate.
4. The trihydrate is finally filtered off and calcined to anhydrous alumina.

Fig. 3.1: BAYER PROCESS SCHEMATIC



There are basic variations however to the Bayer technology. These were determined historically by a variety of factors. The main ones are the mineralogy of the bauxite being processed and energy conservation. Later the principal determinants have been bauxite mineralogy, energy conservation and desired physical characteristics of the product alumina by various smelters.

Two major variants of the technology emerged respectively in Europe and in North America. In Europe, the alumina mineralogy was dominated by the more difficultly soluble 'monohydrate' boehmite and diaspore (both with chemical formula A10.OH). Secondly, even in pre-OPEC days energy was never cheap.

In America (and in the Guianas) the alumina mineralogy was dominated by the more easily soluble 'trihydrate' gibbsite ($A1(OH)_3$) and by the fact that there was less incentive for conservation as energy was very cheap.

These conditions led to Europeans using: (a) rigorous digestion conditions (to solubilize the monohydrate) with temperatures in the order of ca. 200-250^{o}C; (b) caustic concentrations (expressed as Na_2O) in the order of 200-300 g/l; (c) pressure of 30-50 kg/cm^3; and (d) long 'retention' (in the digester system) times.

Americans, on the other hand, used the following parameters: (a) digestion temperature of 140-145^{o}C; (b) caustic concentration (expressed as Na_2O) of 120-140 g/l; (c) pressure of ca. 4 kg/m^2; and (d) short retention times.

The net effects of the above variations are:

1. High productivity in European plants - 100-110 kg/m^3 and 70-80 kg/m^3 at the digestion and precipitation stages, respectively, vs. 60-65 kg/m^3 and 50 kg/m^3, respectively, at

the same two stages in the American plants. (Productivity expressed as kg/m^3 is defined as the number of kg of alumina precipitated per cubic metre of clear precipitation or digestion liquors.)

2. Precipitation liquor concentrations of 140-160 g/1 Na_2O, and seed content of 400-500 g/1 Al_2O_3 in European plants vs. 100-110 g/l and 100-150 g/l, respectively, in American plants.

3. The production of North American plants of the so-called 'sandy' alumina vs. the so-called 'floury' alumina by European plants. (The major differences between the two are in respect of their particle size distribution particularly those under 44 microns; and the α-alumina content. This is indicated in Table 3.1.

TABLE 3.1: Some Typical Sandy and Floury Alumina Physical Specifications*

Physical Parameters	Floury	Sandy
L.O.I.	0.3%	0/9-1.2%
Specific Surface Area	5 - 10 m^2/g	40 - 45 m^2/g
αAl_2O_3	60 - 70%	20 - 30%
Bulk Density	0.95 - 1.0 t/m^3	0.88 t/m^3
Angle of Repose	40 - 45^o	28 - 32^o
+100 mesh	0.1%	2 - 8%
-325 mesh	50 - 55%	6 - 10%

*There is not much difference in respect of the chemical specification.

4. Lower energy consumption per unit of alumina produced by European plants.

Two major developments will have an impact on future technological choices. First is that of the 1973-OPEC action on energy prices which is forcing all operators to reduce energy consumption. Second is the use of the so-called 'dry scrubbing' environmental (fluoride) control system in all modern smelters which requires the more sandy-type alumina. As indicated in a recent report, Millet (1982), alumina plants currently using these different cycles will have to make necessary adjustments to effect a compromise between the objectives of reducing energy consumption and meeting the specifications of sandy-type alumina.

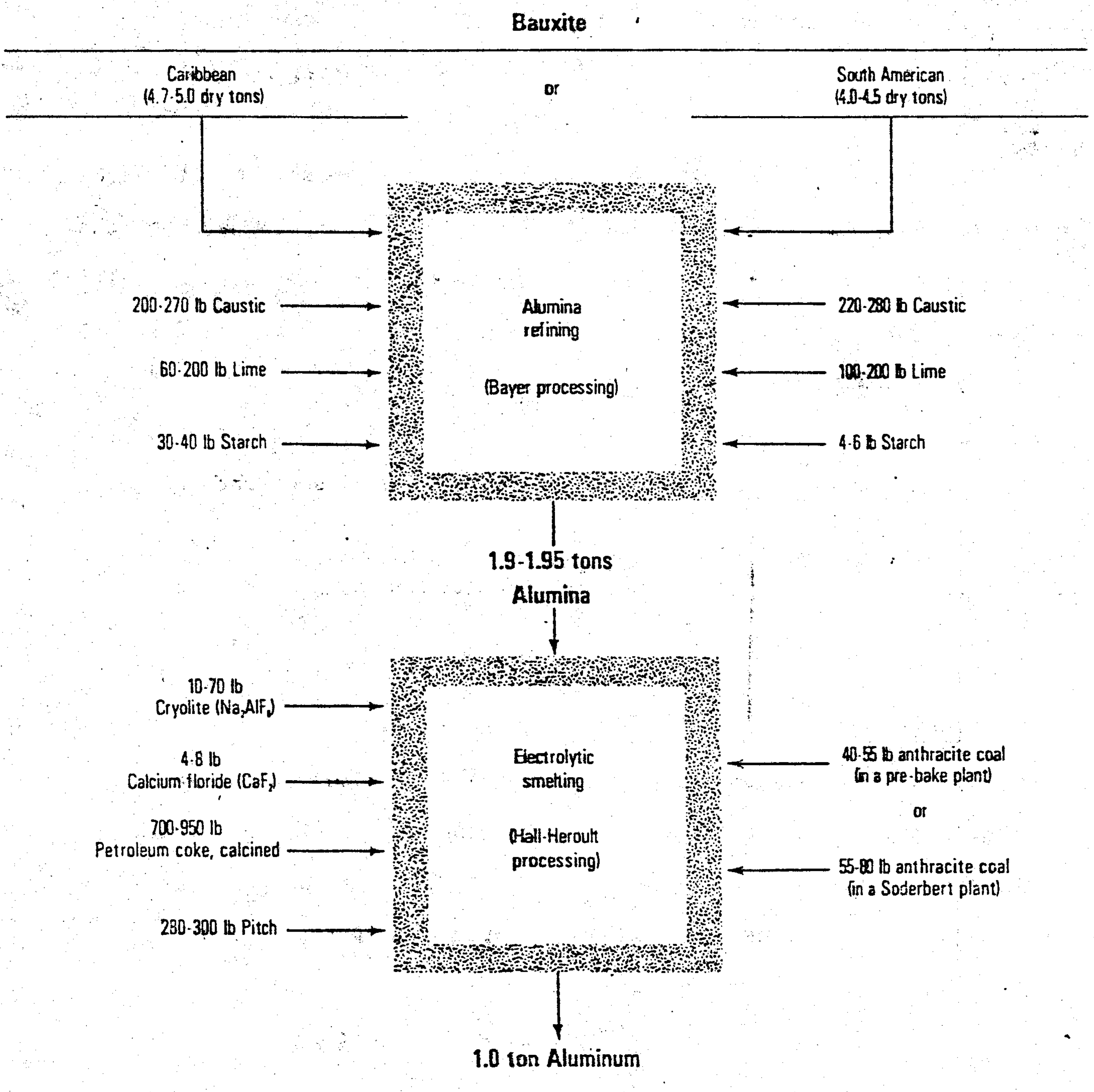
As is obvious from our discussion, apart from bauxite, the major 'materials' for alumina processing are caustic soda and energy. Fig. 3.2 gives some indicative figure of material requirements, except energy. In respect of energy, the average plant requires about 16 GJ (2.4 barrels) for every tonne of alumina produced.

3.3 Aluminium Smelting: The Hall-Héroult Process

The first eight decades of the nineteenth century had seen: (1) the anticipation of the discovery of aluminium; (2) the actual discovery; (3) its production in relatively pure state by chemical and electro-chemical means; (4) the formulation of the laws of electrolysis; and (5) the development and successful application of the dynamo. (See Davis 1980). These were important precursors to the development of the electrolytic process for the reduction of alumina by the American Charles Martin Hall and the Frenchman Paul Toussant Heroult in the same year (1886).

The invention by Hall is described by Carr (1972). It is said that his objective was to find a liquid without water to dissolve aluminium

Fig. 3.2: Materials required to produce one short ton of primary aluminium metal



Primary Source: Stamper, T.W. & Kurtz, H.F. - Aluminum, MCP-14
US Bureau of Mines - May 1978

Secondary Source: Berk, R. et al - Aluminum: Profile of the Industry
(Published by Metals Week 1982)

oxide. On February 10, 1886 he passed an electric current through the molten alumina dissolved in cryolite but found no aluminium in the crucible. He soon determined that the fault was in the clay crucible he used and as a consequence replaced it with a graphite crucible. On February 23, 1886, the carbon crucible was installed and after the direct electric current was passed for several hours, he found "shining buttons of aluminium".

Except for small differences in the electrolyte composition and furnace design, Heroult's invention was for all intents and purposes similar to Hall's. In a speech to the Metallurgical Congress during the World's Fair in 1900 Heroult had this to say of his invention:

> "My practical knowledge of chemistry was at that time of a student of twenty-three. Of special knowledge I had so good as none at all. Under these circumstances it is needless to say that after I had taken out my first patent I sought the counsel and encouragement of those men who were then considered authorities on this subject. Pechiney who I first approached explained to me that aluminium was a metal of restricted usefulness at most it might be used for opera glasses; and whether I wanted to sell the kilogramme for 10 or 100 francs I would not be able to dispose of one kilogramme more. It was otherwise in the case of aluminium bronze of which considerable quantities were handled commercially........."

Fortunately Pechiney's pessimism was to be proved wrong. The firm which bore his name declined to purchase the Heroult patent. (The inventor founded the Schweizerische Metallurgische Gesellschaft which combined with the German firm Allgemaine Elektrizitat (AEG) to form the Societe Anonyme pour L'Industrie de l'Aluminium (AIAG) - the future Alusuisse.)

About 1894, the Societe Industrielle de l'Aluminium was formed to produce aluminium using the Hall patent in a plant at St. Michel de Maurienne in France. Pechiney who had continued to use the by now expensive Deville process was finally convinced of the efficacy of the

electrolytic process and his firm Compagnie de Produits Chimiques d'Alais et de la Camaigue (Alais) took over the St. Michel plant. Compagnie Alais was to later monopolise the industry in France and become the great Aluminium Pechiney.

Over in North America, Hall and a group of Pittsburgh capitalists, notably Andrew and Richard Mellon (of banking and oil fame) formed the Pittsburgh Reduction Company, the future Alcoa. The process invented by Hall and Heroult (like Bayer's) remains basically the same one used by various smelters all over the world. A recent book on the industry by Berk et al (1982) describes the modern smelting variants of the Hall-Heroult process.

The separation of alumina from oxygen is accomplished by high-temperature electrolysis. The electrolyte is a molten bath of alumina and cryolite (a sodium aluminium fluoride). The reduction cells or pots which contain the bath are 3 - 4.5m (10-15 ft.) wide, 6 - 12m (20-40 ft.) long and 1 - 1.3m (3-4 ft.) deep, lined with carbon and electrically connected in a series of 100 to 240 cells called a potline. High amperage low voltage direct current is passed through the cryolite bath - by means of carbon anodes suspended in each pot - to the bottom of the pot which acts as a cathode. The electrical energy decomposes the dissolved alumina. The molten aluminium goes to the bottom of the pot, while the oxygen combines with the carbon anode and is released as carbon dioxide. The layer of molten aluminium which covers the carbon lining at the bottom of the pot becomes the cathode.

Because of the continuous consumption of the carbon anode during cell operation, every primary aluminium facility must have an associated anode preparation plant. The anode raw materials are hard

pitch and petroleum coke crushed and classified into fractions with particle sizes ranging from 0.2 to 15 mm and blended in carefully controlled proportions. The mixture is preheated to 93 - 193°C (200-300°F) to soften the pitch and to achieve uniformity of mix and density. The mix is called the anode paste.

There are two standard industrial anode replacement processes: The Sodeberg and The Pre-baked.

In the Sodeberg method, anode paste or briquettes of coke and pitch are continuously fed into a 1 - 1.6m (3-5 ft.) rectangular shell vertically suspended above the pot. Heat from the molten bath and heat resulting from the electrical resistance within the carbon cause the anode to solidify into a continuous monolithic mass that extends from the electrolyte surface to a level about 50cm (20 ins.) above the bath. As the carbon is consumed in the cell reaction, steel-supporting pins are replaced further up the length of the anode to allow the descent of more carbon into the molten bath.

In the pre-baked anode method the paste is formed into anode blocks in a hydraulic press and baked by a heating cycle at a maximum temperature of 1093°C (2000°F) over a period of about 15 days. The blocks vary in size from one plant to another. One plant, for example, uses blocks that are 50cm (20 ins.) wide, 79 cm (31 ins.) long and 30.5cm (12 ins.) high and weigh about 181kg (400 lbs.). The blocks are suspended in the molten bath by steel studs or rods which conduct the current to the carbon. They are raised or lowered separately to maintain proper position in the bath and are replaced individually as they are consumed.

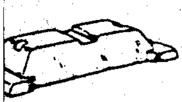
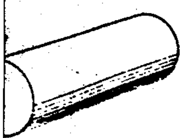
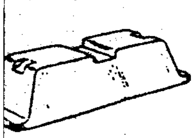
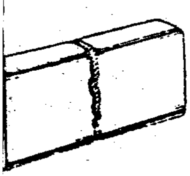
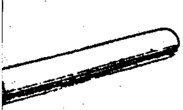
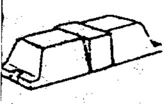
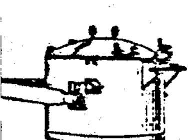
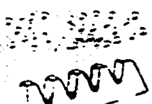
The molten bath or electrolyte may be as deep as 35cm (14 ins.) but the anode is usually 5cm (2 ins.) from the pad of molten aluminium. The alumina content of the bath ranges from 3% to 10%. When the content drops to about 2%, the cell develops a high resistivity. At this point additional alumina is added through the top of the cell. Heat generated by the electrical current maintains the cryolite bath in molten condition.

Every day or two the molten aluminium is removed from the bottom of the cell by a vacuum siphon technique. Thermally-insulated cast-iron pots with air-tight lids and downward sloping spouts are used to draw out the molten metal which is then ready for casting or alloying. After the molten aluminium is extracted from the carbon pots it must be put into a form that can be used by fabricators and other end users. Aluminium can be shipped in its molten form in insulated ladles directly to a user's plant. It can be cast into ingots of varying sizes and shapes or it can be alloyed with other metals and then cast into shapes.

A great variety of aluminium alloys can be prepared. The primary metal is usually sold in a relatively limited number of shapes - the most common ones being extrusion ingot (billet), un-alloyed ingot, sheet ingot and forging stock. (See Fig. 3.3.)

Indicative figures of the materials required for the smelting process are indicated in Fig. 3.2. Energy requirement is highly

Fig. 3.3 Common Shapes of Primary Products

		Common sizes	Common alloys or purity	Principal users
	**Unalloyed ingot** Manufactured in a wide range of sizes. Purity ranges from 98% to 99.9%. Used by wire fabricators, impact extruders, billet manufacturers, foundries making their own alloys, secondary smelters, and chemical companies. Ingot with a purity of 99.99% or higher is known as super purity ingot.	50 lb	99.5% purity	Independent extruders having cast houses to produce their own billet
	**Extrusion billet** Cylindrical and either solid or hollow. Its outside diameter may vary from 3 to 33 in Standard length runs from 26 to 72 in, but this may vary, depending on the requirements of the press in which it will be extruded. Billet is often alloyed. Notable alloys are 1100, 3003, 4543, 6061, 6063, 6463, and some 5,000 series alloys.	6-in and 7-in diameters	6063	Independent extruders
	**Rich alloy ingot** Contains from less than 1% to as much as 50% of the alloying elements desired to be combined with aluminum. The high melting point of many pure alloying elements causes them to go into solution slowly when being combined with aluminum. Addition of this ingot, or "hardener," makes it easier to add alloys to unalloyed aluminum. It also allows for closer control over the amount of alloying metal used.	50 lb	3A-2370 3B-2312	Foundries and independent billet producers
	**Sheet ingot** Largest of the ingot products. It is available in a range of cross-sectional dimensions, and in weights up to five tons. Its flat shape makes it readily available for rolling.	12x36 in 12x48 in	1100 3003 1145	Independent sheet producers
	**Forging alloy ingot** Generally supplied in cylindrical form, 1 to 2 in in diameter and 1 to 4 ft long. However, it is also available in square and rectangular shapes. Most small forgings are made from rolled or extruded stock. Large forgings are often made from cast ingots.	13 in	7075 6061 2014	Forgers with large presses
	**Casting alloy ingot** Available in a variety of sizes. Some uses allow for large quantities of scrap, others do not. Therefore, this shape comes as both primary and secondary ingot.	30 lb	A356-355	Foundries
	**Hot metal** Sometimes, molten aluminum is shipped directly from the smelter to a customer's plant in insulated ladles.	5,000- to 15,000- lb crucibles	—	Automobile industry
	**Shot and notch bar** Common deoxidizing products used in steel production. Use per ton of steel ranges from a few ounces to 4 lb. Largest users are stainless steel and high-carbon sheet producers.	⅜- in shot, 3- and 5- lb notch bar	99.0% to 99.99%	Steel industry

Source : Berk et al (1982).

significant and is a major determinant in respect of smelter location. An average plant may require some 15.5 MWH per tonne of alumina. In other words, a plant of capacity 200,000 tonnes would require some 300 MW of energy to provide the necessary power.

3.4 Semi-fabrication

According to the book Berk et al (1982) "fabrication" (which we prefer to term "semi-fabrication") can be divided into five basic operations: (1) casting; (2) rolling; (3) forging; (4) drawing; and (5) extruding. Each will be briefly described:

3.4.1 Casting

This is the only semi-fabricating process that requires the aluminium to be in a liquid state. Because of this, casters sometimes buy molten aluminium rather than ingot, which they would have to re-smelt. In the casting process the liquid aluminium is forced or poured into a mold. The metal is allowed to harden and is then heat-treated and aged. The fabricated product resulting from the process is a casting.

3.4.2 Rolling

The largest ingots used in the industry are made for rolling into plate sheet and foil. This rolling ingot (or sheet ingot) is rectangular (Fig. 3.3). It is scalped to create a smooth surface, then heated and run through a hot rolling mill. By bringing the rolls closer together and moving the ingot between them, the thickness is reduced and the length is increased. The resulting plate need not be further rolled after the hot mill. If sheet is desired further reductions can be obtained by passing the plates through cold-rolling mills. The sheet may be annealed prior to the final cold rolling. After cold-rolling, heat-treatable sheet and plate are heated and

quenched. Stretching plate and aging both sheet and plate are the final steps. To become foil the sheet must go from cold rolling to further reducing mills annealing surface and then even more reducing.

3.4.3 Forging

This is done by two processes: hammering or on a forging press. In the hammer process, forging stock is heated to a hot-working temperature and then placed on a block which holds a die containing half the product to be forged. A second die which is in the hammer end strikes the stationary block. The process is repeated until the metal conforms to the shape of the two dies. In the forging-press process, the metal which has been heated to proper temperature is squeezed into the shape of the die under continuous pressure from a mechanical or hydraulic press. After the forging comes out of the die, it is heat-treated and aged (Fig. 3.3).

3.4.4 Drawing

This process is used for making rod, bar, wire and drawn tube. In making rod and bar, ingot moves through a blooming mill and is then scalped to give it a smooth surface. The ingot is reheated and reduced in size by rolling. From the rolling mill the metal moves to the draw bench which contains a series of dies. Each die is the same shape but each is smaller in diameter than the previous one. The metal is drawn down to proper rod or bar size at the draw bench. The material is then heat-treated, straightened and aged. Wire follows a similar process but first is rolled to a much smaller diameter. After rolling, the metal is coiled and annealed before being drawn into wire in a wire-drawing machine. When the wire has been drawn it may be stranded into electrical conductor. Drawn tube is initially extruded and then annealed before going to the draw bench. After being drawn to the

proper tolerance, it is heat-treated, stretched and aged.

3.4.5 Extruding

This process can be used for making shapes, tubing, rod and bar (Fig. 3.3). In this process extrusion billet (a round form of billet) is heated and placed in an extrusion press. In the press the heated billet is forced under great pressure through a die and comes out in approximately the same shape as the die opening. Heat treating, stretching, contour rolling and aging follow the extrusion steps.

CHAPTER IV

JAMAICA'S BAUXITE/ALUMINA INDUSTRY: PRODUCTION TECHNIQUES; EMPLOYMENT AND INCOME GENERATION; SCALE AND PRODUCTION COSTS

4.1 Introduction

In this Chapter we consider the techniques used in Jamaica's bauxite mining and processing operations. Next we discuss the question of scale in the world aluminium industry then we examine the impact of the Jamaican industry on employment and income generation and finally an analysis of scale of operations and production costs is presented.

We consider the techniques used in the Jamaican industry under two headings: (a) bauxite and (b) alumina.

4.2 Bauxite

Jamaican bauxites are associated with the Tertiary White Limestone Formation which occupies about 55% of the island's land surface. The fact of this association has led some workers to conclude that the bauxites are derived from the trace quantities of impurities in the limestone. Other workers, including a former distinguished head of the Jamaican Geological Surveys Department, V. A. Zans, have doubted that such large volumes of material could have come from residues in the limestone, and have suggested instead that the source materials derived from older cretaceous and pre-cretaceous rocks which were transported into the limestone via cavern systems and karst streams, and then weathered on the limestone.

Source materials apart, it is generally agreed that the environment of formation favoured bauxitization. Firstly, the temperatures were above 20°C. Secondly, the rainfall was seasonal,

and thirdly, the limestone is porous, enabling good drainage. Following the discovery of huge quantities of bauxite deposits in the 1940's, commercial bauxite production was started in 1952,when the first load was shipped by Reynolds Jamaica Mines.

The bauxite deposits vary in area and depth (the latter varies from 5 metres to 50 metres) and have relatively little or no overburden. Physically the ore is soft to moderately hard, earthy in appearance, highly permeable and porus. While their properties would seem to indicate an easily mineable material, with increasing depth the ore becomes highly consolidated and requires digging forces in excess of 35kg/Cm^2 (500 lbs/ins^2) of bucket width. Roberts (1980) points out that a consequence of this consolidation is an <u>in situ</u> density variation between 1453 and 1696 kg/cu. metre (2430-2835 lbs/c.yd). The form of the deposits varies from a blanket-type formation to elongated glades, saucer-shaped deposits to infilled depressions in limestone.

The report also points out that the selection of the type of excavator equipment is largely determined by the nature of the occurrence of the bauxite - shape, areal extent and depth. Long narrow deposits dictate the use of dragline; wider deposits are amenable to power (face) shovel mining largely as a consequence of the manoeuvrability of the haul units within the pits during the mining of lower benches. However, the clean-up work has to be effectively done by draglines. The above excavator application criteria were largely what operated in the industry during the initial mining years. The main excavator equipment comprised power (face) shovels and draglines.

An hydraulic loader as a mining tool was introduced in the second half of the 1960s. Initially, the unit - a Caterpillar 988

rubber-tyred loader equipped with a 5½-cubic yard bucket - was utilized mainly for blending purposes. An earlier unit, the Caterpillar 950 equipped with a 2½ cubic yard multi-purpose bucket, had proven the capability of the front-end loader in similar operating conditions.

It was recognised at this stage that the loader would not have the ability to work in situ (bank) material. Consequently, there was a pairing of the excavator with a bulldozer of sufficient capacity to match the capacity of the excavator.

The nature of the bauxite lends itself to being effectively ripped utilizing a bulldozer equipped with a multi-shanked ripper. The combination is one of the bulldozer ripping and pushing up bauxite to the front-end loader and the loader reclaiming the material off highway-type trucks. The standard front-end loader lacked the reach of haul trucks 28-35 ton capacity to which they would have been assigned without risking damage to the lip of the body by the bucket of the loader during truck-loading manoeuvres. Loading was significantly improved by incorporating 2-ft long extension arms.

During the 1960s, blending of lower grade ore was emphasized. The conventional face (cable) shovels and draglines had increased in size; selectivity in mining the ore face was to some extent restricted by the relative "immobility" of the machines when compared to the wheeled loader. During the 1970s the hydraulic excavator (hydraulic back-hoe) was introduced.

A summary of equipment used during the decades described by Roberts (1980) is indicated (Table 4.1).

TABLE 4.1: Equipment Changes in Jamaican Mining Industry 1950s - 1970s

Excavator	Decade	Capacity
	1950s	
Face Shovels		2½ - 4 cubic yard
Draglines		1½ - 4 " "
	1960s	
Face Shovels		2½ - 5 " "
Draglines		3 - 5½ " "
Front-end Loaders		5½ " "
	1970s	
Face Shovels		2½ - 6 " "
Draglines		3 - 8 " "
Front-end Loaders		5½ " "
Hydraulic Back Hoes		6 - 12 " "

A summary of major excavating and haulage equipment was given in the EMJ Report (1977). They were as follows:

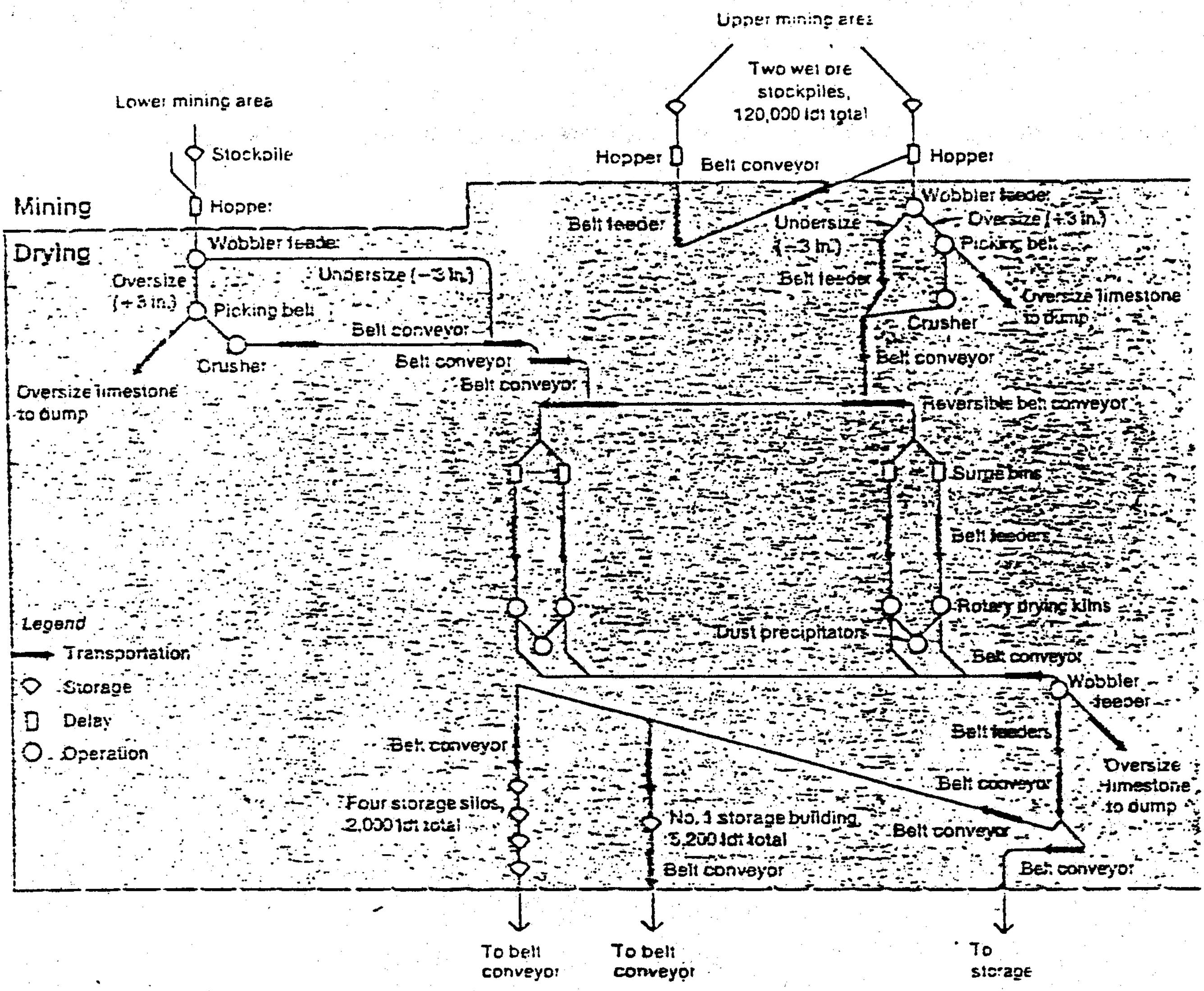
TABLE 4.2: Major Excavating and Haulage Equipment in Jamaica Mining Operations

COMPANY	MAJOR EXCAVATING EQUIPMENT	MAJOR HAULAGE EQUIPMENT
Kaiser	4 P&H 1400 DE Shovels 3 BLH 2400 B Draglines	8 KW Dart Trucks (42-ton) 16 Euclid R 50 Trucks (50-ton)
Reynolds	2 P&H Shovels 3 Marion 111 M Shovels 2 Marion 111 M Draglines 1 Cat. 992 B Loader	21 Cat. 769 B Trucks (40-ton) 1 Overland Conveyor (1,000 tph)
Alpart	2 P&H Shovels (6-yd) 2 Koehring Back-hoes (6-yd) 1 Manitowac Dragline (6-yd)	18 Euclid R 50 Trucks (50-ton)
Alcoa	1 Bucyrus Erie 88 B Shovel 2 P&H 955 A Shovels 1 Bucyrus Erie Dragline (4-5 yd) 2 Cat. 988 Loaders	7 Wabco Haulpak Trucks (50-ton) 7 Oshkosh Trucks (32-ton) 2 Mack Trucks (50-ton)

Source: EMJ Report (1977)

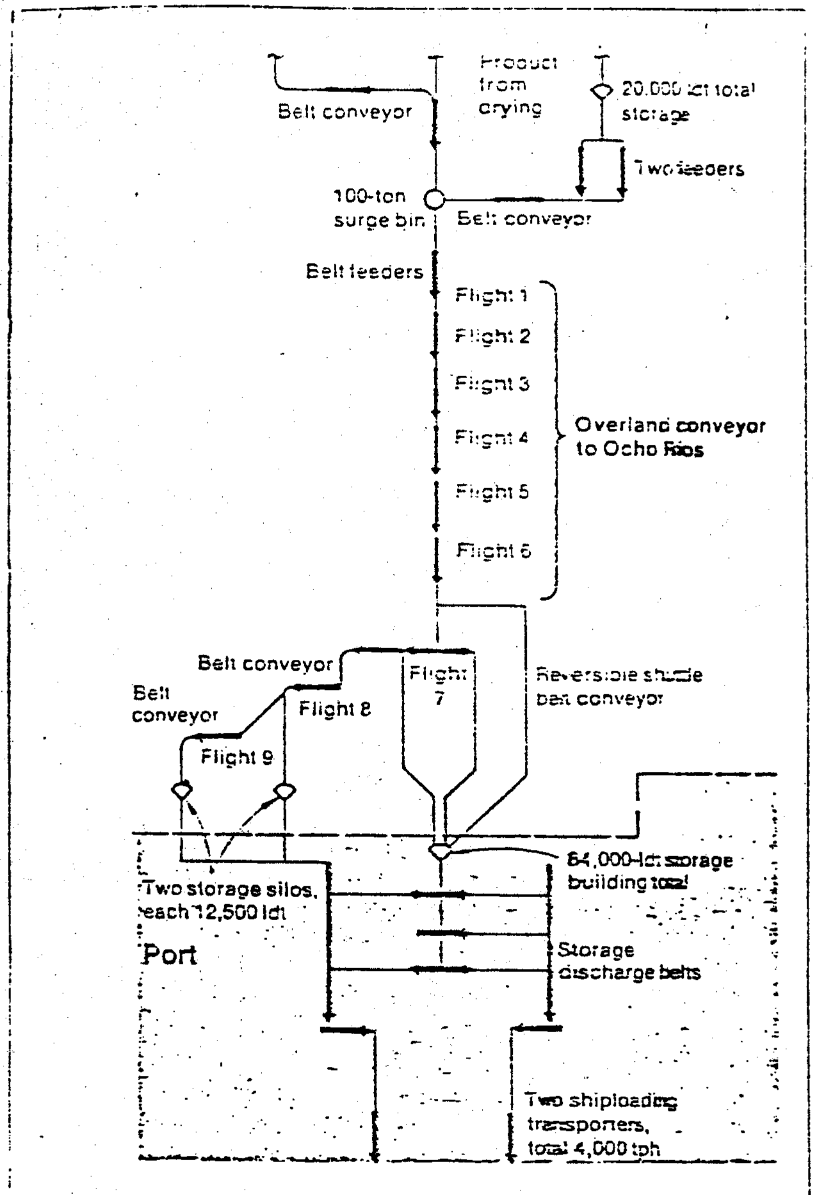
Figs. 4.1 & 4.2 show diagramatically the mining and overland transport system for one of the major Jamaican mines - that of Reynolds.

Fig. 4.1: Flowsheet of Mining Operations - Reynolds Jamaica Mines



Source: Engineering and Mining Journal Operating Handbook of Surface Mining (1977)

Fig. 4.2: Reynolds Jamaica Mines Overland Transport



Source: Engineering and Mining Journal Operating Handbook of Surface Mining (1977)

4.3 Alumina

The Jamaican industry was developed by North American producers. Consequently, they sought to apply the American variant of the Bayer technology. As reported by the then Director of the Geological Survey Department, V.A. Zans, the test in Alcoa's East St. Louis alumina plant of the trial shipment of 2,500 tons of Jamaican bauxite proved unsuccessful. Problems arose because of the monohydrate (boehmite) and the colloidal iron minerals so characteristic of Jamaican bauxite. The two basic problem areas created by these characteristics are in the areas of digestion and clarification (see Fig. 3.4 for identification of these areas in the Bayer process).

In respect of digestion, the American Bayer process, as we described earlier, uses low temperatures and pressure which are wholly adequate for the essentially trihydrate bauxite then used in the USA (from the USA itself and from the Guianas). However, with the relatively small (compared to European bauxite) boehmite contents in Caribbean ores, two problems arose:

1) Extraction was inefficient as only the gibbsite (trihydrate) component was solubilized.

2) The boehmite (monohydrate) when present in concentrations above 2% acts as a 'seed' and precipitates out some extracted gibbsite by a phenomenon known as "reversion"; thereby reducing even further the extraction efficiency.

One approach initiated by Alcoa was a dual digestion system: (a) digestion at 143^{o}C using a "retention" time of approximately 30 minutes to achieve gibbsite extraction (and desilication); and (b) follow this low-temperature digestion step with a short high temperature digestion at ca. 230^{o}C to extract boehmite. See Perry (1969).

Other methods include one digestion temperature of 230-260^{o}C to extract both gibbsite and boehmite and a so-called 'sweetening' process where trihydrate ore is added to the process following digestion. The former is currently being used by Alumina Partners of Jamaica (Alpart) and the latter system by both Kaiser and Reynolds at their US plants using Boke and Brazil bauxites, respectively, to 'sweeten' Jamaican ore.

The second major problem area to which technology had to be adapted to process Jamaican bauxite is that of clarification. The extreme fineness of Jamaican bauxite compared to those in the USA, the Guianas and Europe, was one of the features which made it necessary to modify the then known technology to enable proper clarification. A report by Reynolds clearly identified the problem:

> "..... The red mud was found to be in the form of a fine slime which settled very slowly or not at all. Considerable experimentation had to be undertaken with various additives such as starch to determine what should be done to accelerate the settling rate of the mud. The red mud was also found to be carrying away with it valuable processing chemicals which could be recovered by washing the mud. To make this chemical recovery process economical methods had to be developed for compacting the mud. Special mud-raking equipment had to be developed for the settling tanks. ...... The overflow liquor from the mud-settling operation had to be filtered to remove any red mud particles. They were so fine however that they clogged the filter cloth very quickly. ....." See Davis (1981).

Since those early days, a lot has been done to effect clarification in Jamaican bauxite. Techniques introduced included: (a) the number of washing stages; (b) control of the concentrations of the iron mineral goethite vis-a-vis the better settling haematite; (c) the use of natural (starches) and/or synthetic flocculant. The settling of Jamaican "red mud" still remains in our view the most challenging of the problems faced in processing bauxite into alumina.

4.4 Mud Disposal

The characteristics of Jamaican bauxites (fineness of muds and volume of mud vis-a-vis the amount of bauxite processed) and the environment surrounding the alumina plants greatly influence the systems used in mud disposal.

Currently there are three general types in use or about to be used: (1) the disposal of the mud in unsealed limestone basins near the alumina plants; (2) disposal in artificially-sealed impoundments; and (3) dry stacking. Each of these is discussed briefly:

4.4.1 Disposal in unsealed Limestone Basins

This method is used by three of the four alumina plants operating in Jamaica, viz: Alcan (two plants); and Alpart. This methodology involves the pumping of the effluent to the naturally-occurring basins. While this technique is relatively inexpensive, there are several disadvantages including the contamination (which has in fact occurred) of the groundwater due to seepage of the liquid phase through the substrate rocks.

4.4.2 Disposal in Artificial Ponds

This is the system used in Jamaica by Alcoa, whose plant is located on the plains and where significant acreage is available nearby. Generally this method is expensive as in the case of Alcoa some 40 hectares have to be impounded every five years. The disadvantage of the method as practised in Jamaica is that for a country with limited arable land area so much land is permanently sterilized. For example, the area used by Alcoa hitherto was used for cane growing.

4.4.3 Dry Mud Stacking

As indicated by Douglas (1983) dry mud stacking is a misnomer since the mud is not dry when it is deposited or stacked. Be that as it may, an interesting development which has occurred in Jamaica is that of Alcan's Dry Mud Stacking Technology.

Chandler (1982) describes the method as follows:

1. Dewatering the slurry to a point where it is thick enough to set up an angle of repose of between 2.5 - 6% in the disposal area. This is done by deep thickeners (decanters).

2. The shallow conical pile set up has several advantages over the shallow concave shape resulting from the pumping of unthickened slurry to points around the circumference of a traditional "tailing pond" which advantages are said to be:

    1. The height and cost of dykes surrounding a given weight of disposed mud less.

    2. The slope of the surface of the cone allows rainfall to run off easily and it collects at the lowest point of the circumference from where it can be easily pumped away.

    3. When the disposal area is full or its use is discontinued for any other reason it can be covered with topsoil and returned to use as agricultural land.

The technology which Alcan is in the process of implementing is being watched with great interest as it represents an attempt to adopt technology to suit the characteristics of Jamaican muds and rather restricted environment for disposal of such muds.

4.5 Scale in the Aluminium Industry

The minimum economic plant sizes are dependent on a number of factors including: (a) location; (b) infra-structure; (c) transport; (d) capital costs; (e) energy costs; (f) the cost and quality of raw material inputs; and (g) the extent to which the plant is domestic or export oriented.

A combination of the first three factors for example, often implies a minimum level of investment in basic physical infrastructure. There are therefore scale economies to be reaped from expansion of the processing or smelting plant, since there may be no further need for investment in infrastructure. Such considerations have combined with others to lead to the present state where the first three stages of aluminium manufacturing: bauxite mining, alumina processing and aluminium smelting are moving to larger-sized operations. We discuss each of these briefly.

4.5.1 Bauxite Mines

In respect of bauxite mining, the following data for some mines in four of the principal producing areas, viz: Australia, Guinea, Jamaica and Brazil, are indicative:

TABLE 4.3: Sizes of Some Major Bauxite Mines

Country	Name of Mine	Size (Per Annum)
Australia	Weipa	ca. 10 million tonnes
	Gove	" 5 " "
Guinea	Boke	" 9 " "
Brazil	Trombetas	" 3.5 "" " (currently)
Jamaica	Kaiser-Jamaica Bauxite Company	" 4.0 " "
	Jamaica-Reynolds Bauxite Partners	" 2.8 " "

There are smaller economic mines of course. For example, the Alcoa mine in Clarendon, Jamaica, has a current capacity of about 1.5 million tonnes per annum. But this small size is compensated by the close proximity to the alumina plant which processes the bauxite.

4.5.2 Alumina Plants

In a recent paper Perry and Russell (1982) drew attention to the fact of the changing of alumina plant capacity vs. time. Fig. 4.3 shows a plot of this relationship by the authors. Some specific examples illustrate this trend:

The two first alumina plants in Jamaica were built by Alcan (in 1952 and 1959, respectively). Both were designed for maximum capacity of 550,000 tonnes per annum each. Both plants have since reached this capacity and they have a combined work force of approximately 2,400.

The next generation of alumina plants in Jamaica (mid to late 1960s) were as follows:

(a) Alcoa: initial capacity 550,000 tonnes per annum and capable of being expanded to 1,650,000 tonnes per annum; permanent workforce was approximately 950.

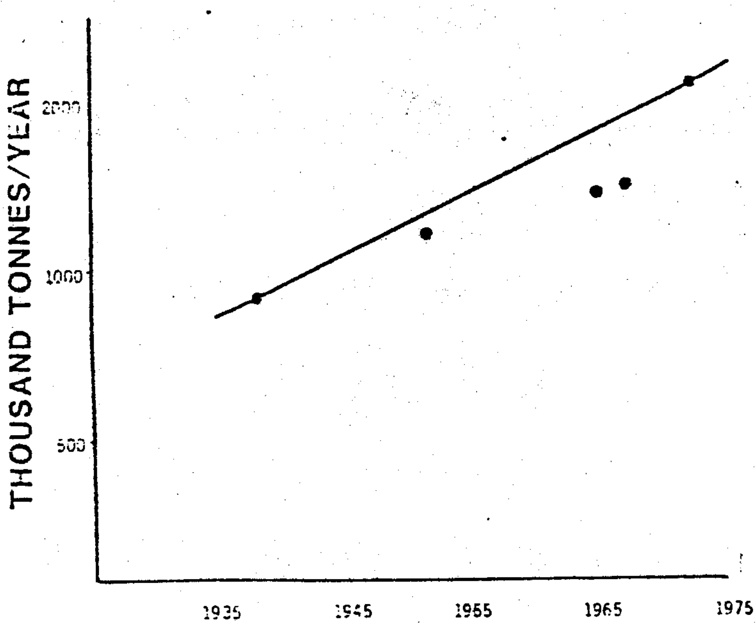
(b) Alpart: initial capacity of 700,000 tonnes per annum; later expanded to 1,100,000 tonnes per annum and capable of being further expanded to ca. 1,800,000 tonnes per annum; initial permanent workforce of 1,900 but subsequently reduced to about 1,650.

(c) Revere: initial capacity of 200,000 tonnes per annum capable of being expanded to 800,000 tonnes per annum; permanent workforce of approximately 600.

(It should be noted that one reason why the Revere operations collapsed was its small initial capacity of 200,000 tonnes.)

The developments in the Australian alumina industry illustrate even more emphatically the trend to bigger alumina plants. In 1960 the only alumina refinery in Australia was at Bell Bay, Tasmania, with production of 30,000 tonnes annually. This capacity was later doubled but the refinery was closed down in 1973. In 1963 Alcoa of Australia began alumina production at Kwinana, Western Australia,

Fig. 4.3: Alumina Plant Capacity vs. Time



Perry & Russell (1982)

Source: The Journal of the Geological Society of Jamaica Proceedings of Bauxite Symposium V June 1982

with an initial rated capacity of 210,000 tonnes per annum which was expanded in stages to a design capacity of 1.4 million tonnes per annum by the end of 1970.

The next plant built - the Queensland Alumina Ltd. (QAL) refinery in Gladstone, Queensland, had an initial capacity of 609,000 tonnes per annum (1967) and was expanded in stages to a design capacity of 2.0 million tonnes per annum by 1973 and has actually operated at a rate of 2.4 million tonnes per annum and is now being expanded by an additional 300,000 tonnes per annum. A refinery was constructed at Gove, Northern Territory, by Alusuisse and Australian interests in 1972. The design capacity was initially 500,000 tonnes per annum but was expanded over time to a current 1.2 million tonnes per annum.

Alcoa of Australia commissioned its second refinery in 1972 at Pinjarra, Western Australia, with an initial production capacity of about 400,000 tonnes per annum. Rapid expansion and improvement of existing equipment and technology have led to a current design capacity of ca. 2.5 million tonnes per annum. Alcoa of Australia constructed a third alumina plant at Wagerup, Western Australia, with an initial capacity of 500,000 tonnes per annum capable of being increased to 2 million tonnes per annum. Another alumina refinery was constructed in Western Australia by a consortium led by Reynolds Metals Company. The initial design capacity of this plant is 1 million tonnes per annum but it is capable of being expanded to 2 million tonnes per annum.

Other new alumina plants illustrating this trend to larger capacity plants (initial or ultimate) are:

Aughinish, Ireland	...	...	800,000 mtpa
Endasa, Spain	...	...	800,000 "
Interalumina, Venezuela		...	1,000,000 "

4.5.3 Aluminium Smelters

The size and scale of aluminium smelters have also seen dramatic upward movements. Whereas most of the early plants in Europe (some of which are still in operation) had capacities of under 50,000 tonnes per annum, capacities currently planned (whether by expansion of existing capacity or the building of new ones) for a minimum size of 150,000 tonnes per annum and in some cases close to 300,000 tonnes per annum. Some examples of this trend toward larger-sized plants, which became apparent from the late 1960's, are as follows:

TABLE 4.4: Sizes of Selected Smelters

Alcoa	Evansville, Indiana	263,000 mta	
	Massena, New York	205,000 "	
	Tennessee	200,000 "	
	Rockdale, Texas	310,000 "	
	Wenatches, Washington	200,000 "	
Alcan	Arvida, Quebec	432,000 "	
	Kitimat, B.C.	268,000 "	
	Grand Baie, Quebec	171,000 "	
Kaiser	Chalmette, Louisiana	236,000 "	
	Mead, Washington	200,000 "	
Reynolds	Listerhill, Alabama	183,000 "	
	Longview, Washington	190,000 "	
	Baie Comeau, Quebec	159,000 "	(to be expanded to 272,000 mta)

TABLE 4.4 (Contd.)

National Southwire	Hawesville, Kentucky	163,000 mta
Noranda	New Madrid, Mass.	204,000 "
Alumax	Mt. Holly, S.C.	179,000 "
Eastalco	Frederick, Md.	160,000 "
Intalco	" "	254,000 "
Martin Marietta	The Calles, Ore.	167,000 "
Anaconda	Sebree, Kentucky	163,000 "
	Columbia Falls (Mont.)	163,000 "
Venalum	Venezuela	280,000 "
Aluminium Bahrain (ALBA)	Bahrain	171,000 "
Indonesia Alum. Company	Indonesia	150,000-225,000 mta
Aluminia Expanol	Spain	180,000 mta
ASV	Norway	183,000 "
Norsk Hydro	Norway	170,000 "
Pechiney	Holland	170,000 "
Pechiney	Quebec	225,000 " (Planned)
Gladstone	Queensland	206,000 "
Alcoa Australia	Pt. Henry, Victoria	165,000 "

4.6 Employment and Income Generation

4.6.1 Level of Employment in Industry (1976-1982)

Table 4.5 provides data on employment levels in the companies involved solely in mining and exporting of bauxite for the period 1977-1982. It will be seen that the employment level for 1982, is less than half of the average for the 1976-'81 period, reflecting the sharp downturn in production which began in 1981, resulting from the recession in the U.S. economy, the major market for bauxite exports. If it is assumed that this downturn is an anomalous situation, a more normal picture employment level is derived from considering the 1976-1981 period. During this period, average employment in this sub-sector was 1,400.

TABLE 4.5: Employment in Bauxite Mining (1976-1982)

YEAR	SUB-SECTORS			NATIONALITY		TOTAL
	Mining & Drying	Port	Other[1]	J[2]	N/J[3]	
1976	737	101	535	1367	6	1373
1977	699	94	547	1334	6	1340
1978	576	84	738	1390	6	1398
1979	697	63	698	1452	6	1458
1980	687	60	684	1424	7	1431
1981	614	54	731	1391	8	1399
1982	161	15	488	654	10	664

[1]Other includes management Staff, Transportation, construction, etc.

[2]J - Jamaican

[3]N/J - Non-Jamaican

Source: Jamaica Bauxite Institute

The data for the corresponding period for those companies involved in alumina production are presented in Table 4.6 The table shows that for the seven year period, average employment by the integrated mining and refinery facilities was 4,940, ranging from a high of 5,378 in 1980 to a low of 4,306 in 1982. The fact that the 1982 figure is the lowest is not surprising in light of the recession in the world industry. However, what is of significance is the difference in the level of decline between the sub-sector involved solely in exporting bauxite ore and that which also carries out refinery in Jamaica. The difference is related to the more diversified nature of alumina exports as was discussed in Section 2.4.2.

TABLE 4.6: Employment in Integrated Mining and Refining Facilities (1976-1982)

YEAR	SUB-SECTORS					NATIONALITY		
	Mining & Drying	Alumina Plants	Port	Other	Agri-culture	J	N/J	Total
1976	628	3522	336	109	297	4818	74	4892
1977	585	3602	286	97	206	4713	63	4776
1978	608	3654	300	72	228	4800	62	4862
1979	648	3745	285	85	281	4985	59	5044
1980	636	4131	275	76	260	5309	67	5378
1981	608	3705	291	439	285	5260	68	5328
1982	493	3107	234	380	92	4269	37	4306

Source: The Jamaica Bauxite Institute

In both sub-sectors of the Jamaican industry, the level of employment of non Jamaicans is extremely low, never exceeding a total 80 in any year.

In terms of contribution to national employment, total employment in the bauxite/alumina sector is relatively unimportant. Table 4.7 provides data on the comparison between national employment and employment on the one hand and employment in bauxite/alumina over the period 1976-1982

The table shows that the bauxite/alumina sector has accounted for less than 1% of total employment for any of the years under review. When compared to the level of unemployment, total employment in the bauxite/alumina sector represented, at most, 3.2% of the pool in the seven-year period. The data imply that even a major expansion in the size of the present industry, or alternatively a more intensive use of labour (say a doubling of the present workforce) would have very little direct input on the level of employment.

4.6.2 Contribution of Bauxite/Alumina to National Income

The data presented in Section 4.6.1, demonstrates clearly the relative insignificance of the bauxite/alumina industry when compared to the Jamaican employment picture. We now consider the sector's role in the national economy. Table 4.8 presents data on its contribution to GDP.

TABLE 4.8: Jamaica: Percentage Contribution of Major Sectors to GDP (1977-1981)

Sectors / Year	1977	1978	1979	1980	1981
Agriculture	8.6	9.4	8.5	8.5	9.6
Bauxite/Alumina	7.0	7.2	7.2	8.6	8.6
Manufacture	17.6	16.8	16.1	15.1	14.8
Construction	6.7	7.0	7.0	5.3	5.3
Distribution	16.6	15.8	15.3	15.1	15.5
Real Estate	10.9	19.6	11.0	11.6	11.8
Producers of Govt. Services	16.5	17.4	18.6	19.8	19.7
Others	16.1	16.8	16.3	16.0	15.5
TOTAL	100.0	100.0	100.0	100.0	100.0

Source: Department of Statistics

TABLE 4.7: Jamaica: Employment Levels for National Economy & Bauxite/Alumina Sector (1976-1982)

Year	Total Employed 000' Persons	Total Unemployed 000' Persons	Employment in Bauxite/Alumina		
			000' Persons	As %Age of Total Employed	As %Age of Unemployed
1976	658.8	197.8	6.3	0.96	3.2
1977	689.8	220.2	6.1	0.88	2.8
1978	708.5	230.5	6.3	0.89	2.7
1979	689.0	264.7	6.5	0.94	2.5
1980	720.4	270.8	6.8	0.94	2.5
1981	752.4	262.5	6.7	0.89	2.6
1982	756.6	286.4	5.0	0.66	1.7

Source: The Department of Statistics and Jamaica Bauxite Institute

The table shows that over the five-year period, bauxite/ alumina competes closely with agriculture in terms of contribution to GDP, both being second only to manufacture, in the productive sector. This contribution is at about the 7.0% level for the 1977-1979 period climbing to 8.6% and over in 1980 and 1981. An important point which must be borne in mind, is that while agriculture and bauxite/alumina are roughly equal in terms of GDP contribution, the former provides jobs for approximately eighty (80) times the number employed in the latter.

The real importance of the sector's contribution to the economy is its earning of foreign exchange. The foreign exchange inflows from the sector are derived from three primary services; wages and salaries for employees; other local costs of operations and payments for royalties and the production levy. In recent years, with an increased role played by the State in marketing bauxite and alumina, there is a new source of foreign exchange, which is profits earned on such sales. However, the inflows to date are small compared to other three sources and are excluded from Table 4.9.

TABLE 4.9: Contribution of Bauxite/Alumina to Foreign Exchange Inflows 1981-1982

(US) $m.

Year	Bauxite/Alumina Inflows				Total National Foreign Exchange Earnings	Bauxite/ Alumina As %age of Total
	Wages & Salaries	Other Costs	Local Levy & Royalties	Total		
1978	54.5	74.2	195.2	323.9	533.2	60.7
1979	49.9	29.0	194.2	273.1	628.5	43.5
1980	60.8	75.7	105.7	342.2	692.7	49.4
1981	66.6	58.3	195.1	320.0	610.1	52.5
1982	76.2	71.3	137.0	284.5	610.3	46.6

Source: Jamaica Bauxite Institute and Bank of Jamaica

The table shows that in the five year period 1978-'82, bauxite/alumina accounted for over a half of total foreign exchange earnings for Jamaica, with 1978 being a high (60%). There are two additional points, which can be made about the figures presented in Table 4.9. The first relates to the foreign exchange inflows for wages, salaries and other local costs in 1979, which show decreases compared with 1978. These decreases reflect the impact of the series of devaluations of the Jamaican currency, put into effect as part of the Extended Fund Faculty Agreement between the Government of Jamaica and the International Monetary Fund. Then devaluations reduced the inflows needed by the multinational companies to take care of the local costs which are denoted in Jamaican currency.

The second point is that the industry's share of total foreign exchange earnings, is underestimated in Table 4.9. This underestimation derives from the fact that, while the inflows for other sectors (e.g. tourism) are gross figures, with no account taken of the corresponding outflows needed for their (the sectors') operations, the figures presented for bauxite/alumina are net of the costs of imported inputs. Ideally, the basis of comparison between sectors, should be the net earnings, but it is not possible to carry out this exercise, since data on the cost of imported inputs are not available for most sectors.

4.7 Scale in Bauxite Mining and Refining

4.7.1 Investment Costs and Size

At the present time, there are four (4) alumina plants operating in Jamaica. These plants operate as integrated bauxite mining and alumina processing facilities. A fifth facility, Revere Jamaica Alumina Ltd., operated up to September, 1975 when production was suspended due to economic difficulties. There are two bauxite mining plants which produce bauxite which is exported in its primary form. Table 4.10 below sets out the production capacity and investments costs of the integrated bauxite and alumina facilities while Table 4.11 sets out similar data for the bauxite mining facilities.

TABLE 4.10: Production Capacity and Investment Costs of Integrated Bauxite and Alumina Facilities in Jamaica

Name	Date Established	Capacity (Metric tons)	Investment Cost per tonne	Investment Cost (U.S.)[1]
Alpart	1969 1972-3	1,180,000	$300	$350m[2]
Alcan 1. Kirkvine	1952	550,000	$150)	$165m
2. Ewarton	1959	550,000	)	
Alcoa	1972	550,000	$296.4	$163m
Revere	1970	200,000	$415	$ 83m

[1]Costs quoted in current dollars.

[2]This figure is total of original investment and 1972/3 expansion.

Source: Jamaica Bauxite Institute

TABLE 4.11: Production Capacity and Investment Costs of Bauxite Mining Facilities in Jamaica

Name	Date Established	Capacity (metric tons)	Investment Costs (U.S.)[1]
Kaiser Bauxite Co.	1953	4,100,000	$68m
Reynolds Jamaica Mines	1952	3,500,000	$55m

[1]Costs quoted in current dollars.

Source: Jamaica Bauxite Institute

The fact that investment costs for the bauxite and alumina facilities are only available in current dollars places an important restriction on the comparisions that can be drawn between size and investment costs. Nonetheless, the differences between Alcoa and Revere in terms of size and investment costs (taking into account the time difference) illustrate the economies of scale that can be derived in terms of investment costs since Alcoa's capacity is 2.75 times that of Revere whereas its investment costs were just less than 2 times. It is possible that differences in the infrastructure costs may partly account for this situation but the evidence available indicates that size was the important factor.

Comparison of the data for Alpart and Alcoa would seem to suggest that per tonne investment costs were higher for the larger size plant i.e. there were diseconomies of scale in the establishment of ALPART. However, it is generally agreed that the infrastructure costs associated with the Alpart plant were unusually high due to land costs, extensive railway facilities and other factors to do with the location of the plant.

In the case of the bauxite mining facilities, the data available indicate a significant difference in the investment costs of the two facilities. The difference is due mainly to the difference in the sizes of initial landholdings.

Overall, analysis of the data available for the Jamaican industry, suggests that economies of scale can be derived from large size facilities. However, other factors such as infrastructure costs and construction efficiency are also very important. In today's world of high interest rates, the economies of scale can be wiped out by time over-runs in the implementation of projects.

4.7.2 Employment and Size

This section examines production and employment data for the integrated bauxite and alumina facilities as well as the bauxite mining facilities. Tables 4.12 and 4.13 below set out the data for 1980 which was a fairly normal year as compared to the recessionary periods of the mid 1970's and of 1981-'83.

TABLE 4.12: Production and Employment Figures for Integrated Facilities (1980)

Name	Production of Alumina (metric tons)	No. of Persons Employed	Production (metric tons) per employee
Alpart	947,791	1634	588.0
Alcan 1. Kirkvine) 2. Ewarton)	1,025,947	2247	456.5
Alcoa	482,132	886	544.0
Revere (1974)	162,231	642	252.7

Source: Jamaica Bauxite Institute

TABLE 4.13: Production and Employment for Bauxite Mining Facilities (1980)

Name	Prod. of Bauxite (metric tons)	No. of Persons Employed	Production per employee
Kaiser Bauxite Company	3,636,350	486	7,482.2
Reynolds Jamaica Mines	2,498,172	201	12,428.7

Source: Jamaica Bauxite Institute

The data clearly demonstrate a greater production per unit of labour in the case of ALPART (capacity of 1,180,000 tonnes) as against ALCOA (capacity of 550,000 tonnes) and ALCAN (2 plants capacity of 550,000 tonnes each). The difference in the labour output ratios between Alcoa and Alcan are to a large extent due to the difference in age and the more modern technology of Alcoa. The data for Revere shows the very low output per employee ratio at the plant which was an important factor in the decision to suspend production there.

On the other hand, the narrow difference between labour/output ratios of ALPART and ALCOA would seem to suggest that there are other important factors determining the output of labour. These factors include management practices, labour efficiency and the efficiency of the technology.

4.8 Production Costs in Bauxite Mining and Refining

4.8.1 Production Costs in Bauxite and Alumina Refining

Data on the production costs of the integrated bauxite and alumina refining facilities operating in Jamaica is shown in Table 4.14 below. The data is for the year 1980, which is considered a fairly normal year in view of the changes in the industry in recent years.

TABLE 4.14: Disaggregated Production Costs for Integrated Facilities in Jamaica - 1980 (U.S.$ per tonne)

Items Raw Materials	Plant A	%	Plant B	%	Plant C	%
Bauxite (excl. bauxite levy)	15.17		13.58		11.93	
Lime	1.85		2.79	17.0	1.54	
Caustic Soda	14.72	14.3	10.91		17.21	17.4
Flocculants	3.34		2.26		3.16	
Other	1.47		0.26		-	
Operating Supplies						
Fuel	94.63	37.0	54.62	31.2	51.81	26.7
Other	4.69		0.75		1.96	
Utilities						
(Steam, power, water)	-		4.35		-	
Direct Labour & Plant Maintenance	26.25	10.3	19.53	11.1	25.39	14.5
Fixed						
Interest	15.46		-		-	
Depreciation	12.94	12.0	4 50	3.0	24.55	13.0
Other	2.04		0.95		0.39	
Indirect Costs	11.41		11.45		2.80	
Transportation & Storage	2.54		7.45		0.96	
Mud Disposal	0.42		-		-	
Outside Services	4.98		-		6.84	
Bauxite Levy	42.52	17.0	41.15	23.5	45.69	23.5
	254.43		174.55		194.23	

Source: Jamaica Bauxite Institute

It can be seen from the breakdown of the production costs for the three facilities listed above, that the major variations in production costs are accounted for by the differences in fuel costs, the bauxite levy, interest charges and depreciation charges. To a lesser extent, differences in costs of caustic soda, labour and transportation also account for the variations. With fuel cost being the single highest cost component, it is extremely important that these facilities be as energy efficient as possible. The adaptation of the most advanced energy technology is therefore vital to the future survival of the alumina industry in Jamaica. Company A is the largest of the three facilities, but has the highest per tonne fuel costs, raw materials costs, and debt charges. Hence, efficiency in the use of fuel and raw materials weigh more heavily than benefits arising from large size.

4.8.2 Production Costs in Bauxite Mining in Jamaica

The data in Table 4.15 indicate the major cost differences between Mine A and Mine B arising in areas of Drying and Storage and the bauxite levy. The differences in drying and storage costs can be attributed to economies of scale as Mine A is a larger size operation than Mine B and the technology being utilised is similar. However, differences in the bauxite levy payments, are accounted for by the differences in the quality of bauxite ore being mined, since the bauxite levy is also based on ore quality with higher grade ores being charged a higher levy. The differences in mining costs, can be attributed to the larger scale operation of Mine A, since the larger size mining equipment result in economies of scale.

TABLE 4.15: Disaggregated Production Costs for Bauxite Mining Facilities in Jamaica (1980)

Items	U.S. $ per tonne Mine A	Mine B
Mining	2.862	3.261
Drying & Storage	2.315	5.183
Depreciation	0.734	0.391
Administrative Expenses	0.825	0.012
Bauxite Levy	13.658	19.642
Royalty	0.276	0.275
	20.678	28.764

Source: Jamaica Bauxite Institute

4.8.3 Labour Costs in Bauxite Mining and Alumina Refining

The data contained in Sections 4.8.1, indicate that the cost of labour is an important item in the overall production cost of alumina. However, there are several more important items such as fuel, raw materials, debt charges and the bauxite levy.

The largest of the three plants listed Plant A, has the highest labour cost. Plant B and Plant C, which are of similar size, show a significant difference in labour costs.

4.8.4 Factors Affecting Production Efficiency

The information presented in Sections 4.8.1 and 4.8.2 clearly illustrate that size of operation can bring about economies of scale. However, other factors can more than compensate for these economies

of scale. Therefore the overall production costs of the bauxite and alumina industry depends on these factors as well as the size of individual plants. The factors that appear to be important are:

(i) the cost of raw materials, fuel and money;

(ii) technological efficiency in terms of the per unit consumption of raw materials, energy, labour.

Production efficiency requires mastery of both sets of factors and not just labour productivity as is the common belief. The data adequately demonstrates that differences in the cost of raw materials and in the consumption rate of these materials, can far outweigh the differences in labour costs.

CHAPTER V

ATTEMPTS AT REGIONAL AND INTERNATIONAL COOPERATION

5.1 Introduction

In 1974, the Jamaican Government, in addition to introducing the bauxite levy, commenced for the first time, serious analysis and planning for the future of the local bauxite/alumina industry. An integral part of this planning exercise was the establishment of the institutional framework which would increase the Government of Jamaica's ability to assess trends and make medium and long-term projections for the world aluminium industry. The development of this institutional framework is discussed in greater detail in Chapter VII.

In the mid-1970s the Jamaican industry analysts were able to anticipate some of the developments which seemed likely to adversely affect the industry in the future. The main factors which were perceived then were

(i) the declining relative importance of the USA in the world aluminium industry;

(ii) the high energy prices of USA aluminium producers;

(iii) the expanded role of recycling of aluminium scrap which now accounts for about 20% of total aluminium consumption;

(iv) the drastic cutback in the automobile industry especially in the USA and

(v) competition from other producers with energy resources that allow for the development of integrated complexes from bauxite mines to aluminium smelters.

5.2 Prospects for World Aluminium Industry in the 1980s

The world economic recession being experienced in the early 1980s has had a negative impact on the world aluminium industry leading to cutbacks in bauxite and alumina production as well as the shutdown of aluminium smelters in North America and Western Europe. Most forecasters predict that the world economy will continue to experience sluggish growth in the 1980s as compared to the rapid expansion of the 1950s and 1960s. The list of reasons for pessimism is long: economic stagnation in the industrial countries; the developing countries' adverse terms of trade and depressed export volumes; borrowing; large debt repayment burdens; continuing high energy prices. In this context the outlook for the world aluminium industry is weak as it is particularly affected by two factors: the weak demand in the industrial countries and the high energy prices.

The projections by industry analysts show world production of the primary aluminium growing at 2.8% per annum in 1980-85 and at 3.9% in the 1985-90, compared to 4.1% in the 1970s. The production in the USA (which is the natural market for Jamaica's exports of bauxite and alumina) is projected to grow at 1% per annum in the 1980-85 period and 0.4% in the 1985-90 reflecting the shift of production away from the USA to countries with cheap energy supplies. Table 5.1 sets out the projected growth rate of aluminium production for various countries and economic regions.

TABLE 5.1: Growth in Primary Aluminium Production (%)

Countries/Regions	Actual 1970-1980	Projected 1980-1985	1985-1990
USA	2.4	1.0	0.4
Canada	0.0	2.2	9.6
EEC	7.1	2.1	4.1
Japan	2.4	-8.5	2.7
Centrally Planned	3.4	1.7	2.4
Developing	11.7	7.7	4.2
Asia	9.4	11.2	5.3
World	4.1	2.8	3.9

Source: Price Prospects for Major Primary Commodities, World Bank, July 1982.

5.3 Main Policy Options

The projections made for the world aluminium industry in the mid to late 1970s have come to pass and, not unexpectedly, the Jamaican industry has suffered a severe decline. The impact on the Jamaican economy can be deduced from the discussion in Chapter 1 of the sector's overall importance. However, since the mid 1970s the Jamaican Government has been pursuing three major policy options for the local industry. They are namely

(i) diversification of markets for bauxite and alumina with special priority to those markets with reasonably priced energy resources;

(ii) expansion of local refining capacity, financed on a consortia basis, with both regional and extra-regional partners;

(iii) developing and implementing affordable projects which will increase integration of the local industry.

The attempts to pursue the first two of these policy options are discussed in detail in this Chapter. The third option, increased integration of the local industry, is analysed in Chapter VII.

5.4 Attempts at Market Diversification

There were several attempts at market diversification; in fact some were to be derived from the expansion of alumina refining capacity.

The efforts at market diversification produced two important successes: the contract for the USSR to purchase 250,000 tons of alumina per year for an initial period of seven (7) years (this agreement has been converted to 1 million tons per year of bauxite) and the contract to supply 1 million tons of alumina to Venezuela over the period 1978-85. These two contracts are valued at some US$370 million (in current dollars) and therefore represent important foreign exchange earnings for the Jamaican economy. The sale of Jamaican bauxite to the USSR also represents the first step in diversifying the market for Jamaican bauxite which is now supplied only to the USA.

5.4.1 USSR/Jamaica Co-operation in the Bauxite and Alumina Industry Trade Agreement

In April 1979 following discussions at the Prime Ministerial level the USSR and Jamaica signed trade agreements under which trade between the two countries was to be significantly expanded by:

(a) the purchase of alumina from Jamaica by the USSR on a short term and long term basis

(b) the purchase of raw materials and capital goods by Jamaica from the USSR.

Under the short-term agreement the USSR was to purchase 50,000 tons of alumina from existing sources in Jamaica at world market prices for the period 1980-83. This amount was subject to increases based on USSR needs and the ability of Jamaica to supply. This short-

term contract proved important to the efforts of the Jamaican Government to increase capacity utilisation of the local alumina plants, especially the Alcan Ewarton plant which was operating at 50% capacity since the recession of 1975/76. Important benefits were forthcoming in the form of increased government taxes, foreign exchange earnings and employment.

The main element of long-term trade between the USSR and Jamaica was the commitment of the USSR to purchase 250,000 tons of alumina, per annum, starting in 1984 from the planned South Manchester Alumina Plant, (formerly JAVEMEX). This commitment was the result of fresh efforts by the Jamaican Government to find new markets for alumina following the withdrawal of Mexico from the proposed JAVEMEX plant. (See Section 5.5).

5.4.2 Alumina Sales to VENALUM - Venezuelan State Company

In 1974, the Venezuelan government indicated its interest in the purchase of bauxite and alumina from Jamaica for the planned expansion of its industry. These plans were part of their policy to diversify the Venezuelan economy and to utilise the energy resources as the basis for rapid industrialisation.

Venezuela proposed expanding smelter capacity to 400,000 tonnes p.a. and this would require 800,000 tonnes of alumina annually. Part of this alumina requirement would be met by a new alumina plant and the deficit would be covered by imports. In 1975 negotiations were initiated for the supply of bauxite and alumina in the short and medium term from existing capacity. These negotiations were later adjusted to take account of the discovery of large deposits of bauxite in Los Pijiquaos area of Bolivian State.

A contract was signed in August 1977 for the supply of 1 million tonnes of alumina by the Jamaican Government to VENALUM, the state-owned aluminium company. This contract then represented the first concrete result of the efforts of the Government to diversify marketing arrangements for the industry and to expand production. The contract had a total value of over US$200 m.

The agreed supply schedule was as shown in Table 5.2.

TABLE 5.2: Supply Schedule for Venezulan Contract

Year	Quantity of Alumina (tonnes)
1978-1979	150,000
1979-1980	150,000
1980-1981	150,000
1981-1982	150,000
1982-1983	150,000
1983-1984	150,000
1984-1985	100,000

The delays and technical problems experienced in the smelter facilities of VENALUM have brought about variations to the supply schedule. Furthermore, the world recession, the poor state of the aluminium industry and weakening position of the Venezuelan economy have also combined to adversely affect the quantity of alumina supplied to date.

5.5 Attempts to Expand Refining Capacity

Over the period 1974 to the present, the Government of Jamaica has seriously explored the possibility of expanding local alumina refining capacity. To date none of the initiatives has borne fruit. Table 5.3 shows the results of th initiatives in summary form. However, it is important to examine each of the efforts in order to understand the reasons for the lack of success, to date.

Table 5.3: Bauxite and Alumina Expansion Projects, 1974 - 1981

PROJECT	DATE ANNOUNCED	ALUMINA (tons) PROPOSED OUTPUT	ALUMINA (tons) PROPOSED MARKETS	PRESENT STATUS
1. JAVEMEX Govt. of Jamaica 51% Govt. of Mexico 29% Private 20%	August 1974	600,000 -900,000	Mexico -300,000 Venezeula -200,000 Algeria -150,000 Trinidad -200,000	Project abandoned in April 1978 following Mexican withdrawal and stalemate in Regional smelter involving Trinidad, Guyana and Jamaica. VENALUM contract for 1M tonnes of alumina 1978 - 1985 signed.
2. South Manchester[a] Alumina Project Govt. of Jamaica 51% Venezeula 10% Algeria 10% Others 29%	1979	600,000	USSR - 250,000 Algeria - 150,000 Iraq - 150,000	Project abandoned following withdrawal of Iraq in 1980. USSR alumina contract converted into bauxite supply contract for 1M tonnes 1984 - 1990
3. ALCOA Expansion	1979	550,000	Norway - 250,000 Trinidad[b] - 100,000	Project abandoned as a result of depressed aluminium market and abandonment of Trinidad smelter following short-lived revival in 1979-80.

[a]JAVEMEX renamed South Manchester Alumina project following Mexican Government withdrawal

[b]Alumina to supply proposed Regional Smelter which has been scaled down from 200,000 tons of metal originally proposed in 1974 to 100,000 tons.

Among the more important expansion projects were the Regional Smelter Project involving Trinidad and Tobago, Guyana and Jamaica, the JAVEMEX Project involving Mexico, Venezuela, Algeria and Jamaica, and later the USSR, and the ALCOA Expansion Project involving Norway, Jamaica and ALCOA. Below we set out a brief overview of the objectives of each of these efforts and the present status.

5.5.1 Regional Smelter Project

In mid-1974 the Governments of Trinidad and Tobago, Guyana and Jamaica announced their intention to establish an aluminium smelter of 200,000 short tons per year capacity in Trinidad. The project was identified as a concrete step in the regional economic integration process with the possibility of spanning the full range of activities from raw material production to finished goods, bauxite production to aluminium fabrication producing finished goods in the form of pots, pans, building material and so on.

The main features of the Project were:

(a) Smelter of 200,000 short tons per annum owned jointly by Trinidad and Tobago, Guyana and Jamaica;

(b) the regional market needs to be fully met by the smelter;

(c) supply of alumina requirements of 400,000 short tons to be shared equally by Guyana and Jamaica;

(d) Trinidad and Tobago to supply power requirements using its natural gas as energy source, and

(e) each country to take responsibility for its share of financial input.

5.5.1.1 Feasibility Studies

Detailed feasibility studies were carried out by consultants employed by the Governments to examine among other things:

(i) the economic size of the smelter;

(ii) the markets in the Caribbean, Latin America, North America and Europe;

(iii) the financial requirements for establishing the smelter including the capital and operating costs;

(iv) raw material requirements including alumina and energy;

(v) technology supply and training requirements;

(vi) environmental problems and

(vii) fabrication facilities.

The feasibility studies provided the necessary technical data for choosing a suitable technology and the cost data. However, the market possibilities were less than encouraging since the regional market amounted to only 26,000 metric tons per annum while the minimum economic size smelter recommended was 73,000 metric tons per annum. Furthermore, the total capital cost in 1975 dollars amounted to $134 m. which would require an equity of US$40 m. and loans of US$94 m. at an acceptable equity/debt ratio of 30/70.

5.5.1.2 Evaluation of the Project

These requirements seemed formidable for the two capital deficient countries Guyana and Jamaica, but were within the reach of Trinidad, which at the time was enjoying foreign reserves of US$1 billion as a result of the oil price increases of 1973. Even more problematic was the question of the pricing models for alumina and energy, the two inputs to be provided by the partners. Several months of negotiations

ended without any agreement on the relative weighting of these two inputs in the overall cost of production of aluminium. The most intractable issue concerned the level of taxes, royalties and levies allowable in the pricing of bauxite and natural gas.

5.5.1.3 Political Obstacles

An important political factor which affected the approach of the governments to the Project turned out to be the Jamaican Government's attempts to undertake similar joint venture projects with Mexico and Venezuela. The latter projects were initiated subsequent to the Regional Smelter Project and were seen by both Guyana and Trinidad as receiving greater priority treatment by the Jamaican Government.

The combination of the failure to agree on the broad principles of a pricing model and the suspicions surrounding Jamaica's new relationships with Venezuela and Mexico led to a breakdown of political direction and hence an absence of the policy directions that were required to take the Project beyond the study stage. Attempts by the technocrats of the three countries to keep the project alive by the continuation of technical work and the preparation of marketing and financial plans ended in stalemate.

5.5.2 Joint Venture Projects with Mexico and Venezuela

In July 1974 the Mexican and Jamaican Governments announced plans for establishing an integrated aluminium complex to be jointly owned by the two governments.

The main features of this proposed joint venture project were:

(a) an integrated aluminium complex consisting of a bauxite mining company operating in Jamaica with 51% ownership by the Jamaican

government, 29% ownership by the Mexican government and 20% for third parties;

(b) a new alumina plant with a capacity of 600,000 short tons per annum to be located in Jamaica with 51% ownership by the Government of Jamaica, 29% by the Government of Mexico and 20% for third parties;

(c) a new aluminium smelter with a capacity of 120,000 metric tons to be located in Mexico and owned 51% by the Government of Mexico, 29% by the Government of Jamaica and 20% for third parties;

(d) fabrication facilities located in Mexico and jointly owned by the two governments;

(e) the establishment of a 60,000 metric tons per annum caustic soda plant in Jamaica with Mexico supplying the salt requirements;

(f) the Mexican domestic market was projected to absorb all of the aluminium production within the first five years of the project life hence minimising the market risks;

The task of developing the project was assigned to three (3) development companies which were established in the two countries:

(i) JAMEX - set up by the Jamaican government to prepare detailed plans for the bauxite mining operations of the project.

(ii) JAVEMEX - established by the Jamaican Government to conduct detailed feasibility studies and planning for the alumina plant.

(iii) JALUMEX - established by the Mexican Government to plan the development of the smelter and carry out the necessary technical and financial studies.

Shortly after the announcement of this project the Venezuelan Government indicated its interest in participating as an equity holder in the alumina plant and also in purchasing bauxite and alumina for proposed new alumina and smelters in Venezuela. The Venezuelan Government agreed to 10% equity in the alumina plant.

Detailed feasibility studies were carried out for the alumina plant and the smelter including estimation of capital and operating costs, plant locations were investigated as well as proposals for financing the project. Table 5.4 provides the details of the planned JAVEMEX alumina plant.

TABLE 5.4: Details of the Proposed JAVEMEX Alumina Plant

Capital Cost	:	US$326 m. (1976)
Capacity	:	600,000 short tons
Debt/Equity Ratio	:	70/30
Jamaica's Equity Contribution	:	US$49 m.
Long Term Debt	:	US$229 m.
Interest During Construction	:	US$45 m.
Construction Period	:	4 years
Rate of Return of Investment	:	10%
Internal Rate of Return to Jamaican Economy	:	26%
Employment	:	850, permanent; 2,000 in construction
Alumina Price	:	US$175 per ton
Assumed Alumina Price	:	60¢ per lb.

Source: JAVEMEX Alumina Ltd.

As Table 5.4 indicates, the alumina plant offered the possibility of significant foreign exchange earnings to Jamaica in terms of the bauxite levy and other local expenses. However, it required

large amounts of capital and as the projected employment level shows, it was highly capital intensive. The smelter aspect of the project was of a similar nature involving a large capital investment with a high debt burden. Table 5.5 provides the details.

TABLE 5.5: Details of the JALUMEX Smelter

Capital Cost	:	US$241 m.
Capacity	:	120,000 tonnes
Aluminium Price	:	60¢ per lb.
Debt/Equity Ratio	:	70/30
Long Term Debt	:	US$169 m.
Jamaica's Equity	:	US$21 m.

Source: JAVEMEX Alumina Ltd.

In the negotiations between Mexico and Jamaica, the problem of the pricing of alumina and energy proved to be the major stumbling block as in the case of the regional smelter project. Each Government sought to protect the value of its raw material input.

Almost as important in determining the fate of the project was the size of the total investment required to implement the project. Both Governments seemed to be intimidated by the enormous debt in excess of US$400 m. (1976 dollars) at a time when the economic recession combined with inflationary pressures in the market economies had begun to place great strain on the balance of payments position of the two countries. The project was eventually abandoned in 1978 at the request of the Mexican Government, which at the time was undergoing economic austerity. An important aspect of Jamaica's development plans was scuttled in the process.

5.5.3 Algeria/Jamaica Cooperation in the Bauxite and Alumina Industry

The attempts at economic cooperation between Jamaica and Algeria were based on the plans of the Algerian Government to develop an integrated aluminium complex to utilise the large reserves of natural gas of that country. Discussions commenced in February 1976 in Algiers.

The plans envisaged that Algeria would

(a) establish by 1980, an aluminium smelter of 150,000 tons p.a. capacity

(b) would construct fabrication facilities to process 50,000 tons of aluminium to fulfil the projected needs of local industry and

(c) purchase of 150,000 tons of alumina from the JAVEMEX Alumina plant described at Section 5.5.2 above.

A preliminary agreement was signed between the two countries in February 1976 which called for further negotiations to settle the price of alumina to be supplied by Jamaica and the terms of possible Algerian Government participation in the JAVEMEX Alumina Plant. Detailed negotiations between the two countries had to await the finalisation of financial and technical studies of the JAVEMEX Alumina Plant and the Algerian Aluminium smelter. Final agreements were reached on the price of alumina and the terms of Algerian financial assistance to the JAVEMEX Alumina Plant.

The difficulties in agreeing on the price of alumina were significantly minimised by the fact that the relationship took the form of an ordinary trading arrangement without the complications of joint ownership and cost sharing. However, the Algerian Government was unable to finalise contractual arrangements with the USSR under

which the USSR would supply machinery and equipment for the smelter in exchange for aluminium metal. The breakdown of negotiations between the two countries led to the cancellation of the Algerian Smelter project and hence the agreement with Jamaica for the supply of alumina.

5.5.4 <u>The Present State of the Planned Alumina Plant</u>

The agreement with the USSR for alumina supply of 250,000 tons per annum gave an important fillip to this project and represented a stable and secure market for 42% of the planned capacity of 600,000 tonnes per annum. In addition, the USSR undertook to provide assistance in the design of railway network for transportation between the proposed plant and port and to supply machinery and equipment for the railway network and the alumina plant. The engineering design of the plant, which was stalled due to Mexico's withdrawal now proceeded, together with the preparation of the necessary financial reports. The Algerian smelter project represented a possible market for a further 150,000 tons per year or 25% of the planned capacity. Hence the Algerian and Soviet markets would account for 67% of the planned output of the plant. The relatively positive market prospects of the project at the end of 1979 suggested that a firm decision to implement could be taken. However early in 1980 the Algerian smelter project was suspended as outlined in Section 5.5.3.

The market viability of the project has since been further eroded by the generally poor world economic conditions and the most severe recession in the history of the aluminium industry. The excess supply of alumina worldwide and therefore the weak pricing position combined with the high cost of capital and the lack of indigenous energy, makes the project uneconomical at the present time.

5.5.5 Jamaica/Norway Cooperation

Jamaica developed as an important source of supply of alumina to the Norwegian aluminium industry in the 1960s. Alcan held significant ownership in smelter capacity which operated on cheap hydro-electricity and supplied alumina from its Jamaican plants to this market.

Table 5.6 provides data on Jamaica's alumina exports to Norway.

TABLE 5.6: Norway's Alumina Imports from Jamaica: 1974-80

('000 tonnes)

Source	YEAR 1974	1976	1978	1980
Total Imports	1,258	1,314	1,198	1,287
Jamaica	614	435	314	401
Jamaica's % of Total Imports	48.8	33.1	26.2	31.2

Source: Jamaica Bauxite Institute.

The sale of Alcan's shares in the Norwegian industry to the Government of Norway between 1974 and 1979 brought about a decline in the influence of the company in this market and placed Jamaica's alumina exports to that country at great risk.

The expanded planning and monitoring apparatus of the Jamaica Government enabled it to make an early assessment of the possible negative effects of these developments in Norway. As a result, negotiations at a government to government level in the context of trade development between the two countries were initiated by the Jamaican government.

In 1979 agreements were reached which involved:

(a) Norwegian government intervention to minimise the loss of alumina exports from Jamaica consequent on the Alcan divestment;

(b) investigation of a joint venture project to expand ALCOA's alumina plant by 550,000 tons per annum with 250,000 tons of this for the Norwegian market.

5.5.5.1 Joint Venture Project

Detailed economic and technical studies were undertaken by the Jamaican Government, ALCOA and representatives of the Norwegian aluminium industry on the proposal for expanding ALCOA's alumina plant in Jamaica and the marketing of alumina in Norway. These studies revealed that the capital costs of the expansion were about US$470 m. and that the projected future growth of aluminium production would provide a market for 250,000 tons per annum.

In the light of these findings negotiations were conducted between the three groups on the financing arrangements for the project. However, political changes in the government of Norway, the recession in the world aluminium industry and generally adverse economic conditions have combined to halt progress on implementing the project.

5.6 Overall Assessment

Only two of the attempts by the Jamaican Government to expand production in the bauxite/alumina industry can be said to have met with success. These were the sale on long-term contracts of alumina and now bauxite to the USSR and the sale of alumina to Venezuela. However, none of the attempts to expand local alumina production capacity have borne fruit despite technical and economic analyses having been carried to very advanced stages, especially in the case of the proposed South Manchester plant.

In fact, the failure of any of these ventures to be implemented may be said to reflect more the difficulties of international economic cooperation than the absence of technical and economic feasibility. It is instructive to note that the two successes of the Government's new policy thrust were trade agreements. These, although of obvious importance, require far less in terms of financial commitments, than involvement in the actual construction of a production facility.

CHAPTER VI

INTEGRATION OF LOCAL INDUSTRY

6.1 Introduction

In Chapter 5 we described in some detail the main attempts which Jamaica has made over the last nine years to expand production in its bauxite/alumina industry. One of the major factors contributing to failure in certain instances is the difficulty of raising financing for the projects. This problem is discussed in greater detail in Section 6.5.

However, the Government of Jamaica has also recognized that there exist possibilities to increase integration in the local industry which do not require the level of financial commitment which, say, the Regional Smelter project did. In addition, these "smaller" projects have the added positive attribute of increasing the linkages between the bauxite/alumina industry and other sectors of the Jamaican economy.

Two such projects are the construction of an aluminium sheet rolling mill and a caustic soda plant. The following are brief descriptions of the projects and comments on their potential impact on the industry.

6.2 Aluminium Sheet Rolling Mill

A detailed study has been undertaken by the Jamaica Bauxite Institute into the feasibility of establishing a plant to manufacture aluminium rolled products. The study provided the following information:

6.2.1 Products

Jamaica presently imports a wide-range of products used in the construction, packaging, consumer durables, electrical machinery and transportation which are manufactured from aluminium sheets. The products could be manufactured locally at competitive prices with the availability of aluminium sheet. The products include:-

Construction	-	Roofing sheets, window frames, gutters, awnings, irrigation tubes, ladders.
Packaging	-	Cans, foil and flexible packs, tubes for toothpaste, bottle caps.
Consumer Durables	-	Foil, household utensils, electrical appliances, office furniture.
Electrical Machinery	-	Cables.
Transportation	-	Sheet.

6.2.2 Markets

The domestic market is estimated at 6,000 tonnes per annum. The CARICOM market, including Jamaica, is estimated at 12,000 tonnes per annum. The available information also indicates that it is possible to secure markets in the EEC and the USA.

6.2.3 Capital Costs

The estimated capital costs for a 20,000 tonnes plant in 1983 prices are:

(a)	Equipment and Technology	-	US$36M
(b)	Land, Building and Infrastructure	-	US$11M
(c)	Interest during Construction and Initial Working Capital	-	US$18M
	TOTAL		US$55M

6.2.4 Employment

It is estimated that the project would generate employment as follows:

(a)	Construction Workers	-	220
(b)	Permanent Workers	-	156
	TOTAL		376

6.2.5 Raw Materials

The main raw material requirements of the mill are scrap and primary aluminium. It is proposed that 70/30 ratio of scrap to primary aluminium be utilized, thereby reducing the costs of the raw material as scrap prices are roughly 30% lower than primary prices. The primary ingot could be supplied from the tolling arrangements.

6.2.6 Financing

Equipment suppliers have indicated willingness to provide credit to cover a significant proportion of the foreign costs at competitive interest rates.

6.2.7 Summary

The above project appears to offer some important advantages to Jamaica as compared to alumina refining and aluminium smelting:

(1) the capital requirements are moderate and should be within the reach of the Jamaican public or private sector;

(ii) the domestic and CARICOM markets represent roughly 60% of proposed output and therefore the uncertainties of marketing arrangements are minimised;

(iii) the cost per job created is far below that in the alumina refining and aluminium smelting;

(iv) the energy requirements per ton is such that it could be supplied from the national grid.

6.3 Caustic Soda Plant

Caustic Soda is an important raw material in the production of alumina. The total caustic soda requirements of the local alumina industry are presently imported from the USA by the alumina companies. The large size of the local alumina industry makes Jamaica one of the major markets for caustic soda in the Western Hemisphere. The consumption of caustic soda in the alumina industry is approximately equal to a tenth of alumina production. Table 6.1 shows the pattern for the period 1976-81.

TABLE 6.1: Consumption of Caustic Soda by Local Alumina Industry - 1976-81

('000 tonnes)

Year	Quantity	Total Alumina Production
1976	156	1,627
1977	188	1,976
1978	223	2,113
1979	220	2,094
1980	240	2,400
1981	255	2,549

Source: Jamaica Bauxite Institute

A significantly smaller volume of approximately 8,000 metric tons per annum of caustic soda is utilized by Seprod (Ja.) Ltd. to manufacture soap products and also by the national electricity generating company. Hence the local market for caustic soda therefore falls in the range of 160,000 - 230,000 metric tons depending on the level of alumina production.

Since the 1960s policy makers in Jamaica have given consideration to the establishment of a caustic soda plant to supply the needs of the domestic market. Progress in this direction has been hampered by the impact of the world energy crisis on the process technology of caustic soda production.

There are two methods used for the production of caustic soda:

(i) The Electrolytic Process

(ii) The Solvay and Lime-Soda Process.

6.3.1 Electrolytic Process

The electrolytic process is the modern process used by most producers of caustic soda. It involves the passing of an electric current through a sodium chloride (NACL) solution, resulting in the formation of a 10-12% sodium hydroxide (NAOH) solution with hydrogen and chlorine as co-products. The chemical reaction is as follows:

$$2NACL + 2H_2O - 2NAOH + H_2 + Cl_2$$

The major co-product generated by this process is chlorine. Chlorine is a major raw material for the petro-chemical industry. In the absence of a ready market, its disposal poses a serious environmental problem.

The energy required to produce a ton of caustic soda is approximately .9 GJ (ca. 6 barrels of bunker sea oil).

The major raw material is salt which is obtained from brines, salt mines or the evaporation of sea water. Some sodium carbonate (Na_2CO_3) is used in the process to purify the brine solution. The salt requirement is 1.66 tons per ton of caustic soda.

6.3.2 Solvay and Lime-Soda Process

There are two stages involved in this process. In the first stage - the Solvay Process - a saturated brine is treated with carbon dioxide (CO_2) and ammonia (NH_3) to form a sodium bicarbonate ($NAHCO_3$) precipitate. The chemical reaction is

$$H_2O + NH_3 + CO_2 + NaCl - NH_4Cl + NAHCO_3$$

The sodium bicarbonate is then calcined to give "light" soda ash.

The second stage (Lime/Soda Process) involves the causticizing of soda ash with lime to form sodium hydroxide and a calcium carbonate precipitate.

$$Na_2CO_3 + Ca(OH)_2 - NAOH + CaCO_3$$

The main co-products arising from the first stage are calcium chloride and sodium chloride. For each ton of soda produced, an additional one (1) ton of calcium chloride and 0.5 tons of sodium chloride are generated. In the second stage, the main co-product is calcium carbonate. Approximately 0.5 tons of calcium carbonate is generated with each ton of caustic soda. The traditional method of disposal of these co-products has been either recycling as in the case of sodium chloride or utilization in the chemical industry. The intermediary products, sodium carbonate and sodium bicarbonate are also utilized in industry.

Intermediary and Co-Products	Industry
Sodium Carbonate	Glass, pulp and Paper, Water Treatment, Detergents, Fertilizers
Sodium Bicarbonate	Baking, pharmaceutical
Calcium Chloride	Liming agent, drying agent for cement products
Calcium Carbonate	Paint

The raw material requirements of electrolytic process are summarised in Table 6.2.

TABLE 6.2: Raw Material Requirements of the Electrolytic Process

Description	Consumption/ton of NAOH
Limestone	2.48 tons
Salt	1.60 tons
Ammonia	2.0 lbs.
Coke	1.45 lbs.
Socium Sulphide	2.0 lbs.

This process requires 0.3 GJ of energy (ca. 2 barrels of bunker sea oil) per ton of caustic soda or approximately 2 barrels of Bunker 'C' oil. This is approximately 1/3 of the energy requirement of the electrolytic process and less than the requirement for producing a ton of alumina.

6.3.3 Comparison of Processes

Three factors appear to be important in the selection of the appropriate process for producing caustic soda locally. These are

(a) Energy consumption
(b) Source of raw materials
(c) Disposal of Co-products

The Solvay - Lime/Soda Process enjoys a clear advantage in all of the above stated considerations.

The energy requirement of the Solvay/Lime Soda Process is roughly 1/3 of that of the electrolytic process. This consideration is of paramount importance in the Jamaican situation where 97% of the energy requirements is imported. Furthermore, the available alternative energy resources which can be developed are extremely limited. The difference in energy costs is also an important consideration in the ability to compete with the present suppliers.

Limestone which is the primary raw material used in the Solvay Process happens to be the most abundant mineral resource in Jamaica. The possibility of producing salt by solar evaporation is presently being investigated and indications are that a significant portion of the sale requirements could be produced by this method. The use of these two materials for caustic soda production would provide opportunities for developing two new industries based largely on local resources.

The development of the electrolytic process in the developed countries was in response to the rapid development of the petrochemical industry which utilizes chlorine as an important raw material. Hence caustic soda could be produced more cheaply by the electrolytic process since chlorine became a marketable co-product (chlorine and caustic soda are produced in equal volumes in this process). In addition, the environmental problems posed by the disposal of chlorine were eliminated.

For developing countries like Jamaica where energy is expensive and the market for chlorine non-existent, the electrolytic process is not considered appropriate. The co-products generated in the Solvay/Lime Soda Process which are basic sodium and calcium compounds can be more easily absorbed in the manufacturing industries of these countries and therefore the problem of disposal is more easily managed.

6.3.4 Potential Benefits of Caustic Soda Production

Preliminary indications are that the development of a caustic soda industry based on the Solvay/Lime-Soda Process would provide several advantages to the Jamaican economy in the form of:

(i) further backward integration of the bauxite and alumina industry to the rest of the local economy thereby providing the opportunity for development based on local raw material resources;

(ii) earnings from the sale of caustic soda which are presently paid for by the companies in foreign exchange (estimated value is US$50M per annum);

(iii) employment creation at significantly reduced investment costs per job;

(iv) expansion of production with relatively low import content;

(v) availability of raw materials for the local chemical industry.

6.4 Overall Assessment of Proposed Projects

For two of the three important factors, market and finance, influencing the development of the local bauxite and alumina industry and which proved negative in the case of the expansion projects proposed in the 1970s, prospects are more favourable in respect of the caustic and aluminium sheet rolling mill. Although the factor of energy remains a problem, the requirements are relatively small as compared to the present energy use of the alumina plants and smelters. The choice of the Solvay Process further reduces the energy intensity of Caustic soda production.

The Jamaican Government is at the present time giving active consideration to these projects for possible investment in the future. In the case of the Caustic Soda project, a Soviet State firm has been engaged to conduct a full scale feasibility study for establishing a

soda ash/caustic soda complex based on the Solvay Process. Completion of this study is expected by the end of 1983. The outcome of the study will have important implications for the future of the bauxite and alumina industry.

In the other case of the aluminium sheet rolling mill, a feasibility study has already been completed and detailed information is available. Marketing arrangements are now being examined in conjunction with overseas interests. A positive decision to implement now rests on the conclusion of firm contracts for sale of that portion of the output which will be exported.

6.5 Financial Constraints to Expansion of the Jamaican Industry

The world-wide trend toward larger sized plants in both alumina and aluminium production has meant increased capital costs and therefore increased financing requirements for projects. For a variety of reasons, Jamaica cannot be evaluated as a priority for investment in this industry. Table 6.3 summarises the country's attractiveness, relative to competing countries, using the availability of bauxite, energy, market and finance as the criteria.

TABLE 6.3: Factors Affecting Investment in the Aluminium Industry

Country	Bauxite	Energy	Market	Finance
Australia	√	√	X	?
Brazil	√	√	√	?
Venezuela	√	√	?	√
Suriname	√	?	X	?
Guyana	√	?	X	X
Jamaica	√	X	X	X

√ - Factor available
X - Factor unavailable
? - Factor may be available but needs further development.

Source: "The Bauxite Industry: Strategies for Survival" Paper by Dr. Carlton Davis to Geological Society of Jamaica, Feb., 1983.

Therefore, in order to neutralise the disadvantages caused by the unavailability of three of the four factors, namely, energy, market and finance, Jamaica needs to develop innovative policies which will result in mutual benefits to both potential investors and to itself.

The expansion projects contemplated by Jamaica are estimated (at 1982 prices) to be in the order of US$2.2B[1] and would involve loan financing of US$1.5B and equity financing of US$0.7B assuming a debt-equity ratio of 70:30. If a four (4) year implementation period is assumed, this would mean an annual expenditure of US$550M for the period and could be equal to the entire capital budget of the central government.

Table 6.4 sets out data on the capital cost, employment potential, market prospects and the local cost component of the projects. This data indicate that the positive impact of the projects on the

[1] US$350M of this would be the responsibility of Guyana and Trinidad for the regional smelter.

Table 6.4 Capital Cost, Employment and Markets for Bauxite/Alumina/Aluminium Expansion Projects
(1982 prices)

Project	Product	Market (tonnes)	Capacity (tonnes)	Capital Cost (US$)	Local Expenditure (US$)	Employment
1. South Manchester Alumina	Alumina		800,000	$960M	$288M	2,000 Construction 850 Permanent
2. Alcoa Expansion	Alumina		550,000	$470M	$141M	700 Construction 250 Permanent
3. Regional Aluminium Amelter	Aluminium Ingot	CARICOM 25-30,000	150,000	$525M	$157M (Trinidad & Tobago)	
4. Aluminium Sheet Rolling Mill	Aluminium Sheet	Jamaica 6,000 CARICOM 12,000	20,000	$ 55M	$ 11M	220 Construction 156 Permanent
5. Caustic Soda	Caustic Soda	Jamaica 200,000				
(a) Caustic Soda	Caustic Soda	Jamaica 200,000	100,000	$180M	$ 39M	300 Permanent
(b) Limestone		250,000	250,000	$ 3M	$ .25M	100 Permanent
(c) Solar Salt		160,000	160,000	na.	na.	na.

Jamaican economy is seriously limited by the relatively small number of permanent jobs to be created (the projects are highly capital intensive) and the high ratio of foreign to local expenditures.

The possibility of implementing expansion projects in the mining sector, bearing in mind the size of the investment capital required, appears to be extremely weak in the present period. This assessment is based on the present weak position of the local economy in several important respects:

(i) The decline in export earnings as a result of recession in market economies;

(ii) Heavy debt charges which are currently running at 47% of export earnings;

(iii) The unavailability of local capital resources to finance equity share.

This assessment serves to emphasise the need to give priority to other investments which have lower capital requirements and higher labour-capital ratios.

6.6 Comparison of Investment Requirements and Employment Creation

In Table 6.4, a profile of the projects under consideration which have the objective of increasing the level of integration of the Jamaican bauxite/alumina industry is outlined. The capital costs of the projects range from US$3m for limestone production for a caustic soda plant to US$960m for a new alumina plant.

Given our interest in the employment creation aspects of such projects, it is useful to focus on this question in some greater detail. Table 6.5 presents a comparison of the cost of creating a new job in each of the proposed projects.

TABLE 6.5: Comparison of Costs of Job Creation in Proposed Projects

PROJECT	CAPITAL COSTS (US$ M)	NO. OF PERMANENT JOBS	COST ON EACH NEW JOB (US$'000)
1. South Manchester Alumina Plant	960	850	1,130
2. ALCOA Alumina Plant Expansion	470	250	1,880
3. Aluminium Sheet Rolling Mill	55	156	352
4. Caustic Soda Plant	180	300	600
5. Limestone Production	3	100	30

It is clear from the table that activities such as the sheet rolling mill and the linkage industries, (caustic soda and limestone) have a much lower investment requirement for each new job to be created than expansion of alumina refining capacity. Secondly, the total requirements of these former activities are more within the reach of a country such as Jamaica, with virtually no foreign exchange reserves.

There is yet another factor which favours giving priority consideration to the linkage industries, especially in the cases of the caustic soda factory and limestone production. It is that the existing alumina plants represent an existing domestic market which is virtually guaranteed providing the output is cost-competitive. The same cannot be said of the market for the alumina which would be produced as a result of capacity expansion.

CHAPTER VII

CREATION OF LOCAL INSTITUTIONS

7.1 Introduction

Jamaica's role in the world aluminium reached its zenith in 1974 when the country produced 15.2 million tonnes of bauxite (18% of the world's total) and 2.9 tonnes of alumina (10% of the world's total). Despite this obviously important position, as demonstrated by share of output of both bauxite and alumina, the country had very little involvement in the development of the local industry to that point. This lack of involvement did not relate solely to the fact that both the mining and refining operations were totally owned and controlled by TNCs. It went beyond that with successive governments having very limited knowledge of either the world industry or its local component.

The best example of the country's limited knowledge of this most important industry is given by the fact that, in 1974, the information available suggested that total bauxite reserves were between 600,000 and 800,000 tons. Work by local scientists subsequently conclusively established these reserves at 2,000 million tons.

The Government's limited knowledge extended to almost all aspects of the industry. Since all sales were handled by the TNCs, there was no understanding of marketing strategies. Similarly, there was no specific knowledge of the manner in which profitability of the industry was sensitive to changes in energy costs. Hence the potential impact of the post-1973 energy price increases was not anticipated. There was too, little or no local appreciation of the extent to which expansion of more fully integrated industries, such as Australia's,would eventually pose serious competition for Jamaica.

In the early 1970s, the Government of Jamaica made the decision that, given the vital importance of the bauxite/alumina industry to the country's economy, it would begin to play a more active role in influencing it. The most publicized aspect of the Government's greater involvement has been the imposition of a new production levy. However, although important, the levy represented only one of a series of measures undertaken by the Government to increase the country's knowledge of the industry and hence lay the basis for greater involvement in its future development.

In other words, the national capability in the bauxite/alumina industry was increased. At the heart of this increase in capability was the development of a set of institutions. These are discussed more fully in the following sections.

7.2 The Development of Institutions

The most important of these institutions established by the Government was the Jamaica Bauxite Institute (JBI). The Jamaica Bauxite Mining Co. Ltd. (JBM) and the Bauxite and Alumina Trading Co. (BATCO) are the other important institutions with direct involvement in the industry. A fourth institution which was created, the Jamaica Merchant Marine (JMM) is not completely involved in bauxite/alumina industry. However, transport of bauxite/alumina from Jamaica is its most important function.

7.2.1 The Jamaica Bauxite Institute (JBI)

The JBI was the institutional outgrowth of the National Bauxite Commission, which was established in 1972 to advise the government on the best ways of increasing the country's benefits from the industry.

The Commission comprised specialists, from both the private and public sectors, in a variety of fields, including taxation, law, business, finance, diplomacy and the earth sciences.

The JBI was given a wide range of responsibilities. In general, it was required to monitor the major developments in the world aluminium industry in order to advise the government on possible implications for the Jamaican component. As such, it is required to be the main source of information for the Government of Jamaica in negotiations with the local companies or any potential partner in the industry.

7.2.1.1 Mapping and Managing Reserves

More specifically, the JBI was charged with mapping and managing the bauxite reserves. Up until the 1970s, the Government of Jamaica had left the local companies to conduct all geological work in bauxite. Hence, the state had no precise knowledge of the extent of bauxite reserves. Furthermore, because the companies were able to own surface rights, there were inequities with one company being able to tie up reserves way beyond its feasible production capability, while another would be uncertain about its future production because of limited reserves.

7.2.1.2 Economic Research and Financial Analysis

The JBI has the responsibility for providing a yearly forecast of aluminium ingot prices. The importance of these forecasts rests on the fact that the payments for the levy are made quarterly on the projected average realized price for aluminium ingots. A large under-estimate of the price will imply that the country will be denied

foreign exchange due to it until up to twelve months later, when the actual price is known. On the other hand, an overestimate will mean that the country will owe the companies money which will have to be repaid in the following year, thus reducing that year's foreign exchange budget. A major error in either direction would be of serious consequence to the country, given the need for foreign exchange outlined in Chapter 1.3.

7.2.1.3 Process Research

The JBI, as part of its responsibilities is required to verify the amount of ore used in alumina refining and the alumina recovered as this information is needed for the calculation of the levy. In addition, the Institute carries out research into the characteristics of Jamaican ore, and the handling of red mud effluent from the refining process. Although these activities may seem routine, it must be realized that prior to the establishment of the JBI, the Government relied on the companies to provide this information.

The JBI has embarked on an ambitious endeavour, the construction and operation of a pilot alumina plant. This is described more fully in Section 7.3.

7.2.2 Other Institutions

The two companion institutions to the JBI were the JBM and BATCO.

7.2.2.1 Jamaica Bauxite Mining (JBM)

The JBM was established to look after the assets of the Government of Jamaica in the local bauxite/alumina companies as well as to be responsible for the development of the project leading

to the possible construction of an alumina refinery. These assets in the local bauxite/alumina companies were acquired as part of the decision for greater national involvement in the industry.

These assets include 5% equity in joint venture partnerships in the mining operations of Kaiser and Reynolds, with management function remaining with the companies. As regards the alumina producers, the assets include 6% ownership of the ALCOA Plant (JAMALCO) and 7% ownership of the two Alcan plants (JAMALCAN). Again, the companies retain management functions.

7.2.2.2 Bauxite and Alumina Trading Co. (BATCO)

Under the term of the new partnerships with the TNCs, the Government of Jamaica has an annual entitlement of 33,000 tons of alumina from ALCOA and 77,000 tons from ALCAN. BATCO has responsibility for marketing this alumina. Similarly, BATCO can purchase from the bauxite companies, ore for sale in non-traditional markets. The execution of these tasks has implied acquisition of local knowledge about trading in the aluminium markets in particular, and in the metals market, in general. The extent of success in these endeavours is considered in Section 7.3.2.

7.3 Major Achievements of the Institutions

The objective of increasing local knowledge of the aluminium industry is clearly a laudable goal and provides the rationale for the decision to establish the various institutions. However, the real proof of the correctness of the decision must be in the ability to identify concrete benefits resulting from the operations of these institutions.

7.3.1 Economic Forecasting

In Section 7.2.1.2 we identified the annual task of forecasting the average realized price for aluminium ingot, and hence the production levy, as one of the main responsibilities of the JBI. The record of the Institution in this forecasting is shown in Table 7.1. The data show that over the eight year period the largest margin of error was 3.36%. Hence the costly errors referred to before, in either over- or under-estimating the amount of levy due has been avoided over the years.

TABLE 7.1: JBI Forecast and Actual Levy Rate per Long Dry Ton (1975-82)

	LEVY RATE (US$)		
Year	Forecasted	Actual	Margin of Error (%)
1975	13.60	13.56	+0.29
1976	14.65	14.82	-1.15
1977	17.79	17.77	+0.11
1978	18.49	18.69	-1.12
1979	20.93	20.25	+3.36
1980	20.54	20.75	-1.01
1981	21.20	20.38	-0.88
1982	18.81	18.30	+2.79

7.3.2 Marketing

In Chapters II and VI, we discussed the dangers inherent in Jamaica's historical over-dependence on the North American market. Major efforts have been made to diversify and not all of the efforts have met with success. However, the sales to Venezuela and the U.S.S.R. represent significant breakthroughs. The agreement with the U.S.S.R. to sell 1 million tonnes of bauxite annually for seven years is of

particular importance in that it represents the first sale of bauxite to a country other than the U.S.A.

7.3.3 Research and Analysis

The JBI has greatly advanced the country's technological expertise in different aspects of the industry. Below we consider some of the major achievements.

7.3.3.1 Size of Reserves

As was indicated before, the exact size of Jamaica's bauxite reserves were not known to the country prior to the early 1970s. Previously, the estimates, based on data from the companies indicated reserves of between 600 and 800 million tons. The JBI's geological surveys established that the reserves were approximately 2,000 million tons. This knowledge, combined with the return of control over all reserves, has allowed the Government to establish a rational system for allocating mining rights to the individual companies.

7.3.3.2 Verification of Ore Quality

The rate of payment for bauxite ore delivered as part of marketing contracts is dependent on the time taken for test results of the shipments to be submitted to the buyer. The JBI's process laboratory has responsibility for this verification exercise. To date,in the instances of government to government contracts with the U.S.A. and the U.S.S.R., payments have been prompt because of the efficiency with which these analyses have been carried out.

At the same time, the process laboratory has successfully rebutted the claim of one of the local companies concerning the

unsuitability of nodular bauxite for processing in its alumina plant. These serve as examples of the practical benefits of the Government's developing its own technical capability.

7.3.4 The Construction of a Pilot Alumina Plant

Apart from the analytic work described in 7.3.3, the JBI has embarked on a major initiative, that of the construction of a pilot plant to produce alumina from bauxite ores of various grades. The JBI has been able to attract supportive funding from the UN Interim Fund for Science and Technology for Development (IFSTD), totalling US$950,000.

The plant will become operational in late 1983 and will provide information on

(i) efficient methods for processing geothitic bauxites

(ii) to research techniques for the treatment of high silica and high phosphorus bauxites, and

(iii) to research appropriate disposal and/or utilization of red mud effluent.

The pilot plant will be the only one of its kind in the Third World, and will enable the JBI to monitor the efficiency of the processing practices being followed by the existing plants, possibly ensuring the use of bauxite ores of varying grades. It will provide the opportunity for training technicians in the industry, Jamaicans as well as nationals of other members of IBA.

7.3.5 Technical Assistance and Sale of Expertise

As a result of the skills developed since the beginning of greater involvement in the industry, the Government of Jamaica has been

able to provide assistance to other Third World countries. Specifically, the Governments of Haiti and Suriname have in the past requested and obtained assistance from Jamaica in their negotiations with the TNCs.

At the same time, the JBI has won commercial contracts to carry out research activities from the Dominican Republic and the U.S.A. In the latter case, the contract from the Hercules Co. can be regarded as a reversal of the normal direction of technology transfer.

7.4 Conclusions

As was indicated at the beginning of the study, we feel that "technology" in a given field must be defined in the broadest sense, to include not only the machinery and equipment, but also knowledge and expertise in areas of finance, economics and marketing. In the final analysis such knowledge may be as beneficial as that related solely to the actual operation of the machinery and processes involved in mining, refining and smelting bauxite ore.

Using this definition of technology, we can assess Jamaica's attempt to expand its knowledge of the industry and adapt technology to suit local conditions. This "adaptation" has implied attempting to derive the maximum financial benefits from the industry while at the same time pursuing policies for expansion and market diversification. Policies aimed at greater integration of the industry on a regional basis have been unsuccessful to date. However, it is important that the initiatives were made, in the first place. There are also present plans to increase the level of integration of the local industry by the construction of a caustic soda plant and a sheet rolling mill. These options have been chosen following an objective assessment of market availability and energy requirements.

The Study has boldly stated that inherently the industry is highly capital-intensive, and is becoming increasingly so. Given that markets can only be won and retained if the local industry is cost competitive, there is no possibility of altering this trend, especially in the absence of indigenous energy sources. However, given its unique position in the econmy, the industry is in the position to greatly affect employment generation by facilitating increased imports of investment goods for more labour-intensive activities and by virtue of its overall contribution to government revenue.

The lessons for developing countries similarly endowed with mineral deposits are clear. The maximum benefits from these minerals can only be derived when local knowledge is increased. This holds whether exploitation of the resource is controlled by TNCs or whether the country is attempting to develop the industry on its own. Given that, all developing countries for one reason or another, will not be able to develop similar expertise to that of Jamaica in the bauxite/alumina industry, the need for increased cooperation between Third World countries becomes most urgent.

APPENDIX: MINING TECHNIQUES USED IN WORLD ALUMINIUM INDUSTRY

A.1 Introduction

Bauxite was discovered in 1821 by the French chemist Pierre Berthier, near the village of Lex Baux (from which the ore derived its name) in Provence, France. In 1883 a material similar to that discovered by Berthier was found at Hermitage near Rome, Georgia, USA, and commercial production began in 1887. Bauxite was also found near Little Rock, Arkansas, and later in Georgia and elsewhere in Arkansas.

Bauxite is a material formed by the weathering of aluminium-bearing rocks under conditions conducive to: the chemical breakdown of minerals in the parent rock; the retention of aluminium oxide minerals; and the leaching of other constituents from the parent rock. Conditions most favourable for the formation of bauxite most frequently occurred in: areas and geological periods which provided warm wet climates; parent aluminous rocks with high permeability and easily soluble minerals; good subsurface drainage; and long periods of tectonic stability that permitted deep weathering and preservation of land surfaces.

The discovery of bauxite coincided with important developments (*infra*) in respect of isolating aluminium from its oxide. One of the future Alcoa's (then called the Pittsburgh Reduction Company) early founders, Captain Alfred Hunt was initially interested in bauxite as a direct source of aluminium. In 1897 he wrote the inventor Hall (*infra*) as follows:

> "If it be true as I understand from you that we can make as much aluminum per unit of horsepower from bauxite (of which we can obtain large quantities) as from pure alumina then it would seem that this is the field which is now ripest for us to investigate for increasing the economy of manufacturing." See Carr (1972).

Direct reduction of bauxite did not prove feasible - and still has not - for producing aluminium of desired purity. It was a process invented by Dr. Karl Josef Bayer in 1888 (_infra_) and patented by him that enabled the extraction of high purity alumina from bauxite.

A.2 Bauxite Mining Techniques

The nature and occurrences of bauxite ores vary considerably. This is particularly true in respect of factors such as hardness, depth below ground, extent of overburden, extent of non-bauxite "contaminants", configuration of deposits and distance from ports or inland areas, where the ore is processed into alumina.

These variations greatly influence the types of technology used to extract the ore. We will cite five examples to illustrate these differences viz: (1) The Sangaredi mine in the Republic of Guinea, West Africa; (2) The Alcoa Lelydorp mine in Suriname; (3) The Bermine mine in the Republic of Guyana; (4) The Reynolds mine in Haiti; and (5) The Trombetas mine in Brazil.

A.2.1 Sangaredi, Guinea

The deposit is a solid plateau of bauxite with no overburden on the surface and no waste inclusions. The configuration of the orebody permits a single-level railway haulage along a 1.6 kilometre-wide face, with a slight downgrade to the switchyard. From the mine, ore is transported by rail to the plant at Kamsar, 137 km to the south-west. Located in the estuary of the Rio Nunez, 17 km from the Atlantic, the Kamsar plant crushes bauxite to less than 15 cm and dries it to a 5% moisture content before shipping.

The equipment required for mining, transportation, crushing and drying are as follows:

Drills, (rotary): Four Ingersoll-Rand DMHS and one T4 with 6½ in. diameter bits.

Shovels: Three R&H 1900 9 cu. yd. electric plus three Cat.998 rubber tyred.

<u>Haulage</u>: Mainline locos - 7 GM SD-40 diesel electric (3,000 hp); mine-tramming locos - four S, SW-1001 diesel electric (1,000 hp); 400-plus open Gondola Gregg ore cars, each carrying 75 tonnes.

<u>Ancillary Equipment</u>: Two Cat. 14 graders, two Cat. D8 and two D9 track dozers, Pioneer ballast plant 60-ton rubber-tyred lowboy; numerous P&H mobile cranes.

Mining at Sangaredi is analagous to eating a two-layered cake. The bottom of the upper layer is at an elevation of 229 metres - 40 metres above the Sangaredi switchyard.

To open up the initial face a box-cut was drilled, blasted and excavated across the southern perimeter of the orebody. Tight drilling and small fragmentation of the ore was required for the box-cut because it was excavated with front-end loaders and 10-ton trucks. Once completed the cut was graded and a drainage ditch was opened to the southern slope. Single line standard-gauge track was laid from the switchyard up a ramp of filled and compacted bauxite to the face. Active mine track is set on bauxite ballast prepared at a stone crushing and screening plant near the mine entrance. In the pit bauxite is drilled, blasted and loaded from the 12-meter high face into 75-ton railroad cars.

Five Ingersoll Rand DM 4 and T4 6¼ ins. diameter rotary drills are available for blast holes but only three are used on a single drilling shift. The holes are drilled in staggered rows parallel to the face. A 12-18 metre-wide buffer zone is kept between the pit face and subsequent blasts to prevent rock thrown from damaging mine track.

After the holes are checked they are loaded from an ANFO (Ammonium nitrate fuel oil mixture) truck. The mixture of 94.5% AN and 5.5% fuel oil is metered in the truck mixing bin while the auger system delivers the mix to each hole.

A yard locomotive pulls 20 - 25 ore cars around the loop in front of each shovel. Loading is done by two P&H 1900 electric shovels on each shift with a third shovel as standby. After the cars are loaded they are hauled to the switchyard and made up into trains of 85 cars for the trip to the plant at Kamsar. There, the bauxite is unloaded, crushed, dried, stickpited and shipped using equipment of extraordinary size.

A simplified flow chart of the mining system is indicated in Fig. A.1.

A.2.2 The Alcoa (Lelydorp) Suriname Mine

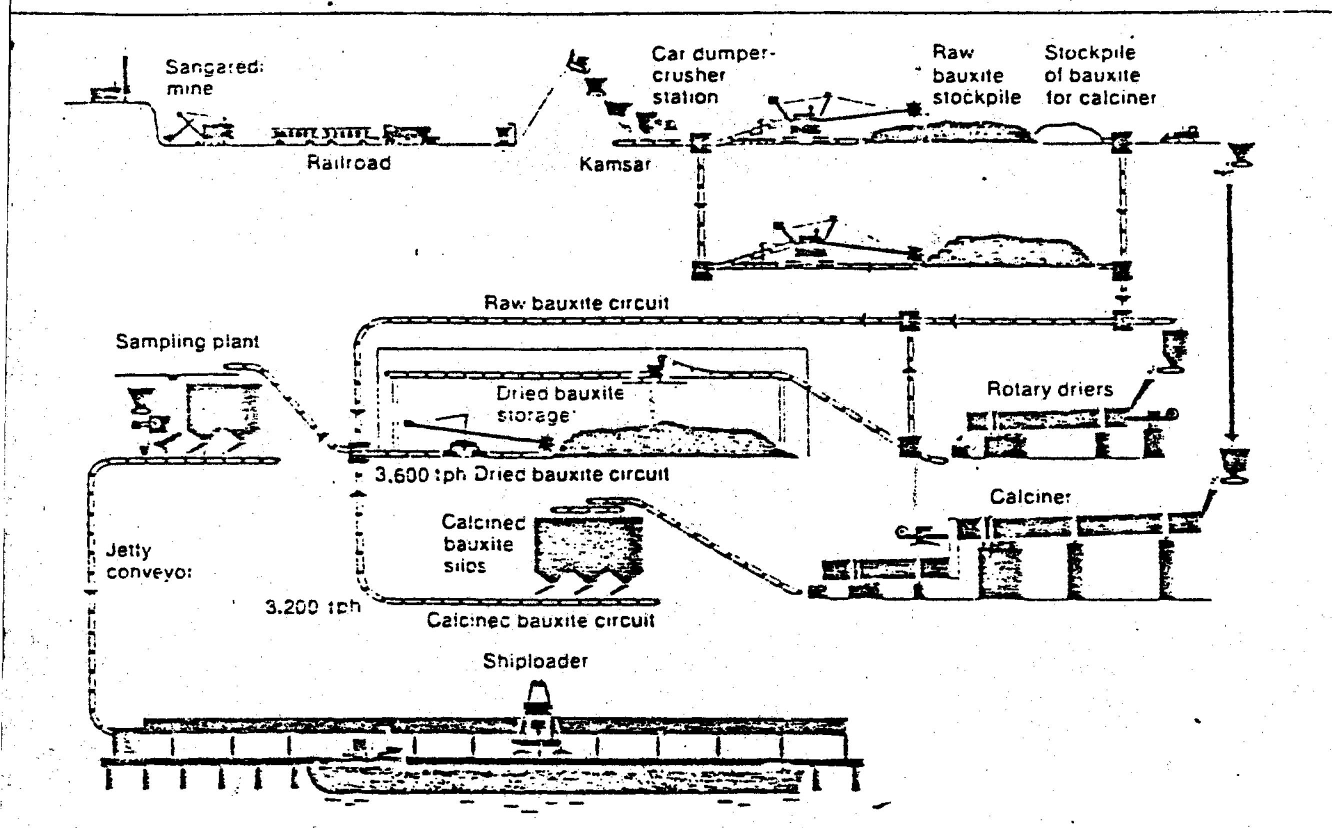
The basements of Suriname, Guyana, French Guiana, southeastern Venezuela and a huge section of Brazil north of the Amazon occupy the Guyana Precambrian shield. Suriname is on the northern edge of the shield. Laterite deposits have been formed in the environment of platform cover. Chemically residual deposits as bauxites,low-grade iron ores, have been formed.

Two types of bauxite are distinguished: the partly buried deposits of the coastal plain typified by Suralco's (Alcoa) Lelydorp and Billiton's Onverdacht and the Plateau type of the hinterland such as Moengo and Bakhuis.

The bauxite deposits of the coastal plain were formed as a result of weathering and decomposition of arkosic and subarkosic sediments. (These are one of a group of detrital sedimentary rock typically sand stones in which the particles range in size from 0.125mm - 2mm). Those of the hinterland were formed mainly by bauxitization of basic rocks of the basement. The main ore mineral is gibbsite. It is thought that bauxitization of the coastal plain and the plateau

Fig. A.1

Simplified Bauxite Flowsheet of the
Sangaredi Mine in Guinea



Source: Engineering & Mining Journal
Operating Handbook of Surface Mining (1977)

deposits took place during the early Tertiary on a peneplain. The buried deposits have been subjected to a continued tropical weathering. During this process the alumina of bauxite starts to recombine with silica to form kaolinite. Also, percolating solutions attack the iron-rich capping leaching most of the iron.

The mining at Lelydorp involves considerable overburden removal. EMJ (*supra*) describes the bauxite deposit at Lelydorp 2 as having an overburden which consists of an upper horizon of saturated sands and silts of about 12m thick to the southwest thinning to about 6m thick in the northeast. The lower overburden which contains hard clay inter-mixed with river sands and silt is about 6m thick on the southwest side and thickens on the northeast to about 24m - 30m.

The stripping and mining panels are oriented southwest-northeast. The bauxite zone 7 to 8.5 metres thick is underlain by kaolin clay and is sandwiched top and bottom by 5 cm layer of high grade pebbles. The average thickness of the overburden is about 38 metres while the maximum depth of the bauxite is about 33 metres below sea level.

A dragline walkway is established on the southwest boundary of the mining zone, at right angles to the panels. From the walkway, 71 metre-wide finger ramps are driven 288 metres into the mining zone. The upper overburden near this perimeter is excavated by draglines. The main haul road provides access to the exposed bauxite level from the southeast, opposite the mid-point of the high wall. The cut at this point is about 1800 metres wide - 945 metres on the northeast side and 855 metres on the southwest side. The hard clay of the lower overburden forms a parting and dragline bearing surface between the upper and lower high walls. As it is excavated, the material is used

to dike the pit for protection against the annual rainfall of 2030-2540 mm.

Because of the depth of the mine, a large excavator - the 1350W unit - is used. This unit weighs 2,300 tons and is equipped with a 87-metre (285 ft.) triangular boom angled 32^{o} above horizontal. The boom provides a 61-metre (200 ft.) reach, 61-metre cast and a maximum of 46 metres (150 ft.) of span above the horizontal. The excavator is fed from a 13.8 kw high-tension cable.

The 1350W cannot cope with the thicker sections of the overburden. Accordingly, the "Slurrifier" system was utilized. The Slurrifier is an hydraulic earth-moving fortress mounted on skids. The four hydraulic guns are remotely controlled from an operator's cab and are programmable through various arcs of sweep as determined by localized excavating conditions. Freshwater from a nearby swamp is delivered by three Gould pumps at 2,000 gpm through a 50-cm (20 ins) spiral-weld pipeline. Three boosters on the skid-mounted barge feed water at 200 - 250 kg/cm^2 through 15 cm (6 ins.) pipelines to the hydraulic guns.

Equipped with "intelligants" having 2½ ins. nozzles the four water cannons jet 45tpm of water against the working surface which may be either an upper highwall or loosely consolidated virgin material or material stacked by the 480W 10-yd dragline for the Slurrifier. The 50-cm (20 ins.) slurry line is equipped with four booster stations each consisting of Pettibone pumps driven by 1000 hp engines. These units deliver the slurry at 25-30% solids, 4 miles to a 1,200-acre disposal area. As the solids settle the clear water is decanted from the disposal area safely beyond the identified mining areas. Make-up water is drawn from drinking water reservoirs in the district.

The mining fleet is composed of two Bucyrus Erie (BE) 5-yd draglines of which one is usually in reserve. In addition, a loader handles dragline stockpiled material. Of the eighteen 35-ton Euclid haul trucks, eleven are utilized in the mining cycle. Two Cat. D8 ripper dozers work with the mining excavator.

The ore must be drilled and blasted. Blastholes are drilled by two Mobile auger drills mounted on Cat. D4s which auger 4 ins. holes to a depth of 8 - 10 ft. The spacing of the holes are loaded with bagged ANFO which is primed with water gels. The shipping programme establishes a 150 ft. wide strip along the spoil toe from the side wall to the haul road.

A.2.3 Guyana Mines

The bauxite deposits of many of the mines are overlain by as much as 61m (200 ft.) of overburden. For example, the East Montgomery mine, the 10.7m (35 ft.) thick zone, is buried under as much as 76m (250 ft.) of cover. Generally, the upper overburden consists of fine white compacted sand up to 45.7m (150 ft.) thick. Below the sand is a layer of hard clay, 9-15m thick. The clay is usually hard to dig and may be saturated with water. The bauxite zones are 10-12m thick. Primary stripping removes the upper sandy formation with interbedded clays. Stripping is usually done with bucket wheel excavators, although hydraulic monitors have been used occasionally to undercut and slump upper layers for collection and pumping to a settling basin.

At the time of the EMJ Report (1977) the mine had six digging wheels, the largest of which was capable of excavating 3500 tons per hour. Secondary shipping of the hard clay is usually done with dragline. The largest one at the time was a 28-yd BE 1300W walking machine having a 99m (325 ft.) boom angled at 32^{o}.

A.2.4 Trombetas, Brazil

High quality bauxite was first discovered in the Trombetas area in 1966 and site work was started in 1971.

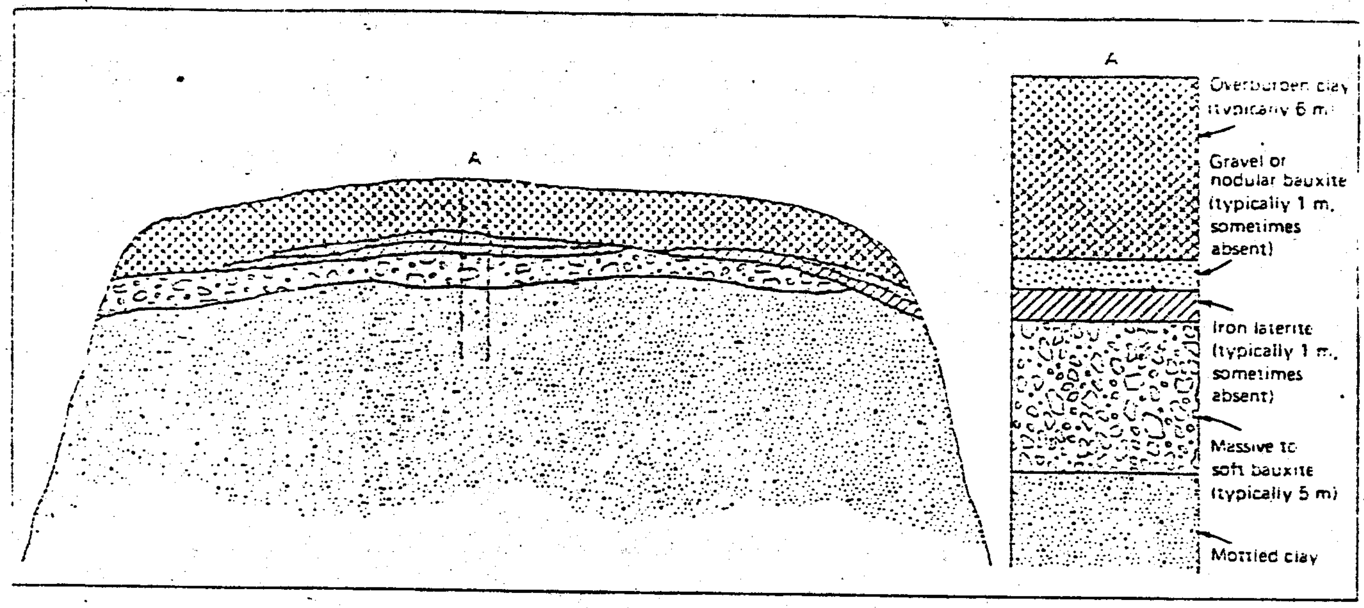
The bauxite is found on flat-topped plateaus, remnants of an original peneplain which lie some 70-120m above the surrounding country. The plateaus are highly dissected and vary in shape and size from a few hectares to several thousand hectares. Fig 3.2 shows a typical vertical section of the plateau in the Trombetas region.

A report in World Mining (June 1979) before commercial mining had commenced, described the basic mining technology which was to be open pit as clearing overburden, stripping, mining transportation, crushing, benefication and drying. Shipping of overburden was to be by 17 cu. yd. BE walking dragline and by Caterpillar scrapers. The bauxite was then to be drilled and blasted and loaded by three Northwest 6.5 cu. yd. back-hoes into seven Caterpillar 939 35-ton capacity trucks with aluminium bodies. At the crushing plant bauxite would be reduced to less than 3 ins. (7.5 cm). From the crusher the bauxite would be carried over 942 ins. (2393 cm) cable belt conveyor to a car-loading station 240 ft. (72 metres) below the crushing plant level.

At the loading station the bauxite would be loaded on to 70-ton Gondola cars by a 60 ins. (150 cm) retractable belt from a surge stockpile located on the railroad which would be a 1-metre 40kw long from the mine to the parallel car dumpers at the port site. The crude bauxite would go by belt conveyor from a rotary car dumper at the port railway terminal to the surge pile feeding the washing plant. At the washing plant the crude bauxite would be slurried with water in drum scrubbers followed by washing in trommel screens with less than ½ ins. (1 cm) fines from the trommel screens being washed on a

Fig. A.2

Typical Cross-section of Plateau in Trombetas Region



Source: Engineering & Mining Journal
Operating Handbook of Surface Mining (1977)

14-mesh vibrating screen. The $>$14 mesh to $- < \frac{1}{4}$ ins. (1 cm) material would be recovered as also $<$14 mesh to $>$85 mesh bauxite fines.

Water for washing the bauxite would come from the Trombetas River and the non-pollutant tailing would be pumped into a lake. Two rotary driers would dry the bauxite to 3% moisture. From the dryers the bauxite would be carried by conveyor belt to a 80,000-ton dry storage building.

A flow diagram of the process is indicated in Fig. 3.3.

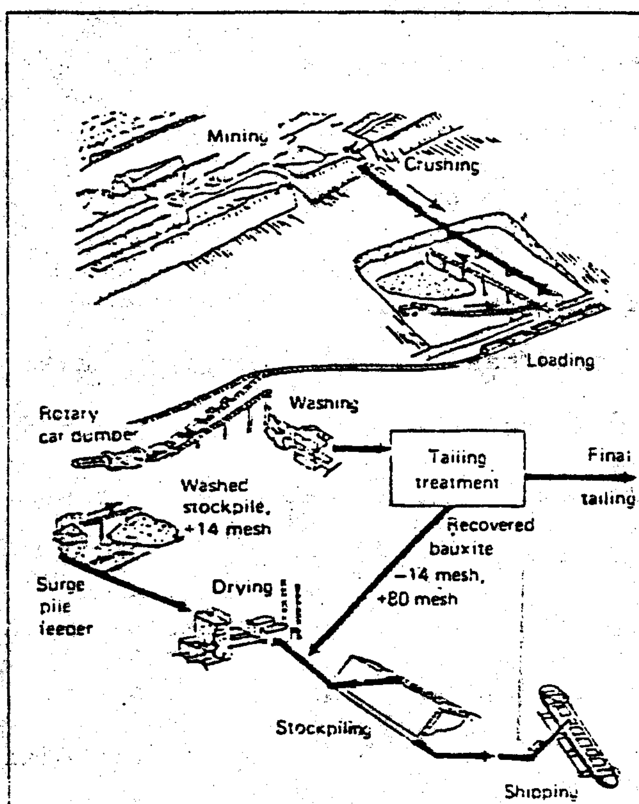
Reynolds Haitian Mines

Bauxite mining has been terminated in Haiti after nearly 30 years. However, we will use the mining system which then operated to illustrate the contrast between the mining system of a typical Caribbean bauxite versus the ores we have described above.

The bauxite deposits occur in pockets in eroded limestone surface of Miocene age. Shallow pockets of ore vary from 1 - 3m thick; deeper ore is 3 - 12m thick. Conventional combination of shovels with trucks and front-end loaders with trucks are used to mine the ore. Top soil which varies from 15-30cm is removed by bulldozers and stockpiled for resurfacing prior to reclamation.

Ore was mined in two daily shifts, five days per week - using one of two mining systems, depending on ore thickness. In shallow bauxite two front-end loaders - one 6-yd Cat. 992 load into 35-ton dump trucks. Deep ore was mined with two 4-yd Marion 111 diesel shovels, one of which was always on standby. The trucks were specially fitted with heated aluminium bodies. Apart from lightness the aluminium bodies are durable as the ore is not highly abrasive and contains few large lumps except for occasional limestone boulders. Bauxite at about 25% moisture is dumped at the wet ore stockpile prior to drying.

Fig. A.3 Bauxite Flow Diagram, Trombetas Project



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