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28 February, 1992

ORIGINAL: ENGLISH

MINABLE BAUXITE RESERVES IN JAMAICA
UC/JAM/90/239/11-52/J13207

J A M A I C A

Technical Report

Based on the work of: R.C. Bryan
Consultant

Backstopping Officer: T. Grof
Metallurgical Ind. Branch
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ABSTRACT

Guaranteeing the future availability of Jamaica bauxite reserves will require active planning and guidance by the Jamaican Government. The following tasks are recommended:

- Set policies which will encourage the optimum exploitation of bauxite reserves.
- Produce detailed land utilization plans containing bauxite inventories integrated with other critical land use, legal and environmental data.
- Establish an agency with the clear authority to regulate the bauxite mining industry, including the authority to issue and revoke mining permits, levy fines and inspect all aspects of the mining process.
- Encourage and promote research of new measurement, mining, reclamation, estimation and waste management technologies as applied to the bauxite/alumina industry.
- Establish environmental standards, and develop technical abilities to sample and analyze environmental data independent of the bauxite/alumina industry.

OVERVIEW OF CHAPTER

Jamaica's present economic fortunes are tied to these reserves. Future plans have bauxite taking a leading role in economic development. This chapter discusses technical, economic and policy issues which can affect the minability of bauxite reserves. The sections are:

- **RESERVES**

Reserves in this report are defined as the quantity of bauxite ore which is profitable in the short run to a mining firm, and in the long run to Jamaica. Given the circumstances of their location, and sequence of mining, an insitu reserve can fail to meet this definition.

- **LAND USE PLANNING**

If Jamaica follows the trend of the developed countries, there will be vigorous competition for alternative uses of the land where bauxite deposits exist, and more of the bauxite reserves, previously discussed, could become permanently unavailable.

- **EXPLOITING MARGINAL RESERVES**

Given certain economic conditions, technical skills or levels of information, insitu bauxite reserves can be of a marginal category. By changing any one of these aspects, this same ore may become minable.

- **NEW ADVANCES IN TECHNOLOGY**

Over the coming decades, advances in technology for mining, processing, detecting and estimating bauxite will most likely accelerate. The Government must see that the mining industry is aware of any technology which can help the country compete in the world bauxite/alumina market.

- **REGULATORY INSTRUMENTS**

Existing regulatory instruments such as taxation and royalty charges must be updated to effectively promote efficient exploitation of bauxite in the coming decades.

- **NEW ENVIRONMENTAL CONCERNS**

Jamaica has acknowledged its need to protect the environment with the Natural Resources Conservation Authority Act of 1991. This Act requires that the Government take such steps as are necessary to ensure the conservation, protection and proper use of its natural resources.

SECTION I: RESERVES

BACKGROUND ON JAMAICA'S BAUXITE RESOURCES

A. DEFINITION OF BAUXITE AND USES

Bauxite is the primary ore for aluminum production and is, in turn, a primary income source for Jamaica. The final product derived from bauxite is generally aluminum and to a lesser extent, refractory alumina. However, the intermediate product of alumina has its own end uses, such as for filling materials, ceramics, alum, cement, abrasives and other chemical uses.

Bauxite's name was derived in the 1800's from the town Les Baux of Southern France, where it was first described. Since it is a soil derived from the weathering of aluminous rocks, bauxites around the world can have strikingly different mineralogical compositions. The key distinction of bauxites to other soils are their high exploitable aluminum content. Dr. C. Davis, Chairman of the Jamaica Bauxite Institute, has defined bauxite as:

> Bauxite is ... "a heterogeneous, naturally-occurring material composed of varying amounts of minerals, with the alumina minerals being dominant and with lesser amounts of others, including iron, silicon, titanium, phosphorus, zinc and manganese minerals."

It is this high proportion of alumina hydroxide minerals which makes bauxite such a valued commodity. The major alumina minerals are the alumina trihydroxide gibbsite ($A1_2 0_3 . 3H_2 0$) and alumina monohydroxide, boehmite ($A1_2 0_3 . H_2 0$). The chemical composition of the bauxite varies from location to location. While the main variation is in silica and iron content, other elements such as titanium, phosphorous and calcium can also vary considerably. Minor elements, with less than one percent of the total, are magnesium, vanadium, gallium, manganese, zirconium, chromium, zinc and rare earth metals.

The main constituents found within many large deposits in Jamaica are:

	Percent
Combine Water (H_2O)	26.0 - 27.8
Silica (SiO_2)	0.4 - 3.5
Iron Oxide (Fe_2O_3)	17.5 - 22.8
Titanium Oxide (TiO_2)	2.4 - 2.6
Phosphorous Pentoxide (P_2O_5)	0.3 - 2.8
Calcium Oxide (CaO)	0.1 - 1.2
Alumina (Al_2O_3)	46.4 - 50.3

Source: *Mineral Resources of Jamaica, Bul. No. 8, 2nd Edition, 1981*
Jamaica Geological Survey

B. WORLD PRODUCTION OF BAUXITE

The Western World's bauxite reserves and production from 1986 through 1990 are shown in Table 1. In 1990, just under a hundred million metric tons of bauxite was produced. This is compared to an overall reserve base of 22,500 million tons. Additionally, 102,795 million tons are currently classified as resources. These additional tons are either of lower economic quality, more difficult to exploit, or insufficiently delineated to be classified as reserves. A general caveat is that the quality of these reserve figures vary from country to country.

Distinctions of quality of bauxite, existing infrastructure, stability of economy and a host of other issues are not reflected in these figures. We will see, in a following section, that bauxite is a complex ore with characteristics that can affect the economics of mining and process.

Country Name	Reserves (÷000,000)	Resources (÷000,000)	1986 (÷000)	1987 (÷000)	1988 (÷000)	1989 (÷000)	1990 (÷000)
France	30	200	1,379	1,228	878	720	559
Greece	450	300	2,225	2,400	2,440	2,576	2,504
Yugoslavia	200	500	3,459	3,394	3,106	3,252	2,952
India	1,200	1,000	2,338	2,814	3,829	4,845	4,340
Indonesia	700	2,000	650	635	518	862	1,206
Malaysia	50	15	566	482	361	355	398
Turkey	50	200	280	180	269	455	498
Ghana	250	300	226	226	300	375	369
Guinea	5,900	5,000	14,835	16,282	16,810	16,520	17,524
Sierra Leone	400	300	1,242	1,391	1,403	1,548	1,445
Brazil	2,300	30,000	6,446	6,565	7,728	8,051	8,500
Dom. Rep.	40	20	0	211	168	165	85
Guyana	900	25,000	2,074	2,785	1,774	1,321	1,424
Jamaica	2,000	800	6,964	7,660	7,408	9,395	10,937
Surinam	600	10,000	3,731	2,581	3,394	3,461	3,283
Venezuela	500	1,500	0	240	700	760	1,000
United States	40	400	510	581	508	670	496
Australia	4,600	6,000	32,384	34,102	36,192	38,585	41,390
Others	2,290	19,260	41	60	31	32	113
TOTALS	22,500	102,795	79,330	83,817	87,817	93,948	99,023

TABLE 1: BAUXITE RESERVES AND PRODUCTION

Sources: IBA Review, 1991
WBMS, ABMS, USBM, Metallgesellischaft

• JAMAICA BAUXITE COMPARISON

Jamaica is an island within the Caribbean with a size of 10,926 square kilometers; it has over 2,000 million tons of bauxite in reserve (U.S. Bureau of Mines estimate). Through the efforts of mining companies and government, over many years, Jamaican reserve tonnages are comparatively accurate and well documented. Jamaica's resource is an additional 800,000,000 tons. Other countries with extensive bauxite reserves, have large resource categories. Australia has reserves of 4,600,000,000 tons with resources of 6,000,000,000 tons. Brazil has 2,300,000,000 tons in reserve, with 30,000,000,000 tons in resource.

Despite its diminutive size, Jamaica has 8.9 percent of the world's bauxite reserves (see Figure 1) and in 1990 supplied 11.4 percent of the world's production. Of these insitu reserves, a significantly smaller tonnage can be considered minable. To be considered minable, bauxite must be profitable not only to the mining company, but to Jamaica as well. National interests require that the mining of bauxite, in a particular area, will not create future liabilities. Future liabilities can be the loss of agricultural lands, a loss in tourism, contamination of water or air, etc. Future profits to Jamaica are items such as the increase of the GNP, the construction of modern communities, the legacy of well designed interior roads, water systems, etc.

Figure 2 on page 7, shows a map of Jamaica, oriented with the north coast with bauxite load-out ports of Ocho Rios and Port Rhoades to the left; the south coast with alumina export ports of Port Kaiser to the right. Bauxite resources fall within the central one third of the island, shown with a dotted pattern. Located in the southern portion of these bauxite resources are consolidated mining areas for Jamalcan, Jamalco and Alpart mining companies shown with a box symbol. To the north, the mining areas for Kaiser and Jamalcan are also shown. Surrounding these box symbols are areas shown with a diagonal hatching pattern, which designates the forty year reserves to be discussed in the next section.

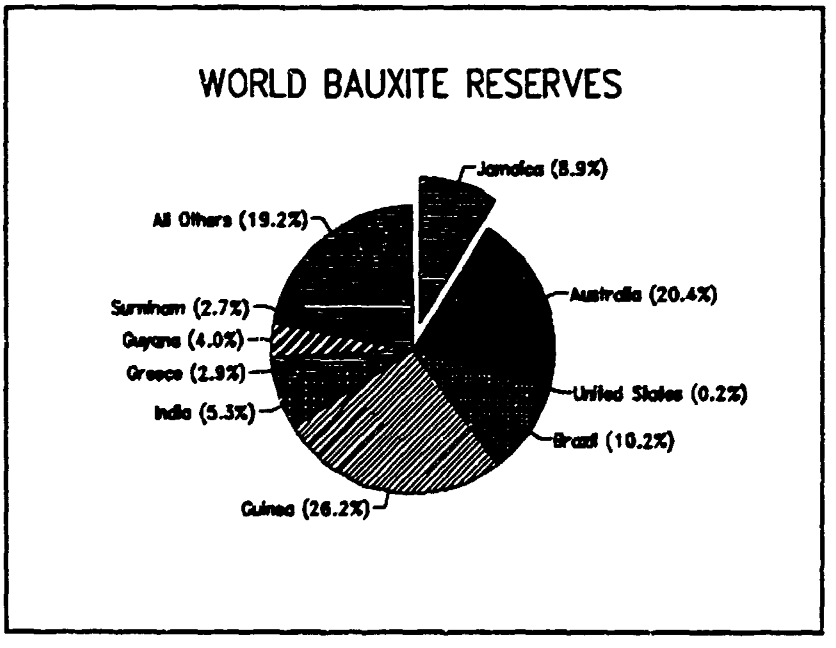


FIGURE 1: WORLD BAUXITE RESERVES

Bauxite from Jamaica is located in karstified limestone throughout the Island. The bauxite orebodies occur generally in topographic lows, such as karst depressions, valleys and eroded fault zones. Most of the bauxite is rich in iron oxide minerals, particularly hematite (Fe0.0H) and goethite ($Fe^2 0_3 . H_2 0$), imparting a characteristic reddish color. The main deposits are in the Manchester, Trelawny, St. Ann, St. Catherine and Clarendon parishes. The largest portion of Jamaica's bauxite lies right on the surface with no overburden stripping required. The ore is mined in open pits with the required preparation consisting of vegetation removal, along with scraping the top six inches of soil for the reclamation phase. (12-18 inches).

As of 1990, producers above five million tons per year were Australia at 41,390,000 tons, Guinea at 17,524,000 tons, Jamaica at 10,937,000 tons and Brazil at 8,500,000 tons. Using 1990 as the base year, Jamaica production was a positive 14 percent, an increase of 1,500,000 tons compared to 1989. These four producers most likely constitute the greatest contributors to growth into the coming decade. The most salient features of Jamaican bauxite vis-s-vis competitiveness with other producers are:

- Limited overburden removal
- No crushing
- Relatively low labor costs
- Good transportation and shipping

Another important feature is that Jamaican bauxite is of a known quality to a ready market. While the majority of Jamaican bauxite is reprocessed to alumina in Jamaica, a good percentage is dried and shipped.

A 1970 survey in the Engineering and Mining Journal, ranked Jamaica third among the four countries discussed. This ranking was according to factors such as the possibility of political unrest, the possibility of artificial exchange rates, any restriction on repatriation of capital and profit, freedom of investment, and the level of corruption of the government. In addition, the article then ranked the countries according to geological potential, transportation, health hazards, labor, fuel, and mining righis.

- **Positive Aspects of Jamaican Bauxite**

In summary, the points which make Jamaica a strong competitor vis-a-vis other bauxite rich countries are:

- Stable political environment
- Good infrastructure of roads, communication and power
- Proximity to markets
- Access to high quality of labor
- Ease of mining with limited strip requirements, short haulage distances
- Ore with known metallurgical properties.

- **Negative Aspects of Jamaican Bauxite**

Compared to the bauxite reserves of Brazil and Australia - Jamaican bauxite is not remote from human settlements. This places an additional cost burden on Jamaican bauxite miners in a variety of ways:

- Bauxite mining companies must become involved in land acquisition and consolidation of mining areas.
- Before mining, individuals must be relocated. When a large population is involved, such a relocation means at times the planning and construction of a new community.
- Operating mining equipment in inhabited areas requires the building of mining access roads, staging areas etc.
- A greater level of scrutiny of mining, remediation and discharge of wastes.

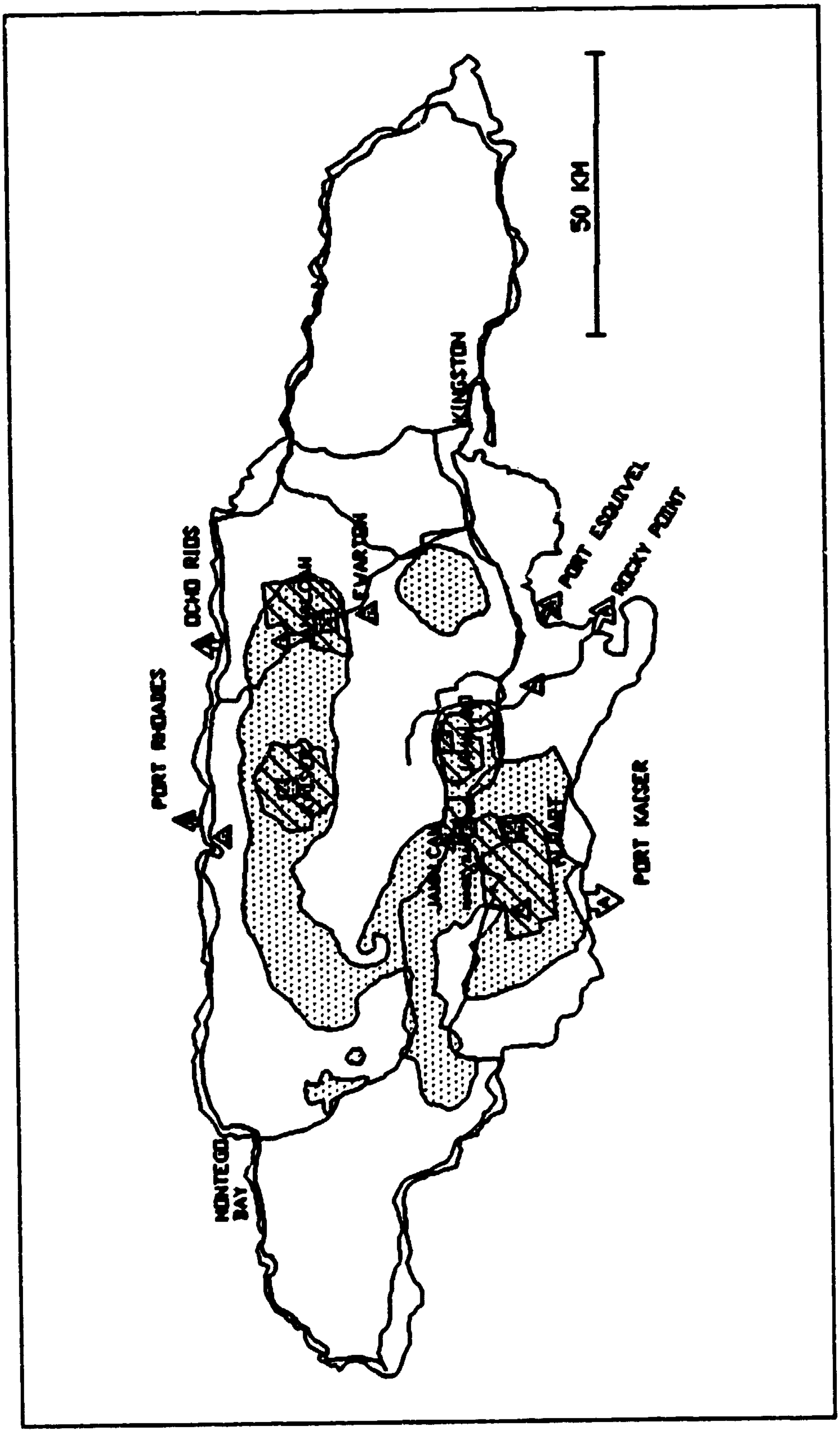


FIGURE 2: JAMAICA BAUXITE RESERVES

SECTION II: LAND USE PLANNING

In the previous section, we saw that Jamaican bauxite is probably less competitive with other major suppliers with regard to mining within populated areas. The potential for the loss of large amounts of bauxite by uncontrolled subdivision, was and is, of great concern. Established in 1976 as a quasi-governmental organization, the Jamaica Bauxite Institute's primary task is to act as a technical advisor to the Jamaican Government with issues related to the bauxite/alumina industry. Following the consolidation of company reserves, The Jamaica Bauxite Institute (JBI) took on the task of supporting the Ministry of Mines and The Department of Agriculture in coordinating the mining reserve issue. To do so, the JBI set forth the following goals:

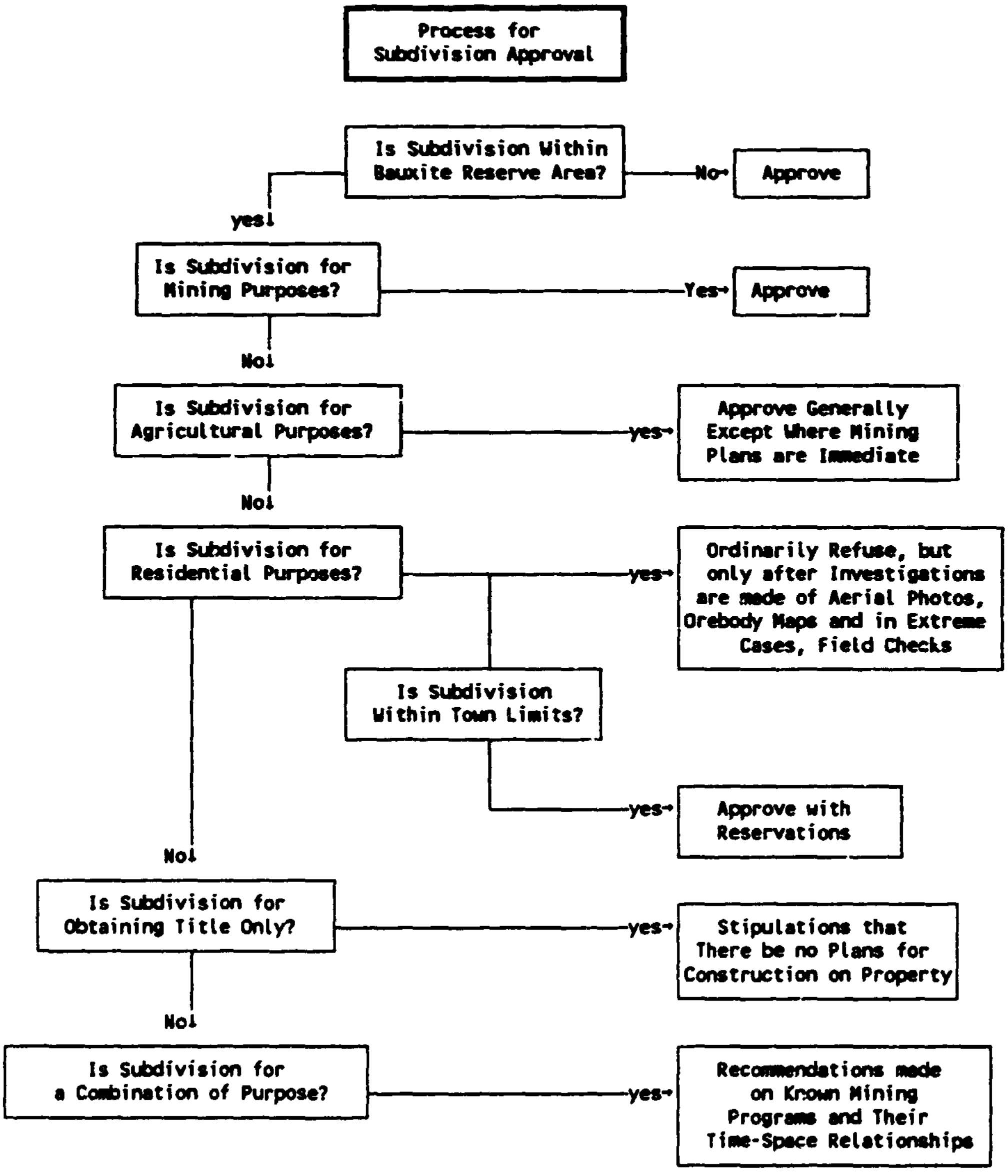
- Lands required for mining were allocated to various mining companies based on their then forty-year requirements.
- From this forty-year bauxite reserve, five year mining blocks were restricted to mining.
- All other bauxite lands were to be used for agricultural purposes.
- Re-settlement was to be planned jointly between the government and the companies. This was to ensure that those re-located would be guaranteed of a high quality of life.
- Plans were made to guide the future use of mined-out and reclaimed land.

These five points acknowledged that there is a logical sequence to maximize the returns from Jamaica's bauxite lands. The general sequence is to use the mine reserve areas for agriculture, then mining and finally, rehabilitation back to agriculture, etc.

The plan defined that other potential land uses had to be coordinated with the Companies' mining plans for a medium term (5 years) and long term (20) years. The five-year blocks are still considered to be exclusively for mining. Beyond five years, the blocks are made available for agriculture, provided that the crops chosen would be scheduled to be harvested before mining. Within this medium time frame, no permanent structures or capital intensive development would be allowed. Within the medium and long term mining reserves, constant monitoring must be done to control any sub-divisions which would remove these reserves from the mining base. This last paragraph implies a decision process which requires close communication with each company.

A process for careful use of bauxite reserves is shown below. The demands for integrated information becomes apparent as one moves through the process.

SCHEMATIC 1: LOGIC FLOW OF LAND USE APPROVAL IN A MINING AREA



This decision diagram emphasizes the importance of pulling together disparate information. To do so, these general comments follow:

- That the system utilize modern computers to speed the process.
- That computer system utilize an information data base such as a Geographical Information System (GIS) format.
- That the GIS produce the requisite maps and reports, to facilitate land use decisions.
- That due to its experience, the JBI be selected to set up, operate and maintain the system.
- That the GIS system created, be an open resource for both government and industry.
- That the JBI and the companies pool their information resources, to produce a decision tool useful to government and industry.
- That the present equipment and software be upgraded to be powerful enough to allow for real-time access of the GIS information.

Currently at the JBI, there exists:

- Micro-computer mapping capabilities of bauxite reserves
- Archived maps and documents containing the location of roads, buildings and mining claims.
- Experience in interpreting aerial photographs.
- Skill in digitizing topographic maps.

This equipment, staff and skills can be used as the foundation to implement a GIS database. However, additional resources will be needed to implement such a system.

- Economic resources to purchase the computers needed to support a GIS system.
- Increasing the staff at JBI to initiate and maintain such a system.

MINING COMPANY PERSPECTIVE ON GIS

During my on-site visits of mining companies in Jamaica, I interviewed executives on their perspective of a GIS data base. Generally, this idea was well received. During my discussions these points were made:

- From the mining industry's perspective, an integrated information system would be advantageous.

- Such a system would promote efficiency and optimization of planning. There would be improved ore pit identification and volume estimates, essential to overall planning and any relocation of population could be planned far in advance.

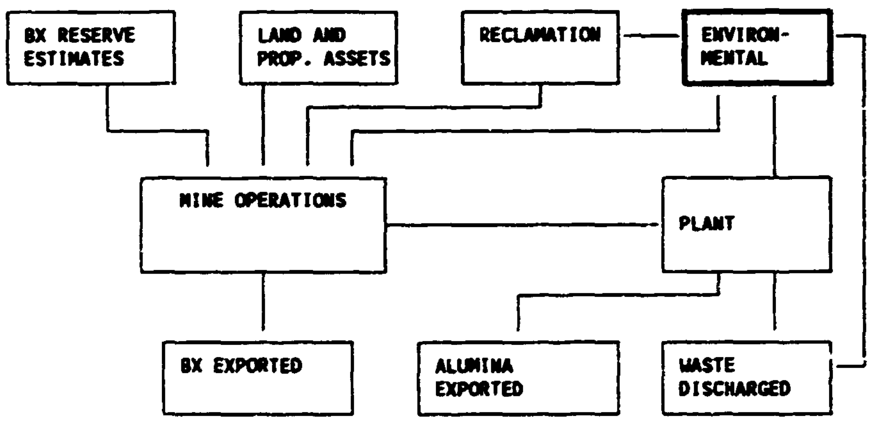
- With such a system, bauxite reserves of an area could be extracted and processed efficiently. After mining, the reclamation and restoration efforts could be conducted on a timely basis. During the total cycle, disruption of local residents could be minimized and a good working relationship with the Government of Jamaica would be enhanced.

- Attributes required on the GIS maps would be:

  1. Property records
  2. Reserve estimates
  3. Mine planning information
  4. Mining operations information
  5. Reclamation information

- The system would require this basic flow of information:

SCHEMATIC 2: INFORMATION FLOW FOR A MINING FIRM



- The bauxite reserves would be the foundation information of the whole GIS system.

- The environmental planning group would require information from all the phases of the mining and plant operations.

SECTION III: EXPLOITING MARGINAL RESERVES

Figure 3 illustrates an idealized section through a bauxite deposit. Note that the bauxite ore is bounded by limestone, and that a sub-portion labeled "unmined bauxite" representing marginal ore will not be exploited for various reasons.

IDEALIZED SECTION OF BAUXITE PIT

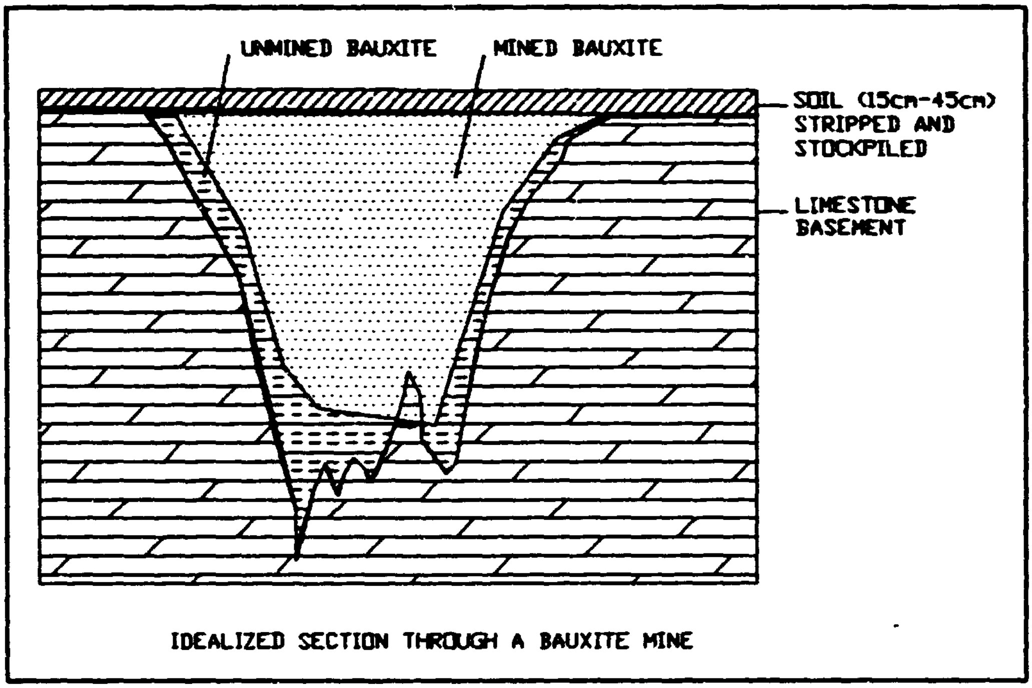


FIGURE 3: IDEALIZED SECTION OF BAUXITE PIT

Marginal Ore Due to Geometrical Constraints

During several visits to ongoing bauxite mining operations, I noted the following cases:

- **Case 1:**

  One company was engaged in an experiment of using a Jamaican contract miner to obtain bauxite from a marginal zone. The area to be mined was a relatively thin deposit on a steep hill. The company's equipment at hand was not suited for the case. In this particular case, the use of a contractor was successful. The company interviewed confirmed that without a lower cost contract miner, these particular reserves would have been abandoned. Further discussion revealed that there was a very limited pool of contract miners from which to accept bids. The company official felt that few Jamaicans had access to the capital to acquire the necessary equipment.

The first example illustrates an opportunity for the Government of Jamaica to encourage the development of a specialized service sector of contract miners.

- **Case 2:**

In the second example, I observed a deep bauxite deposit that was being abandoned with an estimated 30% of bauxite left behind. In this case, the mining engineer pointed out that his mining equipment, an older dredge, was unsuitable to mine the steep pit wall geometries. His solution to the problem has required the investment in a modern long-reach miner. Since then, this new equipment was, in fact, purchased and is reported to be better suited for the mining geometries.

The second example illustrates an additional opportunity for the Government to act as a clearinghouse of technological solutions.

Marginal Ore Due to Unsuitable Parameters

Case 3:

Bauxite can also be of marginal economics due to the concentrations of different parameters. In Figure 4, portions of a mining area may not meet required specifications of the alumina plant. The percentage of boehmite may exceed current concentrations allowed for the current alumina plant's configuration. This same material may become acceptable ore when an alumina plant alters its process or upgrades its equipment. In the current mining sequence, this marginal ore is abandoned, and is essentially lost forever.

In this third example, it is recommended that the Government encourage the stockpiling of such marginal reserves until a time that they can be processed.

BAUXITE PARAMETERS DO NOT MEET CURRENT TECHNICAL SPECIFICATIONS

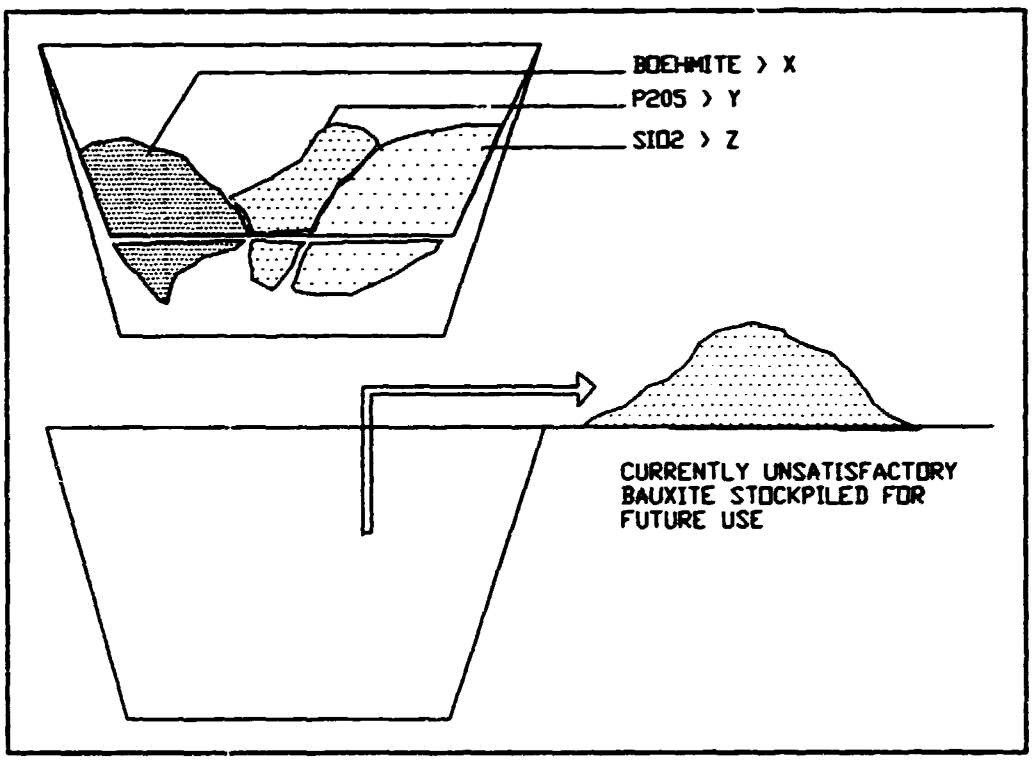


FIGURE 4: QUALITY PARAMETERS AND MARGINAL ORE

The Effect of Marginal Ore:

Figure 5 shows, schematically, that an additional cost, for any reason, such as an increase in taxation of ore insitu or an increase in royalty will tend to increase the proportion of marginal ore. In essence, a mining company will preferentially move laterally, versus a policy maker's desired vertical direction.

The second part of figure 5 illustrates that poor estimation of an in-place reserve can have the same effect. In this case, a mining firm has underestimated what mining reserves exist at an ongoing location, hence preparation of a new mining site, with the premature removal of mining equipment from the existing site.

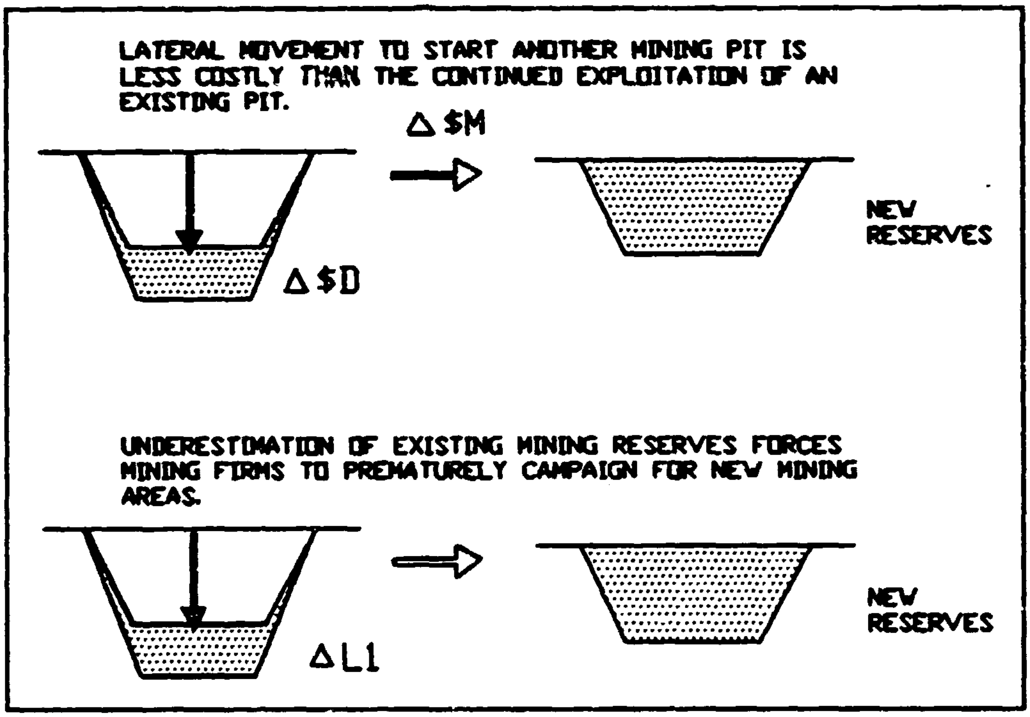


FIGURE 5: MOVING SIDEWAYS INSTEAD OF DOWN...ECONOMICS AND INFORMATION

An additional incentive to move on to a new location may be a misconception that additional reserves are almost inexhaustible. This perception may have come from a misinterpretation of the forty year agreement. There seems to be a widely held belief that if a mining area is exhausted, the Government will grant additional reserves.

It is important that the Government clarify the forty year agreement.

SECTION IV: ADVANCES IN TECHNOLOGY

Importance of Good Estimations

One of the points made in the last section, was that inaccurate reserve estimation can reduce the efficiency of exploitation, in that an orebody may be prematurely abandoned.

Estimation techniques in bauxite have, for the most part, changed little since the 1920s. This is in spite of some good advances in methods of calculation and in new methods of measure. Figure 6 illustrates the polygonal reserve estimation technique, a standard. Shown in plan view, the position of the drill holes used to sample ore quality and depth are shown as plus symbols.

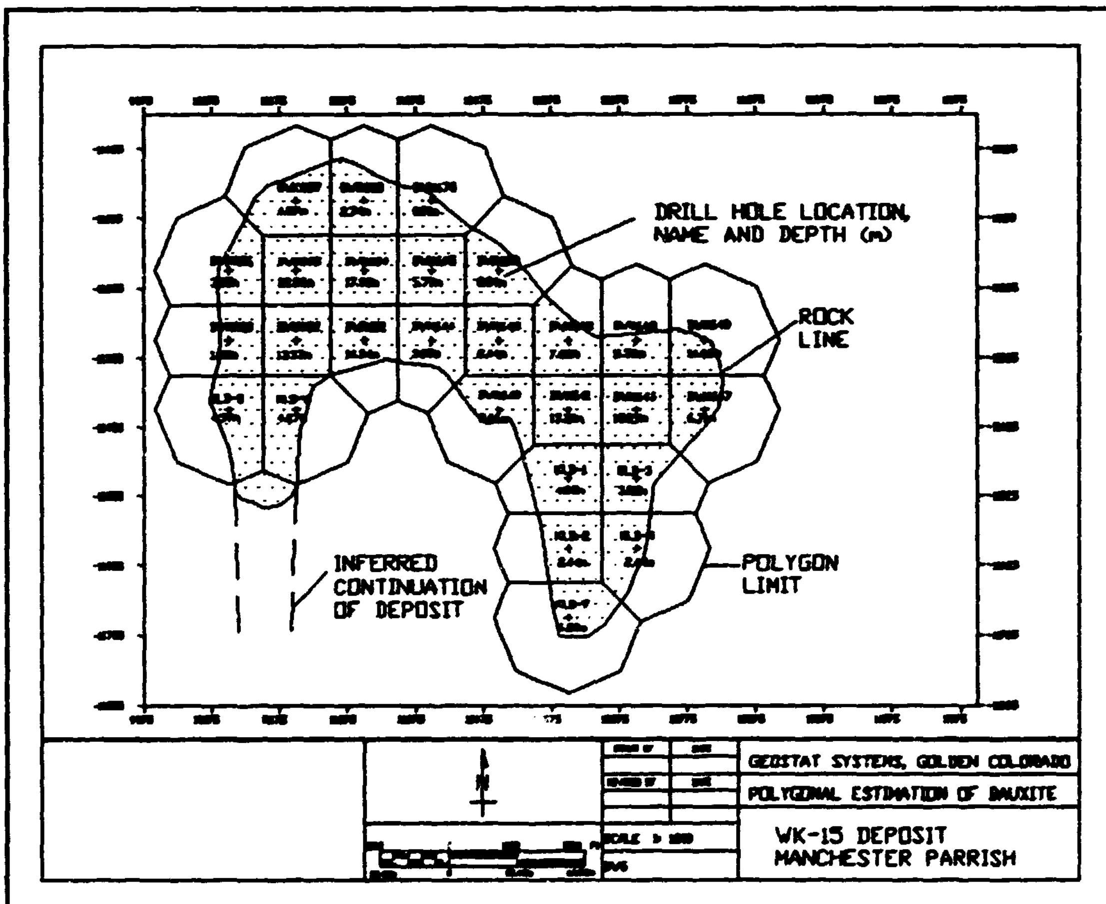


FIGURE 6: PLAN VIEW OF POLYGONAL ESTIMATE

Measured values such as SiO_2 and Al_2O_3 percentages or depth to bedrock are assigned the volume of the surrounding polygonal shape. The outside edge of this polygon is, many times, limited to a maximum radius (polygon limit) or to an observed boundary such as the outcrop of the basement rock. In figure 7, a cross section dramatically shows some of the limitations of the method of estimating depth.

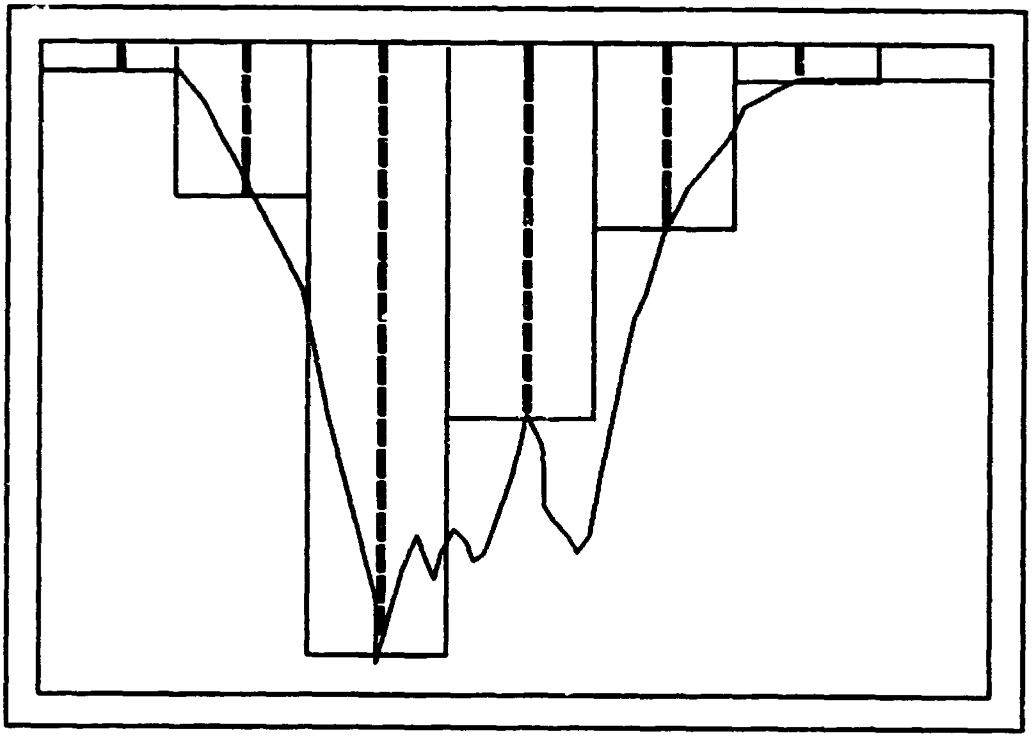


FIGURE 7: SECTIONAL VIEW OF POLYGONAL ESTIMATE

The karst topography underlying the bauxite can be quite rugged, with extreme peaks and depressions. Drill-holes cut on a 100 or even 50 foot grid can be too coarse a density to measure extreme changes in depths, which in large measure will control overall tonnage.

With such inaccuracies, over and underestimation can occur. Mining engineers, are generally conservative in their estimates, and have developed corrections so the inherent inaccuracies will not error on the high side. A study by the JBI in 1981, clearly shows this conservatism by comparing a mining company's estimate of 25 orebodies, accounting for 7.3 million tons of mined bauxite. The mining firm estimated the total reserves at 5.15 million tons, 73% of actual. In addition, these actual mined tonnages most likely left potential ore unmined, significantly reducing this already poor estimation to one approaching 60% of the recoverable ore.

- **Kriging and Geostatistics**

Technological advances have occurred in the last decade. The first is effective use of powerful computers and modern estimation techniques developed by the mining industry. Preliminary research has shown that, in particular, geostatistical techniques of variography and kriging can significantly improve grade and tonnages from reserve estimation.

- **Ground Penetrating Radar**

In addition, the new technological revolution of ground penetrating radar (GPR) shows great promise in measuring the thickness of bauxite with great accuracy. Figure 8 shows a schematic of a GPR field system, using the reflection of high intensity radar measure depth to bedrock, but cannot measure other parameters such as Al_2O_3. Even with this limitation, GPR shows great promise; yet further study is recommended that, as currently employed, this technology has its limitations. For instance, there is a maximum depth of penetration of the radar, which is at times more shallow than some of the deeper orebodies. Also, false depths can be registered by changes in moisture content, changes in density or erratic boulders within the bauxite. And, with present day technology, access to steep terrain and dense vegetation can hamper its use.

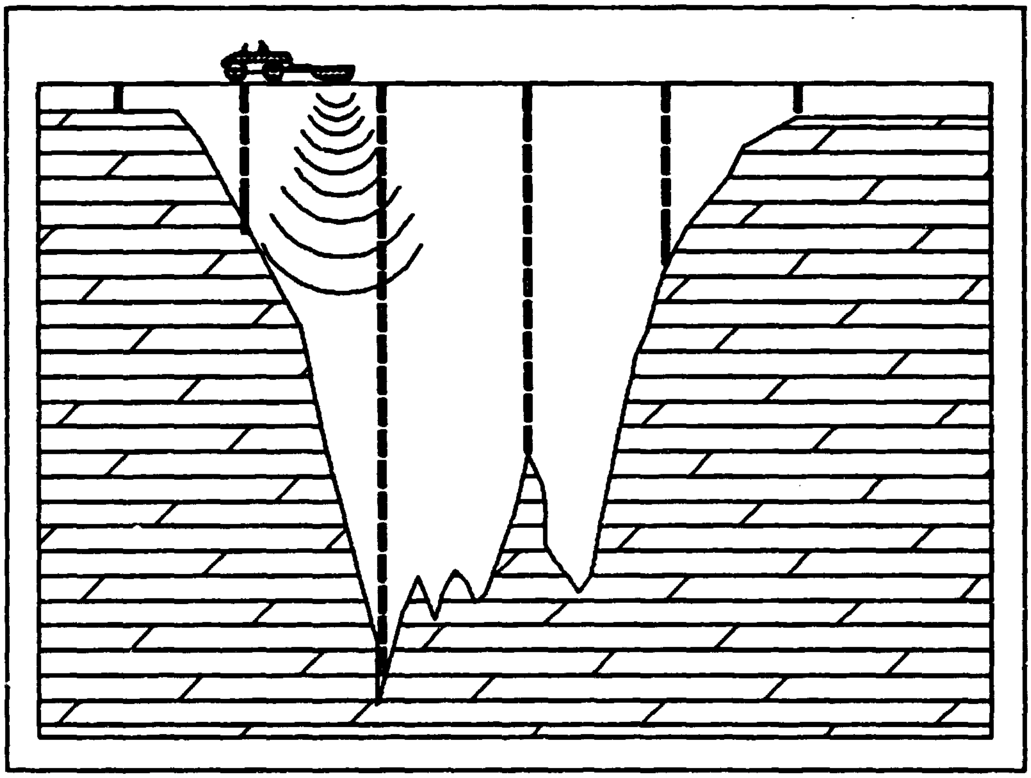


FIGURE 8: GROUND PENETRATING RADAR MEASURING DEPTH OF BAUXITE

To make GPR a universally accepted tool, the Government should support industry in their continuing research and development. One role that the Government can play is that of a clearinghouse for technological advances, assisting the communication throughout industry.

SECTION VI: REGULATORY INSTRUMENTS

The goal of achieving greater efficiency through methods such as taxation or royalty charges will most likely be ineffective or even counterproductive. It has been shown previously, instead of reducing, such a policy will increase the quantity of marginal ore left in place.

Surprisingly, a greater taxation on reserves may in fact increase investment on the alumina processing side. The level of capital investment for Jamaican, Jamalco, Alpart, Kaiser and Reynolds in mining equipment for the periods of 1979 to 1989 was US$ 63,374,000.00 while it was US$ 127,615,000.00 for alumina investment. This is almost a two-fold difference in investment. Furthermore, the value of alumina versus bauxite is nearly ten times. It can, therefore, be rational for a mining company to try to meet any increase in cost, by increasing productivity on the alumina side.

An additional observation is that most policy instruments directed at producing a more efficient bauxite operation will generally be ineffectual from the alumina product end. The increase in value of the product, the level of capital investment on the alumina side vis-a-vis the bauxite mining, should mean proportional reduction in waste on the alumina side. In other words, relative to alumina, bauxite is cheap.

A careful review of capital expenditures of the mining/alumina industry should disclose this bias towards the alumina side of the industry. Therefore, any regulatory instrument striving for greater productivity on the mining side must be based on other principles.

A related problem is that governmental figures for the amount of bauxite mined, are not measured amounts, but a back calculation from product shipped. We will see that the conversion factor of the number of tons of bauxite needed to produce one ton of alumina for example is, in reality, a negotiated number. It is impossible to determine how much ore was left in the pit or lost in each step of the mining/alumina process.

Figure 9 shows a schematic of loss of bauxite through the complete cycle of mining to transport. During the first step, a bauxite pit is mined, with a loss of L1. This loss is identical to leaving behind marginal ore. After each step, such as the transport of bauxite via truck, train or conveyor belt and stockpiling, losses L2 through L4 occur. If bauxite is directly shipped at this point, then this sum constitutes the level of the total loss.

The following discussion will focus on the situation of bauxite being converted to alumina before shipment. In this case, it takes approximately two and one-half tons of bauxite to produce a ton of alumina and the value of such a ton is over ten times.

For taxation purposes, the most available measure of tonnage is from the freighter manifest.

Note that if:

T	=	Tons of Alumina on board ship for export
T+(L5+L6+L7+L8)	=	The tons Alumina including loss.

The loss of bauxite through the system is generally calculated with the chosen equivalence factor bxEQ.

Tbx	=	Reported tons of bauxite mined.
Tbx+(L1+L2+L3+L4)	=	Total bauxite including lost tonnage
bxEQ	=	Tbx/T The ratio of reported tons of bauxite mined to tons of alumina shipped.
ΔbxEQ	=	(L1+L2+L3+L4)/(L5+L6+L7+L8) is the correction for bauxite equivalency.
bxEQ*	=	bxEQ + ΔbxEQ

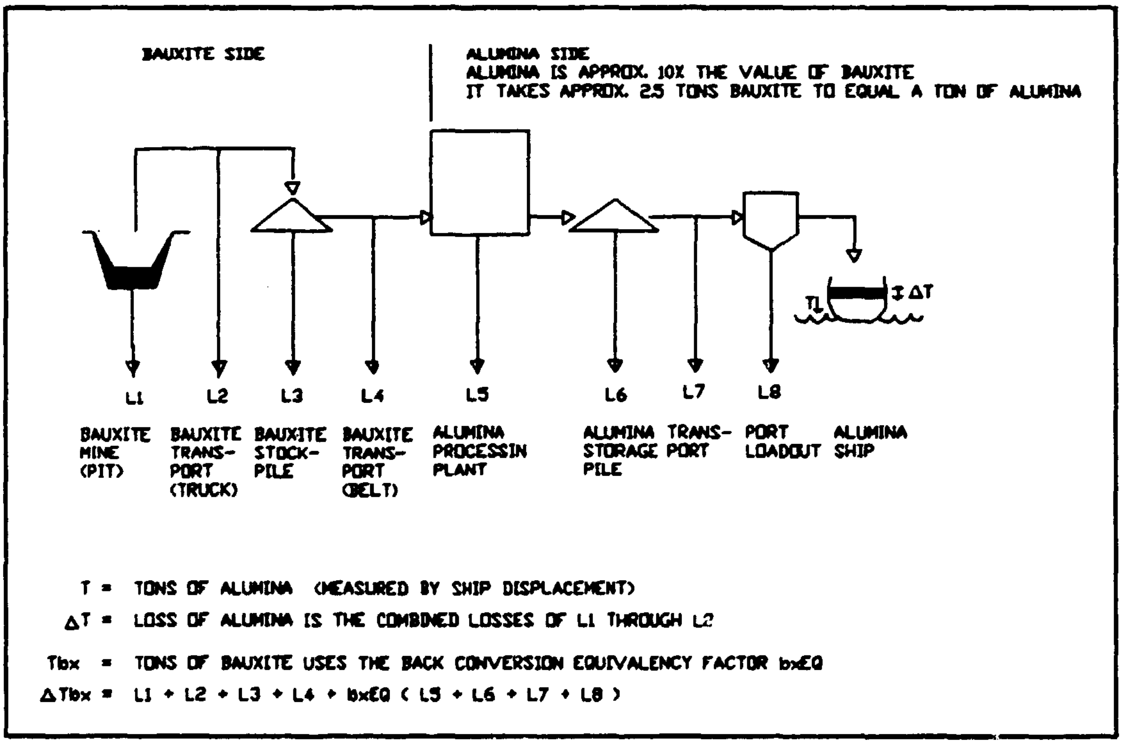


FIGURE 9: SCHEMATIC OF MASS LOSS FROM MINE TO SHIPMENT

The present day system of bauxite equivalency ignores any losses of bauxite in the system, particularly L1, which is lost in the pit. Since careful auditing of the true amount of bauxite mined is not tracked, nor are any inefficiencies within the alumina circuit, any measure of L2 through L8 are mere speculation. Under the present system, all mining and processing losses are born by the Jamaican government. Recommendations are:

- Research how to stimulate mining practices with little wasted ore.
- Research must be done to find the best way to measure this true conversion factor bxEQ*
- The true conversion factor bxEQ* should be tracked and used for information and taxation purposes.
- It is anticipated that obtaining the true conversion factor will require direct observations and measurements at the pit level, discussed in the next section

Figure 10 illustrates the problem.

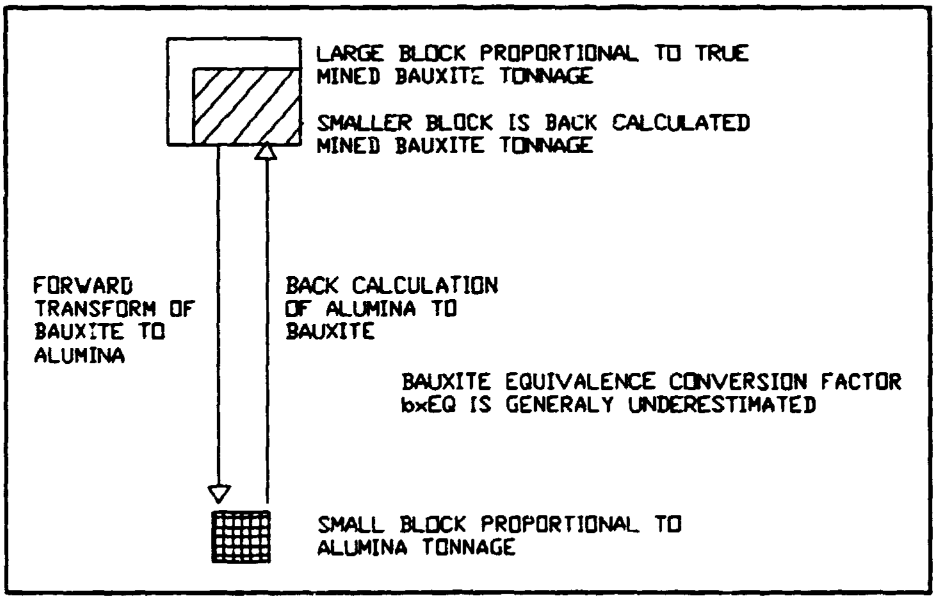


FIGURE 10: MASS BALANCE WITH bxEQ FACTOR

- **DETAILED OBSERVATION**

Unless research discloses otherwise, limiting ore waste during the mining process is simply a matter of inspection. The best and final chance for a Jamaican official to promote optimum exploitation of each orebody is at the point at which a mining company seeks a "pit closure" certificate.

Currently, there is no communication between the final inspector and the initial planner. A rationalization of information transfer between planning and final inspection is required.

- A Government representative must be able to recognize appropriate mining practices, and discriminate between bauxite and waste.

- A Government representative should have the authority to issue fines or penalties for non-compliance.

This one step might have the greatest impact. For many years, regulations have existed on how a completed mining deposit should be remediated. Under the Mining Act of 1947, the holder of a mining lease was required to restore every acre of land mined to at least the level of agricultural or pastoral productivity which existed before mining. This legislative Act is enforced by the Commissioner of Mines. The initial fine of fifty pounds sterling per acre was considered a token fine by the 1980's and compliance tended to be poor. A dramatic increase in compliance in restoration compliance occurred when fines were raised to US$ 4,500.00 per acre in 1988.

- There should be direct communication between front end planning and pit closure inspections.

Currently, not only are the functions separate, but so are the governmental agencies who perform these tasks. It is recommended that planning and final inspection should be done by the same agency. Present day inspectors are not given adequate training, nor are there any formal arrangements to coordinate the issuance of pit closure certificates with the Ministry of Agriculture or the Jamaican Bauxite Institute.

SECTION VII: ENVIRONMENT

Overview:

Bauxite deposits in Jamaica are located in the karstified, white limestone which makes up almost three-quarters of the island. The orebodies occur in karst depressions and provide the only soil cover and flat lands in these areas. Mining, by the open pit method, is therefore, easy as there is practically no overburden.

Jamaican law governs the restoration of land areas which have been disturbed by mining activities. The Mining Regulations (1947), require that after mining operations are concluded; the mining company is required to restore the mined land. At a minimum, restoration should be at such a level that the land will have agricultural or pastoral productivity to the pre-mining level.

The restoration process begins at the pre-mining stage, where the topsoil is removed to a depth of not less than six inches. This topsoil is stockpiled some distance away from the periphery of the orebody, for use in reclamation work after mining.

The mining process then follows. The mining of bauxite usually produces numerous pits, and the process of reclamation consists of recontouring these pits and replacing topsoil. The total area disturbed and graded has been estimated to be almost two times the original size of the orebody. Because of the resulting thin top soil layer, traditional use of reclaimed lands has been for cattle grasslands and pasture. There is a common belief that this reclaimed land is only good for cattle ranching. This is a misconception that the Jamaican government must remedy. There are now examples of reclaimed lands being used successfully with other agricultural uses. These other agricultural usages are new enough that it is incumbent upon the Jamaican Government to implement an educational program. The most common scenario now is that prior to mining, the land owners are small farmers raising tree crops such as citrus along with other cash crops. After mining, when the lands have been restored, these same farmers have very little knowledge of their options in applying new agricultural crops to the land. At this point, a visit from an agricultural extension agent may help to inform this farmer what new crops and animal husbandry techniques are available.

Three Steps to Reutilization

Bauxite can be considered the original soil, generally overlaying limestone. Much of the environmental impact is based on the removal of the soil cover in vast tonnages. Regulations designed to mitigate this impact have three phases: reclamation, restoration and reutilization.

- **Reclamation**

This refers to all the activities necessary to reshape and resoil a mined area. Bauxite deposits mined out can leave deep pits which are filled in while recontouring the surrounding land. Pre-stripped soil is placed on top as a part of the reclamation process.

- **Restoration**

This refers to all activities necessary to produce a crop on the land after it has been reclaimed. Routinely, this means the planting of pasture grasses on top of the reclaimed area.

- **Reutilization**

This refers to the use of the land after restoration. After reclamation and restoration, the Ministry of Mining inspects the land and issues a Certificate of Fitness if criteria are met.

Integrated Planning

A review of the flow of information for a modern bauxite/alumina firm (schematic 2) shows that the environmental aspects of the bauxite/alumina issue touch all stages of a company's decision process.

New Regulations

The Natural Resources Conservation Authority Act (NRCA), passed in 1991, is a broadly based bill focused on the environment. Significant portions of the provisions clearly relate to bauxite mining and alumina processing. This bill may become a major force influence in determining what and how bauxite is mined and processed. This may occur in that:

- The bill is comparable to legislation within the United States, Canada and Europe, in which environmental issues have had profound impact on the mining industry.
- Most regulations and agreements related to the bauxite industry generally do not have strong provisions if there is a breech. With the NRCA, however, if the provisions are contravened, considerable fines and imprisonment can occur.
- The bill establishes the Natural Resources Conservation Authority, with functions of managing the physical environment to ensure the conservation, protection and proper use of Jamaica's natural resources.
- The Authority has been given the charge to formulate standards and codes of practice to be observed for the improvement and maintenance of the environment, including the release of substances into the environment in connection with any works, activity or undertaking.

The last point focuses upon a primary area of importance. Environmental discharge regulations, must be issued by governmental regulators knowledgeable in the bauxite and alumina industry. Any new standards must not be arbitrary, but on conditions found in Jamaica. All too often, standards set by organizations such as the World Health Organization, the United States Environmental Protection Agency, etc. are enforced without research. It is recommended that Jamaican officials conduct seminars and training programs to learn how such limits are calculated.

- **Potential Erosion**

To mine bauxite, large areas are stripped of vegetation. In many mining situations around the world, catastrophic erosion of top soil can be of concern if appropriate surface contouring is not maintained. One nice feature of the majority of Jamaican bauxite is that the remaining soil limestone is so porous that post-mining erosion tends to be quite resistant to erosion. Still it is prudent to recontour the post-mine landscape to minimize any potential erosional problems.

- **Post-mining Ground Water Quality:**

The mining of many ores around the world can cause an extreme change in ground water quality. Experience, in both metal and coal mining, has shown that ground water flowing through waste and spoil piles can become quite acidic. This drop in pH, can then bring high metal levels into water percolating through, reducing the resulting ground water quality considerably. Fortunately, this is not the experience in mining bauxite. After mining, both the bauxite ore, and the remaining material does not exhibit any dramatic change in geochemistry.

Table 2 lists the current parameter thresholds in water as specified by various parties. It will be a major task of the Government to establish what the allowable level for each parameter is and then have the capacity to perform on-site measurements. In turn, the Government must select what sampling protocols, analytical techniques, averaging methods and reporting standards are acceptable.

PARAMETER	INTERNATIONAL STANDARD	PROPOSED GOVT. STANDARD	PROPOSED INDUSTRY STD.
pH	6.5 - 8.5	6.0 - 8.0	6.5 - 8.5
TDS	1000 ppm	400 ppm	1000 ppm
SULPHATE	400 ppm	50 ppm	400 ppm
CHLORIDE	250 ppm	150 ppm	250 ppm
NITRATE	10 ppm	20 ppm	20 ppm
MAGNESIUM	50 - 150 ppm	50 ppm	
TURBIDITY	5 NTU	5 NTU	5 NTU
SODIUM	200 ppm	80 ppm	200 ppm
TOT. HARDNESS		500 ppm	500 ppm
ALKALINITY	150 - 300 ppm	350 ppm	
ELEC. COND.	<750 mmhos/cm³	750	

TABLE 2: WATER QUALITY

- **Dust, Air Pollution and Noise:**

The process of mining, re-handling and loading bauxite can create dust . Furthermore, the transport of bauxite by haulage trucks can also create a dust problem. The issue of whether bauxite dust is of concern as a health issue has not been established. However, extensive dust production can create a public relation problem for mining companies. It was observed by this author, that the mining companies currently producing bauxite are very aware to this potential problem, and have developed dust suppression methods. These methods are broken into three basic categories: wetting roads with water, spreading oil on haul roads, and the use of magnesium chloride as a road armor. If waste oil is used for the oiling process, an analysis of any hazardous contaminants is recommended. With regard to water and magnesium chloride, both these methods are currently considered to be environmentally save. The mining process, and particularly the transport of bauxite by beltway can create high noise levels. Because the mining and the transporting of bauxite can occur in populated areas, some concern exists for the effects on local citizens. Frequent noise monitoring of belt-ways, re-handling stations and load-out facilities should be done. Just as in the case of dust, noise issues may be more of a public relation concern than a proven health problem. Mining and haulage equipment must be properly maintained and have effective exhaust mufflers. This authors observation of older belt systems, indicates that they can be quite noisy; especially if lubrication and other maintenance is not maintained. Observation of newer belt systems, shows that they are significantly quieter, with shrouded motors and rubber wheeled idlers.

The Mining Safety and Health Regulations of 1977 is unique in that it sets limits for ambient air quality in a mine or industrial plant. Under these regulations, dust and gas emissions must be measured at an adequate interval to determine compliance. This act has not been too effective as it does not authorize for strong enforcement.

Table 3 on page 27, lists air quality and noise standards. There are extensive measurement and sampling protocols available. The Jamaican government must select which protocols will be accepted and require industry to conform.

PARAMETER	AVERAGING TIME	INTERNATIONAL STANDARD	MINING REG. STANDARD
SO_2	8h 24h	 0.14 ppm	5 ppm
NO_2	8h 1 yr (arith. mn)	 0.05 ppm	5 ppm
CO	8h	9 ppm	50 ppm
SUSP. PART. MATTER		$5g/m^2/mth$	
NOISE	8h	90 dba	50 - 60 dba (proposed Govt Std.)

TABLE 3: AIR QUALITY

In summary, it is recommended that the Jamaican Government, through a selected agency:

- Specify acceptable parameter emission levels.
- Specify measurement and analytical techniques.
- Specify reporting standards.
- Acquire the equipment and expertise to monitor these parameters unilaterally.

This last point can be addressed with the acquisition of a mobile environmental laboratory which can be scheduled to monitor the bauxite/alumina industry.

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