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NON-FERROUS METALS INDUSTRY

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ARTHUR D. LITTLE, INC.

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I. SUMMARY

I. SUMMARY

A. OBJECTIVES

The objectives of this study are to identify industrial development opportunities for Bolivia in the non-ferrous metals sector of the economy. For those opportunities having the most promising feasibility or prefeasibility studies are recommended.

B. SCOPE

The non-ferrous metals sector was defined to include the products in Appendix A. To these we added uranium, non-ferrous alloys, and ferro-alloys. Opportunities were examined within the context of Andean and world markets.

C. APPROACH

The approach toward screening opportunities placed major emphasis on resources, markets, and minimum economic scale of plant. Our analysis included opportunities for expanding existing industries and for establishing new ones. Field investigations were made in Bolivia, other Andean countries, and major world mineral and metal trading centers to collect data and information. Interviews were conducted with key industry and government personnel in order to develop criteria for the selection of potential opportunities. In addition, we reviewed published and unpublished reports and examined our own in-house information.

A number of steps were taken to screen opportunities. First, we examined the country's non-ferrous mineral resources to determine the products that can be produced in Bolivia for export to the Andean Subregion, Latin America, and World markets. Wherever necessary Bolivia's non-ferrous mineral resources were compared with those in other countries to determine Bolivia's competitive position from the stand point of resources.

The second step in the screening process was to examine the market for resources available in Bolivia in commercial quantities. Our market analysis focused on World markets, the Andean Subregion and Latin America. Because Chile and Peru have large reserves in many of the same minerals available in Bolivia and, in a number of cases such as copper, lead, and zinc, substantial production of the metals derived from these minerals, we have focused a major part of our attention on world markets. An equally important factor in this decision has been that many of the metals produced from minerals available in Bolivia are sold on the world market. Moreover, in many cases the minimum economic scale of plant is beyond the present or foreseeable size of the Bolivian or Andean markets and therefore, World markets are of greater interest.

For upgrading opportunities beyond the metal stage we focused attention on domestic, Andean and Latin American markets.

One of the major difficulties with respect to most of the metals indigenous to Bolivia (i.e. tin, lead, copper, zinc, bismuth, antimony, tungsten), however, is that they are not important structural metals. The use of these metals is largely for specialty applications such as alloying and coating and for the production of chemicals. Zinc and some of the copper based alloys have structural applications, but these are secondary applications as compared to steel and aluminum. Most light and heavy manufacturing and metal working opportunities are based on steel and alumirum; the base and alloying metals play are important but relatively small part.

Many of the metals available in Bolivia such as tungsten, tin, bismuth, antimony and copper have a high value. The opportunities for Bolivia are to take advantage of the value and scarcity of these metals.

Finally we determined for every product that indicated promise the manufacturing considerations affecting its production in Bolivia.

D. CONCLUSIONS

Our analysis of Bolivia's non-ferrous metal resources indicates that tin, bismuth, zinc, lead, copper, antimony and tungsten have reserves in sufficient quantity and quality to be exploitable (table 1). Other minerals are also available but

TABLE 1

BOLIVIAN RESERVES OF NON - FERROUS MINERALS
PROVEN, INDICATED AND INTERFERRED
(In Tons)

Mineral	Proved and Indicated	Inferred
Tin	1,083,428	350,600
Bismuth	13,200	2,000
Zinc	1,210,000	2,000,000
Lead	232,000	495,000
Copper	311,000	500,000
Antimony	145,000	50,000
Tungsten	57,700	100,000

their quantity is unknown. It is probable that as more exploration is conducted the quantity of reserves will increase.

Our study has indicated that it would be to Bolivia's benefit to convert as much of the minerals currently exported as concentrates into metals. Table 2 presents for tin, zinc, antimony, bismuth, and tungsten the value added if Bolivia were to convert its concentrates into metals. It clearly illustrates the benefits derived from upgrading. If Bolivia had sold 1969 production of these minerals in metal rather than in concentrate form it would have earned an additional US$ 23.8 million.

Our analysis has identified a number of opportunities in the non-ferrous sector as follows:

Upgrading of Tungsten, Copper and Zinc;
Production of ferro-alloys and non-ferro-alloys;
Exploration;
Marketing.

1. Upgrading of Tungsten, Copper, and Zinc

a. Tungsten

Bolivia, as a very important factor in world tungsten production and reserves and in view of a very strong world demand, is in a position to upgrade its tungsten concentrates to much higher value products. World consumption of tungsten has been growing at a rate of 4%

TABLE 2

VALUE ADDED BY CONVERSION TO METAL

Metal	Sales Value: Per Ton of Metal Content of Ore		Sales Value: Added by Conversion to Metal	1969 Output (Long Tons)[2]	Gross Sales Value: Ore (U.S. $)	Gross Sales Value: Added by Conversion to Metal (U.S. $)
Tin	3,240	+	120	29,900	96,480,000	3,840,000
Zinc	228	+	72	26,300	6,000.000	1,896,000
Copper	900	+		8,000	7,200.000	864,000
Antimony	960	+	108	12,300	11,760,000	1,776,000
Bismuth	6,960	+	2,640	600	4,176,000	1,584,000
Tungsten	6,000	+	6,000 (1)	2,300	13,800,000	13,800,000

(1) Hydrogen Reduced Power

(2) One Metric Ton = 0.98 Log Ton

per year but in the next several years it should increase at a rate of 5 - 10%.

Our analysis has indicated that there is a very promising opportunity to upgrade concentrates by processing to at least refined tungsten oxide (WO_3) which would yield an increment of 33% in value over that of concentrates. More important there may also be an opportunity to produce ferro tungsten (about a 50% increase in value) or ideally hydrogen reduced powder (100% increase in value). In addition, there are opportunities for upgrading significant amounts of Bolivian tungsten to carbide powder which has a value two-and one-half times that of concentrates and lesser amounts to sintered carbide blanks which have a value four times greater than concentrates and finally to tools with a value over ten times greater than concentrates.

It is also possible that the hydrogen reduced powder could be sintered and swaged into mill products with values ten to thirty times greater than concentrates. However, mill products use relatively small amounts of the total tungsten produced (about 25% of total consumption) and the investment required for their production may be not justified.

The most logical approach towards upgrading tungsten would be to focus on sintered tungsten carbide blanks and tools and the intermediate products which include refined tungsten oxide, hydrogen reduced powder, and tungsten carbide powder. These are the major volume products, accounting for 40% of end use as compared to 25% for mill products and 11% for ferro-tungsten. The remainder of tungsten is accounted by miscellaneous uses such as sheelite and wolframite concentrates which are added directly to steel for alloying and carbon reduced powder used for ferrous and non-ferrous alloys.

The investment required for facilities to upgrade tungsten to carbides and tools would be in the range of US$ 6.0 million, depending on the volume of tungsten concentrates treated and the likely proportion processed to tools.

In summary our analysis has indicated that the upgrading of tungsten concentrates represents an outstanding opportunity for Bolivia.

b. Copper

In comparison to Perú and Chile, Bolivia is a very small producer of copper. In recent years Bolivian yearly production of concentrates has been about 8000 tons as

against 650,000 tons by Chile and 200,000 tons by Perú.

At this time Bolivia does not produce sufficient concentrates to justify the establishment of a copper smelter whose minimum economic scale of plant is about 30,000 - 50,000 tons of blister copper per year. A very promissing opportunity, however, exists for increasing reserves through an increase in exploration effort. After additional reserves have been found Bolivia should consider the installation of a smelter.

A small interim opportunity exists for the production of copper and copper alloys. The copper produced would be used to supply the domestic market; the copper alloys would be a part of a non-ferrous alloy complex. About 10% of the copper in concentrates presently produced in Bolivia is in the form of native (uncombined) copper which could be separated by flotation at the present mills. Native copper which is nearly the equivalent of scrap, could be melted and fire refined to produce copper metal of adequate quality for the production of alloys such as bronze and brass. It would not be suitable for electrical use. As the production of concentrates increases and additional amounts of native copper are separated, a small electro-

lytic refinery producing 1000 tons to 3000 tons per year would probably be justified. This refinery would convert the fire refined native copper to electrical grade copper.

There is also a potential opportunity to recover copper from oxidic copper ores. Most copper ore bodies that outcrop have oxide copper zones at the surface above the massive sulfides. These oxidized ores cannot be concentrated by physico-chemical beneficiation methods such as flotation but instead must be leached with sulfuric acid and the copper recovered by electro-winning the metal from the copper sulfate solution. Electro-winning copper from the solutions will result in high purity copper suitable for electrical use.

c. Zinc

Bolivia currently produces about 26,000 tons annually of zinc concentrate. The reserves of zinc are estimated at 1,210,000 tons, proven and indicated, with an additional 2.0 million tons inferred. We estimate that Bolivian zinc reserves are sufficient to support the present level of mining operations for about 40 years.

The construction of an electro-winning plant to produce zinc metal in Bolivia is in the planning stage. Although zinc smelters in other producing countries have in recent years experienced losses, our analysis has indicated that the

world market outlook for zinc is promising and that a Bolivian smelter would benefit from an improved market. The production of electrolytic zinc in Bolivia should also generate opportunities for die casting and galvanizing, which are the major uses of zinc metal.

2. Production of Ferro-Alloys and Non-Ferrous Alloys

a. Ferro-Alloys

The high volume ferro-alloys are ferro-manganese, ferro-silicon and by product silico-manganese; ferro-chrome and ferro-nickel are also important. Ferro-alloys of molybdenum, titanum, tungsten, vanadium and columbium are produced in much smaller quantities.

Bolivia has known resources for the production of ferro-tungsten and ferro-silicon. Potential resources for the production of ferro-manganese are also known to exist in Bolivia. However, the manganese to iron ratio may not be sufficiently high to produce all the commercial grades of ferro-manganese. Bolivia also has showings of nickel, molybdenum and titanium and a possibility of vanadium associated with uranium. If commercially exploitable quantities of these minerals are found in Bolivia ferro-alloys could also be produced from them.

In the Andean Subregion Chile is the only producer and net exporter of ferro-alloys. The Andean market imports approximately 4000 tons to 5000 tons of ferro-alloys per year.

In other South American countries Brazil and Argentina produce ferro-alloys; of the two only Brazil produces a full range of ferro-alloys.

This analysis indicates that an opportunity exists for Bolivia to produce ferro-alloys to export to the Andean markets and also to selected South American countries. The opportunity for Bolivia would probably be in some of the high value ferro-alloys, particularly those where the raw material is a large part of the value of the end product and where the ferro-alloy metal would be available in Bolivia. Examples of these may be ferro-tungsten, ferro-manganese and possibly ferro-nickel, ferro-molybdenum and ferro-vanadium. The production of alloys such as ferro-silicon do not represent promising opportunity since the cost of the raw materials (i.e. sand and iron ore) are a small proportion of the total cost. It may be necessary, however, to produce ferro-silicon in order to provide a line of ferro-alloys.

A small 5000 ton to 6000 ton ferro-alloy plant would require a capital investment of about US$ 1.5 million for the plant

facilities. A ferro-alloy plant is normally easily expandible by adding furnaces individually. As a result a small plant could be installed initially and subsequently expanded as demand for the product rises.

The profitability of a small ferro-alloy plant would be marginal if it produced only the high volume, low value (US$ 140 - US$ 275 per ton) ferro-alloys such as ferro-silicon and ferro-manganese unless power costs were very low (i.e. in the range of 5 - 9 mills per kwh). On the other hand, if high value ferro-alloys based on Bolivian raw materials were produced such as ferro-tungsten the facilities would be very profitable.

In summary the production of ferro-alloys in Bolivia represents a very attractive opportunity. Its viability however would depend on the market for specific ferro-alloys and on the availability in Bolivia high value raw materials. With the exception of tungsten, there is no significant loss in the value of metals such as manganese, nickel vanadium or titanium if they are converted to ferro-alloys instead of to pure metals. Since tungsten can be easily upgraded to powdered metal and carbide, the best approach would be to convert a portion of tungsten to ferro-tungsten but only if it represented one of a number of ferro-alloys produced. The installation

of a ferro-alloy plant to produce only ferro-tungsten would not represent the most attractive alternative.

b. Non-Ferrous Alloys

The variety of non-ferrous metals available in Bolivia suggests the possibility of producing a broad range of non-ferrous alloys such as a wide variety of solders, bronzes (both tin and phosphor), tin and lead Babbits, white metal alloys, low melting alloys (bismuth), tin-copper, zinc, cadmium, nickel, and lead electroplating alloys and pewter. The viability of this project would depend on the market.

Accurate statistics on the market for non-ferrous alloys are difficult to obtain. Our analysis however, has indicated that the market in the Andean Subregion is in the order of US$ 1.0 per year and in the LAFTA area US$ 4.0 per year. These market figures are subject to confirmation. It is probable that Bolivia could supply part of the Andean market, although Perú produces many of the same metals.

The World market for non-ferrous alloys is large relative to the Andean and LAFTA markets. To enter World markets, however, would involve replacing traditional suppliers which may be difficult. The tin and bismuth based

(high value) alloys would have better possibilities to penetrate the World market than lower value lead and copper alloys.

The availability of tin metal, silver, antimony, zinc, lead metal, and bismuth places Bolivia in a very favorable position to produce non-ferrous alloys. While other countries produce many of these metals, very few produce both tin and bismuth which are the basis for the high value non-ferrous alloys. Another factor which should be taken into consideration is that a certain volume of by-product mixture of metals will be produced at the Klockner smelter which will either have to be refined or converted to useful alloys by appropriate primary metal additions. Refining of these mixtures would probably have to be conducted in Europe and, therefore, the by-product value would be low. A better alternative would be utilize the products in alloy manufacture.

The old Metabol or Peró smelter with additional capital investment could probably produce non-ferrous alloys.

3. Exploration

Our analysis has indicated that large opportunities exist for Bolivia to increase and hopefully discover higher grade reserves and placer deposits of tin through intensified ex-

ploration. Similarly we are optimistic that a well planned exploration program would have a good probability of finding additional reserves of antimony and bismuth and perhaps nickel, molybdenum (often associated with copper), vanadium (often found with uranium) and rutile.

Uranium exploration is of particular interest since demand is expected to increase by 500% over the next ten years. Present consumption is 11,000 tons per year of U_3O_8 and it is forecasted to increase to 63.600 tons by 1980; the accumulative demand during the 1970 - 1980 period is expected to be 363,600 tons. World reserves are currently about 763,600 tons of U_3O_8, adequate for only about 15 years.

4. Marketing

Government controlled Bolivian organizations have had experience marketing concentrates but not in marketing metals. In the near future as smelting capacity is installed Bolivia will be marketing tin, bismuth, antimony metal and oxide, zinc, and perhaps tungsten. Tin, lead and zinc are relatively easy to market since they are sold on the London Metal Exchange common pricing basis. The significance of this is that any new or occasional supplier can expect to obtain the same price as a traditional supplier. This is not the case for antimony, tungsten, and bismuth nor would it be true for non-ferrous alloys. The

market for these metals has been traditionally supplied by a limited number of producers who have established over a long period of time close customer links and who compete more on service, quality, and product variation than on price. They recognize a mutual self interest to maintain a common and stable pricing policy. In other words, they recognize price leadership by one or two companies and stockpile material, or very occasionally ration it, as necessary, giving only limited discounts from a recognized and consistent world price, as indicated by the supply demand balance.

In the late 1950's and 1960's, a number of new suppliers of antimony entered the market who, for various reasons, were either uninterested or unable to establish permanent relationships with customers. As a result, these companies offered metal purely on a price basis, obtaining for their antimony metal whatever price was available at the time; this was a "free market". On most occasions this meant selling the metal at a substantial discount from the existing producer price. On very few occasions did they receive a price near the producer price and only in 1969 was the price at which the antimony metal was sold above the producer price.

In the case of bismuth a free market has been reported by the Metal Bulletin of London as of January, 1969, although the market probably existed two or three years before this date. Such

a market does not presently exist in tungsten but should Bolivia begin to produce and sell an upgraded product such as hydrogen reduced powder or tungsten carbide, this will create a free market, unless permanent customer contacts are established.

Our experience indicates that free market price has generally been 20% to 30% below the producer price (except in bismuth). In practice, the discount has probably been closer to 15% since, as mentioned earlier, producers do in fact discount prices to their better customers during periods when the market is soft. This would not be reported in the Metal Bulletin. It is reasonable to assume that a similar discount would develop in tungsten if there were spot suppliers.

Table 3 indicates the effect on Bolivian revenues from free market discounts for Antimony, Bismuth, and Tungsten. Assuming that Bolivia sells 6,000 tons of antimony, 400 tons of bismuth and 2,000 tons of tungsten, the loss in revenues would be US$ 5.1 million if the discount is 15%, US$ 3.4 million if the discount is 10% and US$ 2.6 million if the discount is 7.1/2%.

E. RECOMMENDATIONS FOR FEASIBILITY OR PREFEASIBILITY STUDIES

Feasibility studies should be conducted to determine the economics underlying the:

Upgrading Tungsten
Upgrading Copper;
Production Ferroalloys
Production non-ferro-alloys

A prefeasibility study should be conducted on the possibility of producing ferroalloys in Bolivia.

We also recommended a study that would identify the market strategy required by Bolivia to gain the greatest revenues from the sale of metals. It would cover antimony, bismuth and tungsten and perhaps non-ferrous alloys and zinc. It would evaluate for each metal the price levels in various countries, the competitive situation, the cost of entry (taxes, freight, etc.), the product forms and quality levels required, the use of agents on direct sales forces technical services required, and the desirability of maintaining stocks in the market areas. This analysis would identify the most profitable markets and permit the creation of a plan aimed at maximizing opportunities within those markets. The information collected on product forms and quality would be of great value in the planning of smelter facilities.

TABLE 3

LOSS IN BOLIVIAN REVENUES DUE TO FREE MARKET DISCOUNTS

Metal	Volume of Metal Long Tons	Sales Revenue At A.D.L. 's Projected Levels of Producer Prices	Revenue with Discount 15% (U.S.$)	10% (U.S.$)	7-1/2% (U.S.$)
Antimony	6,000	6,624,000	5,552,000	5,961,600	6,120,000
Bismuth	400	3,840,000	3,264,000	3,456,000	3,552,000
Tungsten	2,000	14,000,000	20,400,000	21,600,000	22,200,000
		34,464,000	29,316,000	31,017,600	31,872,000
		Deduction of	5,148,000	3,446,400	2,592,000

II. T I N

II. T I N

A. RESOURCES AND PRODUCTION

Bolivia is the world second largest producer of tin-bearing minerals, exceeded in the last decade only by Malaysia (table 4). Within Andean Subregion, Bolivia is the only producer of tin concentrates and metal and there is little question that it should be its major supplier both in concentrates and metal.

It is well recognized that the potential reserves of tin ores are extensive in Bolivia. They are currently estimated at nearly 690,000 tons (Table 5) of contained tin in proven and indicated ore reserves (over 20 years' reserves at current production levels of 30,000 metric tons per year). However, only 247,000 metric tons of contained tin are in proven reserves (8 years at present production). As a result, there is a need to develop additional reserves, particularly higher grade reserves. This is further evidenced by the low grade of COMIBOL's reserves and by BID's request to COMIBOL to prove up additional reserves to support the Vinto project.

Concentrate production figures (table 4) indicate that Southeast Asia is the major supplier of tin in the world. Malaysia is by far the world's largest tin producer, followed by Bolivia and Thailand. Of importance is the decline in importance experienced by Indonesia, in the decade of the 1950's.

TABLE 4

PRODUCTION OF TIN-IN-CONCENTRATES

1950 - 1969

(Thousand Long Tons)[1]

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
WESTERN WORLD TOTAL[2]	162	163	165	170	169	168	166	163	116	119	136	137	142	141	147	152	163	172	182	177
CHINA (Popular Rep.)	4	5	5	6	6	12	14	16	18	21	24	24	24	24	25	25	25	N/A	N/A	N/A
MALAYSIA AND SINGAPORE	57.8	57.4	57.1	56.4	60.9	61.2	62.3	59.3	38.5	37.5	52.0	56.0	58.6	59.9	60.0	63.7	68.9	72.1	75.1	72.2
BOLIVIA	31.2	33.1	32.0	34.8	28.8	27.9	26.8	27.8	17.7	23.8	20.2	20.7	21.8	22.2	24.2	23.0	25.5	27.3	29.1	29.6
INDONESIA	32.1	31.0	35.0	33.8	35.9	33.4	30.1	27.7	23.2	21.6	22.6	18.6	17.3	12.9	16.3	14.7	12.5	13.6	16.6	16.3
NIGERIA	8.3	8.5	8.3	8.2	7.9	8.2	9.2	9.6	6.2	5.5	7.8	7.8	8.2	8.7	8.7	9.5	9.5	9.3	9.7	8.6
CONGO	11.8	11.8	11.9	13.2	13.1	13.1	12.8	12.5	9.7	9.2	9.2	6.6	7.2	7.1	6.5	6.2	9.7	7.0	6.6	6.5
AUSTRALIA	1.8	1.6	1.6	1.6	2.1	2.0	2.1	2.0	2.2	2.3	2.2	2.7	2.7	2.9	3.6	3.8	4.5	5.6	6.8	8.0
THAILAND	10.4	9.5	9.5	10.0	9.7	11.0	12.5	13.5	7.7	9.7	12.0	13.3	14.7	15.6	15.6	19.0	22.5	22.5	23.6	20.8
BRAZIL							.2	.3	.4	.5	1.5	.6	.7	1.1	1.2	1.2	1.6	1.7	1.8	2.4
ARGENTINE	N.A.						.1	.2	.2	.2	.2	.5	.6	.5	.8	1.2	1.3	2.0	1.7	1.9

[1] A metric ton equal .98 long ton.

[2] Excluding China, U.S.S.R., East Germany, Czechoslovakia, North Vietnam (after 1954)

SOURCE: 1950 - 1966 I.T.C. 166 Statistical Year Book.

TABLE 5

TIN RESERVES
(Tons contained Tin)

	PROVEN		INDICATED		Tailings and Dumps	INFERRED
	Ore Content % Tin	Metric Tons Tin	Ore Content % Tin	Metric Tons Tin	Tons Tin Proven & Indicated	Tons Tin
COMIBOL	0.97	170,400	0,62	347,832	246,900	
Medium Mines	1.12	52,745	1.77	43,851	147,700	
Small Mines	2.50	24,000	2.50	50,000	---	
Total Tin		247,145		441,638	394,600	350,600
Total Tin						
Proven & Indicated					1,083,428	
Inferred						350,600

Chinese production of tin has followed a rising trend and although it is not an exporter of tin at present it is expected that in the long-term it will have the capacity to export. Southeast Asian production of tin in the middle to late 1960's has remained at approximately constant levels as a result of limits it encountered in onshore expansion. It is currently attempting to increase reserves through offshore exploration.

Southeast Asia holds the key to the tin situation since it currently supplies more than 60% of Western World requirements, at relatively low prices. Malaysia's onshore reserves are being depleted and those familiar with the area suggest that lack of exploration is not the cause. The future of Southeast Asian production depends on the discovery of offshore deposits. There are indications that Malaysia has limited offshore potential. On the other hand, the possibility of discovering tin in Thailand's and Indonesia's offshore areas is promising.

Southeast Asian mining costs are extremely difficult to identify, as operations range from Chinese family operations to large, internationally financed dredges. However, the following onshore total operating costs, including depreciation and taxes for concentrate at the mine head, for various African and Southeast Asian countries are generally representative:

COUNTRY	OPERATING COSTS (US$/LF)
Thailand	0.45 - 0.90
Malaysia	0.50 - 1.00
Indonesia	Unknown but probably higher than either Thailand or Malaysia
Nigeria	0.75 - 1.30
Congo	0.85 - 1.40

The cost of mining tin in Southeast Asia has been rising as a result of increasing capital costs and wages. This trend will continue since in order to maintain production, offshore tin deposits will have to be exploited. The capital costs associated with offshore mining are about 5% greater than the average for on-shore operations.

1. Costs Include an Unusually High Tax

Bolivia, at present is the highest cost producer of tin concentrates in the world. It is well recognized that the deposits which essentially represent all of Bolivia's reserves are more expensive to mine and mill than the placer deposits which constitute the major part of tin production in other locations. It costs COMIBOL in the range of US$ 0.90 - US$ 1.70 (the average is US$ 1.52) to place a pound of tin concentrates on the world market. Similar costs for the medium miners are about US$ 1.40 per pound. These costs include transport to the smelters. Mining and milling costs are US$ 1.11 - US$ 1.27 per pound. On the other hand, the

costs incurred by a large company in Bolivia for placer operations are US$ 0.60 - US$ 0.80 per pound. Placer mining at present, however, accounts for a minor portion of Bolivia's tin production.

This analysis indicates that at present Bolivia is at a competitive disadvantage in the world tin market. To make a profit it has had to maintain a high minimum price for tin, currently at US$ 1.40 per pound (1).

In the future it is possible that Bolivia's competitive position will improve as the costs of other tin producing countries will rise.

The International tin Council's price range is currently US$ 1.40 per pound minimum and US$ 1.70 per pound maximum use. This will be particularly the case if its current efforts to find placer deposits in the Beni are successful and if higher grade deposits are found. The new beneficiation plant at Vinto and Klockner smelter will also hopefully have a favorable impact on costs.

B. MARKETS

Tin is truly an international commodity with major markets in the industrialized countries, where it is used for tin plating (50%), solder (30%), and alloying, in order of importance. There are a number of other miscellaneous uses, none of which are of great significance. The U.S., Europe and Japan account for over

(1)----------
The International Tin Council's price currently ranges from US$ 1.40 per pound minimum to US$ 1.70 per pound maximum

two thirds of demand (Table 6).

The data in Table 6 also indicates that the market was relatively weak in the 1950's. In the 1960's, however, it underwent a relative improvement mainly as a result of increases in Japanese demand and, to a lesser extent, in countries falling in the "rest of the world" category. The overall growth of tin demand between 1950 and 1969 was 1% between 1963 and 1969 the growth rate was 21/2% per year.

It is difficult to project demand for metal. There are a number of reasons for this situation. First, tin mining countries have a reputation for political instability which continues to encourage the industrialized countries to search for tin substitutes. This has been partly offset by the substantial problems that have been encountered in the adoption of tin free steel. In the future another factor that may help offset losses in tin demand due to substitution is the substantial increase expected to originate from developing countries. Second, demand from Eastern European countries and communist China is a completely unknown factor which could upset any prediction. It has been argued by knowledgeable individuals that the growth in consumption in the late 1960's of 2% per year indicates a permanent turnaround, and that tin in the future will experience continued, if not exciting, growth at about this same rate.

TABLE 6

CONSUMPTION OF PRIMARY TIN METAL

1950 - 1969

(Thousand Long Tons)[1]

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
WORLD EXCLUDING EAST BLOCK AND CHINA	145	132	124	124	132	140	147	139	0	148	162	158	160	162	171	167	170	168	175	181
U.S.A.	71.2	56.9	45.3	54.0	54.4	59.8	60.5	54.4	48.0	45.8	51.5	50.3	54.6	55.2	58.6	58.6	60.2	57.8	58.9	57.4
UNITED KINGDOM	23.3	23.9	22.6	18.9	21.7	22.9	21.8	21.5	19.2	20.6	21.8	20.2	21.4	20.6	19.3	19.3	18.4	17.4	17.1	17.8
JAPAN	4.6	4.1	4.5	5.0	6.0	6.5	9.8	8.3	9.6	10.7	12.9	14.3	13.8	15.9	17.9	17.2	18.6	20.4	22.2	25.5
WEST GERMANY	7.8	7.5	7.3	5.8	6.6	8.2	8.4	9.2	9.8	16.7	27.7	25.8	11.6	11.2	12.4	11.7	10.8	10.7	11.1	13.2
FRANCE	7.8	7.9	7.5	8.0	9.0	9.7	10.4	11.2	11.0	10.9	11.2	10.1	11.2	11.0	11.0	10.1	10.3	10.4	9.9	11.1
CANADA	4.5	4.7	4.2	4.0	3.6	4.0	4.1	3.6	3.3	4.2	3.9	4.0	4.5	4.9	4.8	4.9	5.0	4.8	4.3	4.3
AUSTRALIA	2.3	2.4	2.4	2.3	2.5	2.4	2.3	2.7	3.2	3.5	3.9	3.3	4.5	4.7	4.6	4.5	4.3	4.4	3.8	3.8
OTHERS	33										29									48

[1] A metric ton is equal to .98 long ton.

SOURCES: International Tin Council Yearbook and Statistical Bulletin.

Table 7 presents tin metal prices for the 1950 - 1970 period. The data clearly indicate that prices were stronger in the 1960's than in the 1950's. During the 1950 - 1960 period prices averaged about US$ 1.01 per pound; during 1960 - 1970 the average price was US$ 1.44 per pound. Price varied during 1950 to 1960 from US$ 0.90 to US$ 1.35; the fluctuation during the 1960 - 1970 decade was from US$ 1.00 to US$ 1.77.

All tin metal prices quoted in the Western World are directly related to the London Metal Market (LME). There is no free or producer price. Ore is sold on the basis of the LME metal price for the metal content of the ore, less a refining charge related to the grade of the ore. This charge is quoted regularly in the London Metal Bulletin and while their figures are not entirely accurate they indicate trends.

They also reflect the substantial difference between charges for Southeast Asian ore and for Bolivian ore. Southeast Asian ore, in general, carries a charge of US$ 48/ton, plus 1% deduction of metal content value to cover melt loss, totaling US$ 84/ton. Bolivian ore on the other hand, taking Williams Harvey prices, in the past has carried a charge of US$ 52.70/ton with a 1.3% deduction of metal content value; at present it is roughly US$ 86.40 per ton of concentrate which with the deduction for melt loss amounts to US$ 132.00 per ton. Lower grade ore incurs a conversion charge equal to US$ 144 to US$ 168 per ton. Adjustments to the

TABLE 7

ANNUAL TIN PRICES
1950-1970
(U.S.$ Pound)

Year	Price	Year	Price
1950	0.93	1961	1.11
1951	1.35	1962	1.12
1952	1.21	1963	1.14
1953	0.92	1964	1.55
1954	0.90	1965	1.77
1955	0.93	1966	1.60
1956	0.99	1967	1.51
1957	0.95	1968	1.44
1958	0.92	1969	1.55
1959	0.98	1970(Aug)	1.60
1960	1.00		

Sources: International Tin Council Statistical Yearbook

International Tin Council Statistical Bolletin.

actual toll price are computed, not by increasing the base figure, but by adjusting the interest charges, impurity charges, volume discounts, and other such items.

Metal is sold at the LME price by its owners whether they are smelters, miners, or traders, to customers that can be consumers or traders. A large proportion of tin metal moves without the intervention of a trader. As in copper, the LME market for tin is made on the basis of a small percentage of the volume actually used in the world.

Future tin prices are difficult to predict. Our field work and analysis suggests that the average price during the 1970's will be towards the high end of the range experienced in the 1960's or about US$ 1.50/lb. This projection assumes that there will be little or no inflation and that production will not expand at a rate greater than 5% per year. Moreover, it is probable that prices will fluctuate around this average; indeed they may well fall temporarily during the next few months.

A long-term development of great significance in respect to price is the decision of the International Monetary Fund to support the international Tin Agreement by lending, at a low rate of interest, the funds required of each member country to finance the operation of the buffer stock. In this way the major cost to countries will be the interest charge. Since the IMF has

unlimited ability to supply capital for the buffer stock manager's operations, it is certain that the support of tin prices will be much more effective in the future than in the past. Clearly, the IMF has made this decision because it is conscious of the damage of falling prices to the national budgets of developing countries.

C. SMELTING

Table 8 presents production of tin metal by major producing country during the 1950-1969 period. The data indicate that Malaysia is by far the major producer of tin metal in the world followed by the United Kingdom and Thailand (T.8) Bolivia has never been a significant factor in tin smelting. It is the last major producing country to install a tin smelter. Virtually all other tin, with the exception of that produced in Indonesia is now smelted within national boundaries. In the case of Indonesia it is not producing tin metal due to technical difficulties with their smelter.

At present there is approximately 333,200 tons of tin smelting capacity in the Western World; toll smelters account for one third of this capacity. Trade sources suggest that a good part of this capacity, perhaps as much as 100,000 tons, will have cease operations in the near future for lack of ore, as tin producing countries install their own smelters. Billiton, for example, has a capacity of 20,000 tons and currently processes probably no

TABLE 8

WORLD PRODUCTION OF PRIMARY TIN METAL

BY MAJOR PRODUCER

1950 - 1969

(Thousands Long Tons)[1]

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
WESTERN WORLD TOTAL[2]	170	163	163	174	177	170	167	158	121	114	146	136	145	143	142	149	156	174	184	175
CHINA	4.0	4.8	5.4	6.3	7.5	12	14	16	18	21	24	24	24	24	24	24	24	N/A	N/A	N/A
MALAYSIA AND SINGAPORE	68.7	65.9	62.8	62.4	71.2	70.6	73.3	71.3	45.4	45.7	76.4	79.1	82.1	84.0	71.4	72.5	71.0	76.3	88.2	87.1
UNITED KINGDOM	28.5	27.6	29.5	28.9	27.5	27.2	26.4	34.2	31.3	26.6	26.4	24.5	18.8	17.4	16.8	16.5	17.5	23.3	24.9	26.0
NETHERLANDS	21.0	21.0	27.9	27.0	28.4	26.6	28.2	28.3	17.1	9.6	6.4	2.7	4.3	5.8	15.8	18.1	12.6	13.7	8.0	5.3
THAILAND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.5	16.7	26.5	24.4	22.0
NIGERIA	-	-	-	-	-	-	-	-	-	-	-	0.6	8.0	9.1	8.8	9.3	9.9	9.1	9.8	8.8
U.S.A.	32.1	30.9	22.6	37.6	27.0	22.3	17.6	1.6	5.2	10.7	13.5	8.5	5.5	1.5	3.9	3.1	3.8	3.0	3.5	0.3
BELGIUM	9.5	8.4	10.6	9.0	11.4	10.4	9.7	9.9	8.7	5.9	8.3	6.0	8.6	7.0	5.5	4.2	4.9	4.2	4.8	4.4
BRAZIL	0.1	0.1	0.1	0.6	1.8	1.2	1.5	1.4	0.6	1.2	1.3	1.5	2.3	2.1	2.1	2.1	2.1	1.9	1.7	2.2
SPAIN	0.9	0.9	0.6	0.7	0.7	0.7	0.5	0.4	0.5	0.4	0.5	0.7	0.9	1.5	1.8	1.7	3.0	1.8	2.2	2.1
BOLIVIA	0.4	0	0.3	0.2	0.2	0.1	0.4	0.3	0.7	0.9	1.0	2.0	2.0	2.5	3.6	3.4	1.1	1.1	0.1	0.1
INDONESIA	———	———	———	N/A	———	———	0.3	0.3	1.6	1.9	1.9	2.0e	2.0e	2.0e	1.8e	1.8e	0.8	1.5	4.5	4.5

[1] One metric ton equals 0.98 long tons.

[2] Excludes China, U.S.S.R., East Germany, North Vietnam.

SOURCES: International Tin Council.

more than 5,000 tons of ore annually. Hoboken, Metallgesellschaft, and Capper Pass are probably in the same difficulty. This situation suggests that tin smelting charges by toll smelters have reached their lowest possible point, and that a country, unless it obtains significant transport savings by shipping metal rather than concentrate will not increase revenues by smelting locally. On the other hand, significant marketing advantages can be derived from domestic smelting since it gives a country an optional outlet for its ore. To gain the greatest marketing advantage the best course may be for Bolivia to sell part of its ore as concentrate and part as metal.

The tin smelter to be installed in Bolivia will process about one-quarter of Bolivia's tin production, (i.e., approximately 7,500 tons per year of tin, as compared with a total production of around 30,000 tons of tin produced in 1969 in concentrate form). The smelter project anticipates a second stage that will add an additional 7,500 tons of tin per year capacity and will require incremental investment equal to US$ 3.0 million. It is our view that a second stage would be justified and would improve the overall economics of the Klockner smelter.

The economics of the third stage which would also add capacity are questionable. Some of the British smelters have added facilities and modernized their plants in the expectation of treating tin concentrates from Bolivia. As a result, of Bolivia's plan to in-

crease the amount of tin smelted domestically, it is anticipated that these smelters will have a shortage of tin concentrate. As this shortage develops, the terms for treating tin may become increasingly favorable to Bolivia and may affect the economics of implementing the third-stage expansion of the Klockner smelter. An important factor which should influence the decision to implement the third stage of smelter is the financial and technical success of the first two stages.

An important point with respect to tin production is the purity level required by customers. In the United States, the market requires 99.85% purity as opposed to 99.75% in the United Kingdom; in Russia even lower quality is acceptable. Western Europe requires a higher purity tin than the United Kingdom. This is an important consideration for Bolivia since Williams Harvey has found that it is not economical to treat the Bolivian ore to the extent necessary to achieve U.S. or Western European grades. They prefer raise the purity level by adding higher purity metal or else sell the lower purity metal to United Kingdom or Russia. The implications for Bolivia are that the cost of converting to a higher grade suitable for the Western European and U.S.markets will be greater than currently; otherwise Bolivian tin metal will be subject to a discount of US$ 0.02 - US$ 0.025 per pound for low grade.

Since tolling charges are unlikely to be sharply reduced by processing within Bolivia, the level of smelting capacity needs to be established upon a marketing strategy designed to obtain the best overall return to the country through a combination of ore and metal sales.

D. OPPORTUNITIES

1. Tin Plate

As mentioned earlier, the major use for tin is in the production of tin plate. It would be ideal if Bolivia were in a position to either produce tin plate or to insure that Bolivian tin is used in tin plate produced in the Andean market and preferably in the South American market.

Most tin plate is produced in very large, fully integrated steel plants which can only be justified on the basis of a large growing market. The processing steps involved in the production of tin plate are among the most numerous in the steel industry. They typically include (1) reduction of ore in blast furnaces, (2) conversion to steel in open hearths or converters, (3) casting the steel to ingots, (4) reheating ingots in "soaking pits", (5) rolling to slabs on a blooming or slabbing mill, (6) rolling to coils on a hot mill, (7) pickling, (8) oiling, (9) rolling in a cold mill, (10) cleaning, (11) annealing, (12) tempering, (13) oil preparation, and (14) tinning.

The investment required for the production of tin plate is very large. Table 9 presents per annual ton of production (column 2) typical capital costs for large mills. Yields are included in the calculation and, as a result, if the capital costs at each step are added the resulting figure is the total investment required to produce one ton of tin plate (one-half tin per base box basis) (1) per year. To obtain actual capital cost, annual anticipated production in tons is multiplied by the investment per annual ton of capacity (Table 9). For example, a tandem cold mill with a production capacity of 300,000 tons per year of cold rolled coils with a cleaning, annealing, and temper mill would require an investment of about US$ 22.0 million (300,000 tons x US$ 73.0 = 21,900,000). It must be emphasized that the figures in Table 9 are for large integrated mills located in industrialized countries. Smaller scale facilities with a lower investment costs are also available but typically they have higher operating costs and product quality problems.

It is not possible without careful study to estimate the operating costs associated with the production of tin plate. The reason is that no steel mill is solely devoted to producing

1) One half pound tin per base box is typically the type of tin used in the developing countries. In the industrialized countries quarter pound tin per base box is generally used.

TABLE 9

CAPITAL COST AND VALUE ADDED EACH STEP IN THE

PRODUCTION OF ONE TON OF TIN PLATE

(1/2 lb. tin per base box)

	$/Annual Ton Product	$/Annual Ton Tin Plate	Value Added $/Ton Tin Plate
Direct Iron Ore Reduction	45	50	50
Electric Furnace Steelmaking (including conventional ingot casting)	30	45	30
Slabbing Mill	17	24	4
Hot Mill including pickle and oiling	70	88	29
Cold Mill including cleaning and annealing and temper mill	73	86	26
Electrolytic Tinning including coil Preparation	54	56	31
		$349	$170

a single product like tin plate but rather produce a number of products such as hot and cold rolled sheets, galvanized sheets and strip, both narrow and wide. Before operating costs can be estimated the product mix must be known which, in turn, can only be determined after a careful market analysis.

The value added in plating tin on steel coils, however, can be estimated without a detailed market analysis. It represents only about US$ 31.00 per ton, in comparison to a total cost of producing tin plate of US$ 170 per ton. The tin content is only about US$ 7.50 assuming a tin price of US$ 1.60 per pound. It is evident from this analysis that the cost of tin is a very small percentage of the total cost of producing tin plate.

The investment can be reduced by eliminating the front end of the process, which would require the purchase of either hot or cold rolled coils from Argentina for tinning. This would achieve the objective of placing Bolivian tin on tin plate. It might be accomplished through development of the Mutun project. This would involve direct reduction of iron and the shipment of the reduced iron in large quantities to Argentina. Either hot or cold rolled coils could be backhauled from Argentina to Bolivia for tinning and galvanizing. Although a project of this nature might be viable it must be noted that a very large, risky investment would be made in order to place 10 pounds of tin on every ton of tin plate. A better alternative might be to make an arrangement

with one of the Andean producers of steel whereby Bolivian tin might be used to manufacture tin plate.

It is unlikely that an opportunity exists for Bolivia to sell tin plate in other LAFTA countries. Tin plate capacity in Latin America is 750,000 tons per year; production, however, is only about 400,000 tons, or about 50% of installed capacity, and imports about 350,000 tons. Table 10 presents estimated capacity for South America (i.e. omitting Mexico and Central America). Argentina, Brazil, Chile and Colombia are the major producers of tin plate in South America. Capacity for these four countries in 1970 was approximately 550,000 tons. Production, on the other hand, was 380,000 tons.

The reasons that Latin America imports large quantities of tin plate even though over capacity exists in the area, are better quality and a more competitive price for imported tin plate. If tin plate from the Andean region is to be competitive with that imported from third countries tin plate production should be concentrated in one country in the Subregion where production and quality can be controlled. The consumption of tin plate in Latin America is growing and despite unused capacity there is an opportunity for new, modern facilities capable of producing tin plate at low cost.

2. Alloys

The second most important use of tin is in the manufacture alloys, the most important of which are solders, babbitts and white metal, and bronze and brass, in approximate order of importance. More specifically, tin alloys include the so-called soft solders, automotive and can solders, antimonial tin solders, tin-silver solders, and silver-lead solders. Other miscellaneous uses of tin are in pewter and special lead-based bearing alloys. In addition to tin, these products generally contain antimony, copper, lead, and in the case of bronze alloys, zinc.

Bolivia's raw material position in tin, antimony, bismuth, copper, lead, zinc, and silver makes it uniquely suited to produce this broad range of alloys for sale in the Andean markets and, therefore, is in an advantageous position to request that it be given the reservation for these products. The opportunity to produce soft alloys is discussed in another section of this report where we consider not only tin alloys but also alloys made from bismuth, antimony, copper, zinc, and lead.

TABLE 10

TIN PLATE CAPACITY AND PRODUCTION IN SOUTH AMERICA
(In Tons) 1967-1970

Country	Capacity 1970	PRODUCTION 1967	1968	1969	1970[1]
Argentina	155,000	9,000	5,000	2,000	65,000
Brazil	230,000	203,000	205,000	225,000	230,000
Chile	115,000	35,000	26,000	30,000	65,000
Colombia	50,000	none	4,000	21,000	20,000
	550,000	247,000	240,000	278,000	380,000

1. Estimated current rate

III. B I S M U T H

III. B I S M U T H

A. RESOURCES AND PRODUCTION

Table 11 presents statistics on world production of bismuth ore, according to country, for the 1950-1968 period. The data indicate that Bolivia is currently the second largest producer of bismuth bearing minerals or concentrates in the world; its position is only exceeded by Peru which historically has been the major producer. Bolivia is the only supplier of bismuth obtained from bismuth ore. Peru's production of bismuth is largely a by-product and is dependent on copper production.

Bolivia's reserves of bismuth are currently estimated at 13,200 metric tons of contained bismuth, proven and indicated, plus 2,000 tons of contained metal inferred (Table 12). The proven and indicated reserves appear to be adequate, representing over 20 years of production at current levels. Our field work also indicated that attempts are being made to increase reserves by exploration in the Lipez area.

Our analysis of mining and milling costs for concentrates has indicated that they are not above those of other major producers.

In the near future no significant changes are foreseeable in sources of bismuth supply. Spanish production is growing slowly but from a very small base; Australia could increase output, but

TABLE 11

PRODUCTION OF BISMUTH ORE CONCENTRATES, AND METALS

1950 - 1968

(Long Tons of Metal or Bismuth Content)

MAJOR PRODUCERS	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
PERU(1)	366	478	444	282	309	328	283	359	380	329	408	467	484	555	724	795	747	783	N/A
BOLIVIA(1)	24	68	15	62	45	50	33	40	109	218	180	208	291	276	270	292	367	523	566
MEXICO(1)	260	333	400	330	355	346	621	348	187	235	268	1047	348	420	465	477	447	501	516
CANADA(1)	86	103	73	52	116	119	128	143	184	149	189	213	168	160	179	191	235	298	283
YUGOSLAVIA(1)	60	86	97	97	108	102	109	98	76	89	103	97	89	87	82	87	102	106	84
SOUTH KOREA(1)	N/A	12	109	236	113	128	177	107	89	101	142	149	158	156	500	N/A	98	112	96
JAPAN(1)	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-	311	1006	1184	226	-	N/A	N/A	N/A	N/A
SWEDEN(1)	N/A	N/A	N/A	N/A	50	65	39	54	49	29	35	35	69	69	67	34	34	30	N/A
FRANCE(1)	77	85	90	70	11	59	50	44	50	45	50	52	62	67	68	60	66	55	N/A
SPAIN(1)	9	11	8	26	37	29	65	93	50	27	15	9	2	4	-	-	9	N/A	-
TOTAL(1) (available figures only)	907	1184	1242	1166	1156	1240	1485	1331	1212	1388	1720	3305	2790	2036	2366	1943	1901	2408	-
WORLD PRODUCTION ESTIMATED(2)					average 2160						2390	2530		3050	3250	3930	3100	3455	3450

SOURCE: (1) Overseas Geological Surveys of H.M. Government.
(2) U.S. Bureau of Mines (includes estimate for China).

TABLE 12

BISMUTH RESERVES

		PROVEN INDICATED			INFERRED
		Ore Content % Bismuth	Metric Tons Bismuth	Metric Tons Bismuth	Tons Contained Bismuth
COMIBOL	1.43	6,400	1.20	4,200	
Medium Miners	---	1,100	--	--	
Small Miners	1.25	600	1.25	900	
		8,100		5,100	2,000

Total Bismuth

Proven & Indicated	13,200	
Inferred		2,000

again from a limited base. Peru, Canada, and Mexico are also expected to continue to supply bismuth in relation to their production of copper and lead. However, with lead production likely to decline and with copper production unlikely to experience rapid growth, by-product bismuth may not be as important, a factor in the world market in the future as it was in the past, which would enhance Bolivia's competitive position.

B. MARKETS

As was the case for tin, bismuth (concentrate or metal) is truly an international commodity. Its primary uses are as follows:

Uses of Bismuth	Amount utilized as Percent of total production.
Pharmaceuticals and chemicals including stomach powders, cosmetics, and catalysts.	50%
Fusible low melting point alloys used in fire protection equipment, machining and metal working and as a heat exchange medium	25%
Other alloying applications, primarily additives to metal working alloys to improve machinability.	20%

Table 13 presents the major importers of bismuth ore or metal in 1963, 1965, and 1968. By far France, the United States, and the United Kingdom are the major consumers of bismuth in the world.

Bismuth consumption is difficult to estimate because of U.S. stock pile purchases and fluctuating demand for acrylonitrile catalysts. Growth in demand, however, has been projected at a rate of 2% to 3% per year. The reason for this low growth rate is that part of the market (i.e. acrylonitrile catalysts) may be lost to competitive materials such as uranium-based catalysts. Overall demand, however, appears to be secure.

Table 14 presents London and New York prices for producer metal. Price quotations for metal on the free market have only been available in London and New York since early 1969; in the case of the free market price for ore it became unavailable in the beginning of 1968.

The producer price is established by Cerro de Pasco in Peru, Cominco in Canada, and Mining and Chemical Products in the U.K. The Belgium smelter and the U.S. suppliers usually follow the producer price and only sell minimal quantities on the free market.

The free market is supplied by South Korea, and more recently by Japan, Yugoslavia, and Russia. There are also some small quantities of bismuth produced in multiproduct smelters in Europe which may

TABLE 13

PRINCIPAL IMPORTERS OF BISMUTH ORE OR METAL

1963,1965,1968

(Thousand Pounds)

Country	1963	1965	1968
France	1,465	1,545	2,072
U.S.A.	1,123	1,378	1,266
U.K.	1,567	1,779	1,073
Netherlands	231	330	517
West Germany	560	515	329
Belgium+	2,650	83	200
Italy	96	98	124

+ Metal only

TABLE 14

BISMUTH METAL AND ORE PRICES

ANNUAL AVERAGES

1950-1970

((U.S.$ Per Pound)

Year	(1) New York	(2) London	(3) London
1950	2.25	2.25	0.70
1951	2.25	3.70	1.54
1952	2.25	2.80	1.12
1953	2.25	2.30	0.77
1954	2.25	2.25	0.70
1955	2.25	2.25	0.70
1956	2.25	2.25	0.70
1957	2.25	2.25	0.70
1958	2.25	2.25	0.70
1959	2.25	2.25	0.70
1960	2.25	2.25	0.70
1961	2.25	2.25	0.70
1962	2.25	2.25	0.70
1963	2.25	2.25	0.70
1964	2.30	2.30	0.70
1965	3.43	3.50	0.70
1966	4.00	4.00	0.70
1967	4.00	4.05	0.70
1968	4.00	3.50	
1969	5.40	6.00	

1) U.S. Producer Price
2. Producer Price
3. 30% -35% GRADE

Sources: U.S. Department of Mines Mineral Yearbook
London Metal Bulletin

be sold on the free market. In general, traders are not active in the metal market; sales are made primarily direct from the producer to the customer. The bulk of metal originates from the producers who historically have had control of the market. Supplies to the free market are relatively small as the smelters who generally sell on this market, with the exception of the Korea one, place most of their output on their domestic markets.

The data in Table 14 indicates that prices remained stable from 1950 to 1964, at US$ 2.25 per pound; they started to rise early in 1965, when the producer price was increased. The producer price rose again in early 1966. The free market price increased to a high of over US$ 9.00 per pound in late 1969 - early 1970 and recently has settled to a level close to the producer price of US$ 6.00 per pound. Our interviews with the trade indicated that producer prices can be expected to return to the 1968-1969 levels of US$ 4.00 to US$ 5.00 per pound.

There is no tariff on bismuth ore imported into Western countries, but there is a small tariff on metal: 1.3% of value in the U. S., 4% in the Common Market, and 10% in Japan. No tariff is imposed on bismuth metal imported into the United Kingdom.

C. SMELTING

The list of existing bismuth smelters and bismuth by-product sources is presented in Table 15. Of these, three smelters produce

TABLE 15

BISMUTH SOURCES AND SMELTERS AND ESTIMATED ANNUAL CAPACITIES

S.I.D.E. CHE. Bismuth metal and products only	Brussels, Belgium	N/A
Mining & Chemical Products Bismuth metal and products only	Wembley, England	2,000
S.A. Metallurgie Hoboken Multiproducts	Belgium	25
Norddeutsche Affinerie Multiproducts and by-products	Hamburg, Germany	100
Capper Pass & Son Ltd. Multiproducts	England	300
Five producers Multiproducts and by-products	Japan	800
Eight producers Multiproducts and by-products	U.S.A.	2,000
Cominco Multiproducts and by-products	British Colombia Canada	350
Cerro de Pasco Multiproducts and by-products	Peru	1,750
Korea Tungsten Mining Bismuth metal and products only	South Korea	250
ENAF Bismuth metal and chemicals only	Bolivia	800

only bismuth metal and bismuth products; they are located in Belgium, England and Korea; the Korean smelter is relatively small. The others are facilities for multi product smelting and refining. Present capacity, excluding the proposed Bolivian smelter, amounts to at least 7 million pounds per year of bismuth, which about equals demand by the Western world.

Although smelter conversion rates are not generally available, an examination of historical free prices indicate a margin of US$ 1.32 per pound of metal content in the early 1960's and a margin of US$ 1.20 in October 1968. In both instances the margin is for 99.99% metal, which is the normal range.

The expected growth rate in demand, plus the substantial value added in converting from ore to metal, and the lack of surplus in world smelter capacity makes the bismuth smelter proposed for Bolivia an excellent project which should have an attractive rate of return. (It is our understanding that the investment for this project will be about US$ 2.0 million). The projected capacity of 400 tons/year is two-thirds of present production of bismuth in concentrates and leaves flexibility to market concentrates as well as metal.

We understand that the smelter project is a cooperative venture whereby the marketing is to be conducted by a Belgium firm. The specialist nature of the bismuth market makes, at least for the present, such an arrangement advantageous for Bolivia. Our

analysis of the overall supply/demand bismuth balance, however, has indicated that careful thought must be given to various aspects of this market. Any relationship with an existing smelter should leave Bolivia the freedom to sell metal or ore, as conditions indicate. Moreover, since Bolivia is a major supplier of ore to the Western world it is unlikely that one company can provide outlets for more than a proportion of the smelted metal. As a result, Bolivia should place itself in a position to be able to market its bismuth metal and bismuth compounds.

The problem in establishing market outlets for metal or products is particularly significant in the case of bismuth because Bolivia represents such a large part of the world's supply. Initially this situation gives Bolivia a strong position since customers are almost forced to buy from Bolivia. However, over the longer term it could lead to traditional suppliers regaining market position at Bolivian expense by taking advantage of their geographical and historical links with customers, unless Bolivia plans its marketing policy carefully to ensure it provides the service they require.

In summary, the exclusive arrangement which Bolivia has for marketing the production of the bismuth smelter is probably the proper arrangement for the short term; it is not an appropriate arrangement for the long term. Bolivia should, as soon as possible,

be in a position to market bismuth metal and bismuth compounds produced from the metal; this would involve supplying technical and other services to the customer and would permit Bolivia to obtain maximum return for its production.

D. OPPORTUNITIES

The major opportunity for bismuth as regards Bolivia is associated with producing alloys. Bismuth is an important alloying metal and is a base metal for the low-melting-point alloys and should, therefore, be considered along with the tin and other alloys as part of an alloy project. There may also be an opportunity to upgrade beyond the smelter product, as the Chinese are reportedly planning, to bismuth carbonate and bismuth subnitrate.

IV. Z I N C

IV. Z I N C

A. RESOURCES AND PRODUCTION

Zinc reserves in Bolivia are currently estimated to be 1,210,000 tons, proven and indicated (Table 16) and are sufficient to support the present level of zinc concentrate production for over 40 years.

Bolivia is capable of producing about 26,000 tons per year of zinc in concentrate form. By far the largest producer is the Matilde Mine, which is currently operating at 60 % capacity and is shipping roughly 6,000 metric tons per year of zinc in a 55% concentrate. The mill has a capacity of 10,000 metric tons per year in a 55% concentrate. Medium miners, excluding the Matilde Mine have produced in recent years, 9,000 to 11,000 metric tons of zinc in concentrates per year and COMIBOL has produced 4,000 to 5,000 metric tons per year of zinc in concentrates. The reserves of the Matilde mine would probably justify a substantial increase in capacity; its deposit is a high-grade (17% zinc), low-cost one.

World reserves of zinc are sufficient to support the expected growth in world demand through the 1970's.

Bolivia compared to Peru with its vast reserves is not an important producer of zinc concentrates within the Andean Subregion.

TABLE 16

ZINC RESERVES

THOUSAND METRIC TONS CONTAINED MET

	Proven and Indicated	Inferred
COMIBOL	415	
Matilde Corporation	560	
Medium Miners	212	
Small Miners	23	
Total	1,210	2,000

Peru is fourth among the countries of the Western World in production of zinc in concentrates. In recent years, it has produced 300,000 tons to 400 000 tons of zinc per year in concentrates (Table 17).

B. MARKETS

The current consumption of slab (primary) zinc is about 5.0 million tons per year, 1.0 million tons of which is consumed within Communist countries (Table 18). Galvanized steel accounts for about one-third of world consumption of zinc, while zinc die casting accounts for one-quarter and brass for one-fifth. Past growth however, has been based upon well-established uses -principally die casting, galvanizing, and the manufacture of brass- and as a result it has been closely tied to economic activity in the industrialized nations of the world.

The demand for galvanized steel generally follows construction activity, particularly public works. Two-thirds of the galvanized steel used in the United States goes to this market, while in other countries up to 80% goes to construction. In the early and mid-1960's however, the consumption of zinc for galvanizing was declining in spite of increasing construction activity due to the trend toward the use of thinner zinc coatings. This trend leveled out in the late 1960's and consumption of zinc for galvanized steel is again growing with construction activity. Galvanized steel is also used extensively for construction in developing countries. As a

TABLE 17

PRODUCTION OF ZINC CONCENTRATES

By Mayor Producers

1967 - 1968

(Metric Tons Contained Zinc Per Year)

Country	1967	1968	1969
Canada	1,127	1,166	1,211
United States	548	528	541
Australia	373	384	464
Peru	329	303	363
Japan	263	264	270
Mexico	237	239	244
West Germany	129	134	137
Italy	125	140	133
Congo	122	119	110
Zambia	54	67	67
France	25	22	20
Bolivia	17	11	26

TABLE 18

CONSUMPTION OF REFINED ZINC

BY MAYOR CONSUMER

1967-1969
(TONS)

Country	1967	1968	1969
United States	1,125	1,263	1,350
Japan	458	519	599
West Germany	303	362	400
United Kingdom	256	280	288
France	203	202	245
Asia (except Japan)	174	202	207
Italy	141	155	170
Belgium	116	119	135
Canada	98	113	125
Australia	104	101	104
Africa	77	65	67
Mexico	37	39	40
Total Western[2]	3,421	3,808	4,153
Total Socialist Countries	885	923	1,000
Total World	4,306	4,731	5,153

1. Some smaller consuming countries not included
2. Includes smaller consuming countries not listed
3. Estimated

result, we expect that consumption by the construction industry of galvanized steel and, therefore, zinc will increase at historical rates.

Die casting is the next most important market for zinc in the world. In the United States, however, this market accounts for 40% - 45% of the total zinc consumption, which is lower than that used for galvanizing and for the manufacture of brass combined. Zinc die casting markets have been threatened in recent years by the introduction of injection-molded, high-performance plastics. Although plastics have encountered several problems in penetrating this market, they are gradually replacing zinc dies and can be expected to continue to take away much of the growth that otherwise would have gone to zinc. In the United States, where about 60% of all zinc die casting is performed, authorities expect consumption of zinc by the die casting industry to grow at most 2% - 3% per year. Some knowledgeable individual however, have been predicting a decline in demand. Because of the predominance of the automobile as a market for die castings (particularly in the United States, where two-thirds of all zinc die castings are used by the automotive industry), the growth of this market is influenced over the short term by vehicle production which result in major year-to-year fluctuations. In the world as a whole, the growth of automobile production will more than offset penetration by plastics, but we expect that die castings will be one of the slower growth areas for zinc.

Brass is still a major market for zinc in all countries except the United States. For instance in Europe, brass consumes almost as much zinc as galvanizing, although only a small portion is primary metal. We believe that brass consumption recently reached a turning point, principally because cost considerations have gradually become more important than the traditionalism of designers and manufacturers. Moreover, the high cost of copper in recent years had made it more difficult for brass to compete with aluminum; competition has already run its course in the United States but not in Europe.

Although a number of zinc uses such as zinc extrusions, superplastic zinc alloys, newcasting alloys and forging alloys have received wide publicity, we estimate that these will have little impact in the total market in the next 10 years.

The outlook for zinc is moderately bright, particularly in countries other than the United States. World demand is expected to increase at about 4% per year over the next ten years. There has been and still is a shortage of concentrate supply, but this situation is expected to be reversed as exploration during the recent years of shortage is translated into mine and smelter capacity. Additions to capacity are being made at a lower rate than in the recent past, but capacity is still growing at 5% per year. Zinc mine and mill capacity is increasing at a sufficiently rapid rate so that after the mid-1970's supply and demand will again balance.

Zinc concentrate has been a highly desirable product of commerce in recent years. However, zinc concentrate is expected to be in oversupply in the mid-1970's. Although the excess supply will not be as severe as expected in the case of lead, it will still be sufficient to create downward pressure on prices and severely restrict the marketing of zinc concentrate in world markets.

The price of zinc has already started to decline, reflecting growing conditions of oversupply. The LME price is currently about US$ 0.13 per pound compared to US$ 0.146 per pound a year ago (Table 19). It appears reasonable to expect that the average price of zinc over the next ten years will be near to the range of US$ 0.127 to US$ 0.14 per pound that prevailed during the latter half of the 1960's.

However, during periods of considerable excess supply, prices of about US$ 0.10 per pound can be expected, although the larger producers will attempt to maintain a higher price level by cutting back production.

C. SMELTING

Bolivia is reportedly planning to build an electrolytic zinc refinery with a capacity of 33,000 tons per year to be supplied with concentrates largely from the Matilde mine. Without knowing more about the details of this project, we are not in a position to comment on the wisdom of proceeding with zinc smelting. However, in recent years, zinc smelters have incurred

T AP L E 19

ANNUAL AVERAGE ZINC PRICES

LONDON METAL EXCHANGE

1957 - 1970

(U.S. CENTS PER POUND)

Year	Price
1957	10.1
1958	8.2
1959	10.3
1960	11.0
1961	9.8
1962	8.5
1963	9.5
1964	14.0
1965	13.8
1966	12.3
1967	12.2
1968	10.8
1969	13.1
1970	12.6

1. Recent

losses. On the other hand, the present and at least short-term outlook for zinc is reasonably promising and if a long-term sales contract at adequate prices can be signed for the zinc produced from the refinery a zinc refinery would probably be a profitable project.

The Western world produced over 4.1 million tons of zinc in 1969, up from the 3.3 million tons produced in 1967 (Table 20). Zinc capacity is divided into electrolytic and Imperial Smelting Process capacity. Electrolytic installed capacity in the world is 3-1/4 million tons and it has been increasing, particularly in Japan, Holland, and Canada. Imperial Process capacity is estimated at over 610,000 tons per year, plus older zinc smelting capacity.

Peru is the only zinc producer in the Andean Subregion. Its capacity is relatively small compared to that of major producing countries; however, Peru is the fourth largest producer of zinc concentrates and, at least from the raw material standpoint, has excellent potential for increasing production of zinc metal. Peru because of its importance as a supplier of zinc concentrates and metal has the advantage for supplying the Andean market. As a result, Bolivia will need to focus its zinc metal marketing efforts outside the subregion, perhaps in the Cuenca de Plata area and other world markets.

TABLE 20

ZINC METAL PRODUCTION

BY MAJOR PRODUCER

1967-1969

Country	1967	1968	1969[2]
United States	918	983	1.041
Japan	713	606	516
Canada	368	387	423
West Germany	182	203	281
Belgium	224	247	256
France	186	208	255
Australia	198	208	247
United Kingdom	104	143	151
Italy	89	112	131
Mexico	74	83	75
Peru	63	67	63
Congo	61	63	63
Zambia	45	50	50
Western World Total[1]	3,291	3,669	4,102
Socialist Countries	1,004	1,036	1,050
World Total	4,295	4,705	5,152

1. Includes smaller producing countries not listed

2. Estimated

D. OPPORTUNITIES

If Bolivia proceeds with plans to establish a zinc refinery, zinc metal will be available within the country, suggesting the possibility of producing galvanized sheet and also of producing zinc alloys.

1. Galvanized Sheet

Bolivia imports over 7,500 tons of galvanized sheet. Although the production of galvanized sheet is normally part of the steel industry, it is not unusual in developing countries to have small plants capable of producing 10,000 - 20,000 tons of galvanized sheets per year. Plants of this size are based upon hot rolling sheet bars on a sheet bar mill to sheets with a small galvanizing line. Investment costs for such facilities are in the order of US$ 500,000 to US$ 1.0 million, depending largely on the availability of a used sheet bar mill.

The possibility of exporting to the Andean Subregion is not very promising because both Chile and Peru have the capacity to produce galvanized sheets and tubes and Colombia has the capacity to produce galvanized tubes and wire.

2. Zinc Alloys

Zinc alloys and other nonferrous alloys containing zinc will be discussed in Chapter IX of this report.

V. L E A D

V. LEAD

A. RESOURCES AND PRODUCTION

Bolivia, with current production of about 25,000 tons of lead concentrates, is a minor supplier of lead raw material to the world market. Within the Andean Pact Countries only Peru is a major producer of lead concentrates, ranking fifth in the Western World.

Bolivia's proven and indicated reserves of lead are currently estimated at 232,000 tons of contained metal, representing 10 years of production at current levels (Table 21).

World reserves of lead have increased in recent years as a result of extensive joint exploration activity for lead and zinc. A significant portion of the reserves found have been high grade and relatively low cost. We estimate that known world lead reserves are adequate to meet consumption requirements over the next decade.

Currently, Russia is the world's largest producer of lead concentrates, accounting for 14% of the total (Table 22). Next in line are Australia, the United States, and Canada, each responsible for about 10% of world lead production. The costs of producing lead in Bolivia are probably similar to those incurred by major producing countries, since lead concentrates are by-products of tin and zinc milling. As a result, Bolivia probably would be competitive in the world market.

TABLE 21

LEAD RESERVES

(THOUSAND TONS CONTAINED METAL)

	PROVEN	INDICATED	INFERRED
COMIBOL	84	78	
Medium Miners	35	15	
Small Miners	4	16	
	123	109	495

TABLE 22

PRODUCTION OF LEAD IN CONCENTRATES

BY MAJOR PRODUCER

1967-1969

(In thousand tons)

Country[1]	1967	1968	1969
United States	300	339	473
Australia	373	379	444
Canada	317	330	308
Mexico	166	162	168
Peru	163	165	160
Sweden	72	70	76
South Africa	70	61	78
Morrocò	78	81	75
Spain	63	71	72
Japan	64	64	64
West Germany	65	57	42
Italy	39	36	38
France	27	26	30
Bolivia	20	22	25
Total Western World[2]	2,071	2,134	2,327
Socialist Countries	1,052	1,082	1,116
Total World	3,123	3,216	3,443

1. Smaller producing Companies omitted
2. Includes smaller producing countries not listed

B. MARKETS

Annual world consumption of lead is about 4 million tons, of which about 3 million tons is consumed in the Western World and about 1 million tons in Socialist Countries (Table 23). The United States is by far the most important consumer of lead. In 1969 it accounted for about 28% of demand and 38% of demand in the Western World.

The two most important uses of lead are in automobile batteries and as a gasoline additive, the former being the more important. Lead is used in automobile batteries as cast antimonial lead grids and as lead oxide, which is the active material. Typically, grids are produced from secondary lead and oxide from primary lead. The battery market is stable, since only about 20% of battery sales are for new automobiles; 80% of sales are for replacement of batteries already in service. Thus, the market primarily depends upon those factors which affect the need for battery replacement (e.g., bad weather) rather than economic activity. A corollary of this is that a rapid increase in economic activity, such as the world has experienced in recent years, is reflected in the battery industry only very slowly; conversely, a downturn is not reflected immediately unless the reversal is sufficiently sharp to cause automobiles in service to be placed in storage. There is little sign that increasing demand for personal transportation is diminishing. In the more populated cities, a resurgence in mass transportation is currently beginning and ultimately the amount of commuting mileage will probably be reduced. The effects

TABLE 23

CONSUMPTION OF LEAD METAL
BY MAJOR CONSUMER
1967-1969

(Thousand Tons)

Country[1]	1967	1968	1969
United States	1,031	1,117	1,160
West Germany	257	286	315
United Kingdom	277	276	277
France	164	179	200
Japan	163	181	191
Italy	123	133	150
Spain	54	62	94
Mexico	65	70	69
Australia	66	61	68
Canadá	59	60	62
Sweden	53	56	54
Belgium	44	47	49
Total Western World[2]	2,733	2,903	3,070
Socialist Countries	995[3]	1,060[3]	1,120[3]
Total World	3,728	3,963	4,190

1. Some smaller consuming countries not included
2. Includes smaller consuming countries not listed.
3. Estimated

of such a reduction on battery life are too complicated to predict. However, in view of the slow development of mass transportation systems in the medium term it is unlikely to induce a major change in battery demand.

The primary determinant of new car production in the short term is the scrap rate of old cars. In the United States, typically 75% of new car sales are to replace old vehicles; only 25% constitute net additions to the number of vehicles on the road. As a result, automobile production is highly influenced by the number of vehicles produced in the past and generally follows a pattern of rapid growth, then stagnation, and then another period of rapid growth. In the United Stated, the largest automobile market in the world, the last period of stagnation was 1950-1961; 1962-1965 was a period of rapid growth. We are again at the stagnant phase of the cycle and several more years of stagnation (probably through the early 1970's) are expected.

Tetraethyl lead, an additive to gasoline, has been a rapidly growing market for lead that has paralleled the increase in the number of automobiles on the road. The growing awareness in recent years of pollution problems, particularly air pollution by automobile exhaust, has led to development of nonleaded gasolines for the new automotive engines now being brought into production in Detroit. Other countries besides the United States are also encountering severe air pollution problems, particularly Japan. Thus, major efforts around the world aimed at reducing

automobile exhaust pollution can be expected.

Two principal methods of controlling car pollution are through and afterburner and a catalytic reactor. The afterburner simply burns the exhaust gases at a high temperature; the catalytic reactor reduces detrimental emissions by forming other compounds in contact with a catalyst. The choice of which system to be used is critical to the lead industry, since the presence of lead while not important to an afterburner but is critical to the catalytic system (it poisons it). The development of pollution control devices in the United States, the largest lead market in the world, suggests that the catalytic reactor is preferred.

Even if all new automobiles were to utilize a catalytic reactor-type emmission control system, the negative impact on the demand for tetraethyl lead would probably be gradual, for two reasons. First, it is unlikely that vehicles now on the road but not designed to meet emission control standards will be forced to do so.As a result, they will continue to be a major market for tetraethyl lead to fuel the 220 million vehicles already in existence throughout the world. Second, even if the use of tetraethyl lead was restricted for all vehicles, it would require a number of years to install the additional refining facilities required to produce sufficient high octane gasoline to completely satisfy demand.

There are other relatively small markets for lead. For example, lead sheathing for underground telephone and electrical

cable was widely used a number of years ago and constituted an important third market. However, starting in the United States in the mid-1950's, lead sheathing was supplanted by combinations of aluminum, steel, and plastic. This trend is spreading to Europe and Japan, and consequently the consumption of lead for sheathing is gradually declining. Demand for lead for other uses is remaining approximately constant.

In view of the several downward trending markets for lead, projections for future consumption are pessimistic. In recent years, the world market for primary lead has been growing at a rate of 3% - 4% per year. Most authorities expect growth to be no better than this rate over the next ten years, and many believe that it will be lower.

On the supply side, it is likely that there will be net overcapacity. In recent years new production facilities have been installed to alleviate an undercapacity condition of lead that existed; over the next two years, additional capacity will be put into production. The result will be considerable excess supply through the first half of the 1970's. Moreover, some authorities are predicting that lead production will increase even more rapidly, since exploration efforts for silver, with which lead is generally associated and recovered as a byproduct, are being intensified.

The price of lead will be subjected to increasing downward pressure reflecting the projected lower demand and higher supply

- a trend already in evidence (Table 24). The price of lead reached a high of US$ 0.16 per pound in the latter part of 1969, when supplies were scarce. In recent months, however, demand has slackened and supply has increased, with the result that the price is declining; currently it is US$ 0.145 per pound.

C. SMELTING

In the past five years, European und Japanese smelters have been considerably interested in purchasing lead concentrates under long-term contract to supply their rapidly expanding smelter capacity. With the outlook for excess supply of lead and lower prices, it will be difficult to enter the world concentrate (or metal)market.

Present world lead smelting capacity is over 4 million tons per year, of which over 3 million tons of capacity is in the Western World and 1 million tons is in the Socialist Countries (Table 25). As indicated, Peru is a large producer of lead and is fully capable of supplying the Andean Subregion. Similarly, in the Cuenca de Plata, both Argentina and Brazil have facilities sufficient to supply the area. As a result, the development of lead production in Bolivia would depend on the domestic market - which is small.

Considering that the Metabol smelter was originally built as a conventional lead smelter and could be reactivated to produce as much as 3,000 tons per year of lead, there is little justification for consideration of a new lead smelting project.

TABLE 24

AVERAGE LONDON METAL EXCHANGE PRICE FOR LEAD

1957-1969

(US$ Cents per Pound)

Year	Price
1957	9.6
1958	9.2
1959	9.0
1960	9.1
1961	8.2
1962	7.1
1963	7.9
1964	12.6
1965	13.9
1966	11.7
1967	10.4
1968	12.5
1969	13.1

TABLE 25

LEAD PRODUCTION BY MAJOR PRODUCER

(Thousand Tons)

Country	1967	1968	1969
United States	730	827	1,013
West Germany	296	271	304
United Kingdom	192	234	249
Australia	218	203	215
Japan	150	165	196
Canada	177	183	170
France	144	148	156
Belgium	98	95	97
Italy	72	76	83
Spain	54	62	84
Peru	82	86	78
South Africa	69	55	66
Argentina	30	32	36
Morocco	21	24	27
Brazil	15	16	18
Western World Total[1]	2,664	2,825	3,122
Socialist Countries	938	978	1,000[2]
Total World	3,602	3,803	4,122

1. Includes smaller producing countries not listed.
2. Estimated

Moreover, Salesky has an old lead smelter near La Paz with a capacity of 200 tons per year and plans to build a small new smelter at some future date with a capacity of 10,000 tons per year of lead based on lead concentrates with high silver values. These volumes greatly exceed the domestic market for lead, which would primarily be used for the production of batteries and, to a much lesser extent, to produce sheet and lead-based alloys.

In summary, considering the present and future weakness of the lead market , Bolivia should not consider any large world-oriented lead smelter. Moreover, since Peru is the dominant producer of lead in the Andean Subregion, it is unlikely that Bolivia can be the major supplier to this market. The Cuenca de Plata area is self-sufficient with existing capacity in both Brazil and Argentina. We recommend that no further consideration be given to lead smelting in Bolivia unless lead concentrates with very high silver values become available.

VI. C O P P E R

VI. COPPER

A. RESOURCES AND PRODUCTION

Bolivia's reserves in copper are more than adequate to support the present level of production. They are currently estimated at 311,000 tons of contained copper, proven and indicated, with 500,000 tons of inferred reserves (Table 26). They are adequate to support existing levels of mining activity for the 40 years. They are not, however, sufficient for the establishment of a profitable smelter-refinery complex. Therefore, the major opportunity with respect to copper in Bolivia is in exploration to develop new, large ore bodies. We believe that the prospects of developing major copper reserves in Bolivia are quite promising.

With regard to the exploration program it should be noted that large sulfide type deposits situated near the surface are mineable with modern techniques and with a major mining and milling installation, if they have copper contents of 0.7% and perhaps even slightly lower. Underground deposits require a higher ore grade, in the order of 2.0% copper, to justify development.

We understand that as part of the reserve development program of COMIBOL exploration is presently being conducted in the Lipez area for copper lead and bismuth.

Copper concentrates have been in short supply since the mid-1960's. This period was much longer than most authorities expected

TABLE 26

COPPER RESERVES

(Thousand tons contained metal)

	Proven and Indicated	Inferred
COMIBOL	192	
Medium Miners	56	
Small Miners	63	
Total	311	500

and resulted from a period of rapidly increasing world demand, a number of unexpected problems encountered in bringing new mines on stream, and the 9-month strike in the United States in 1967-68. At present, demand has declined in relation to the decline of economic activity in many countries. Moreover, some of the new mines, which encountered problems earlier, are finally starting operations leading to a further improvement in the supply-demand balance.

Table 27 presents existing and anticipated production of copper concentrates during the 1966-1973 period. The data indicate that production did not grow during 1966 to 1968 but that a 40% increase in capacity is expected by 1973.

The projections for Free World copper concentrate production capacity have in the past repeatedly been considerable above the levels actually achieved. This has been due primarily to the intervention of unexpected catastrophic events such as droughts, landslides, cave-ins, and earthquakes. These natural calamities postponed the time when production from mine and new concentrate capacity could be realized, but did not alter the magnitude of the potential capacity that was ultimately brought on stream. As a result, annual projections of the mine and concentrate capacity expected to exist five years from any point in time have increased every year since the mid-1960's; at the same time, the capacity actually brought on stream in any one year repeatedly has been significantly below the projection made a year earlier. Some of

TABLE 27

PRODUCTION OF COPPER CONCENTRATES

AND ANTICIPATED INCREASES IN CAPACITY

1968-1973

(Thousand Tons contained copper)

Country	1966	1967	1968	1969-1970
United States	1,280	860	1,100	450
Chile	636	660	644	370
Zambia	622	663	635	120
Canada	461	547	554	170
Congo	315	317	320	45
Peru	184	186	204	225
South Africa	162	163	159	10
Japan	112	118	117	20
Australia	112	91	108	60
Philippines	73	85	100	70
Mexico	74	63	66	
Other Western World	295	295	305	310
Total Western World	4,426	4,048	4,312	1,850
Socialist Countries	990	1,030	1,040	275
Total World	5,416	5,078	5,352	2,125

the mine and mill capacity earlier projected is finally starting production and barring excessive additional natural calamities, the supply of copper should be adequate to supply future demand which may develop in the near future. Such a balance will not continue indefinitely, but, with demand expected to grow at 4% per year, it may be the mid-1970's before additional mine and mill capacity, not already under construction, is required.

Bolivia has been a small producer of copper minerals as compared with Pery and Chile (Table 27), Bolivian production of copper minerals over the past ten years has increased from 2,400 tons per year to 8,000 tons per year contained copper. These figures compare with the 700,000 tons contained copper produced by Chile per year and the 200,000 tons contained copper produced by Peru per year. With Chile and Peru being such important factors in the world copper industry, Bolivia is at a comparative disadvantage when competing with these two countries in the Andean market. On the other hand, the bulk of copper production is traded internationally and Bolivia should have no difficulty in disposing of its output.

In view of Bolivia's excellent prospects for finding additional copper deposits and also since its position as supplier to the world market is relatively small, we recommend that a major exploration program be initiated as soon as possible.

B. MARKETS

The consumption of refined copper in recent years has been about 6.0 million tons per year of which about 1.0 million tons is accounted by the Socialist Countries and 5.0 million tons by the Western world. These figures include copper from concentrates and other materials such as blister and recycled scrap; copper from materials other than concentrates account for about 13% of world-wide copper production.

Copper is consumed in a wide variety of industries. The windings of almost every motor are copper; in spite of aluminum's penetration of overhead electric transmission lines, copper continues to be used in home wiring and for many underground transmission lines. Copper is an important constituent of a very large number of alloys, both copper based, such as brass and bronze, and the more exotic alloys, such as Monel (a nickel-base alloy containing around 40% copper).

A consequence of this widely diversified use of copper is that the demand for copper tends to follow overall industrial economic activity closely. Although aluminum, plated steel, and plastics are all encroaching on various markets for copper, much of the market penetration has already been made and the losses to be encountered in the future are probably significantly less than those in the past.

The two principal markets for copper which appear to be most vulnerable to substitution in the short or medium term are automotive radiators and water tubing. Efforts to develop an economic aluminum automotive radiator have continued over a number of years and success and imminent production have been reported several times. The principal deterrent to commercialization apparently is the problem of field maintenance where fixing a leaking aluminum radiator is significantly more difficult than fixing a copper one. It is not at all certain that aluminum will supplant copper radiators, since maintenance problems would appear to be a major obstacle, but research continues and the threat should not be discounted simply on the basis of past failures.

Copper has long been the standard material for conducting water within homes. Attempts have been made to develop plastics suitable for such service and there has been success for cold water lines, but not for those carrying hot water. However, new plastics are being developed continually and it seems likely that ultimately copper water tubing will be replaced, at least in many of its present applications. Regardless of when a suitable substitute will be developed, penetration of the market will be very slow because of the problems associated with obtaining building code approval and with labor union jurisdiction over materials requiring new methods to install.

Offsetting potential declines in the relative use of copper

in the highly industrialized countries is rapidly growing demand in some of the less developed nations.

Taking all of these trends into account, the industry foresees an average growth rate slightly greater than 4% per year over the next decade.

The growth in copper demand during the last three years has been double this rate and for the previous three years about one-quarter of this rate. These comparisons, however, are not valid because of a number of disrupting influences during these periods. For example, U.S. producers' deliveries were badly distorted by the 1967-68 strike. In 1966 and the first half of 1967, anticipating the strike, producers and consumers increased their inventories. These inventories were utilized during the strike; some consumers increased them to such an extent that they were still utilizing them in 1969.

Historical copper wirebar prices on the London Metal Exchange are presented in Table 28. Prices increased rapidly during the 1960's as copper was in short supply. In recent months as new mine and mill capacity started operating and as economic activity declined, copper prices have fallen; the London Metal Exchange price has dropped to below the U.S. producer price for the first time since the first few months of 1964. We expect that prices will continue to decline during the first half of the 1970's as additional mine and smelter capacity begin production.

TABLE 28

ANNUAL AVERAGE LONDON METAL

EXCHANGE PRICE FOR COPPER WIRE BARS

1957-1969

(US$ Cents per Pound)

Year	Price
1957	27.6
1958	24.7
1959	29.4
1960	29.8
1961	28.9
1962	29.1
1963	29.3
1964	41.4
1965	53.8
1966	67.1
1967	50.5
1968	61.7
1969	64.8

It is difficult to judge the minimum price to which copper will fall during this period of excess supply since such conditions have not prevailed since the early 1960's. The current price is about US$ 0.535 per pound.

C. SMELTING

Present Bolivian production of copper in concentrate form of 8,000 tons per year of contained copper is inadequate to justify a smelter-refinery installation, This is true despite the indications given by Nitto Mines that their parent, Dowa Mining, was interested in installing a smelter in Bolivia to produce a refined copper by the conventional smelting and refining process. At 8,000 tons per year, this smelter would be small compared with most copper smelters found throughout the world. There exist several conventional smelters in the world with capacities of approximately 8,000 - 15,000 tons per year, but these are quite old and use substantial amounts of copper scrap as feed; their output is consumed locally. Currently, most of the experts in the copper field feel that the economical size of a copper smelter is in the range of 30,000 tons to 50,000 tons per year of blister copper.

World annual copper production in recent years has been over 5 million tons of blister copper and about 6 million tons of refined copper (Table 29). The difference between the two figures is due to recycled scrap which enters the refinery along

TABLE 29

WORLD PRODUCTION OF BLISTER AND

REFINED COPPER

BY MAJOR PRODUCER

1967

(Long Tons)[1]

Country	Blister Copper	Refined Copper
Australia	81,800	96,800
Austria	11,000	17,600
Belgium	59,000	305,000
Bulgaria	27,000	26,000
Canada	424,900	453,600
Chile	630,400	353,300
China	100,000	115,000
Congo (Kinshasa)	321,500	161,000
Finland	41,300	34,200
France	7,700	37,000
Germany East	20,000	40,000
Germany West	121,800	382,400
India	8,300	8,900
Italy	-	17,500
Japan	386,800	470,000
Mexico	50,200	46,900
Norway	19,900	14,100
Peru	165,500	35,800
Poland	27,000	42,200
Rhodesia	17,000	16,000
South Africa	120,900	15,200
S.W. Africa	31,700	-
Spain	43,000	71,700
Sweden	47,700	47,700
Turkey	25,400	8,100
Uganda	14,600	-
United Kingdom	-	179,100
United States	846,500	1,396,700
U.S.S.R.	825,000	960,000
Yugoslavia	68,400	66,200
Zambia	638,400	535,100
World Production	5,182,700	5,953,100

(1) One metric ton equals 0.98 Long Tons

Source: World Bureau Of Metal Statistics

with the blister copper from the smelter. Generally speaking the developing countries produce more blister than refined copper, selling the blister copper to the industrial countries for refining near the markets. Many of the developing countries also produce more refined copper than they consume internally. As a result, both blister and refined copper are traded internationally.

World capacity to smelt copper is over 5.5 million tons per year; to refine copper it is 6.25 million tons per year. During the recent period of shortages and high copper prices there was no shortage of smelting and refining capacity; the shortages were in mine and mill production and capacity.

Typical smelter charges for normal concentrates are about US$ 0.045 to US$ 0.055 per pound of copper. Reducing charges are US$ 0.035 - US$ 0.045 per pound of copper. Taking the high end of these figures, the total smelter plus refinery charges amount to US$ 0.10 to convert a pound of copper in concentrates to a pound of refined copper in the form of wirebar, which currently has a value of US$ 0.53 per pound. If the smelter purchases the concentrates they will pay about US$ 0.40 per pound of copper in concentrates; transport costs amount to US$ 0.03 per pound. Thus, the value added in smelting and refining is about one-third the value of the concentrate.

D. OPPORTUNITIES

1. Exploration

Because of Bolivia's promising potential for finding additional copper reserves exploration efforts should be intensifed; this will provide the basis for the future larger copper future development of larger copper mining operations that will more easily justify a major smelter and refinery complex. If Bolivia's inferred reserves could be proven as workable reserves, (i.e., economic for copper mining), and if additional discoveries are made, Bolivia could, perhaps over the next several years, develop its copper mining activities to a level of 30,000 tons per year, which would be sufficient to justify a copper smelter-refinery project in the country to serve world markets.

2. Smelting and Refining

Bolivia at this time should not consider the installation of a copper smelter since present known copper reserves are not sufficient to justify an economic sized smelter-refinery. Another reason that Bolivia should not be in a hurry to establish a smelter refinery is that by far the largest proportion of profits are earned at the mine and the mill rather than at the smelter refinery end of the process.

For example, copper mining and milling operations typically have a 40% rate of return; a smelter producing wirebar from

concentrates has a rate of return of 15%.

The establishment of a copper smelter in Bolivia would probably result in substantial transport cost savings. Currently it costs about US$ 0.05 per pound to ship copper to the smelter from Bolivia or about 100% more than that incurred by other copper producing countries.

3. Native Copper

An opportunity exists for the establishment of a small fire refined native copper smelter which would produce copper metal from native copper of a quality adequate for alloying purposes and for the production of copper sulfate and copper wire. The output of these facilities would be primarily for the domestic market. It is our understanding that 10% of the copper presently mined is native copper which could be separated at the mill operated by NITTO BOLIVIA MINING COMPANY and that of COMIBOL located at Coro-Coro.

A small fire refining smelter utilizing the native copper currently available in Bolivia would produce 800 tons per year of copper suitable for alloying purposes and could justify a small brass and bronze foundry which would produce castings for utilization in the manufacture of brass and bronze parts, such as pumps, valves, and plumbing fixtures. Fire refined copper could also be used in the manufacture of a number of alloys, particularly lead

based bearing alloys, and the various bronze alloys, tin babbitts and miscellaneous alloys, such as pewter and tin based die casting alloys.

Bolivia reportedly imports about 500 metric tons per year of copper sulfate which is equivalent to around 130 tons of copper. This amount will double once the Matilde Mine in operating at full capacity. Copper sulfate could be manufactured in Bolivia in a simple operation by reacting selected oxidized copper ores with sulfuric acid. The savings in foreign exchange earnings would be about US$ 190,000.

4. Oxide Copper

The potential also exists for the production of copper from oxide ores leached with acid and treated by electrowinning to produce copper cathodes which would be adequate in quality for the production of wire bar. The production of wire bar from cathodes with a quality sufficiently high to meet international standards is technically very difficult. It would be less of a problem for Bolivia to produce wire rod and coarse wire.

VII. A N T I M O N Y

VII. A N T I M O N Y

A. RESOURCES AND PRODUCTION

Antimony reserves in Bolivia (Table 30) are currently estimated at 145,000 tons of contained antimony improven and indicated reserves, with an additional 50,000 tons of inferred reserves. EMUSA, the major Bolivian producer of antimony concentrates, has by far the largest proven reserves. They are located near Tupiza in Potosí.

Proven and indicated reserves are adequate to support antimony production at present levels for about 12 years. Exploration is required to obtain additional reserves. It is our understanding that EMUSA is investing over US$ 200,000 for exploration directed at antimony in Southern Bolivia and that a total of US$ 350,000 has been committed towards antimony exploration in the country as a whole.

Table 31 presents data on world production of antimony concentrates between 1950 and 1969. South Africa, China and Bolivia, in order of importance, are the major suppliers of antimony concentrates to the world market. Together, they account for nearly two thirds of the world's production. Antimony concentrates production during the last several years and until 1969 did not increase substantially

TABLE 30

ANTIMONY RESERVES

(Tons Contained Antimony)

	PROVEN		INDICATED		INFERRED
	Ore Content % Antimony	Metric Tons Antimony	Ore Content % Antimony	Metric Tons Antimony	Tons Antimony
EMUSA	5.85	30,944			
Medium Mines	9.90	35,012			
Small Mines	13.50	30,825	6.56	48,326	
TOTAL		96,781		48,326	50,000

Proven and Indicated	145,107
Inferred	50,000

TABLE 31

PRODUCTION OF ANTIMONY

BY MAJOR PRODUCER

1950 - 1969

Metal Content in Ore[1]
(Thousand Long Tons)

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
ESTIMATED WORLD TOTAL[2]	44.8	61.5	45.2	31.0	36.0	50.0	52.0	50.0	45.0	52.0	52.0	51.0	52.0	55.0	62.0	60.0	60.0	58.0	62.0	63.0
SOUTH AFRICA	8.2	15.6	7.1	2.7	8.5	14.0	13.9	9.8	7.1	12.1	12.1	10.5	10.4	11.0	12.7	12.3	11.2	12.2	16.6	
CHINA[3]	6.0	8.0	8.0	8.0	8.0	12.0	12.8	13.7	14.5	14.5	14.5	14.5	14.5	15.0	15.0	15.0	15.0	12.0	12.0	
BOLIVIA	8.6	11.6	9.7	5.7	5.1	5.3	5.0	6.2	5.2	5.4	5.2	6.6	7.1	7.4	9.5	8.6	10.5	11.3	10.9	
U.S.S.R.[4]	N/A	N/A	N/A	N/A	N/A	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	
MEXICO	5.8	6.7	5.4	4.2	4.1	3.8	4.5	5.1	2.7	3.2	4.2	3.6	4.7	4.8	4.7	4.4	4.4	3.7	3.4	
YUGOSLAVIA	3.2	1.9	2.2	1.8	1.5	1.6	1.6	1.7	1.6	2.2	2.4	2.4	2.6	3.6	3.6	3.9	3.6	3.0	3.0	
CZECHOSLOVAKIA[5]	2.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2.0	2.0	2.0	2.0	2.0	2.0	
TURKEY	1.6	2.7	1.1	0.8	0.9	1.6	0.9	1.1	1.6	1.2	1.4	1.2	1.8	1.6	1.7	1.6	1.6	1.2	1.5	
MOROCCO	1.0	1.1	1.2	0.3	0.7	0.7	0.3	0.4	0.2	0.2	0.5	0.4	0.4	0.6	1.5	2.2	1.2	1.5	1.3	
ITALY	0.6	0.7	0.6	0.4	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.5	0.3	0.3	0.6	1.2	
ARGELIA	1.2	1.4	1.3	1.8	2.3	1.2	2.4	1.4	1.2	1.5	0.8	0.6	0.1	-	-	0.0	0.0	0.0	N/A	
U.S.A. PRIMARY	2.2	3.1	1.9	0.3	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	
THAILAND										-	-	-	-	0.3	1.4	1.2	1.2	1.1	1.2	
AUSTRALIA										0.6	0.2	0.1	-	-	1.2	1	1	1	0.9	

[1] One metric ton equals 0.98 long tons.

[2] WORLD 1950-1954 - Excludes U.S.S.R., Afghanistan and Iran.

[3] WORLD 1955-1968 - Excludes Antimony Ore produced in Hungary, Afghanistan and Iran.

[3] CHINA 1950-1955 - Figures based on Western estimates.

[4] U.S.S.R. 1955-1968 - Figures based on Western estimates.

[5] CZECHOSLOVAKIA 1950 - 1963 - Figures based on Western estimates.

SOURCES: OVERSEAS GEOLOGICAL SURVEYS OF H.M. GOVERNMENT
U.S. BUREAU OF MINES.

Moreover, very little interest has been demonstrated in the past on the part of antimony producers to extend efforts aimed at increasing production. More recently there has been fear that high antimony prices may lead to its substitution by. other products. One major supplier, Consolidated Murchinson, has announced that it intends to increase production to bring supply and demand into balance at lower prices. This company has provided capital funds to increase mine production (measured in antimony metal) from 18,000 tons in 1969 to 30,000 long tons by 1972, or an incrase equal to nearly 20% of 1968 world production. Australia is increasing production at a rate of 2,400 tons of metal a year, but reserves are reputed to be limited. The U. S. also has some limited expansion plans.

Currently the cost of producing antimony by some of the larger concerns in Bolivia is about US$ 5.70 per ton unit of antimony contained in concentrates. This cost does not include royalties which are related to the value of antimony metal. While this cost leaves a considerable margin between the cost of producing concentrates and the value of the antimony metal produced from a smelter, it is considerable higher than that incurred by Murchison. Their total costs at the mine head, including depreciation and overhead, in 1969 were about US$ 2.16 per ton. In 1970, becuase of higher capital charges, their costs will be about US$ 2.35 per ton. This comparison suggests that Bolivia needs to improve the recovery of metal in the concentration stage.

B. MARKETS

The largest market for antimony is antimonial lead for automobile batteries; it accounts for about 40% of consumption; about 20% is used in metal end uses, such as type metal, solder, collapsible tubes, and bearing metal; and about 35% is utilized in oxide form for flameproofing chemicals and compounds and for the ceramics, glass and plastics industries.

World consumption of antimony is currently about 65,000 metric tons per year. It has remained static over the last several years.

Demand for antimony is expected to grow at a rate of 3% to 5% per year, through the 1970's. The most important factor that will determine the rate of growth of antimony consumption is its use in lead batteries and as an oxide. The use of antimony metal in lead batteries has been declining. About ten years ago there was over 10% antimony used in batteries; at present only 3% to 6% antimony is used and recently DELCO introduced a sealed Battery that uses no antimony. The decline in the antimony of battery's is at least partly offset by its use as an oxide, particularly in flame retardant applications.

These appears to be a limited opportunity for Bolvia to increase its supply of antimony concentrate or metal to the world market as a replacement for reduced Chinese supplies

and also to satisfy normal growth in world demand. Since China could resume its flow of antimony to the world market and in view of ambitious expansion programs planned by smelters with an entrenched position in the world market, Bolivia, however, should proceed cautiously.

Bolivia also has a good possibility of becoming the sole supplier of antimony metal to the Andean Subregion. The rationale underlying this conclusion is that Bolivia is by far the area's major producer of antimony.

As in the case of other metals such as bismuth, the price of antimony metal is quoted on a producer and free market basis. In the long-run the producer metal price is established by Associated lead in the United Kingdom and National Lead in the United States. The free market price for metal and ore is quoted in the London Metal Bulletin and Metals Week. The free market metal price is an estimate of the price at which Russian, Chinese, Yugoslavian, Turkish and recently Japanese are willing to supply antimony metal to the world market.

Table 32 presents antimony ore and metal prices per ton of contained metal for the 1950-1968 period. Figure 1 presents price for antimony ore and metal for 1968, 1969 and part of 1970. In 1969 prices increased very rapidly as a result of China reducing supplies to the market. More recently prices have fallen as a result of the decline in economic activity and from sales of antimony by the United States from its stock pile.

FIGURE 1

ANTIMONY ORE AND METAL PRICES

1969-1970

(U.S. $ PER TON)

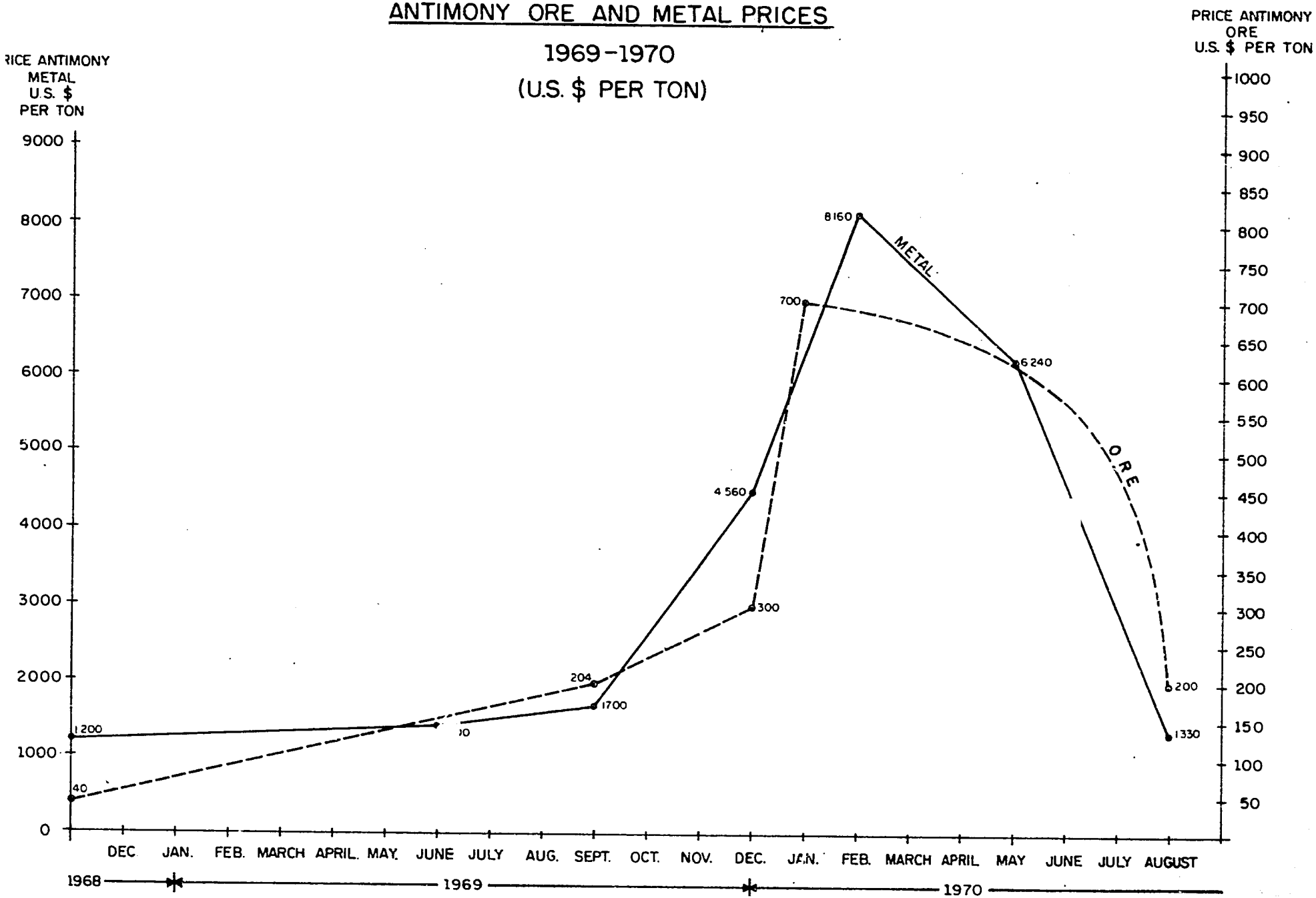


TABLE 32

ANTIMONY ORE AND METAL PRICES

ANUAL AVERAGES

1950 - 1970

(US$. per ton)

YEAR	PRICE			MARGIN	
	ORE[1]	METAL			
		FREE	PRODUCER	FREE[2]	PRODUCER[1]
1950	247	N.A.	423	176	-
1951	587	N.A.	846	259	-
1952	364	N.A.	653	289	-
1953	249	N.A	529	275	
1954	259	N.A.	494	235	-
1955	270	N.A.	494	223	-
1956	275	371	494	96	219
1957	247	388	482	141	235
1958	228	364	447	136	216
1959	228	341	447	113	216
1960	247	353	470	105	223
1961	294	353	505	59	223
1962	306	505	47	200	
1963	341	404	588	63	247
1964	635	846	846	212	212
1965	541	646	823	105	282
1966	447	505	764	59	317
1967	529	611	799	82	270
1968	623	751	846	129	223
1969	-	-	1,058	-	-
1970	-	-	2,656	-	-

1. CIF London price; 60%-65% concentrate grades

2. Based on free market ore and metal prices

3. Based on free market ore and producer metal prices

While price prediction is hazardous for a metal that has recently been so volatile, it is generally forecast by the trade that in the 1970's producer prices will generally be near US$ 950 to US$ 1,050 per ton of metal.

C. SMELTING

Currently, with the exception of that from China, most antimony is shipped from producing to industrialized countries where it is upgraded.

Table 33 presents a list of smelters in the Western world. It indicates that only one smelter is located near a mine (Ammi in Italy). However, this company also produces lead and it is government owned, which reduces marketing problems to a minimum. There are two other pure antimony smelters, Lucette in France and Hibino in Japan. Both of these have tariff protection on metal and good-sized local markets.

Other large smelters such as Campine in Belgium, National Lead in the United States, Associated Lead in England, and two smelters in Japan produce antimonial lead and other products, in addition to antimony. The majority of smelters produce antimony as one of a large number of products from a wide range of ores, where antimony is generally a by-product. The only smelters outside the industrialized countries where antimony is strictly a by-product are located in China, Peru and India.

TABLE 33

ANTIMONY SMELTERS, PRODUCTS, RANGES AND CAPACITIES

(Long Tons)[1]

1. Compagnie Metallurgique de la Campine - Brusels, Belgium

   lead & antimony and alloys thereof, lead products include antimony regulus, oxide & antimonal lead

2. Associated Lead - London, England

	Capacity
lead & antimony alloys as above	6,000 currently being double

3. Société Noubelle des Mines de la Lucette, Paris, France

   antimony regulus - 200 tons capacity
   antimony oxide - 1,500 tons capacity

4. Société Industrielles Chemique Aisne (SICA) - France

   antimony oxide

5. Ammi - Rome, Italy

   antimony regulus - 1,000 - associate produces antimonal lead
   antimony oxide - 100

6. Hibino Industry Corp. - Osaka, Japan

	Capacity
antimony oxide & regulus	4,000

7. Mikumi Smelting & Refining - Osaka

	Capacity	
antimony	1,200	
electrolitic antimony	30	also produce antimonal lead
antimony trioxide	100	

8. Mitsui Mining & Smelting - Japan

   antimony as by product

9. American Smelting & Refining Co.-U.S.A.

10. Anchor Alloys Inc. - U.S.A.

11. The Bunker Hill Co. - U.S.A.

12. K. Hettleman & Sons - U.S.A.

13. National Lead - Texas Smelting & Mining Division - U.S.A.

antimony alloys ' metal, antimonial lead

14. U.S.S. Lead Refinery Inc. - U.S.A.

All the above save Matimal Lead produce antimony as by product.

15. Cerro Corporation - Peru

by product

16. Star Metal Refinery - Bombay, India

	Capacity
Antimony metal	1,200

1. One long ton equals 0.98 metric tons.

There are a number of reasons underlying this distribution of smelter capacity. First, antimony is frequently found as a by-product and, therefore, it is processed by smelters having the capacity of handling complex ores and extracting ore from a wide range of sources. Second, tariffs on metal imports are substantial thus protecting the smelting industry of the country. For example, the following are the duties imposed by selected countries on metal imports: United Kingdom -25%; Germany and France -8%; Japan 10%; the United States US$ 33 per ton. Third, most smelters located in the industrialized countries are near the markets for the metals and have close relationships with their customers. They produce alloys to the specifications of their customers and, in general, benefit from being in close physicial proximity.

Total world antimony capacity is difficult to estimate because much of it is by-product capacity. It is presently thought to be, however, 66,000 metric tons per year. Recently a number of companies have announced plans to expand their antimony smelting facilities. It would appear from this discussions that ample capacity is available in the world.

In Bolivia our field work indicated that consideration has been given to the installation of two antimony smelters. ENAF, the official smelting agency. has plans for the installation of a 5,000 ton per year smelter near Oruro. The investment required

is estimated at US$ 2.0 million to US$ 3.0 million. The second smelter is being considered by EMUSA, the largest private antimony producer in Bolivia. It would be located near Tupiza and it would have a capacity of 3,000 tons per year. Investment is estimated at US$ 7.0 million.

Our analysis of proven and indicated reserves demonstrates that the most logical location for an antimony smelter in Bolivia would be near Tupiza rather than Oruro. The reserves near Cruro. The reserves near Oruro are not well defined and are largely held by small miners. On the other hand, based upon limited exposure to the details surrounding the smelter proposed by ENAF and EMUSA, it appears that the ENAF smelter which is based on a Czechoslovakia process involves a simpler processing concept and has lower capital requirements than the EMUSA smelter.

Our market examination indicated that the fastest growing antimony product is antimony oxide. The installation of a smelter in Bolivia should have, therefore, the capability of produ producing both metal and oxide.

Of considerable importance in smelter operations is the margin available for the conversion of ore to metal. An interesting characteristic of antimony trade is that no consistent relationship between the free market price of ore and metal exists. Table 32 indicates that the margin for conversion has ranged between US$ 47 per ton and US$ 212 per ton. As a result,

it is difficult to estimate conversion margins for smelters. Our interviews with the trade, however, indicated that in the future a normal conversion margin might be about US$ 125 to 175 per ton. Although, operating cost or profit data are not available for companies who primarily smelt antimony it is our experience that these companies are quite profitable. On this basis, it is quite probable that the establishment of an antimony smelter in Bolivia represents a good opportunity. We assume that the studies of the proposed smelters have investigated their economics in detail and have determined their viability.

The scale of plant for smelting facilities should be such that management has the flexibility of selling either ore or metal. The wide fluctuations in conversion margin indicates that at times Bolivia would gain greater benefits from selling ore while at other times the sale of metal would yield the larger benefits. On a preliminary basis we estimate that the capacity of the smelter should be no greater than 3.000 to 5,000 tons per year.

D. IDENTIFICATION OF OPPORTUNITIES

1. Antimony Oxide

The availability of primary antimony metal in Bolivia suggests the possibility of producing antimony oxide. The proposed smelter project should consider the inclusion of facilities for the manufacture of this product.

2. Antimony Alloys

There is an opportunity to produce antimony alloys.This possibility will be discussed later in the report under non-ferrous alloys.

3. Marketing

An opportunity exists for the development of a marketing strategy and organization that would gain for Bolivia the greatest benefits from the smelting of antimony concentrates into metal.

Antimony metal is sold on the free market or by producers directly to customers. Sales on the free market are handled by metal traders; direct sales by producers are made by smelters having their own sales organization and long-term relationships with their customers which allow them to follow a stable pricing policy.

Antimony metal traded on the free market accounts for about one-third of total sales. It is sold solely on the basis of price which tends to fluctuate substantially; in normal times it is well bellow the producer price (Table 32). Most antimony sales are made by producers.

The producer price is generally received by the larger smelters for their metal. The smaller smelters who sell directly to customers have in periods of ample supply dificulty selling

at the producer price and offer a limited discount. Conversely, in times of shortage they receive a slight premium for their metal.

Within this frameworks it is clear Bolivia's need to have a marketing strategy that will enable them to obtain the highest possible price for antimony metal. This is particularly true at the present time since smelter capacity in the Western World appears to be adequate and the introduction in Bolivia of a smelter would have a substantial impact on metal prices. A Bolivian smelter converting one-half of its ore could increase the volume of metal traded on the free market by as much a 25%.

Bolivia must ensure that it achieves outlets for its antimony products without having to reduce prices to the point where the smelter is uneconomic. The discount that antimony metal producers selling on the free market have offerred in the past to move their metal has at times been very high. For example in 1966 the free market price was US$ 505 per ton. In comparison the producer price was US$ 764 per ton. Similarly in 1967 the free market price was US$ 611 per ton versus a producer price of US$ 800 per ton. Countries such as Japan and Russia are able to sell their metal at discount on the free market since these sales are marginal. The major part of their production is sold in their domestic markets at higher prices.

In summary, the success of a smelter in Bolivia will in large part depend on the price it is able to obtain for its products. If Bolivia is to sell antimony metal at the highest possible price it will require a well developed marketing strategy.

VIII. T U N G S T E N

VIII. T U N G S T E N

A. RESOURCES

The tungsten mineral resources of Bolivia have been described by K.C. Li[1] as being found:

"throughout the tin belt, usually in separate deposits and rarely associated with tin ores. The principal mines are in the Department of La Paz, with smaller producers in the Departments of Oruro and Cochabamba (and Potosi). The ore deposits occur in the metamorphosed quartzites, usually in fissures normal to the contacts of the granite intrusives, as at the Chojlla and the Araca mines. In some instances, the deposits are parallel to the bedding planes of the sedimentaries, as at the Bolsa Negra mine, but they rarely occur within the granite intrusive. Wolframite is the most common mineral, although scheelite is also prominent in some of the deposits. These minerals occur in the vein deposits with quartz alone or associated with pyrite, arsenopyrite, and chalcopyrite, and occasionally with cassiterite. There are also brecciated deposits in the form of irregular lodes in quartzites in which scheelite occurs in the matrix of cementing material, as at the Juliana mine in the province of Oruro. In general, both the geological features and mode of occurence of the tungsten deposits are similar to those of the tin deposits".

(1) Li, K.C., Tungsten, Third Edition, Reinhold Publishing Corp. 1955

The potential resources of tungsten in Bolivia were indicated in 1965 (by P.T. Flawn[2]) to be about 87,000 short tons on a 60% WO_3 basis. This estimate indicates that Bolivia has about 3% of total world and 10% of Western World potential resources. The current reported Bolivian reserves of contained tungsten (on a 60% basis) are presented in Table 34. They are estimated to be about 157,000 tons of which 57,700 tons are proven and indicated and 100,000 tons are inferred.

In recent years, production of tungsten by Bolivian mines has been reported to have achieved levels in excess of 2,000 tons per year of 60% WO_3 concentrate (Table 35). Current rates of production could be maintained for about 25 years, based on the estimate of total indicated reserves. The total inferred reserves data would suggest the possibility for mineral operations to continue for about 50 additional years.

COMIBOL in 1969 reported the cost of producing tungsten concentrate at US$ 22.50 per ton. In order to arrive at total costs, royalties, transportation, and related costs of marketing must be added to production costs. These amounted to about US$ 20 per ton bringing the total cost to US$ 42.50. Prices for tungsten concentrate during 1970 were about US$ 69 per ton, down from the US$ 98 per ton price peak achieved in the beginning of the year.

(2) Flawn, P.T., Mineral Resources, Rand McNally & Company, 1966

TABLE 34

TUNGSTEN RESERVES IN BOLIVIA

60% WO_3 BASIS

(Tons)

Proven and Indicated	Tons
COMIBOL	4,100
Medium Mines	53,000
Small Mines	600
	57,700
Inferred	100,000
TOTAL:	157,700

TABLE 35

BOLIVIAN TUNGSTEN PRODUCTION

1960 - 1969

(Thousand Tons)

YEAR	COMIBOL PRODUCTION	PRIVATE MINES PRODUCTION	TOTAL
1960	0.5	8.0	1.3
1961	0.4	1.3	1.7
1962	0.3	1.2	1.5
1963	0.2	1.2	1.4
1964	0.1	1.1	1.2
1965	0.1	1.0	1.1
1966	0.5	1.1	1.6
1967	0.7	1.3	2.0
1968	0.6	1.5	2.1
1969	0.7	1.6	2.3

Table 36 presents tungsten production between 1950 and 1968. In the last several years world production has been about 33,000 to 38,000 tons annually. China, Russia, the United States and South Korea are the major suppliers to the world market. North Korea and Bolivia, both of which have similar importance are the next largest suppliers.

In the Andean Subregion, Perú is a substantial supplier of tungsten ore, with its production being about 40% that of Bolivia. Other producers in South America are Brazil, with an output somewhat less than Perú, and Argentina which produced about 300 tons during 1969.

Between 1950 and 1968 world production of tungsten ore increased an average of 4% per year.

B. MARKETS

1. Uses

Tungsten has been used historically by the steel industry as an important additive for the production of alloy steel, tool steel, and hot work die steels. It can be used directly as concentrate of wolframite or scheelite ores, or first upgraded to ferrotungsten. Tungsten is also refined and converted to a variety of metal products, which are used in a wide range of industries, and particularly in the electrical industry. It is also used in the production of carbide products.

TABLE 36

TUNGSTEN PRODUCTION

ORES AND CONCENTRATES

1950 - 1968

(Thousand Long Tons[1] - WO_3 Content[2])

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
WORLD ESTIMATE MAJOR PRODUCERS[3]	18.2	24.3	32.2	40.0	38.0	40.0	39.0	33.0	30.0	32.0	38.0	41.0	38.0	33.0	34.0	33.0	33.0	34.0	38.0
CHINA[4]	7.4	7.8	9.7	12.0	11.0	11.0	11.0	9.0	9.0	12.0	13.0	13.0	13.0	13.0	12.0	10.0	9.0	9.0	9.0
U.S.S.R.[5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.0	5.3	5.6	5.9	6.2	6.5	6.5	6.8	7.3	7.6	7.6
U.S.A.	2.2	3.3	4.0	5.2	7.4	8.9	8.3	4.5	2.0	2.0	3.9	4.4	4.5	3.0	5.0	4.3	4.8	4.9	5.7
SOUTH KOREA	0.8	1.1	3.7	7.3	2.4	2.0	2.4	2.4	1.9	1.9	3.1	4.0	3.7	3.0	3.0	2.0	2.0	2.3	2.6
NORTH KOREA[6]	1.0	1.2	1.2	1.2	1.0	1.0	1.0	1.5	1.8	2.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
BOLIVIA	1.5	1.6	2.2	2.3	2.6	3.2	2.8	2.6	1.3	1.4	1.3	1.7	1.5	1.3	1.2	1.1	1.6	1.9	2.2
PORTUGAL	1.7	3.0	3.1	3.0	2.7	2.7	3.0	2.5	1.1	1.3	1.7	1.8	1.5	1.0	1.0	1.0	1.2	1.4	1.7
CANADA	0.1	0.0	0.6	1.0	1.0	0.9	1.0	0.9	0.3	-	-	-	-	N/A	N/A	1.7	1.9	0.2	1.6
AUSTRALIA	0.7	1.1	1.3	1.4	1.4	1.5	1.6	1.5	0.9	0.7	1.1	1.5	1.0	1.0	1.0	1.2	1.3	1.2	1.3
PERU	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5	0.5	0.4	0.4	0.5	0.3	0.4	0.3	0.4	0.5
BRAZIL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.3	1.8	1.3	1.3	1.0	0.2	0.2	0.2	0.3	0.4
THAILAND	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5	0.5	0.5	0.4	0.2	0.2	0.3	0.3	0.5	0.5

NOTES:
1 One metric tone equals 0.98 long tons.
2 WO_3 contains 79.3% Tungsten (W).
3 World - 1950-1957 - Excluding U.S.S.R.
4 China - 1950-1968 - Western estimates.
5 U.S.S.R. - 1958-1968 - Western estimates.
6 North Korea - 1950-1968 - Western estimates.

SOURCES: Institute of Geological Sources, United Kingdom Government
Statistical Summary of Mineral Industry.
U.S. Bureau of Mines.

The United States provides a good example of the distribution of tungsten among its uses. Of total tungsten consumption approximately 20% is used as alloy additions to tool steels and high speed steel in the form of ferrotungsten or other tungsten-base additives to alloy steel production operations. The remaining raw tungsten is converted first to refined tungstic oxide and then reduced to metallic tungsten. Substantially less than 5% of the refined tungsten is utilized in specialty and chemical applications which include direct use of ore concentrate and crude oxide. About 33% of refined tungsten is consolidated to metallic tungsten products, either mill forms or special shapes via powder metallurgy. The balance is converted to tungsten carbides.

Worldwide the major demand for tungsten is for the manufacture of carbide products. Cemented carbides are specialty metal products manufactured by sintering tungsten carbide powder with relatively ductile metallic cobalt. Products fabricated from sintered tungsten carbide have high abrasion resistance and high strength characteristics.

Fabricated tungsten carbide products have an average price of about US$ 40 per pound or approximately US$ 35 per pound above the value of tungsten powder. In the United States during the period 1962 - 67, the product value of fabricated carbide has increased at a rate greater than 15% per year.

Tungsten carbide applications can be divided into three broad categories: (1) Chip removal, (2) wear and abrasion resistance, and (3) high compressive strength. The chip-removal category includes all metal-cutting applications: single-point cutting, multi-point cutting, and continuous cutting such as drilling. Chip-removal applications are segregated into steel and cast iron cutting and non-ferrous metal cutting. The wear - and abrasion - resistant category encompasses dies for the drawing of rod and wire, wear parts of mechanical equipment, snow tire studs, and soft stone cutting tools. High-compressive strength uses include press operations requiring punch faces and die body liners, and hard rock drilling and mining tools. The utilization of carbides by each of the major categories is as follows:

Application Category	% of Total
Chip removal	
Steel Cutting	60
Cast Iron and Non-Ferrous metal cutting	10
Wear and Abrasion Resistant	15
High Compressive Strength	15

Recently there has been growing demand for sintered carbide for rock and well drilling tools, in preference to the steel tools historically utilized. The use of tungsten carbide in wear-and abrasion-resistant parts for expensive

equipment, to increase its lifetime and reduce downtime, has also been increasing. There is no immediate prospect for the replacement of cemented carbides in present uses although industry has made continuing efforts to utilize other materials for these applications.

2. Consumption

Table 37 presents recent tungsten consumption for selected countries during 1965 to 1969. More complete statistics are not available. Growth of world tungsten consumption is believed to have been at a higher rate than 4% during recent years but has been disguised by the effect of sales from the United States stock-pile.

In the future the demand for tungsten will grow at a rate of 5% to 10% per year. We expect that the demand increase in carbide products will be greater than that of either ferrotungsten or tungsten metal.

3. Prices

The price of tungsten products depends on the price of ore rather than that for metal as is the case for products manufactured from other metals. The world price for tungsten ore (outside the United States) is greatly influenced by the London Metal Bulletin quotation, and most contracts are related to this price in one way or another.

TABLE 37

CONSUMPTION OF TUNGSTEN ORES AND CONCENTRATES
SELECTED COUNTRIES
1965 - 1969
(Tons)

Country	1965	1966	1967	1968	1969
Actual Consumption					
Australia	(50)	(50)	(50)	(50)	(50)
Austria	1,810	1,904	1,425	1,280	1,[illegible]
Canada	203	204	184	(200)	-
Japan	1,471	1,819	2,608	2,265	-
Portugal	197	155	312	238	312(p)
Sweden	(983)	(942)	612	1,167	-
United Kingdom	3,416	3,015	2,219	2,682	3,488
United States	6,290	8,191	6,287	5,007	(5,761)
Apparent Consumption Including Stock Variations					
France	1,198	1,381	1,054	891	-
Apparent Consumption Excluding Stock Variations					
Argentina	53	42	50	54	-
Belgium-Luxembourg	20	29	25	76	-
Fed. Rep. of Germany	2,848	2,485	2,005	2,550	-
Italy	7	19	10	28	-
Netherlands	145	261	130	129	222
Poland	1,237	1,564	1,283	1,727	-
Spain	-	82	77	-	-
Yugoslavia	(90)	51	-	-	-
Total, Above Countries	20,018	22,194	18,331	(18,344)	

Notes: Sweden (1965-1966) - Apparent Consumption
(p) - Preliminary Data

Conversion Factors:
Belgium-Luxembourg : 0.4758 (or 0.60 x 0.793)
Italy (1965-1966): 0.51545 (or 0.65 x 0.793)
Netherlands: 0.793

Source: United Nations Tungsten Statistics

Figure 2 presents the pattern of prices since 1955 for tungsten ore of 65% WO_3 content. Until the General Services Administration started to make surplus stocks available, the United States price was virtually the same. The chart indicates that price started climbing from a low in 1962 and reached a high in 1969. In recent months it has experienced some decline.

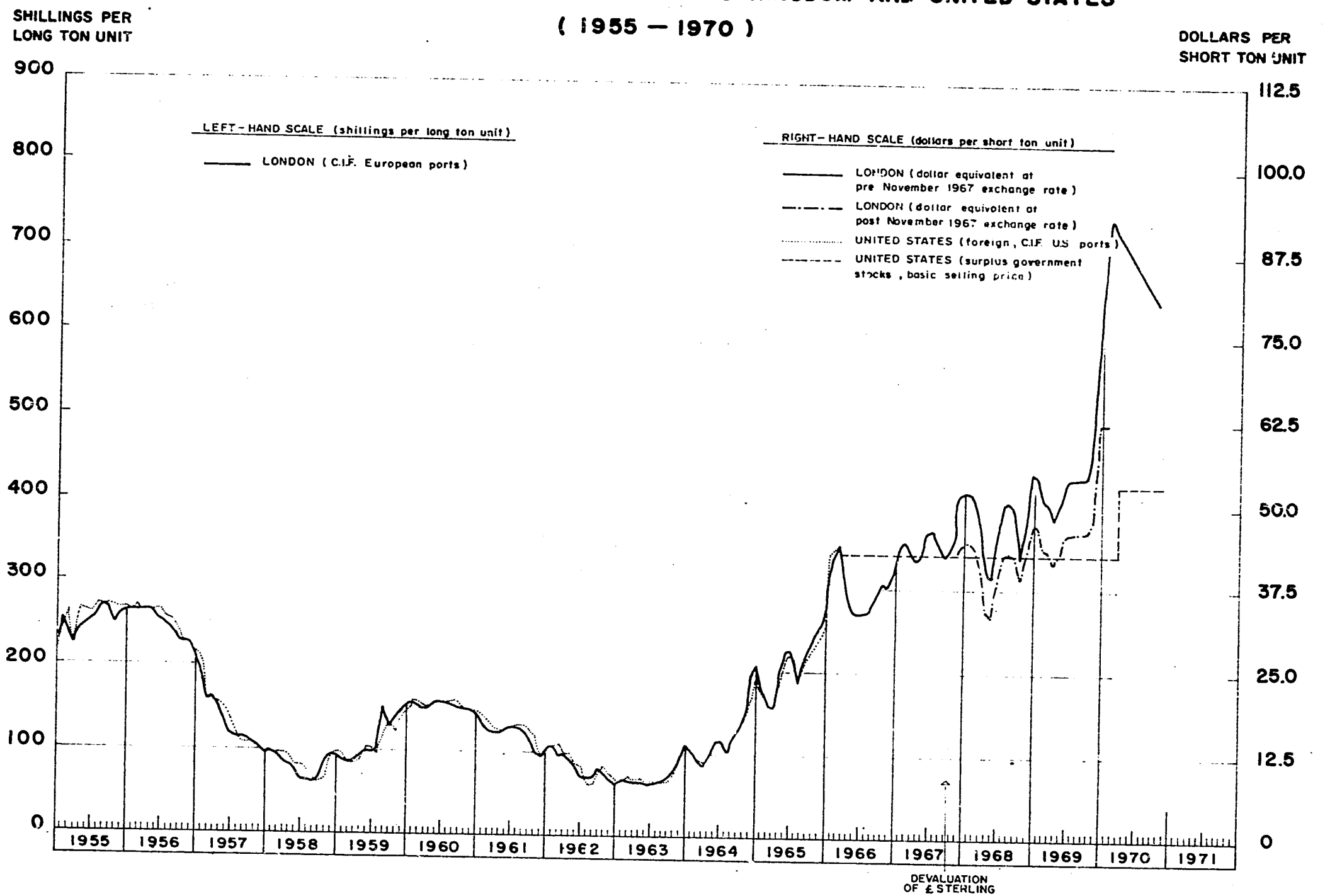
In the future it is expected that prices should level at about US$53 to US$ 65 per ton or about US$ 3 per pound of contained metal. This figure is substantially above the historical average.

It is difficult to project tungsten prices due to the uncertainty associated with predicting Chinese activity. For example, the sharp increase in 1969 prices was mainly due to the unexpected withdrawal of China as a supplier. The activities of the General Services Administration which buys from and sells to the United States stockpile also introduce a great deal of risk to price forecasting. It is expected, however, that if China continues not to sell tungsten, the United States can replace Chinese supply from its stockpile. The expansion plans in Australia, particularly the Peco Wallsend project which should triple production, and smaller projects planned for Canada, Portugal and the United States should also help dampen the effect on prices of a prolonged withdrawal of tungsten supplies.

— Figure 2 —

PRICES : TUNGSTEN CONCENTRATES UNITED KINGDOM AND UNITED STATES

(1955 — 1970)



SOURCE : UNITED NATIONS TUNGSTEN STATISTICS

4. Conversion Margins

Price quotations in the London Metal Bulletin present the basis for estimating conversion margins. In August 28, 1970, for example, the price of ore was quoted at US$ 74 - US$ 78 per ton; metal was quoted at US$ 5.60 per pound and carbide powder at US$ 7.20 - US$ 8.00 per pound. On this basis conversion margins are US$ 2.15 per pound of tungsten between ore and metal and US$ 4.75 per pound tungsten between ore and carbide. Ferrotungsten was quoted at US$ 5.00 per pound of 80%-85% grade contained tungsten.

It should be noted that the margins are based on published quotations which do not reflect discounts available for long-term contractual arrangements between refiners and fabricators. Actual margins may be as much as 10% lower than those we have presented.

5. Commercialization

World trade is primarily in tungsten ore, which is shipped from producing countries to industrialized countries and converted into ferrotungsten, powder, carbide, and other tungsten products. Within the Andean Subregion we are not aware of any facilities for upgrading tungsten. In South America, Brazil has some facilities for upgrading tungsten to ferroalloys and to tungsten carbides.

Because ore comes from a number of countries, many of which have a relatively small output, traders have an important part in the transfer of tungsten ore from producer countries to converter countries. This is not the case for upgraded tungsten. Converters generally have close relationships with their customers, offering a wide range of products and tailoring specifications to very demanding standards.

The major converter countries are the United States, United Kingdom, West Germany, Japan, France, Austria and Sweden. With the exception of the United States all other converting countries import essentially all their tungsten ore requirements. Outside the United States, important purchasers of tungsten ore are companies such as Murex in England, Starck in Germany, Fagersta and Sandvik in Sweden, and Metallwerke in Austria.

6. Import Duties

Import duties for upgraded tungsten products in the consuming countries vary with the product. For example, the duty on ore imported to the United States is about US$ 0.50 per pound metal content. For ferrotungsten the duty is US$ 0.60 per pound plus 25% of the value. A duty of 25% is imposed on metal powder and up to 60 cents duty plus ad valorem charges on fabricated products. Similarly in the United Kingdom the duty is US$ 2.10 per pound on powder and US$ 2.04 per pound on ferrotungsten; these duties are scheduled to drop in 1972 to US$ 1.50 per pound on

powder and US$ 1.80 per pound on ferrotungsten. Germany imposes duties of US$ 0.72 on powder and US$ 0.84 on ferrotungsten.

C. MANUFACTURING TECHNOLOGY

1. Introduction

Primary refined tungsten is initially produced from the ore by chemical extraction processes in the form of purified chemicals and finally metal powder. By a parallel electrothermal reduction process, the tungsten ore can also be converted to ferrotungsten. The two process routes, either to refined product or to ferrotungsten are mutually exclusive. Off-grade-by-product from the refining operations could be salvaged by conversion to the ferroalloy. We would suggest the initial effort in tungsten should not consider the production of ferrotungsten, unless it is produced as a one of a line of ferroalloys.

The bulk of world production of tungsten ore is refined to metallic powder. Most of the refined powder is reacted with carbon to form tungsten carbide which is fabricated to tools and wear resistant components. Some of the metallic powder is used directly in the production of tungsten-base parts by powder metallurgy. The balance of the powder is converted to dense billet and fabricated to solid bodies or mill shapes in extended hot and cold metal-working operations.

For the production of powder, the ore concentrate from the mines is purchased by refiners on the basis of a nominal content of 60-70% tungstic oxide. A maximum content of 0.002% of molybdenum is preferred for material destined for high quality products, but material with higher molybdenum contents may be used for the production of powder for carbide.

2. Refining to Powder

In a typical refining treatment, wolframite ore is ground and then digested in batch quantities of 200 Kg. to 1,000 Kg. with hot caustic soda to form a solution of sodium tungstate which is crystallized by evaporation. The residue or the liquor can be further processed for extraction and conversion to synthetic scheelite.

The purified sodium tungstate is redissolved, precipitated as tungstic acid, settled, washed to lower the sodium content to less than 0.01% and then dried. This initial purified product has its value increased about 1/3 above the value of concentrate. The tungstic oxide material is suitable for carbon or hydrogen reduction to tungsten powder and for subsequent tungsten carbide production. The dried precipitated oxide can be carbon reduced to metal powder.

The best quality tungsten is produced by redissolving the initial tungstic oxide in ammonia solution which is then treated

to remove residual impurities and to precipitate purified ammonium paratungstate (APT). The APT is thermally decomposed to high purity tungstic oxide. For hydrogen reduced powder, the oxides are blended and reduced in a two-stage treatment. Typical furnace temperatures are a first zone of 500°C, a second zone of 750°C and a third zone above 900°C, with a hydrogen flow velocity of 5 feet per minute through the furnace. Hydrogen is frequently produced on the site. Depending upon the end product use, several grades of powder can be produced ranging in particle size from 1 to 10 microns. Highly purified tungsten has a value of about US$ 3.0 per pound greater than tungsten concentrate.

3. Conversion to Mill Products

The conversion to tungsten powder to sintered ingot and subsequently to mill products (bar, rod, wire, and flat rolled sheet and strip) has been estimated to cost about US$ 1.00 to US$ 1.25 per pound. This estimate is based on analysis of large production runs for three major operations of pressing, presintering, and sintering with allowances for charges for auxiliary equipment, labor and operating costs for hydrogen facilities, vacuum equipment, powder blending and in-process control functions.

Tungsten powder for wire production is treated to obtain the largest possible grain sizes in the sintered bar. Sintered billets for wire grade bars should have only about 10 grains across the bar section, and attempts have been made to obtain single crystal

bars. The large grain sizes can be obtained only by the use of powder washed with hydrofluoric acid. Unwashed powder which is used for the production of rod results in a fine-grained bar with a grain size on the order of 14,000 grains per mm^2.

The sintered billet for rod and wire is swaged to reduce the bar size to drawing diameters and to obtain preferred metallurgical structure. Each product category governs the degree of reduction, sequence of operations performed and the equipment employed. After the basic swaging operation, the treatment of the material will be dependent in part on the particular grade and the metallurgical characteristics desired; e.g., the wiremaking operations require frequent intermediate anneals as the wire is continuously reduced in size.

Depending upon the decree of metal working involved tungsten mill products would have a value of US$ 10.0 to US$ 100.0 per pound greater than the concentrate.

In order to achieve the required level of processing for the tungsten, substantial investment in equipment is required. All important producers of tungsten rod and wire have substantial captive consumption in integrated manufacturing operations for production of electrical components and equipment which contain fabricated wire and rod. As a result, it is unlikely that this area represents an opportunity for Bolivia.

4. Tungsten Powder Metallurgy Parts

The direct production of small parts from powder is also accomplished by cold pressing and hydrogen sintering. For heavy metal alloy and composite contact parts, resistance heated atmosphere furnaces with temperature capability of 1600°C would be adequate. The throughput of a powder consolidation facility will be very dependent on the size mix of the parts being produced. The resultant cost per unit of product will reflect the variation of throughput. We believe that the production of this type of tungsten products is much too specialized and serves markets too widely dispersed to be an attractive opportunity for Bolivia.

5. Tungsten Carbide

The conversion of purified tungsten oxide to tungsten carbide powder results in the highest value added by tungsten powder. The initial step in the manufacture of tungsten carbide is the production of metallic tungsten powder via extraction from tungsten ore concentrates and purification to ammonium paratungstate (APT). Thermal decomposition of the APT to tungstic oxide is followed by hydrogen or carbon reduction of the oxide to metal powder as described earlier. Throughout these thermal treatments, the time-temperature schedule is carefully controlled to attain desired particle sizes. The hydrogen-reduced tungsten powder is converted to the monocarbide by reaction with carbon in a graphite tube furnace at about 1600°C. Control of the carburization treatment

yields selected sizes for various grades and applications.

The value added to the tungsten powder by converting to tungsten carbide ranges from US$ 1.0 to US$ 2.0 per pound, increasing with decreasing particle size.

Cemented carbides are produced from tungsten carbide (with additions of titanium and/or tantalum carbide, in the case of steel-cutting tool grades) blended with cobalt in proportions ranging from 3% to 25% by weight. For example, mining tools would contain 9% to 15% cobalt. The blended powder is then pressed and sintered at 1400°C - 1550°C in a hydrogen atmosphere or vacuum, depending upon the grade of carbide or the producer. The pressed blank shrinks almost 50% in volume to desired final dimensions and essentially zero residual porosity is achieved. After sintering, the carbide piece is at full hardness and is finished to precision dimensions by diamond grinding. (The finishing of tungsten carbides is the greatest single use of diamond grinding wheels. The fabrication of cemented carbide by conventional powder metallurgy processing technology approximately adds 100% value to loose carbide powder. Precision diamond grinding could add as much as 100% to the value of the carbide, depending upon the degree of grinding required.

6. Investment Requirements

The investment cost for a tungsten refining and carbide producing operation would be dependent upon critical factors of product mix and planned production rates as well as on characteristics of the initial concentrate. However, considering the range of typical investment costs of primary refineries for refractory metals, we would expect an investment in the range of US$ 4,000 to US$ 10,000 per annual net ton of capacity. Taking advantage of the lower costs of labor in Bolivia, we would estimate a cost of US$ 6,000 per ton for a moderate size plant consistent with Bolivian tungsten production, of about 1000 tons or a total investment of US$ 6.0 million.

D. OPPORTUNITIES

At present Bolivia's tungsten production, nearly 2500 tons per year, is exported to world markets as concentrates which is the lowest value tungsten form. A very important opportunity exists for Bolivia to upgrade tungsten concentrate. The various upgrading possibilities are: (1) primary refining to tungstic oxide, to carbon reduced metal powder, and to crude carbide suitable for mining and rock drilling tools; (2) purification through ammonium paratungstated to hydrogen reduced metal and fine carbide powder which would be suitable for metal cutting tools; (3) production of mining, rock drilling, and metal cutting tools.

The benefits that would be derived by Bolivia from further upgrading are substantial. For example, if the 2500 tons per year of concentrates now sold on world markets were to be converted and sold as tungsten carbide the incremental value would be nearly US$ 50.0 million. This would represent about 10-15% of the world market for tungsten carbide.

In view of the importance of this opportunity we recommend that a feasibility study be undertaken. It would cover a number of areas. First the market for different tungsten products would be examined in order to determine the preferred product mix and to establish a plan for the development of production. Included in this investigation would be an evaluation of competitive sources, market growth, and marketing requirements (e.g. sales organization and warehouse outlets). Second, a suitable process flowsheet for the extraction and refining of the tungsten metal from the ore must be determined. This is an important step in view of the variety of tungsten ore grades mined in Bolivia. Third, the most suitable plant required for the production of tungsten products would be identified and capital investment, operating costs, acquisition of technology costs, and other costs would be estimated. These estimates would take into account future expansion of the facilities.

IX. U R A N I U M

IX. U R A N I U M

At present there are no known reserves of uranium in Bolivia. The government of Bolivia, however, asked Arthur D. Little, Inc. to include a discussion of the opportunity for uranium in the event that current and future exploration activities discover reserves.

Our analysis focused on: (1) the factors determining minerable reserves such as required ore grade, size of reserve, and tons of U_3O_8 contained in deposit; and (2) the world market outlook for uranium.

Throughout the analysis we use the United States as an example because it accounts for approximately 50% of the world's demand for uranium and in the past has been responsible for a much higher percentage of supply. The United States is also regarded as having ore deposits which are competitive with most others in the world, although recently there have been rumors of major discoveries of large, low-grade, open-pit deposits in countries other than the United States which might be exploited at costs lower than those incurred in the United States.

A. RESOURCES

World reserves of uranium are currently estimated at 840,000 tons U_3O_8, up 20% from the 700,000 tons U_3O_8 known in 1967. This increase reflects some of the results of recent extensive and successful exploration activity, but does not include deposits which have not yet been verified since exploration for uranium has been actively pursued only within the last four years.

In the United States, many of the deposits close to the surface were found during the intensive exploration activity of the 1950's aimed at satisfying demand by the United States Atomic Energy Commision, because commercial nuclear power did not develop as rapidly as expected, the industry ceased virtually all exploration activity during the mid-1960's (some development drilling of known deposits, however, was continued. In recent exploration activity in the United States there has been a tendency to drill deeper, seeking deposits that were not uncovered earlier.

In most other countries near-surface occurrences have not yet been thoroughly explored and there appears to have been some recent major surface finds. Significant deposits have been discovered in Australia and in Africa and there are indications that some of these may be of major importance. For instance, it is reported that newly discovered deposit in Australia could supply total world demand. Even if this report is greatly exaggerated, it is indicative of the fact that in order to be competitive in

the future a uranium deposit will have to be reasonably low cost. This suggests that marginal deposits will become less competitive in future uranium markets. Thus, a country considering entering this field should have reasonable geologic indications that the deposits that are likely to be found will be competitive with those existing in other parts of the world. Without such indications, we believe that funds could be invested in other areas with more probable possibilities of higher returns.

1. Nature of Uranium Occurrences

Uranium deposits are mined by both open-pit and underground methods. Generally speaking, the open-pit mines extend to a maximum depth of about 400 feet. If the ore occurs at depths below 500 feet, underground methods are generally used.

a. Mode of Occurrences

Deposits containing uranium minerals are in either of two modes-stratiform or vein.

Stratiform deposits are tabular masses: i.e., the length and width dimensions tend to be large in comparison to the thickness. These masses lie nearly parallel to the bedding planes of the host rock. They can be divided into three types according to the rock in which they are found: sandstone and conglomerate bedded, limestone bedded, and

lignite bedded.

Vein deposits are localized along fractures, or other structural features, that generally cut the host rocks at steep angles. Vein deposits are further classified by the nature of the structural features: namely, whether they are faults, contact faces of intrusions into the host rock, or breccia pipes in which the deposits are intermixed with fragments of older rock distributed within the pipe formation.

By far, the most common mode of occurrence is the stratiform type in which the uranium mineralization occurs in sandstone and conglomerate.

Since the beginning of large-scale uranium mining in 1948, about 95% of the U.S. reserves have been found in this form.

b. Uranium Minerals

More than 100 uranium-bearing minerals are known, but only few are significant (Table 38). The primary minerals are those which now exist as originally formed: i.e., by precipitation from solution into a favorable horizon, usually one in which a source of carbonaceous material was present. The secondary minerals are formed by alteration

TABLE 38

PRINCIPAL URANIUM MINERALS OCCURING IN THE UNITED STATES

Mineral Name	Chemical Formula	Description
Primary		
Uraninite	UO_2	The natural mineral is a crystalline oxide. It is more or less oxidized so that the actual composition lies between UO_2 and U_3O_8.
Pitchblende	UO_2	A massive and amorphous form of the oxide.
Gummite	$UO_3.nH_2O$	An end product of the oxidation and hydration of uraninite. Physical properties and Chemical composition vary widely.
Secondary		
Carnotite	$K_2(UO_2)_2(VO_4)_2\text{-}nH_2O$	Ayellowhish hydrous basic vanadate of potassium and uranium.
Tyuyamunite	$Ca(UO_2)_2(VO_4)_2.nH_2O$	A yellowish hydrous basic vanadate of calcium and uranium.
Torbernite	$Cu(UO_2)_2(PO_4)_2.nH_2O$	A greenish hydrated phosphate of copper and uranium.
Autunite	$Ca(UO_2)_2(PO_4)_2.nH_2O$	A yellowish hydrated phosphate of calcium and uranium.
Uranophane	$CaO(UO_3)_2(SiO_2)_2.7H_2O$	A yellowish hydrated silicate of calcium and uranium.
Coffinite	$U(SiO_4)_{1-x}(OH)_{4x}$	A basic uranium silicate usually associated with carbonaceous materials.

Source: Arthur D. Lettle, Inc.

of the primary forms through combined leaching and oxidation processes. "Gummite" is listed as a primary mineral, although it is a partially altered form of the uranium oxide UO_2.

The predominant mineral is uraninite, which occurs as the major constituent of most of the U.S. deposits. The one exception is in the Uravan Mineral Belt in the Colorado Plateau, where the predominant minerals are the secondary ones plus other primarily vanadium-bearing minerals

2. Depth, Size, and Grade of Mineable Deposits

The development of the uranium mining industry has been such that, in general, open-pit operations, as mentioned above, can extend to depths of about 400 feet. However, in practice many of the shallower deposits are also mined by underground methods. Therefore, open pit reserves, at least in the United States, are significantly less than might be expected (about 58% of the total). Distribution of uranium reserves by mining mode (open-pit or underground) is practically independent of the selling price of U_3O_8. The reserves per deposit tend to be small as compared with other minerals. The average reserve of about 70% of the properties is less than 5.5 tons of contained U_3O_8.

Reserves are based upon cutoff grade or the grade below which is no longer profitable to mine the property. The cutoff grade depends on a specific mining plan for the property and is

set at levels which permit profitable operation at a selling price of US$ 6.00 to US$ 8.00 per pound of U_3O_8. These figures cover the range of the existing contracts. Practically all of the reserves in the United States have a grade less than 0.35% U_3O_8, and reserve figures are based on the existing selling price range of US$ 6.00 to US$ 8.00 per pound U_3O_8. Therefore, if the price of U_3O_8 were US$ 10.00 per pound instead of present levels, cutoff levels would be lower and reserve estimates would be larger. The present average grade for open-pit mines in the United States is in the range of about 0.19% to 0.25% U_3O_8 and for underground mines 0.25% to 0.33% U_3O_8 at a selling price of US$ 6.00 to US$ 8.00 per pound U_3O_8. Should the price of U_3O_8 increase to the US$ 10.00 per pound level, we estimate that average grades of underground mines will be 0.19% U_3O_8 and open-pit mines 0.15% U_3O_8. The above gives some guidelines as to the grade of ore that constitutes reserves.

B. EXPLORATION

One peculiarity of many U.S. uranium deposits, particularly in the Uravan Mineral Belt, is that the ore occurrences are difficult to explore in order t estimate reserves accurately before the deposits are developed as mines. The reasons are the small, scattered, spotty, and unpredictable nature of most of the deposits--a situation not generally true of other mineral deposits.

The starting point in most areas is the knowledge that the geology of the sandstone horizons is generally favorable for uranium deposition. This knowledge is the result of past exploration, and operation of mines. The procedure for exploration is to drill holes through the known promising horizons to try to find economically exploitable deposits. Sufficient drilling is conducted, usually on a fixed grid pattern, to identify ore in quantities adequate to justify only the initial mine development costs. When exploration reaches this point, the mine is developed with the general assurance that on the basis of experience in the area the reserves of ore will be 3 or 4 times greater than those initially discovered. Quite commonly, therefore, uranium mines will have only a few years of reserves identified, but will continue to operate for twenty or more years on only small tonnages of reserves proven periodically.

It is, of course technically feasible to initially drill sufficient exploration holes to determine the total reserves in any block of land. But in most districts this would require the drilling of holes on a 6' - 10' grid pattern, if not less, in order to locate all the isolated and small ore bodies that otherwise would later be located more easily from the mine workings. Often, such holes would have to be drilled 500' - 1000' deep. Except in large continuous deposits, the cost of such an exploration effort could not be recovered from the profits of the eventual mining operations.

The procedure for finding isolated and small ore bodies is to explore by long-hole drilling from the underground openings after the mine is in production. As drifts, raises, and cross-cuts are driven, long holes (100' - 300') are drilled in all directions to define the limits of known and producing ore bodies, as well as to locate new ore bodies. When a new ore body is located in this way, openings are dug to reach it from the point of discovery, and further exploration is done from the new workings. Thus, mines in most uranium deposits are under continual development, and the future course of the workings is more or less unpredictable.

The ore bodies in United States uranium deposits vary in size from one hundred to two hundred tons up to several hundred thousand tons, or in some unusual cases to over one million tons. Depending on the location, size, grade, and relationship of the smaller ore bodies to the existing pattern of mine development, it may be unattractive to extract the ore found by underground exploration. These are judgments to be made by the mine management as the mine develops.

Another judgment which mine operators must make is whether to advance a heading some major distance in waste rock to reach a surface-drilled exploration hole which indicates some uranium mineralization, but which may not necessarily be promising. The decision is whether or not to invest in drilling additional deep

holes from the surface, or to invest in extending an underground opening to explore the questionable area.

In making such decisions, a good deal of intuition, experience, and luck is needed. Many mines considered essentially depleted by one operator have been revived and operated by some other operator who had ideas of where he might find additional ore accessible from the existing workings.

After exploration has been completed, and a uranium ore body (or series of ore bodies) has been defined, a decision must be made as to the method of exploitation. Exploration has to be done beforehand to define the size, shape, grade, location, and tonnage of the ore bodies to the extent that the capital investment can be justified. With this justification, the exploration results, price forecasts for the product ore, and alternative production cost estimates, a decision can be made on the preferred mining method.

C. MINING

The most important criterion in determining the choice of method between open pit or underground mining is the break-even stripping ratio. To determine this ratio, estimates are required beforehand of the mining costs, the ore recovery, and the ore dilution with waste to be expected with each method.

The break-even stripping (overburden removal) ratio is estimated as follows:

Break-even stripping ratio (BESR) =

$$\frac{\text{(Underground mining cost per ton ore)} - \text{(Open-pit mining cost per ton ore)}}{\text{(Open-pit stripping cost per ton overburden (waste)}}$$

A ton of overburden is taken usually to occupy in site about 0.5 cubic yard.

The ratio specifies the maximum quantity of waste that can be removed per ton of ore recovered, such that at the maximum the operation breaks even on production cost regardless of the method used. The BESR is a function of the cost involved in the two types of mining operations.

Next, at each depth for which the BESR has been determined, the ratio of waste to ore is calculated from the physical situation in the ground as disclosed by the drilling data. If, for example, the BESR is 25, and the ratio of waste to be removed to ore recovered is less than 25:1, then mining operations by open pit would be profitable. If the ratio is greater than 25:1, then an underground operation is indicated.

Generally, knowledge of similar deposits will indicate whether to mine open pit or to go underground. For example, if one has ore bodies below 1000 feet deep, it is obvious that these could only be economically exploited by underground methods. The

experience in the United States is that open-pit mines generally extend to a maximum depth of about 400 feet, and that deposits deeper than that level are usually exploited by underground methods.

1. Open-Pit Mining

Open pits usually require a substantial amount of waste to be stripped in order to reach the first ore bodies in a deposit for mining. However, in a few uranium open-pit mines that have been developed, the ore outcropped, so that stripping and ore production started together.

In general, stripping ratios (ratio of waste expressed in cubic yards moved to tons of ore mined) in uranium open-pit operations are higher than in pits operated for the recovery of other metals, such as copper or iron ore, which usually have stripping ratios of 2:4. In uranium open pits, it is not uncommon to have stripping ratios of 60-70 tons (30-35 cubic yards) of waste per ton of ore mined. For example, published information on one Wyoming pit indicates the need to move 13,500,000 cubic yards of waste to make available 400,000 tons of ore, a ratio of about 68.

Waste stripping and ore mining are carried out with conventional earth-moving equipment. In waste stripping, it is common practice to use scraper-loaders assisted by bulldozers for ripping and push loading.

Ore can be mined using conventional shovel-truck equipment or with smaller, more specialized equipment. For example, in the pits in some districts in Wyoming where ore bodies are small and variable in size and shape, backhoes have been useful for digging and truck loading.

2. Underground Mining

If underground mining of a deposit is preferable, a number of techniques are available. The best combination varies with the size, type, location, number, and position of the ore bodies to be mined.

The shallower and more randomly occurring ore bodies, such as those in the Uravan Mineral Belt and in the Big Indian District, often can be reached by digging adits, or slopes. For the deeper deposits, or where the topography does not permit adits, such as in the Grants Mining District, vertical shafts are more convenient and cheaper.

Because the bulk of the reserves of the presently mined uranium ores occurs in fresh water sediments as sandstone lenses, overlain and underlain by shales, the most common ore extraction method is by room and pillar techniques, the waste being left as pillars wherever possible. The sandstone ores are generally quite soft and porous, and are easy to drill and blast, although powder consumption can be as high as it is for hard rock mines.

Water can present a problem; and if present in the ore-bearing horizon, special measures may be necessary to take care of it. For example, in the Ambrosia Lake area, it has been found helpful to drive openings below the ore bodies before mining to help in draining water from them; consequently, some mines in that area are mined through sub-level openings.

D. URANIUM CONCENTRATION

Uranium concentration consists of recovering the uranium values from the ore in the form of "yellowcake" (U_3O_8).

Uranium ores are chemically processed to produce a high-grade concentrate. The processing method is determined by the composition of the uranium minerals present in the ore and by the chemical and physical composition of the ore-bearing formation.

The more prevalent primary uranium ore minerals are uraninite and pitchblende, which are essentially combinations of the tetravalent and hexavalent oxides of uranium. In the absence of an oxidizing agent, pitchblende and uraninite are insoluble in normal ore-leaching agents. Consequently, the dissolution of pitchblende or uraninite requires an oxidizing leach. Among the secondary uranium minerals are a large variety of hydrated oxides, silicates, phosphates, vanadates, sulfates, and carbonates, some of which can be leached without oxidation.

Uranium ore is also often mixed with various carbonaceous materials, as, for example, in the lignites in North and South Dakota. Because the carbonaceous matter is difficult to treat with aqueous leaching agents, it must be destroyed by roasting before the ore can be treated for uranium recovery.

Most metallic (except uranium) ores can usually be upgraded by a combination of physical concentrating methods, such as sorting, gravity concentration, flotation, or magnetic and electrostatic separation. There has been very little success in adapting these methods to uranium ores.

Uranium ores are usually leached with either acid or alkaline agents, and the uranium is then recovered from the leaching solutions. Acid leaching with sulfuric acid is preferred. But for high-lime ores, which contain acid-consuming constituents, basic or carbonate leaching is economically more attractive.

1. Leaching

A typical uranium milling plant has facilities where the ores it receives are blended, sampled, and stockpiled. From the stockpiles, the ores are fed to the first milling step, crushing and grinding (either wet or dry--but usually wet), followed by leaching. Where roasting is required (such as with carbonaceous ores, or with uranium-vanadium ores, where a salt roast is often used), the ore is dry-ground. In acid leaching, sufficient acid is added to maintain a pH of 1.0-1.5. The oxidant is usually

manganese dioxide or sodium chlorate. Leaching times can vary from a few to as many as 24 hours.

After leaching, the undissolved solids are separated from the acid solution, usually by various combinations of classifiers, thickeners, cyclones, and filters. It is quite common to wash fine solids by decantation, using several thickeners in a row, in which case the solids flow countercurrent to the flow of the removed liquid--thus called countercurrent decantation, or CCD. In a CCD plant, the solution which contains the uranium must be purified further by ion exchange or solvent extraction. The active agent in the ion exchange resin, or in the solvent, removes uranium from the solution as a chemical complex, and most of the unwanted ions in the solution are discharged as waste. Finally, the uranium is removed from the resin, or solvent, by treatment with a suitable acid or salt solution--the product is a purified uranium solution.

From the purified solution, uranium is obtained as a concentrate by precipitating it with ammonia, magnesium oxide, or sodium hydroxide. The concentrate, usually a mixture of uranium oxides and sodium and ammonium uranates, is dewatered by thickening and filtration (or centrifuging), and then dried. The dried uranium product of this process-- the product of most mills--is called "yellowcake", primarily U_3O_8.

High-lime ores are alkaline-carbonate leached with a mixture of sodium carbonate and sodium bicarbonate. For some ores, carbonate leaching is competitive with acid leaching. The ore is often ground with the carbonate leaching solution. Leaching times vary from 5 to 96 hours, depending on the use of pressure leaching at elevated temperatures. The carbonate solutions dissolve fewer impurities with the uranium than do sulfuric acid solutions. Therefore, the slurries from alkaline leaching can usually be filtered to remove the solids, and the uranium concentrate can then be precipitated from the filtrate by adding sodium hydroxide. The concentrate, filtered and dried, is the yellowcake.

2. Purification

In general, for solutions produced from acid leaching, the uranium must be separated from impurities by selective purification processes, such as ion exchange, or solvent extraction, or both. In the column ion exchange (IX) process, the clear pregnant acid solution from the liquid solid separation is passed through a series of ion exchange columns. In the columns, the uranium is selectively absorbed as an anionic complex by a strong base quaternary amine, which is in the form of resin beads ranging in size from 16-50 mesh. When the resin in the column becomes loaded, the flow is advanced to another column and the uranium is eluted with an acid or an acid solution of sodium or ammonium salts of chlorides, sulfates or nitrates.

Another ion exchange process that is well suited for treating slimy ores that are difficult to thicken and filter is the resin-in-pulp (RIP) process. In this process, baskets of ion exchange resin move up and down through the flowing pregnant slimy pulp. When the resins are loaded with uranium the uranium is eluted from the resin with sulfuric acid or acidified chloride solutions.

In the solvent extraction (SX) process, clear pregnant acid liquor is contacted in a continuous countercurrent of immiscible organic liquid containing an extractant that can complex uranium. The uranium is transferred to and concentrated in the organic liquid, which is only about 1/5 of the volume of the acid liquid. Uranium is re-extracted or stripped from the organic solution with an aqueous solution and the organic is recycled to the extraction circuit. The stripping solution volume is only a fraction of the organic volume and therefore the uranium is further concentrated during stripping operations. The stripping solution often contains 100 times the uranium content of the acid leaching liquor.

A more complex processing sequence is the addition of a solvent extraction circuit to an ion exchange process, referred to as the ELUEX process. In this process, the uranium is eluted from the resin with a strong sulfuric acid solution, while the amine solvent containing uranium is stripped with an ammonium sulfate solution maintained at a pH of 4.0-4.5. Uranium is usually precipitated from this solution with ammonia and the barren stripping solution

is recycled. Concentrates from the ELUEX process are usually of higher grade than those from processes using only solvent extraction or ion exchange.

The quality of yellowcake,- the first marketable product from the uranium mines and mills,- varies with the ore composition fed to the mill and with the process used. The U_3O_8 content can range between 75% and 100%, but commonly it ranges between 75% and 80%.

Although we have a great deal of information on the costs and profitability of mining and milling of uranium ores it is meaningless to discuss them until the size and nature of the deposit is known. Moreover, the profitability of uranium mining and milling to produce yellowcake is dependent upon the grade of the ore, the scale of the operations, and the nature of the ore, which dictate the requirements of the milling or extraction process to produce yellowcake. The value of a property can accurately be determined by knowing the grade of the ore, the reserves, and the nature of the deposit; and the costs associated with these can be compared against the selling price of U_3O_8 which will probably be in the range of US$ 7 - US$ 10 per pounds of U_3O_8.

It is clear, however, with its low labor costs, Bolivia should be in a favorable cost position over the U.S. and many other sources for exploitation of equivalent mining properties.

E. MARKETS

The major future market opportunities for uranium are for nuclear power generation where it will be used in enriched form.

Enrichment facilities are available to western world producers and consumers at the United States Atomic Energy Commission (USAEC) installations which have adequate capacity for at least the medium term future. Moreover, the USAEC has set the cost of separative work for enrichment at a level such that enrichment will not be a significant cost in the uranium power cycle.

The present situation in the United States is that only uranium from United States sources can be used in United States installations (i.e., there is an embargo on the use of foreign uranium in United States installations). It is expected, however, that this will be relaxed in the near future and that there will be no embargo on foreign sources.

1. Demand

The annual Free World demand for uranium is projected to increase from about 10,900 tons of U_3O_8 in 1970 to slightly over 63,600 tons in 1980. The United States accounts for approximately 50% of this demand, followed in order by Europe, Japan, and other countries grouped together. Cumulative demand from 1970 through 1980 is projected to reach 363,600 tons of U_3O_8.

There are many large power plants throughout the world that are scheduled to come on-stream in the next two years. The utilities need to obtain operating experience with these large facilities before they feel justified in making major commitments for additional plants. In addition, major delays are being experienced in power plants now under construction, due mainly to labor problems. In fact, a survey has shown that average construction time has slipped from the planned 4 years to about 5 years and some utilities are now assuming that construction of a nuclear facility will require 6 or 7 years. Although most authorities believe that actual operating experience will confirm the expected favorable economics of nuclear power and thereby the ultimate levels of projected growth in demand for uranium, this will not be confirmed before the mid-1970's and the specific time at which any particular demand will be realized will probably be significantly delayed from current projections.

Although uranium demand is typically projected only to 1980, it is generally agreed that growth will continue beyond that time, regardless of the breeder reactor which has raised questions in some minds about the future market for uranium. It is unlikely that the breeder reactor will be commercial before the mid-1980's at the earliest. Assuming the breeder does prove commercially viable, it still will be many years before there will be any material eff[illegible] on the growth of uranium demand, since the then existing inventory of non-breeder reactors will still have to be

fueled for the remainder of their useful lives which is generally considered to be around 30 years.

The Organization for Economic Cooperation and Development has recently prepared a report in which it estimates that the annual world demand for uranium of 38,000 tons U_3O_8 which will exist around 1975 is equivalent to the total existing production capacity. The USAEC, last year, made a similar estimate that United States present productive capacity could supply annual demand through 1976, taking no account of the U_3O_8 inventories which could be built up in early years when demand is well below productive capacity. In addition, new capacity is being and will be brought on-stream, although not as rapidly as would be justified if the demand were significantly higher. In fact, there are a number of deposits in the United States which are not being developed at this time, not because they would be uneconomic, but because the owners prefer to wait until they can project the demand with a little more certainty. This conservatism reflects the current oversupply of uranium, and the fear on the part of mining company management that current projections of demand will prove to be overly optimistic as has been the experience in the past. The reticence on the part of miners to proceed with development work without a clear outlook for demand has been validated in recent weeks with the announcement that United Nuclear Corporation is being asked by all of its utility customers to delay uranium deliveries by up to 5 years. United Nuclear claims

that it will be 1978 before the U.S. uranium mining industry picks up.

F. OPPORTUNITY

The major opportunity for Bolivia with respect to uranium is in exploration activity. The outlook for uranium is very optimistic throughout the World. Free World demand is expected to increase more than fivefold over the next 10 years. While supply is adequate at the present time, and is expected to continue adequate through the mid-to-late 1970's, considerable additional reserves must be found to satisfy projected ultimate demand. However, for extensive uranium exploration to be an attractive opportunity for Bolivia, we believe that there must be indications of a good possibility (in geologic terms) of finding low-cost reserves. If the geology of Bolivia is such that only marginally economic deposits can be expected, then this opportunity should be downgraded substantially, at least for the short and medium term. In any case, there is little time pressure since new reserves will not be required for several years. This timing would permit further exploration for the development of reserves.

The dilemma with respect to uranium activity is largely with respect to timing for development in view of the possibility of the discovery of large low-cost deposits. Many believe that, even if

large, low-cost deposits are found, there is little reason for their owners to initiate a price war since there would be no significant increase in the total demand for uranium. Oh the other hand, if large, low-cost deposits are found sufficient to supply practically the entire demand, as may be the case in South Africa and Australia, then such operators may institute a price reduction which could significantly change the nature of uranium mining industry, unless controls were exercised on the use of such uranium in the major consuming industrial areas, as is presently the case in the United States. We believe that it is more likely that low-cost operators would utilize their low operating costs to obtain contracts to develop such deposits without upsetting the price structure of the industry.

The possibilities of selling uranium to the other Andean Countries are limited since only Chile has announced plans for the installation of a nuclear power plant.

X. NON - FERROUS ALLOYS

X. NON - FERROUS ALLOYS

Bolivia possesses a wide range of minerals such as tin, high purity bismuth, antimony, zinc, lead, and copper which are used to produce non-ferrous alloys. The extent of the opportunity to reduce non-ferrous alloys in Bolivia, therefore, depends primarily on the market for these products.

A. MARKET

1. Andean And South American

It is difficult to estimate the market for non-ferrous alloys in the Andean region and South America due incomplete and unreliable data. A summary of available data for Chile, Perú, Bolivia and Ecuador, however, indicates that approximately 1500 tons with a value of nearly US$ 950,000 are imported each year. Of this amount 1000 tons with a value of US$ 300,000 represent lead based alloys utilized in the manufacture of batteries (Table 39). Statistics for Colombia were not available. However, we have estimated on the basis of certain economic indicators that Colombia probably imports nearly 700 tons of non-ferrous alloys each year, of which about 450 tons are lead based alloys.

To determine potential demand, United States consumption of metals utilized in the production of non-ferrous alloys was calculated and related to Gross National Product. (GNP) The resulting coefficients of consumption (Table 40) were then utilized to

TABLE 39

ANDEAN PACT IMPORTS NONFERROUS ALLOYS

	Metric Tons	Value US$
TIN ALLOYS		
Tin-Based Alloys	43.7	$163,000
Tin-Based Antifriction Alloys	63.8	51,700
Tin-Based Solders	45.4	112,360
Tin for Alloying	4.3	4,251
	157.2	331,300
LEAD ALLOYS		
Lead for Alloying Batteries	1,090.2	$302,000
Type Metal	113,7	35,000
Antifriction Alloys	0.2	300
Lead-Based Solders	53.7	38,400
	1,257.8	$375,700
ANTIMONY ALLOYS - Total	34.4	$ 37,300
BISMUTH ALLOYS - Total	0.06	$ 400
COPPER ALLOYS		
Copper-Based Alloys (ingots and bars)	38.8	$ 56,700
Brass Bars, etc.	4.4	12,800
Other Copper Alloy Bars	6.3	9,800
Phosphor Bronze Wire	11.9	25,700
Other Copper Alloy Wire	20.3	37,700
Bronze Powder	15.5	35,500
Other Copper Alloy Powder	11.3	23,500
Total Copper Alloys	108.5	$201,700
TOTAL ALLOYS	1,557.9	$946,400

TABLE 40

METAL DEMAND COEFFICIENTS IN

THE UNITED STATES

Metal	Consumption as metals (net tons) in alloys	Demand Coefficient (tons US$ billion)
Antimony	9,000	10.0
Bismuth	650	0.7
Lead	690,000[1]	770.0
Tin	60,000[2]	67.0

1. Excludes 580,000 tons per year in batteries and 270,000 tons per year in gasoline.

2. Excludes tin in tin plate of 30,000 tons.

extrapolate the potential demand of the Andean countries (Table 41). The data indicates that the actual demand represents only about 10% of potential demand and there exists wide latitude for growth.

In Table 42 potential demand has been calculated for both Latin America and the world and compared to that of the Andean Subregion. South American potential demand is nearly 64.0 million tons. This compares with a potential demand of 14.9 million tons in the Subregion. World potential demand was estimated at 2.1 million tons.

The extent to which Bolivia can supply the Andean, South American and world markets will depend on transport costs. Low value alloys, such as the lead and copper based alloys cannot be expected to be shipped over great distances. High value tin and bismuth based alloys, however, can carry much higher transport costs.

Lead alloys account for a large share of total non-ferrous alloy consumption; solders are next in importance. It is unlikely that lead alloys represent a promising opportunity for Bolivia since it is relatively easy to alloy 7% to 13% antimony into lead at the battery plant. Moreover, antimony levels in batteries have been dropping. Solder and bismuth based alloys on the other hand, may represent a very promising opportunity.

TABLE 41

POTENTIAL METAL DEMAND

ANDEAN SUBREGION

METAL IN ALLOYS

Metal	United States GNP Demand Coefficient (Net Tons/ U.S.$ billion)	Potential Demand					
Country		Bolivia	Chile	Colombia	Ecuador	Peru	Total
Antimony	10.0	8.0	56.0	59.0	14.0	40.0	177.0
Bismuth	0.7	0.6	4.0	4.0	1.0	3.0	13.0
Lead [1]	770.0	610.0	4300.0	4500.0	1070.0	3070.0	13,550.0
Tin [2]	67.0	53.0	370.0	390.0	90.0	270.0	1,170.0
		671.0	4730.0	4953.0	1175.0	3383.0	14,910

1.- Excludes consumption in batteries and gasoline

2.- Excludes tin in tin plate.

TABLE 42

POTENTIAL METAL DEMAND

METAL IN ALLOYS

ANDEAN SUBREGION, SOUTH AMERICA, AND WORLD

Metal	GDP Demand Coefficient (net tons/ $ billion)	Potential Demand (Net Tons) Andean Subregion	South America	World
Antimony	10.0	177.0	760.0	55,000.0
Bismuth	0.7	13.0	53.0	2,800.0
Lead [1]	770.0	13,550.0	58,000.0	1,900,000.0
Tin [2]	67.0	1,170.0	5,100.0	180,000.0
TOTAL		14,910.0	63,913.0	2,137,800.0

1. Excludes battery lead and lead in gasoline

2. Excludes tin used in tin plate.

In general solders are alloys of lead and tin and extend over the entire range of lead and tin mixtures. Some solders also contain other metals present in Bolivia such as antimony, bismuth, and silver.

For many solders, tin is the principal alloy agent. In general terms, the soldering action and the mechanical properties are improved with increasing tin content. Since tin constitutes approximately one-half the material in solder and since solder utilizes about 25% of available tin, world solder consumption can be estimated at about 100,000 tons. Adjusting this quantity for the recycle of secondary metal, we estimate that about 60,000 - 70,000 tons annually are produced from primary tin.

Bismuth - based alloys are generally known as the local melting point alloys. Although the volume consumed is relatively small compared to lead, copper, and tin alloys, they have high value.

Antimony is also used in a wide variety of non-ferrous alloys. It is a relatively valuable ingredient in many of the non-ferrous alloys.

B. ALLOY PRODUCTION

Non-ferrous alloys are normally produced in the industrial countries from both scrap and primary metals. The value added over the cost of the primary metals is relatively small (10%-20%)

since these alloys are typically low melting and therefore require little in the way of specialized equipment and facilities. They are produced in small gas or oil fired furnaces. The normal industrial practice is for solders to be produced in relatively simple shapes of cast bars, extruded rods, and large-diameter wire. Thu , only the most basic and unsophisticated metalworking equipment is required for their production. Capital costs for facilities to produce these alloys are therefore minor, in the order of US$ 600,000.

Producers of non-ferrous alloys generally try to use as much scrap metal as possible, only adding primary metal to achieve the desired composition. Although Bolivia does not have large amounts of scrap, it will have in a sense an alternative to scrap, i.e., residues and reverts from the Klockner smelter which will contain tin with a variety of impurities. This mixture of metals, whose composition will vary with the concentrates, represent perhaps an equivalent to scrap. Such material can alternatively be used to produce appropriate master or final alloys or can be refined either in Bolivia or in Europe to separate and recover the metals as individual primary metals.

C. OPPORTUNITIES FOR THE UTILIZATION OF THE PERO AND METABOL SMELTERS

Our investigation has indicated that opportunities exist for the production of non-ferrous alloys in the Peró and Metabol

smelters. Other alternative uses, however, also exist.

1. Description

a. Peró Smelter

This smelter was originally designed as a tin smelter. It consists of a small reverberatory furnace and 7 rotary furnaces. The reverberatory furnace has not been used for a long time. When the smelter was producing tin, it used 3 furnaces for reducing and 3 furnaces for slag fuming. It had a capacity of 3,000 tons per year when it was operating on 40% concentrates and 5,000 tons per year on 60% tin concentrates.

b. Metabol Smelter

The Metabol smelter was originally installed for lead smelting; its capacity was 3,000 metric tons per year of lead. Apparently it has not smelted lead for many years. There are two small lead blast furnaces and refining kettles in fairly good condition, but the sintering machine is in poor condition. It has 2 rotary reduction furnaces and 2 fuming furnaces capable of producing up to 1,500 tons of tin per year from high-grade concentrates and 150 tons per year of tin from low-grade concentrates, i.e., 4% - 5% tin-bearing material. It is not well equipped for tin smelting and is not very efficient. It is also highly over staffed.

2. OPPORTUNITIES FOR UTILIZATION

A number of ideas have been suggested for the use of the Metabol and Peró smelters.

a. Peró

i. Expansion of tin smelting capacity from 3,000 - 5,000 tons per year to 7,500 tons per year.

ii. The fuming of low grade tin concentrates; capacity of 7,000 tons of 4% to 8% tin. The smelter has recently been used for this purpose.

iii. The fuming of antimony concentrates containing gold. The operation would yield antimony oxide or antimony and gold enriched residue from which gold could subsequently be recovered.

iv. The readjustment of tin alloys from the Klockner smelter to produce appropriate alloys by the addition of primary metal.

b. Metabol

i. The fuming of low or off-grade (high iron) tin concentrates. This smelter has the capacity to fume 7,200 tons per year of 4% - 8% tin concentrates.

ii. Smelting of oxide bismuth concentrates. Availability of oxide bismuth ores or concentrates is currently limited to

about 48 tons per year of contained bismuth.

iii. Tin smelting, but this smelter has a capacity of only 3,600 tons per year.

iv. The production of tin, lead, copper and bismuth based alloys.

3. Recommendation

To evaluate the various opportunities for the conversion of the Peró and Metabol smelters a study should be undertaken to include the following:

a. Evaluation of the existing facilities to determine the alternative uses. This examination should be preliminary and would eliminate the less interesting possibilities on the basis of such factors as inadequate raw material supplies, insufficient markets, and extensive facility revisions.

b. The more promising alternatives, including non-ferrous alloy production should be evaluated in detail. The analysis would estimate reserves, investment, operating costs, and markets.

XI. FERROALLOY

XI. FERROALLOY

Ferroalloys are alloys of iron and manganese, iron and silicon and iron and other ferroalloying metals used in steel-making and for alloying steel. The most important ferroalloys are ferromanganese, ferrosilicon, silicomanganese, ferrochromium, ferrotungsten, ferrovanadium, ferrotitanium, and ferromolybdenum, in this approximate order of importance.

Ferroalloys are normally made in electric reduction type arc furnaces, although some grades of iron silicon and iron manganese ferroalloys are made in blast furnaces, mostly by carbon reduction of oxide ores having the correct ratio of iron to the ferroalloy metal; some ferroalloys involve reduction of mixtures of iron oxide ores and oxides or concentrates of the ferroalloy metal.

A. TYPES OF FERROALLOYS

1. Manganese

Manganese ferroalloys represent the largest tonnage of ferro-alloys used by the steel industry. Products which are used by a highly diversified steel industry include high-, medium-, and low-carbon grades of ferromanganese and silicomanganese, a by-product of the ferromanganese production. In addition, some electrolytic manganese is required in certain stainless steels and in copper, aluminum, and manganesium alloys. The low iron raw materials

needed for production by electrolytic manganese plants is often obtained from ferromanganese slags. Ferromanganese is 74%-80%, manganese balance iron, with specifications on maximum carbon and phosphorus content on certain specific grades. Silico-manganese is 60% - 65% manganese, 12% - 20% silicon, 2% - 3% carbon balance iron.

2. Silicon

Silicon ferroalloys represent the next most important tonnage. Grades of 45% silicon to 94% silicon are produced for steelmaking, while silicon at 96% - 99% is also produced for use in aluminum alloys and also in certain steels. Carbon is specified at low levels (o.15% carbon) for the higher value alloys. There is usually no shortage of raw materials, particularly for ferro-silicon. A good quality sand and a high quality iron scrap or iron ore are all that is required. Directly reduced iron ore beneficiated magnetically after reduction would represent a good source of iron.

3. Chromium

Chromium makes up the largest tonnage of materials used solely for alloying purposes. Ferrochromium contains 65% - 72% chromium balance iron, with a maximum of 2% silicon. The grades are classified by carbon content from the very low carbon (0.06%), expensive grades, to the lower value high-carbon (4.5%-8.5%)grades.

It is most unlikely that chromium is available in Bolivia and, therefore, any ferrochromium produced would have to be based on imported high-grade ores. Most ferrochromium production throughout the world is based on imported chromium ores. In Bolivia, however, the transport cost associated with importing chromium would be high and would place ferrochromium alloys at a competitive disadvantage.

4. Nickel

Ferronickel, containing a range of 25% - 75% nickel with the balance iron, can be used for alloying a wide variety of steels and stainless steels. Pure nickel, as anodes or briquettes, is required for some types of stainless alloys, nonferrous alloys, and in electroplating. Colombia is in a far better position to produce ferronickel than Bolivia who has no known resources of nickel, except evidence of small high-grade nickel showings.

5. Other

Other ferroalloys, the most important of which contain molybdenum, titanium, tungsten, vanadium, and columbium, are generally used in much smaller quantities. Of these, the most important to Bolivia is ferrotungsten which is 70% - 80% tungsten with the balance iron, with carbon specified at 0.60% carbon maximum.

B. RESOURCES AND PRODUCTION

Our preliminary study of ferroalloy metals mineral resources indicates that Bolivia has tungsten, manganese, and silicon in sufficient quantity to support a commercial ferroalloy operation. Of these, tungsten and manganese have the higher value; silicon of adequate quality for ferrosilicon is generally available. However, with the exception of tungsten there is no data on the ferroalloy metal reserves and as a result we have speculated partly on the basis of our study of geological information.

There is no question that tungsten reserves in Bolivia, currently estimated 58,000 tons proven and indicated, are adequate to support the production of ferrotungsten which is a very valuable product, but which has a relatively small market.

Manganese-bearing ores, according to GEOBOL, are generally found along or near a line running north from Villazon to Potosi. However, these deposits have not been extensively explored and information on iron and manganese content is limited. The manganese and iron content and the iron-to-manganese ratio are particularly important for the production of a broad range of ferromanganese grades.

It is probable that molybdenum is present in Bolivia. One geological report mentions the presence of molybdenum sulfides in the Condor Hate and Viloco mines near La Paz.

Our examination of geological surveys has also found mention of the presence of nickel associated with antimony and arsenic in the Don Carlos mine.

There is a possibility that economically attractive vanadium and titanium resources also exist in Bolivia. Vanadium is a common by-product of uranium and there has been persistent mention of the existence of uranium in Bolivia.

Our interviews with COMIBOL geologists have indicated that they expect to find titanium in the form of ilmenite and rutile in the Beni area. Titanium showings have also been found near La Paz and Potosi.

Geologists see little potential for finding chromium in Bolivia This situation is not unusual and major sources of chromium ore suitable for ferroalloy production are found in only a small number of locations in the world.

At this time, however, sufficient information does not exist to determine whether molybdenum, nickel, vanadium, and titanium exist in sufficient quantities to support a commercial ferroalloy operation. On the other hand, sources of vanadium, nickel,

molybdenum, and titanium need not be large because these ferroalloys are generally produced in small quantities.

Table 43 presents estimated production of various important ferroalloys in selected Latin American countries. Brazil is the major producer of ferroalloys in South America and it is expected that production will grow. It is the only country in South America producing essentially a complete line of ferroalloys, with the exception of ferrotungsten. Chile is the only ferroalloy producer in the Andean Subregion. Production is concentrated largely in the manganese and silicon alloys with ferrochrome being produced in smaller quantities.

C. MARKETS

Table 44 presents estimated consumption of various types of ferroalloys in selected Latin American countries. The data indicates that Brazil, Mexico, and Argentina are the largest consumers of ferroalloys in Latin America. Chile and Venezuela are also substantial consumers.

Overall Latin America is a net importer of ferroalloys with Colombia, Peru, and Venezuela being the largest net importers. The Andean Subregion imports about 4000 - 5000 tons of ferroalloys per year.

TABLE 43

PRODUCTION OF FERROALLOYS

IN LATIN AMERICA

1964-1968

(Tons per year)

		Ferro Manganese	Ferro Silicon	Silicon Manganese	Ferro Chromium	Others
ARGENTINA	1964	11,894	2,099	1,383	-	17
	1965	10,648	4,138	2,769	-	19
	1966	11,987	6,458	3,571	40	6
	1967	10,177	6,454	1,635	-	-
	1968	14,391	6,874	3,307	-	-
BRAZIL	1964	20,643	8,230	8,693	1,130	3,475
	1965	26,390	9,396	9,759	2,025	3,893
	1966	31,314	13,552	6,009	2,995	4,001
	1967	31,308	15,625	5,625	1,665	4,857
	1968	35,336	15,859	6,906	3,642	4,945
CHILE	1964	5,188	2,920	2,355	-	-
	1965	6,617	2,350	4,024	-	100
	1966	6,226	2,980	2,506	-	647
	1967	3,887	3,842	1,904	-	455
	1968	5,539	1,706	2,059	-	458
MEXICO	1964	32,178	7,520	2,295	574	-
	1965	31,349	9,120	1,024	1,227	-
	1966	30,622	7,541	6,121	323	47
	1967	35,540	11,160	6,447	1,074	166
	1968	39,095	11,257	3,613	2,143	139

TABLE 44

ESTIMATED CONSUMPTION AND NEW IMPORTS OF FERROALLOYS IN LATIN AMERICA
1964-1968
(TONS PER YEAR)

ARGENTINA	Production	15,302	15,574	22,062	18,266	24,572
	Consumption	18,659	20,178	18,688	19,558	22,892
	Net Exports (+) or Imports (-)	-3,357	-4,064	+3,374	-1,292	+1,682
BRAZIL	Production	42,191	51,463	57,871	59,080	66,768
	Consumption	41,409	41,660	58,543	57,434	66,530
	Net Exports (+) or Imports (-)	+ 782	+9,803	- 672	+1,646	+ 238
CHILE	Production	10,463	13,091	12,359	10,088	9,762
	Consumption	8,614	7,021	8,511	9,307	8,407
	Net Exports (+) or Imports (-)	+1,849	+6,070	+3,848	+ 781	+1,355
COLOMBIA	Production	-	-	-	-	-
	Consumption	3,392	3,569	3,186	3,805	3,702
	Net Exports (+) or Imports (-)	-3,392	-3,569	-3,186	-3,805	-3,702
MEXICO	Production	42,567	42,720	44,654	54,337	56,247
	Consumption	34,412	36,211	40,754	44,694	48,055
	Net Exports (+) or Imports (-)	+8,155	+6,509	+3,900	+9,643	+8,192
PERU	Production	-	-	-	-	-
	Consumption	1,209	1,386	1,180	1,180	1,549
	Net Exports (+) or Imports (-)	-1,209	-1,386	-1,180	-1,180	-1,549
URUGUAY	Production	-	-	-	-	-
	Consumption	206	192	147	192	118
	Net Exports (+) or Imports (-)	- 206	- 192	- 147	- 192	- 118
VENEZUELA	Production	-	-	-	-	-
	Consumption	6,505	9,219	7,921	10,177	9,750
	Net Exports (+) or Imports (-)	-6,505	-9,219	-7,921	-10,177	-9,750
LATIN AMERICAN NET EXPORTS (+) OR IMPORTS (-)		-3,883	-9,066	-1,984	-4,576	-3,652

(Page 183)

Net exporters of ferroalloys in Latin America are Argentina, Brazil, and Chile. Brazil is likely to become a much larger exporter in the future.

Table 45 indicates usage of various ferroalloys for different steel making processes. Steel produced by the electric furnace is by far the most important consumer.

The demand for the high volume ferroalloys, ferro-manganese and ferro-silicon is directly related to steel production. Demand for the lesser volume ferroalloys such as ferro-chromium, ferro-nickel, ferro-molybdenum, ferro-titanium, ferro-vanadium and ferro-columbium is related to the production of alloy and stainless steel.

In recent years ferroalloy consumption in Latin America has grown at a rate of about 9% per year. If this growth rate is maintained consumption will double in about eitht years.

Prices of ferroalloys vary somewhat but there are no wide fluctuations as is the case for some of the base metals such as copper, lead, zinc, antimony and bismuth. The following are typical producer and distributor prices for major ferroalloys in South American markets:

TABLE 45

TYPICAL FERROALLOY CONSUMPTION IN

LATIN AMERICA BY STEEL PROCESS

(Kilograms per ton)

	Siemens Martin Open Hearth	Basic Oxygen Furnace	Electric Furnace
Ferromanganase	7.9	6.2	5.4
Silicomanganase	3.8	-	1.5
Ferrosilicon	1.5	1.4	16.1
Ferrochromium	--	--	2.5
Total	13.2	7.6	25.5

Ferroalloy	Producer (US$ Per Ton)	Distributor (US$ Per Ton)
High Carbon Ferro-manganese	162-235	265
Silicomanganese	184-267	230
Ferro-Silicon - 45% Silicon	55-144	230
Ferro-Silicon - 75% Silicon	203-221	299

Prices in the international market for various grades of ferro-silicon and ferro-manganese are as follows:

FERROALLOYS	US$ Per Ton
FERRO-MANGANESE	
Standard - 74% - 76% Mn	170 - 187
Standard - 78% Mn	195
Low phosphorus	216
SILICOMANGANESE	
12.5% - 16% Silicon, 3% Carbon	214
High Manganese - 15.5% - 17% Silicon 1.75% - 2.25% Carbon	235
16%-18.5% Silicon, 2% Carbon	214 - 224
18.5% - 21% Silicon, 1.5% Carbon	230 - 260
FERRO-SILICON	
45% Silicon	140 - 170
75% Silicon	232 - 276

FERROALLOYS	US$ Per Ton
OTHER FERROALLOYS	
Ferro-chromium - .01 - .0% Carbon	772 - 805
Ferro-tungsten - 77 - 83% Tungsten	9,900
Ferro-nickel - 75% Nickel	2,130
Ferro-vanadium - 45% Vanadium	3,450 - 4,075
Ferro-titanium - 70% Titanium, low carbon	2,200
70% Titanium, medium carbon	415
70% Titanium, high carbon	340

The above price list is not complete, but probably covers all ferroalloys that might be produced in Bolivia. It presents a range of quoted prices for spot purchases, prices on contract sales would be significantly lower.

D. PRODUCTION OF FERROALLOYS

Generally, ferroalloys are produced in areas in the world where low-cost power (o.5c-0.9c/kwh) and low-cost scrap iron sources are available. Production is concentrated in the highly industrialized countries and convenient to steelmaking areas. The reason for this is because the high-volume ferroalloys--ferro-manganese, silicomanganese, and ferro-silicon--are relatively low value materials (7c-15c/lb) which cannot support high transport charges.

Bolivia may have the raw material resources to produce ferro-tungsten, ferro-silicon, ferro-manganese, silicomanganese, and

possibly ferro-vanadium, ferro-titanium, ferro-nickel, and ferro-molybdenum. Low-cost source of raw materials, particularly high-grade manganese ore and sources of vanadium, molybdenum, and titanium ore and low-cost power would help the viability of a ferro-alloy project.

The manganese ferroalloys are the most important in terms of volume produced and consumed. High grade metallurgical ores, especially those with a high manganese ferrous ratio, are needed for the production of many types of ferro-manganese. It is of great importance, therefore, to determine the type of manganese ores available in Bolivia.

In the reduction of a given manganese ore, the iron oxides are converted almost quantitatively to metal and the manganese recovery is typically 85%. This relatively poor recovery of manganese from the ores has led to the practice of using the slag from a ferro-manganese furnace as raw material to an electrolytic manganese operation because the iron is very low (i.e., Mn/Fe ratio is high) and because volatile metallics such as zinc have been removed. However, the relatively poor recoveries of manganese compared to iron require that the manganese-to-iron ratio in the raw ore fed to the furnace must be higher than the ratio of manganese to iron in the alloy.

in Ferroalloy	Manganese-to-Iron Ratio in Ore
[illegible] (Spiegeleisen)	[illegible].3 : 1
75.0 (High Carbon)	[illegible]4.2 : 1
82.5 (Medium Carbon)	[illegible]5.7 : 1
87.5 (Low Carbon)	[illegible]9.4 : 1

Since manganese is [illegible] iron, it [illegible] practical to alter the manganese iron alloy coming from a furnace by fractional oxidation as is done to upgrade a low-nickel ferro-nickel. (In that case, iron is more easily oxidized than nickel). On the other hand, it may be practical to produce a grade of iron-manganese alloy that is somewhere in between spiegeleisen and conventional ferro-manganese if Bolivian ores have a lower Mn/Fe ratio than required. An off-grade manganese alloy will undoubtedly cause some unhappiness with the steel plant operators--but it could be offset by establishing a favorable price for the contained manganese values.

[illegible]t would be diffi[illegible]

[illegible]al markets, but perhaps not in the Andean Subregion.

[illegible] feasible ferroalloy production operation might consist [illegible]ctric furnace installation producing ferro-manganese, silico-manganese, ferro-silicon, and ferro-tungsten.

Conditions in Bolivia are such that production could begin on a very small scale sufficient to supply the Andean Market.

Production of ferroalloys requires the availability of low-cost power and carbonaceous reductants, although fuel requirements need not be large if prereduction is accomplished with natural gas. Power costs should be as low as possible and preferably below 7 mills/kwh. Most ferroalloy production facilities throughout the world have power supplied at costs less than 9 mills/kwh and as low as 3 mills/kwh. Table 46 shows the percentage of total costs for major ferroalloys and ferro-tungsten accounted by the raw material and power components.

The data indicates the importance of low-cost power, particularly for the low raw material cost ferroalloys such as ferro-silicon and the high power consumers like ferro-silicon and ferro-chromium.

Because ferro-manganese and ferro-silicon are the products with the greatest potential volume, it is logical to locate near sources of manganese ore specially since silica of adequate quality is generally not difficult to find. In the case of tungsten, vanadium, molybdenum, and nickel, the concentrates are sufficiently valuable to carry the freight charges resulting from movement over longer distances. This might suggest a location in the South, perhaps near Villazon, except that there are no known inexpensive sources of low-cost power currently existing in the Villazon area. To make this project feasible, natural gas with a cost in the

TABLE 46

TYPICAL COST DISTRIBUTION

IN FERROALLOY PRODUCTION

RAW MATERIALS AND POWER COMPONENT

(Percentage of Total Cost)

	Ferro manganese	FERRO SILICOM 45	75	90	Silicon manganese	Ferro Chromium	Ferro tungsten
Ores	52.4	8.4	9.2	8.8	43.5	53.9	37.7
Ferrous Scrap	-	10.4	5.0	3.5	-	-	1.6
Reductant	23.8	36.6	39.0	37.8	28.9	13.1	35.6
Power (7 mills kwh)	19.0	43.4	45.5	48.6	24.6	33.0	16.4
Other	4.8	1.2	1.3	1.3	3.0	-	8.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Power Consumption Kwh per ton	3500	5200	9500	12300	4800	7700	5000
Effect of one mill power cost change	3.50	5.20	9.50	12.30	4.80	7.70	5.00

U.S.$ Per Ton

range of US$ 0.15 - 0.25 million but would also need to be piped in to generate power and possibly minimize the consumption of expensive charcoal.

Cochabamba might be a better location for a ferroalloy plant since it is expected that natural gas will be available in the area in the near future. There is also the potential for obtaining low-cost power from hydro projects such as those at Corani, Santa Isabel, and others currently under study. Cochabamba is also served by rail transportation facilities. Moreover, recently a small rich iron ore deposit has been found at Changola that might support an associated small alloy and carbon steel production.

E. IDENTIFICATION OF OPPORTUNITIES

A promising opportunity exists for the production of certain ferroalloys for export to the Andean Subregion.

The feasibility of such a project will probably depend upon the cost of electric power and the grade of manganese ore available in Bolivia. If the manganese ore is high grade, it will be a strong indication that ferroalloy production in Bolivia is potentially viable. Bolivia could also produce ferro-tungsten. However, since tungsten can be easily upgraded to powdered metal and carbide, the alternative which would probably yield the greatest benefits to Bolivia would be to convert a portion of tungsten to ferro-tungsten with the remainder being used to produce other tungsten products.

It would be unwise to build a ferroalloy facility to produce only ferro-tungsten.

A small (5,000 - 6,000 tons/year) ferroalloy plant would require a capital investment of about US$ 1,500,000 for the plant facilities. A ferroalloy plant is normally and easily expandable by adding furnaces, one at a time, so that the small plant could be a beginning and expanded as the market grows. The profitability of such a plant would be marginal if it produced only the high-volume, lower value (US$ 140 - US$ 275/metric ton) ferro-alloys such as ferro-silicon and ferro-manganese, unless power costs were very low (i.e. in the 0.5¢ - 0.9¢/kwh range). However, if the facilities produced primarily high-value ferroalloys based upon indigenous raw material sources, it could be quite profitable. The most illustrative example of a high-value ferroalloy is ferro-tungsten (80% - 85% tungsten) which is valued at about US$ 10,000 per ton. Another example would be ferro-nickel, valued at over US$ 2,100 per ton.

Because of its promise a prefeasibility study should be conducted examining the economics of establishing ferroalloy production facilities. The study would analyze in greater detail the market in the Andean Subregion for specific ferroalloys.

We suspect that most of the imports, currently at about 5,000 tons per year, are the high-value low-volume ferroalloys. World market opportunities for some of the high-value ferroalloys

which are capable of supporting high transport costs should also be analyzed. At the same time, the quality of manganese ore deposits and geological information on some of the more valuable metals such as molybdenum, titanium, nickel and vanadium should be investigated.

Since power and transportation costs are important components of total costs alternative locations for the project should be evaluated.

Depending upon the results of the above, we would suggest that a proposed product mix be prepared in order to establish the necessary facilities to produce the products in the volumes anticipated. This will require identifying appropriate facilities and estimating the capital and operating costs associated with the production.

A P P E N D I X A

NON-FERROUS METALLURGIC INDUSTRY

NON-FERROUS METALLURGIC INDUSTRY

NABALALC	Product
Chapter 74.	Copper
74.01	Blister copper and other unrefined copper.
74.02	Master alloys of copper.
74.03	Bars, rods, angles, shapes, sections and wire of copper.
74.04	Plates, sheets and strip of copper.
74.05	Copper foil.
Chapter 75.	Nickel
75.01	Nickel and nickel alloys, unworought.
75.02	Bars, rods, angles, shapes, sections and wire of nickel.
75.03	Plates, sheets, strip, foil, powders and flakes of nickel.
75.04.0.01	Tubes and bars, hollow.
75.05	Electroplating anodes of nickel.
Chapter 76.	Aluminium
76.01	Aluminium and aluminium alloys, unwrought.
76.02	Bars, rods, angles, shapes, sections and wire of aluminium
76.03	Plates, sheets and strip of aluminium.
76.04	Aluminium foil.
76.05	Aluminium powders and flakes.
76.06	Tubes, pipes and blanks therefor, hollow bars of aluminium.
Chapter 77.	Magnesium, Beryllium
77.01	Magnesium and beryllium.
77.02	Magnesium, unwrought.
77.04.0.01	Berryllium, unwrought.
Chapter 78.	Lead
78.01	Lead and lead alloys, unwrought.
78.02	Bars, rods, angles, shapes, sections, and wire or lead.
78.03	Plates, sheets and strip of lead.
78.04	Lead foil, powders and flakes.
78.05.0.01	Tubes and bars, hollow.

Chapter 79.	Zinc
79.01	Zinc and zinc alloys, unwrought.
79.02	Bars, rods, angles, shapes, sections and wire of zinc.
79.03	Plates, sheets, strip, foil, powders (excluding dust) and flakes of zinc.
79.04.0.01	Tubes and bars, hollow.
Chapter 80.	Tin
80.01	Tin and tin alloys, unwrought.
80.02	Bars, rods, angles, shapes, sections and wire of tin.
80.03	Plates, sheets and strip of tin.
80.04	Tin foil, powders and flakes.
89.05.0.01	Tubes and bars, hollow.
Chapter 81.	Other Metals
81.01.1	Tungsten (wolfram) unwrought.
81.02.1	Molybdenum unwrought.
81.03.1	Tantalum unwrought.
81.04.1.01	Uranium impoverished in U_{235} unwrought.
81.04.1.02	Torium unwrought.
81.04.2.01	Bismuth unwrought.
81.04.2.02	Cadmium unwrought.
81.04.3.01	Cobalt unwrought.
81.04.4.01	Manganese unwrought.
81.04.4.02	Antimony unwrought.
81.04.5.01	Vanadium unwrought.
81.04.5.02	Zirconium unwrought.
81.04.5.03	Gallium unwrought.
81.04.5.04	Germanium unwrought.
81.04.6.01	Hafnium unwrought.
81.04.6.02	Indium unwrought.
81.04.7.01	Niobium unwrought.
81.04.7.02	Rhenium unwrought.
81.04.8.01	Titanium unwrought.
81.04.8.02	Talium unwrought.
81.04.9.01	Cermetas unwrought.
Plus 73.12.4.01	(Tin plate).