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SURVEY OF OPPORTUNITIES FOR BOLIVIAN INDUSTRY

Volume III

Non-Metallic Minerals Industry

report to

THE MINISTRY OF PLANNING

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Arthur D. Little, Inc.

MINISTRY OF PLANNING

GOVERNMENT OF BOLIVIA

SURVEY OF OPPORTUNITIES FOR BOLIVIAN INDUSTRY

VOLUME III

NON-METALLIC MINERALS INDUSTRY

DECEMBER 1970

ARTHUR D. LITTLE, INC.

PRUDENCIO CLAROS Y ASOCIADOS

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I. S U M M A R Y

I. SUMMARY

A. OBJECTIVES

The objective of this study is to identify industrial development opportunities for Bolivia in the non-metallic minerals sector and classify them according to their promise. For those opportunities having the most promise feasibility or prefeasibility studies are recommended.

B. SCOPE

The non-metallic minerals sector was initially defined to include the following products:

1. (25.02.0.01)	IRON PYRITES
2. (25.06.0.01)	QUARTZ
3. (25.07.0.01)	BENTONITE
4. (25.07.0.02)	KAOLIN
5. (25.07.0.03)	FULLER'S EARTH
6. (25.08.0.01)	CHALK
7. (25.09.1.01)	OCHER
8. (25.13.0.03)	NATURAL CORUNDUM
9. (25.15.2.01)	ROUGH MARBLE
10. (25.15.2.02)	CUT MARBLE, UP TO 5 cm. IN THICKNESS
11. (25.15.2.03)	CUT MARBLE, OVER 5 cm. IN THICKNESS
12. (25.16.1.01)	GRANITE - IN BLOCKS OR CHUNKS
13. (25.16.1.02)	CUT GRANITE
14. (25.16.2.01)	PORPHYRY - IN BLOCKS OR CHUNKS

15. (25.16.2.02) CUT PORPHYRY

16. (25.16.3.01) BALSAT - IN BLOCKS OR CHUNKS

17. (25.16.3.02) CUT BALSAT

18. (25.18.0.01) RCUGH DOLOMITE

19. (25.18.0.02) CALCINATED DOLOMITE

20. (25.18.0.03) AGGLOMERATED DOLOMITE

21. (25.19) NATURAL MAGNESIUM CARBONATE-MAGNESITE

22. (25.19.0.01) ROUGH MAGNESITE

23. (25.19.0.02) CALCINATE MAGNESITE

24. (25.20.0.01) ROUGH OR CRUDE GYPSUM

25. (25.20.0.02) POWDERED GYPSUM

26. (25.20.0.03) CALCINATES

27. (25.22.0.01) COMMON LIME

28. (25.22.0.02) HYDRAULIC LIME

29. (25.24.0.01) ROUGH ASBESTOS

30. (25.24.0.02) ASBESTOS FIBER

31. (25.24.0.03) POWDERED ASBESTOS

32. (25.26.1.01) ROUGH MICA - IRREGULAR SHEETS

33. (25.26.1.02) POWDERED MICA

34. (25.27.0.02) POWDER TALC

35. (25.29.0.01) REALGAR

36. (25.32.0.01) NATURAL SODIUM SULPHATES

37. (CHAPTER 69) CERAMIC PRODUCTS-FINE AND ELECTRIC

38. (CHAPTER 70) GLASS AND GLASS PRODUCTS

Certain non-metallic minerals such as iron pyrites which have predominantly chemical or agricultural use were transferred to the chemical sector. Other minerals such as barite, which were not included in our scope of work but which our field work indicated might be potential opportunities, were also examined. For those non-metallic minerals which are available in Bolivia in commercial quantities and which are of high quality we also considered the possibility for their further upgrading into intermediate and end products.

Opportunities were examined within the context of the Andean subregion. We also considered the possibility of exporting certain non-metallic mineral products to the Cuenca de Plata area and world markets.

C. APPROACH

The approach towards screening opportunities placed major emphasis on resources, markets, and minimum economic scale of plant. As a preliminary step to the study of individual minerals, joint discussions were held between Arthur D. Little, Inc. and representatives of the Ministries of Planning and Mining. As a result of these disccussions a priority list was drawn up for use as the basis for our investigations.

Those minerals that appeared initially to have high or medium opportunities for development were then considered from the point of view of resource availibility. A comparison was made with similar non-metallic mineral resources in Andean countries in order

to determine whether Bolivia had a particular advantage in supplying the Andean subregion with non-metallic minerals or with products manufactured from those minerals.

The next step in the screening process was to examine the market for those resources available in Bolivia in commercial quantities. Our market analysis focused on the Andean subregion. Data and information were collected on production, imports, and exports for Bolivia and the other Andean countries for 1966 through 1968. This analysis was supplemented by a full program of interviews in each of the Andean countries with knowledgeable people in the various industries that might use non-metallic minerals and their derivative products. In this way we established the growth rates and future needs for these non-metallic minerals and their derivative products as well as the price structure prevalent in each country in the subregion. For specific products which might be exported beyond the Andean subregion we also examined world markets.

The final step in the screening process was to determine for every opportunity indicating promise, on the basis of the resource and market analysis, whether the market is adequate to support a minimum economic sized plant. A description of the process required to manufacture the product was also presented.

D. CONCLUSIONS

Our analysis of resources, markets, and minimum economic scale of plant and technology indicated the following opportunities:

1. CONSTRUCTION MATERIALS
2. GLASS
3. CERAMIC TILE
4. MAGNESITE GRAIN
5. ASBESTOS
6. VITREOUS PLUMBING

Other non-metallic minerals and their derivative products were eliminated from further consideration for a number of reasons. First, in some cases Bolivia did not have a mineral in sufficient quantity or quality to justify commercialization. Second, a large number of non-metallic minerals are low in value in relation to bulk and, therefore, are rarely shipped long distances but rather serve the local market. This group of non-metallic minerals includes cement, gypsum, brick, block, sand and gravel, and rocks. Third, in some cases Bolivia did not have any advantage in availibility and quality of specific mineral resources over other Andean countries. Fourth, for some non-metallic minerals and derivative products the market was not sufficiently high to justify a minimum economic scale of plant.

1. Construction Materials

The construction industry in Bolivia and throughout the world is the largest consumer of materials and products manufactured by the non-metallic minerals industry. The basic materials used in construction are steel, cement, sand gravel, and rock. They are used in both crude form and also a major constituents in floor tile,

plaster, pipe, masonry, and other specialty building products, with the exception of certain high value added non-metallic mineral products (e.g. glass. ceramic ware). Most construction products have relatively large bulk and low value and freight costs are a major element of final costs. This indicates that low value construction materials for the most part must look to the domestic market for their principal outlets, with export markets being incremental markets. This is particularly true in Bolivia, where freight costs to markets outside the country are relatively high and most construction products have low value and are readily available in neighboring countries.

It is quite likely that a number of opportunities are available in the construction materials field. The construction industry is highly complex. It involves the non-metallic minerals, forest products, steel, and chemical industrial sectors. Many of the products of construction can be made of a number of different materials such as wood, steel or concrete framing; plastic, clay or steel pipe; wood or metal windows and doors. As a result before many opportunities are identified in this area a careful examination must be made of markets for construction materials, projecting demand, on the one hand, while nothing the likelihood of substitution of one material for another, on the other hand.

2. Glass

At present Bolivia's demand for flat glass is approximately

2,500 tons each year; by 1974 this market is expected to grow to 4,000 tons. Our analysis has also indicated that it may be possible to export flat glass of a thickness greater than 4 mm and specialty glasses to the Andean subregion. On this basis, there may be an opportunity to establish a glass plant in Bolivia to supply the domestic market and perhaps segments of the Andean market.

Before this opportunity is implemented, however, a detailed study should be conducted to investigate factors such as the market in Bolivia and other countries in the Andean subregion for glass of different thicknesses and specialty glasses, the type of process to be utilized, and manufacturing costs. Of critical importance would be the selection of the process. Two processes seem appropriate: the Forcault and the Pittsburg processes. The Forcault process is used in other Andean countries and is relatively inexpensive to install and simple to operate. The problem with the Forcaulty process is that it does not efficiently make glass with a thickness of more than 4 mm.

The second process, the Pittsburg process, is more modern and requires larger investment and greater production volume to be economic than the Forcault process. It produces better glass, however, which could be exported to the other Andean countries. Such an export market is essential to make this project viable. The fact that Bolivia would be the only country in the Andean subregion producing Pittsburg glass could result in the export of the thicker glasses as well as in the quality sensitive very thin glasses.

Starting with a glass industry oriented towards supplying the domestic market its requirements and perhaps the Andean market with certain types of glass, the industry could then be enlarged to provide specialty glasses and perhaps insulating window glass and high quality silica sand, if it is available, to the other Andean countries. Specialty glasses could be produced in a plant utilizing either the Forcault or Pittsburg process.

3.- Ceramic Tile

The current market for ceramic tile in Bolivia is approximately 750 metric tons; by 1974 it will grow to 1,100 tons and by 1985 to 3,750 metric tons. On the basis of the Bolivian market alone there appears to be an opportunity for the establishment of a tile plant producing 1,500 metric tons per year.

There currently exists a number of tile plants in the other Andean countries. These plants are capable of expanding to supply the local needs. The industry in the other Andean countries is characterized by heavy competition and are relatively quality conscious. As a result of these factors, export possibilities for this industry are remote.

4.- Magnesite and refractory bricks.

A very large world market exists for high quality magnesite grain, which is magnesite rock fully benefitiated and burned to drive off various elements.

World markets can easily absorb 40,000 additional tons of this product for use in magnesite bricks, whose demand is growing in

addition, the Andean subregion also represents a market for magnesite grain since their requirements which amount to about 9.000 tons each year are nearly entirely imported. Chile and Peru are the largest importers each accounting for about 3.000 tons.

The succes of this project will primarily depend on the quantity of the mineral resource, the design of the beneficiation process so that it provides the proper material for the burning process, and the design of th b urning process.

At this time, our analysis has indicated that the opportunity to produce magnesite refractory brick for the world market is not very promising. The biggest and more sophisticated users of this product around the world prefer to purchase magnesite brick from firms such as Harbeson Walker and Lota-Green who provide highly technical services as part of their sales effort. Peru, Colombia and Chile all have an established industry producing refractory bricks. Colombia imports a small amount of magnesite brick but the existing industry is expanding its facilities so as to eliminate these imports. It would thus appear that the establishement of a refractory brick plant in Bolivia could not be based on finding an export market for its product in the Andean subregion but would have to depend on the domestic market.

Bolivia currently consumes approximately 2.800 tons of non-magnesite refractory bricks per year. This demand is supplied by the existing local industry. The demand for refractory brick in

Bolivia is expected to grow to 4,300 tons by 1975 and 5,000 tons by 1977.

If facilities for the production of magnesite refractory bricks are established in Bolivia, the excess production would have to be sold in external market. Alternatively the establishment of these facilities could wait until the Bolivian market is sufficiently large to justify a minimum economic scale of plant.

5. Asbestos

Over 75% of the world demand for asbestos fiber and over 90% of the demand in South America is used in cement asbestos products. Two types of asbestos opportunities were studied: asbestos fiber, and asbestos cement products.

Because of the asbestos resources available in Bolivia there may be a very large opportunity for Bolivia to become a significant supplier of asbestos fiber to the world market. The major market for asbestos is in cement asbestos products. These products use asbestos grades 4, 5 and 6 which have an average world price of approximately U.S. $200 per ton. The markets for the longer fibers 1, 2 and 3 are heavily oriented towards textiles, papers and specialty products. The price of these products are declining in the world market where there is excess supply. There are also significant health implications to the use of grades 1, 2 and 3 in products for human consumption.

This analysis indicates that the most promising opportunity for Bolivia in asbestos fiber would be for grades 4, 5 and 6 which

are used to manufacture asbestos cement products. Before this opportunity is realized, however, it must be proven that the asbestos mineral found in Bolivia is suitable for cement asbestos products.

The opportunity for the manufacture of asbestos cement products will depend on the quality of the asbestos mineral available in Bolivia and on the market potential for these products. Even assuming that the quality of Bolivian asbestos is suitable for the manufacture of asbestos cement products, our analysis of the market for these products has indicated that the opportunity is not very promising. All the other Andean countries have sufficient capacity for the manufacture of asbestos cement products to satisfy their domestic needs. The possiblitiy of exporting asbestos cement products to the world market is also not very likely since transport costs would be prohibitive and sufficient capacity exists in the major markets to satisfy their local needs.

In Bolivia a cement asbestos factory with capacity of 13,000 tons commenced production in Cochabamba in 1970. This factory imports part of its asbestos fiber needs. It is of sufficient size to fulfil local requirements for the next few years.

6. Vitreous Plumbing

At present Bolivia imports about 600 tons of vitreous plumbing each year at an average cost of US$ 590 per ton. We expect that by 1973 demand will be 925 tons and by 1985 about 2,500 tons. Our

experience has indicated that the minimum required capacity is approximately 2,000-5,000 tons per year, depending on the kiln. As a result, the Bolivian market will not be sufficiently large to justify a minimum economic scale of plant for the next 8 to 10 years. The immediate establishment of vitreous plumbing facilities would need to export their excess production until Bolivian demand rose to meet capacity.

Our analysis has indicated that the other Andean countries have an excess capacity of about 5,000 tons per year. The possibility of exporting to the Andean subregion, therefore, is limited until about 1973-1974 when capacity will be roughly in balance with demand. It is at that point that perhaps an opportunity may exist for Bolivia to establish a plant which would supply both the Bolivian market and perhaps the Andean subregion. It must be noted, however, that if plants in the other Andean countries expand their facilities Bolivia would find it difficult to compete and the plant would have to depend on a Bolivian market insufficiently large to support the plant.

E. RECOMMENDATIONS FOR FEASIBILITY OR PREFEASIBILITY STUDIES

We have classified the six opportunities identified in our analysis according to whether they shoud be investigated with a full feasibility study or a prefeasibility study. The classification implies in the first case that the project cannot be deemed totally feasible unless all elements of the opportunity are investigated including resource evaluation, markets, production costs, and

marketing and industrial organization. In the prefeasibility studies we have identified one or two critical variables which must be investigated before total project feasibility is evaluated.

The feasibility studies should include the manufacture of (1) glass and (2) ceramic tile. Prefeasibility studies should cover (1) the construction industry,(2) the production of grain magnesite and (3) the manufacture of asbestos fiber. In the case of vitreous plumbing, since the opportunity will probably not exist for a period of years (until domestic demand expands to equal that needed for a minimum economic scale of plant) it is recommended that a study not be undertaken immediately.

II. REVIEW OF THE OCCURANCE, RECOVERY AND ECONOMICS OF NON-METALLIC MINERALS

II REVIEW OF THE OCCURRENCE, RECOVERY AND ECONOMICS OF NON-METALLIC MINERALS

In order to set the proper framework for analyzing opportunities in the non-metallic minerals and derivative products sector we will examine in this chapter the physical and chemical properties of these minerals, their usual mining and production methods, the major products derived from non-metallic minerals, and the typical prices that can be obtained in trade.

The following were included in this discussion:

1. ASBEETOS
2. BARITE
3. BENTONITE
4. CEMENT
5. CORUNDUM
6. DOLOMITE
7. FELDSPAR
8. FULLER'S EARTH
9. GYPSUM
10. KOALIN AND OTHER CLAYS
11. LIME, CALCIUM, AND DOLOMITE
12. MAGNESITE
13. MICA
14. OTHERS
15. QUARTZ
16. REALGAR
17. CRUSHED OR BROKEN STONE

18. DIMENSION OR BUILDING STONE

19. TALC (SOAPSTONE OR PYROPHYLLITE)

20. RAW MATERIALS FOR GLASS MANUFACTURE

21. CERAMICS

A. ASBESTOS

Asbestos is a commercial designation for a generic group of fibrous silicate minerals which are characterized by resistance to heat and flexibility of fibers. The most important type is chrysotile, with crocidolite, amosite, anthophyllite, tremolite and actinolite being other varieties. Chrysotile is graded according to fiber length with groups one to three on the Canadian classification being the largest fibers and groups four to seven being progressively shorter fiber and less valuable. In nature asbestos occurs in three forms:

a) Cross fibers. This is the most important group, and yields the best fibers which are found perpendicular to the face of the asbestos deposit or vein. They may be 2 to 3 inches long. (The Bolivian blue-asbestos is believed to be found as a cross fiber.)

b) Slip fibers. These fibers are found parallel to the deposit face, often 3 inches long, but, because of the difficulty in recovering the asbestos, they are much shorter and less valuable after beneficiation.

c) Mass fibers. This occurs in masses rather than veins,

often with no orientation. Because of this, and high recovery costs, it is the least valuable abbestos and the least important of the three types.

In general, the quality of an asbestos deposit is measured by the amount of processing necessary to reduce it to a saleable product as well as by the fineness and length of the fiber. Asbestos milling practice is generally designed to recover the maximum percentage of the long fiber even at the expense of the short fiber. Flowsheets vary widely and Canada, the world's leading producer, has recently been simplifying its flowsheets. The processing techniques utilize the fact that asbestos has high tensile strength.

In operations smaller than in Canada, hand picking is used rather extensively. The ore is reduced by a jaw-crusher to about 2" to 4" size, dried in rotary-direct fired driers, and then further crushed and screened with suction to collect the liberated fibers. Additional further crushing (usually gyratory units) followed by screening with suction are repeated until the ore has been depleted of the fiber. Normally only about 5% to 10% of the rock mine is recovered as an asbestos product. Of the asbestos recovered, it is likely that only about 10% is a long spinning grade fiber with 90% a short nonspinning grade. Ordinarily these catagories would be broken down into seven or more subclassifications, based on the length of the fibers, and the percent of contained impurities such as grit. Essentially all processing

techniques utilize the above simple operation and, therefore, are dry. This is frequently important since the location of many of the mines are remote from an adequate water source. One current processing problem involves the dust losses and air pollution and has created renewed interest in the wet processing techniques. We know of none that have been adopted.

A typical Canadian asbestos producer might handle 1,000 tons of rock per day and produce 60 to 400 tons of bagged fiber per day. A plant that produces less than 25 to 50 tons per day is rarely profitable for products that ate the 90% nonspinning shorts and 10% spinning grade and for ore containing up to 30% fiber.

The uses of asbestos fibers of all varieties are numerous and range from floor tile to rockets. The longer fibers -- Canadian groups 1, 2 and 3 and their equivalents from other countries --are used for making textile products such as cloth, yarn, tape, and rovings. Only about 5% of world asbestos production enters into asbestos textile products; this market has shown little growth in recent years. Chrysotile is the primary type of asbestos used in the manufacture of textile products, though crocidolite and amosite are used to a minor extent. The suitability of the asbestos for textiles depends on the tensile strength, fineness, and flexibility in addition to the length of the fibers. Use of shorter length fibers and those of inferior strengths is not acceptable for the manufacture of textile products because of the problems created in the machines (broken fibers, high losses in processing) and they

increase the amount of shorter fiber required. The asbestos is spun and woven in much the same way as cotton, silk, or wool. The fabrics are used extensively for lagging cloth, brake linings, clutch facings, safety clothing, packings, and gaskets, etc. Low-iron fiber is used in cable insulation.

Shorter fibers such as Canadian groups 4, 5 and 6 are used extensively for asbestos-cement products such as roofing shingles, pipes, and flat and corrugated sheet. Asbestos cement products consume almost 2/3 of the world's asbestos production and have been experiencing a rate of growth equal to that of industrial construction. These products consist of about 85% Portland cement and 15% asbestos. Canadian groups 4 and 5 are used extensively for making 85% magnesium block and pipe insulation and group 5 is also suitable for asbestos paper and mill board manufacture. Grade 7 fiber, which is a waste commodity, is used for filler applications. Amosite is used for filtered insulation in blanket form for high temperature service up to 900° F as well as for a lightweight, fire resistant marine partition board. Bolivian crocodilite has been found useful in the past for making gas-mask filters.

The world market for asbestos fiber is currently approximately 3 million tons; both Russia and Canada provide approximately 40% of this market. Much of the rest comes from South Africa and Rhodesia and a few other countries provide insignificant quantities. The market for asbestos has been growing at approximately 5% in recent years and this trend is expected to continue.

Three factors are significant in the value of asbestos:

1. The generic type of fiber (90% being chrysotile, approximately 10% crocidolite, or blue asbestos)
2. The fiber length (60% are grades 4, 5, and 6, price averaging US$150-200 per ton and 35% are shorts or waste grade 7) at approximately US$50 per ton).
3. Quality.

Almost 70% of the world asbestos is consumed by the asbestos cement industry producing board, sheet and pipe. Most of this material is in the 4 to 6 length grade. The second largest market is floor tile, in which asbestos waste is mixed with vinyl resins to produce a resilient flooring material. This market is concentrated to a very large extent in the Unites States as little floor tile is produced elsewhere. Asbestos paper and textiles together consume approximately 10% of the world market and tend to be medium to long length fibers and friction materials. Fillers, plastics and miscellaneous products consume the balance, generally a very low value product.

In general, the asbestos cement markets are growing most rapidly in the developing nations of Africa, South America and the Far East, while growth in Western Europe and North America is relatively slow. The market in South America for asbestos is at least 90% directed toward the asbestos cement products field, the balance of the market being focused toward the very low value

filler applications and some specialty expensive fiber used in textiles and friction materials.

B. BARITE

Barite ($BaSO_4$), a commercial source of barium and barium compounds, occurs in two types of deposits: replacement deposits of limestone, dolomite, sandstone and chalk, and residual deposits in which lumps of barite are enclosed in clays. Occurence of barite is world-wide, and is available in many countries on every continent. The output of Peruvian mines is the largest in South America, and Chile and Colombia produce small quantities.

By far the most common use of barite is as a well drilling mud. Drilling muds serve several purposes; they lubricate and cool the bit, plaster the walls of the drill holes to prevent cave-ins, carry the cuttings of the weld to the surface, and restrain oil gas and pressure to their formation levels to prevent blowouts. Crushed barite is used by the steel industry where it is added to melt floxes to save fuel and to act as an oxidizer and decolorizer. Barite is also used as a filler or extender in paints, inks, rubber and other minerals, but these uses are relatively minor. Prices of the drilling mud grade, FOB shipping point per short ton, vary from US$ 12 for the crude grade to US$ 26 for the ground grade.

C. BENTONITE

Bentonite is not an exact mineral or a material with a definite composition, but it is primarily a clayey material which,

is that which has the highest melting point, which occurs when

when moistened with water, will sometimes swell. There are other clayed materials, though no swelling types, which are classified as bentonites as they are derived from the same base, volcanic ash, and consist of montmorillonite and/or beidellite. Bentonites are found in the United States, mainly in Wyoming and California, in Canada, in many parts of Europe and South Africa, and in Argentina.

Bentonite is mined commercially usually by the open-pit method although in a few cases underground mines have been developed. Deposits, which are often wet and quite sticky, are commonly air dried when possible to below 10% moisture. Rotary driers are also used to reduce moisture for shipment. The dried clay is usually crushed in impact mills and if it is to be used for its surface active quality as a bleach or absorbent, it is usually treated with acid.

One of the problems in determining the quality of bentonite is that chemical analyses cannot normally be used for most commercial applications. Tests are required specifically for each application. Major uses are diverse: for example, it is used as a bleach for various oils, as an adhesive for pellets in the iron industry, as a raw material for preparation of oil drilling muds, as an adhesive for sand moulds in foundries; as a carrier of insecticides and pesticides, and many other uses. The largest single consumer is the oil industry which uses bentonite in both drilling for oil and the treatment of petroleum products. Prices, FOB mine, are US$10 -US$15 per ton.

D. CEMENT

One of the most widely known and used non-metallic mineral products in the world today is cement. One hundred and seven countries in the world have at least one production facility, including all ten of the South American nations. By far the greatest use is in the building and construction industry for the manufacture of concrete and plaster.

Cement is an artificially produced mixture of minerals of complicated structure. In the presence of water, these minerals change to a coloidial product which results in hydraulic hardening. Portland cement, aluminous cement and slag cement are examples of hydraulic cement and require lime silica, alumina and ferric oxide for their manufacture. Of these, Portland cement is by far the most important.

The properties of Portland cement are based primarily upon the formation of tricalcium silicate. Its manufacturing process requires an intimate mixture of limestone and clay in proper proportions, followed by burning for the stipulated time and at the correct temperature to produce a quality product. Gypsum is added and ground with the clinker (burned mixture) for control of the cement setting time.

In order to have these desirable qualities, cement must contain the proper percentages of bicalcium and tricalcium aluminates with the correct limestone content. It is therefore

important that the quarry supplying the limestone has accurately predictable chemical properties; the same applies to the clay. It is also important that the clay and limestone contain low, but consistent, amounts of sulphur (SO_3), not exceeding 2.5%. The alkalis, soda and potash, while quite harmless in small quantities, limit the setting time of the cementif present in larger amounts. Magnesium is also an undesirable material often appearing wit the limestone.

The chemistry involved in the production and hydraulic setting is complex and accurate definitions of the amounts of the major constituents are interdependent and, therefore, difficult to discuss within the scope ot this report.

Average values of cement in bulk for each is about US$20/ton CIF to US$ Pacific Ports.

E. CORUNDUM

Corundum is a natural anhydrous aluminum oxide. In its purest form it includes various gemstones, such as ruby and saphire. Emery, usually considered in association with corundum, is a mixture of corundum, magnetite and other minerals. Corundum occurs as a constituent of various igneous and metamorphic rocks, including certain serpentine and crystalline limestone. It also occurs in alluvial deposits.

Corundum and emery are used as abrasive components of grinding wheels and abrasive cloths or for polishing grain; however, their

use has been virtually supplanted by artificial abrasives. World production of approximately 10,000 short tons each year has remained constant and represent only a small portion of the total natural and artificial abrasive consumption.

F. DOLOMITE

True dolomite is chemically represented by the formula $CaMg(CO_3)_2$. This is equivalent to 46% magnesium. In commerce, dolomite is the generic term used to describe a material which usually contains dolomite, calcite and magnesite and the magnesium content of commercial "dolomite" may vary between 10% and 40%.

Dolomite is a material with many uses. When it is located near highly industrilized markets and when it occurs in large masses free of fractures and intrusions of deleterious minerals, it is a useful dimension stone for the construction industry. It canbe used as a source of light magnesium metal if markets are sizable and production requirements can be fulfilled. It canbe used to make a magnesite refractory employed in large part by the steel industry. Magnesium compounds from dolomite are major raw materials used in the paper, chemical, textile and rubber industries. Dolomite's major use, however, is as a concrete or road aggregate.

As a building stone and aggregate, dolomite must be massive and strong but must not be associated with clay. Most important, it must be located near a local market. Because of its general availability and low value the aggregate is not an article of international commerce except in very special areas where high

volume, low cost materials and moved across the border a few miles.

Recovery and processing methods closely parallel those for stone described in other sections of this Chapter.

G. FELDSPAR

Feldspar is a term applied to a group of igneous minerals consisting chiefly of aluminous silicates of potassium, sodium and calcium; one base usually predominating. It may be white, grayish, yellow or a shade of red (from rose to brick) or even green or blueish depending on impurities. It has a vitreous to pearly luster and is among the most widely distributed of rock forming minerals, occuring as a constituent of most rocks. Feldspar occurs in crystals large enough for selective mining only in dikes formed where the crystallization from molten magma has been slow, and quartz and muscovite mica are always associated with feldspar in these dikes.

The deposits are mined chiefly by open pit methods although a few mines are underground. Hand cobbing and sorting are employed at all small mines and perhaps some large ones, not only to upgrade the feldspar but to select high product minerals, such as mica, before crushing. A second method or recovery, and by far the most common, is the use of floatation to separate the feldspar and other minerals for collection. The third method is to mix it with silica and to clean the concentrate for subsequent marketing as structural or glass sand.

World production has continued to increase at a steady rate, and now amounts to some 2 million long tons annually. More than half of this quantity is consumed in the manufacture of glass, about one third in pottery, and the remainder in enamel and other ceramic uses. At one time poultry grit and roofing granules accounted for 20% of the feldspar consumed, but now only minor quantities go to these uses. Prices FOB. U.S. domestic mines for the crude feldspar are approximately US$9.00 per short ton; the ground material sells for about US$13.00 per short ton when sold to merchant mills. Imports to the U.S., CIF port of entry, sell for as much as U.S.24.00 per short ton.

H. FULLER'S EARTH

These clays are essentially montmorillonite or attapulgite, the former closely resembling sub-bentonites and tending to be higher in magnesium.

The clay is mined by open pit methods and then processed by feeding directly to a crusher as it comes from the mine. The crushed and screened material is then fed into pugmills, extruded into spaghetti like forms, and dried in a rotary dryer. Depending on the end use, the particles are crushed to the required specifications. These end uses include various absorbents, insecticides, fungicides and drilling muds. Production costs vary from US$10 to US$15 per short ton, and selling prices FOB the mine are about US$25 per ton.

I. GYPSUM

Gypsum is a crystalline form of hydrated calcium sulfate. Deposits are quite pure in wide areas of the United States and throughout the world. Its value depends on its ability to set into a hard permanent white solid (plaster of paris) in a very short time. There are five forms:

a) selenite - a transparent colorless form

b) satin spar - a silky fibrous form

c) alabaster - a white fine grained form

d) rock gypsum - a compact granular form often impure

e) gypsite - an earthy impure soft form

It is usually found with sedimentary rocks, although gypsite is found in surface beds after evaporation of surface water.

Good commercial deposits occur in many states in the United States; and in the maritime provinces of Canada, the U.K., France, and other European countries. Commercial deposits also occur in Argentina, Brazil, Chile, Colombia, and Peru, and total world production is about 52 million short tons.

Most domestic gypsum is mined by open pit methods and underground mining is confined to deposits where the increased cost is compensated for by a higher quality ore, or proximity to the market.

After recovery, the gypsum is crushed in two stages, the first employing gyratory or jaw crushers and the second hammer mills or

or roll crushers. The large quantity of high gypsum available has discouraged any seriousattempt to beneficiate low grade gypsum ore by floation or gravity methods. The gypsum is calcined partly or completely by dehydration in gypsum kettles, rotary kilns, or under steam pressure in autoclaves.

The properties generally desired in calcined gypsum include: high tensile and compressive strength, hardness, fineness of grain and uniform setting time. Certain other properties are more essential for some applications than others. Plasticity is highly essential in wall plaster intended for use with aggregates, but this property is not as important when calcite gypsum is used in manufacturing prefabricated products such as wallboard and tile. After calcination, wheel grinding, mixing and blending, the gypsum plaster is ready for use. Gypsum is used almost entirely to make wallboard, plaster products in the housing industry and as an additive in cement production. Small quantities are also used as a chemical intermediate for color and as a raw material for glass production. Gypsum board consists of a gypsum plaster core between paper layers. This product is used for walls and ceilings and is fastened directly to wood or metal framing or furring strips; its use is most evident where wood-framed construction predominates.

Gypsum is a low value item, generally worth from US$3 to US$6 per ton as an article of commerce, and like cement, its market is closely related to fluctuations in the building construction field.

J. KAOLIN AND OTHER CLAYS

Kaolin is a mineralogical term referring to a clay in which the predominant clay mineral is kaolinite. China clay is used synonymously with kaolin. Commercial kaolins have a nearly white, dry and fine color and their grades are determined by intended uses. An unending variety of other clays exist in the world. A second major type that is basically kaolinitic, but usually includes other clay minerals such as halloysite and illite, occur in great abundance and are known as fire clays or stoneware clays, depending on usage.

Specifications of clays are based on their uses and practically any earth or soil material that can meet these specifications can be used in the manufacture of a wide variety of products. For use in ceramic wares, the important properties are elasticity, fire color, dry and fired strength, drying and firing shrinkage, and vitrification range. For refractory uses, the most significant single property is the pyrometric Cone Equivalent (PCE) which is determined by comparing the softening behavior of a clay sample subjected to a standard time-temperature schedule with that of standard tones. Clays having a PCE of 33 (3169°F at 270°F heating rate per hour) or higher are used for manufacturing super refractories; those with a PCE of 31 (3061°F) for high duty refractories, and those of a PCE of 30 (3029°F) for low duty refractories.

Serviceable refractories for some purposes can be made from clays having a PCE as low as 15 (2606°F). Clay used for manufac-

turing cement is selected to compensate for deficiencies in chemical composition, such as silica, iron oxide and alumina, otherwise not present in the available limestone or cement rock. For filler clay and paper coating clays, emphasis is on fineness of grain and whiteness of dry, unfired clay; for insecticide carriers, high absorbency is important.

Geologically, clay is of two general types - residual and transported; but in all intances, clay is of second origin, having been formed by the alteration of other rocks. Clays may be found in a variety of forms - as a soft paste, soft solid, or as laminated rock. They may occur at or near the surface or at relatively great depth. The kaolintic clays of commerce are developed largely from feldspatic rocks, and their compositon is usually a result of weathering.

Most clays are mined by open pit methods and kaolin may be marketed after crushing and screening or after separation. The coating clays differ essentially from most filler clays in grain size and additional bleaching is usually required. The filler and coater proportions of the clay are separated by classification sizing, the very fine being coater, the coarser being filler. Fire clay and other miscellaneous clays follow the same processing, but generally go through secondary crushing and screening as well.

Kaolin is widely available in many countries in the world, including Argentina, Chile, Colombia, and, to a far lesser extent in Equador and Peru. World production is approximately 12 millon

short tons annually. The greatest single consumption of Kaolin is in paper filling and coating uses. Minor uses include rubber fillers and the manufacture of refractory brick and blocks. Fire clay is used primarily in heavy clay products and refractories.

Kaolin that is sold by producers averages US$25 per short ton, FOB mine: that used by producers in direct manufacture of products is valued at an average of about US$10 per ton. Fire clays and stoneware clays average US$3.75 per ton and US$6.00 per ton respectively.

K. LIME, CALCIUM, AND DOLOMITE

The calcination of limestone, marble, chalk and dolomite at moderately high temperatures releases carbon dioxide gas and leaves behind a solid residue of quicklime. Addition of water to this quicklime causes rapid hydration to calcium dioxide or hydrated lime. The general term "lime" is often misconstrued to include materials other than the oxides and hydroxides of calcium and magnesium and is applied without discrimination to limestone, shell and gypsum. In industry, the term is used to denote calcium carbonate, calcium sucrate, and calcium ascetate. "Hydraulic lime" is produced by calcination of limestone containing enough aluminous and siliceous material, such as clay minerals, to form a substance that will slake and set or harden under water. "Hydraulic limestone" contains an amount of silica and alumina so that a hydraulic lime will be produced on calcining. Dolomite, calcined at a high temperature with the addition of a stabilizing agent such as iron

oxide, or mill scale, becomes relatively inert to the action of atmospheric moisture and carbon dioxide and is known as "dead-burned dolomite".

Calcium is the fifth most abundant element in the earth's crust and accounts for 3.4% of it. Although calcium is much too unstable to occur naturally, its compounds are very common in nature. It occurs as carbonates (limestones, marble, quartz) sulfates (gypsum), phosphate, fluoride and in many silicate minerals.

Limestone and dolomite used in manufacturing lime are obtained in open pits and underground mines with techniques similar to those described in the section on stone. The calcining of limestone is generally done in shaft and rotary kilns in the U.S., although vertical kilns are responsible for most lime manufactured in other countries.

Quicklime and hydrated lime, including deadburned dolomite, are produced in many countries of the world, but total quantities have remained relatively constant. Although uses are many and varied, metallurgical uses (such as for steel slags) predominate. Chemical and other industrial uses include alkalis, calcium carbide, sewage, and waste treatment, water softening and treatment, and pulp and paper manufacturing. Deadburned dolomite is essentially a refractory lime. Prices vary by end-use and by geographic area, and while average values FOB plant are approximately US$12 - US$ 15 per ton, a delivered price can be as high as US$60.

L. MAGNESITE

Magnesite is a magnesium carbonate which crystallizes in a triogonal system. Crude magnesite ores vary from 38% to 47% magnesia (MgO), the product of calcination or thermal decomposition of several magnesium minerals and compounds, including dolomite (22% MgO). Good magnesite ore also contain as much as 7% silica, 2% to 7% alumina, 2% to 7% iron oxide, and varying amounts of lime.

Magnesite is found in bedded deposits, as deposits in veins and pockets, and as replacement bodies in limestone and dolomite. Recovery is generally by open pit quarrying techniques, and while underground mining is used, this method is often unattractive because of the high cost associated with it. Following the mining, the magnesite is often carefully collected and sorted before being crushed to 5-inch size and carried by belt coveyors to storage piles. In the making of refractory products, this ore is conveyed to cone crushers, which reduce the size to that required and the material is screened and washed. The ground discharge is conveyed to flotation cells where impurities are removed before calcining at temperatures below 1650°F to produce caustic calcined magnesium. Refractory magnesium is produced from crude magnesite by calcining the ore in rotary kilns at temperatures ranging from 2640°F to 3200°F. When magnesite is calcined, the impurities are driven off and the MgO magnesia content of the resulting product approximately doubles in percentage. The best balance in impurities

is that which has the highest melting point, which occurs when the ratio of CaO to SiO_2 if 1.86 to 1 and this is required by purchasers of bricks. In general, approximately 1 ton of magnesite is recovered from every 3 to 4 tons of ore.

Magnesium compounds are principally used as refractory magnesia and the caustic calcined magnesia is used in pulp and paper manufacture, chemical processing and insulation, as well as a wide variety of other flux and ceramic uses.

The steel industry at present requires two qualities of refractory bricks, one for the BOF process, and the other for the open hearth system. The latter process is reducing in popularity, however, and the BOF process has more stringent requirements for refractory brick and a lesser demand per ton for steel produced.

World production of crude magnesite has remained fairly steady at 11 million short tons each year with much of the production coming from Communist countries. Colombia produces small amounts and Brazil about 130,000 tons each year. The increase in production of magnesia from sea water continues to exert competitive pressure on producers of magnesite. It is estimated that some 12 locations in eight different countries derive about 1 million short tons of magnesium (equivalent to 4 million short tons of magnesite) each year from this source. Prices of refractory magnesium, sold or used by producers in the U.S. is about US$67 a ton, while that of caustic magnesia is over US$90 per ton.

M. MICA

Mica is a group name applied to many minerals that have certain physical and chemical characteristics, and are characterized by excellent basal clearage that facilitates splitting into thin, tough, flexible, elastic sheets.

There are two groups: those used for physical properties, including muscovite, phlogopite biotite, and sericite, and those valued for their chemical content, which include lepidolite, zinnwaldite (lithium source) roscoelite (vanadium source).

Commercially, muscovite and phlogopite are the most important. Muscovite is recovered from pegmatites and phlogopite from pyroxenites. Poitite mica is less important because of a high iron content that makes it less valuable, especially for electronic and electrical uses.

Mica is exploited by sinking shafts and digging test pits to determine the mica content and the size and quality of the sheets. Trenching and stripping, usually by bulldozer or similar mechanical equipment is used to outline the deposit. Sheet mica mines can be operated successfully on a small scale. Open pit mines are sucessful in relatively flat country and small underground mines can be successfully operated if care is taken to avoid drilling through good mica crystals.

Because mica is primarily sold in sheet form only a few pounds can be produced per day in a small mine and hand labor is normally

used in preparing mica for market. Consumption of sheet mica consisting of block, film and splittings is decreasing on a worldwide basis mainly due to a reduced requirement for electronic capacitors and tubes. Consumption of ground mica, used in roofing, paint, joints and nuts, and rubber manufacture continues to increase, however. Prices vary from US$44 to US$66 per metric ton for a dry ground mica used in roofing, to US$200 per metric ton wet for ground mica consumed in paint manufacture, to approximately US$550 per metric ton for sheet mica.

N. OCHERS

Ochers are natural earth pigments which are usually associated with clays. Their colors vary from yellow through red and brown, and their use as an ingredient of paint manufacturing was once widespread. However, these ochers are relatively inferior to the manufactured metallic pigments in strength, hiding power, fineness and texture, they are harder to grind and their large average particle size makes them unsuitable in glossy finishes. Their commercial importance has thus reduced considerably.

Ocher is most often mined by opencut methods: the pockety character of the ore and the uncertain market for the product do not justify elaborate equipment. The ocher is then washed, dehydrated and pulverized into powder for packing.

O. QUARTZ

Silica is one of the most abundant minerals in the earth's crust. The types and varieties of quartz range from worthless

deposits of sand in various deserts around the world, to the very rare high purity quartzite crystals used in electronics.

The major deposits of silica occur as sand and gravel, sandstone and quartzite, and have found a low-valu use as a baric concrete and road material. High silica quartz, capable of being used as a glass-making raw material should contain more than 99.0% SiO_2 and less than 0.3% Al_2O_3 and less than 0.05 iron and titanium. However, raw sand containing about 95% SiO_2 2.5% Al_2O_3; 1.5% K_2O and Na_2O; 0.5% CaO and MgO; and 0.4% Fe_2O_3, has been utilized. This material, when used to make glass, alters the viscosity of the glass melt at the working temperature and therefore effects the production rate and the glass quality.

Sand and gravel quartz deposits are excavated with an assortment of equipment: power shovels, bulldozers, front end leaders, drag lines and many others and are often used in combination. Processing is usually limited to screening the material, separating the fine from the coarse minerals, followed by crushing of the larger aggregate to prespecified sizes. Washing is frequently required to free the sand and gravel from clay deposits, especially if the minerals are used in construction. Prices for construction uses generally average US$ 1.00 per ton, while industrial uses such as filtration, molding, and glass manufacture are valued at over US$ 3.00 per ton at the quarry.

P. REALGAR

Realgar is an arsenic sulfide, and normally contains about 70% arsenic, and usually found with lead, silver, gold and tin sulfides, where it is an undesirable impurity. The arsenic sulfide market is small and is decreasing as base metal (copper, lead, zinc, etc.) refining facilities produce far more arsenic as sulfides than can be absorbed in the world market. The stage has been reached where the disposal of arsenic is a serious economic problem, and it is not now an article of commerce.

Q. CRUSHED AND BROKEN STONE

Crushed and broken stone, a basic construction, chemical, and metallurgical raw material, is a major commodity in the world in both tonnage and value. Although it is often similar in geological form to the dimension stone, the term "crushed stone" is applied to irregular fragments of various rocks that are crushed or ground to smaller sizes after quarrying. As before, the major rocks are granite, quartzite and limestone.

Accelerated highway and industrial construction in many parts of the world are major factors in the increasing demand for crushed and broken stone. By far the greatest bulk of stone production goes into road and building construction: the remainder is used in cement manufacture and for various chemical and agricultural purposes. This essentially low-value commodity closely parallels trends in such basic economic indicators as gross national product,

value of construction, and population. Its low value (generally less than US$5.00/ton) has also restricted its tranportability, and transportation costs are a major value in the economics of the industry, often making up more than 2/3 of the delivered price for construction uses. Good quality, finely-ground minerals are relatively valuable and may range up to US$100/ton for low-volume speciality markets.

A variety of mining and quarrying methods utilizing all types of equipment, both stationary and portable are employed. Though surface quarries can be operated at lower costs than underground mines, conditions do not always permit their development. In both quarries and mines, however, a similar series of operation is necessary. After stripping the overburden, or driving underground entries, holes are drilled for explosives to blast the stone loose and the recovered mineral is then loaded into trucks and cars. These convey the material to the crushers, which process the rock into the desired fineness and product size required by the various industries.

R. DIMENSION OF BUILDING STONE

Dimension stone is a term applied to stone sold in blocks or slabs of specified shapes and usually of specified sizes, contrasted with crushed or broken stone covered in another section. Dimension stones are of many types. The principal varieties are granite, trap rock such as basalt, sandstone, slate, limestone, and marble.

a) Marble, a metamorphic rock, is composed essentially of calcite, dolomite, or a combination of the two, but may also include serpentines, ornyx, and travertines.

b) Granites are essentially fine to coarse-grained rocks of igneous origin Quartz and feldspar are the major components, and micas and olovine are accesory minerals.

c) Limestone, which has a more common commercial use as a crushed stone, is a sedimentary rock composed of calcium carbonate.

d) Sandstone is composed of quartz grains, cementdd with calcium carbonate, oxide, clay and other minerals.

e) Basalt is a fine grained, dark colored rock resulting from intense volcanic activity.

f) Slate is an argillaceous rock of sedimentary origin that has the common property of splitting readily into thin plates.

These dimension stones are used for external or interior parts of buildings, foundations, curbing, paving, bridges, and for other architectural and engineering purposes. The desirable properties of dimension stone, in additon to those relating to workability and the tests that measure it, depend on the use of the stone. For interior use, desirable properties incude attractive color and

texture as well as reasonable strenght and resistance to abrasion and cleaning solutions. Exterior building stones and those used for highway construction may be less attractive in collor to those used for interior trim, but must have greater resistence to daily and seasonal changes in temperature, freezing, and artificial contaminants.

Limestone and basalt are widely distributed throughout the world, and due to their relatively high weight, bulkiness, and handling difficulties are not transported long distances. Certain marbles and granites that satisfy special architectural demands find specialized markets in many parts of the world, but require skilled craftsmen to cut and dress the blocks. Because of increased competition due to a wide variety of lower price substitutes, markets for most uses of slate have been decreasing for many years.

Prices vary with the type of stone and its use. Granite ranges from US$ 1.00 per cubic foot rough cut for construction use, to about US$ 20.00 per cubic foot for a dressed stone for monumental use. Marble has a similar range, while limistone, sandstone and quartzite are gene rally much lower in value and frequently less than US$ 5.00 per cubic foot at the quarry.

The stone is mined mainly in open pit operations though the underground method is used as well. While blasting methods are used, care must be taken to minimize breaking of the blocks. Primary cuts are sometimes made, and wire saws have been used with success.

in large operations. Whatever method is used, it is slow, but the primary concern is to achieve the maximum yield in terms of block size for commercial use. The blocks are then lifted out of the quarry by large powerful derricks and trimmed before being sent to the mill for sawing into slabs. Because these operations require large equipment, the capital requirements in terms of derricks, cranes, wire saws and the like are high, and skilled, highly paid technicians are indispensable to the operation.

S. TALC (SOAPSTONE OR PYROPHYLLITE)

Talc is a hydrous magnesium syllicate, but often contains impurities of quartz, calcite, iron oxides, and other minerals. It is a very soft, masive aggregate, often greeny-gray or white in color and sometimes platey like mica, or fibrous like asbestos. Commercial talc deposits are of two classes, those derived from, or associated with ultra basic igneous rocks, and those derived from sedimentary magnesium carbonate rocks. Although there is a considerable variation in each class, talc associated with the latter type tends to be whiter and purer.

Its occurence is widespread in nature, and most industrialized nations produce sufficient quantities to satisfy their requirements. However, the physical and chemical properties of talc vary with its genesis and its uses often depend upon specific properties. Talc from different deposits are not always interchangeable in industrial applications. Few, if any, minerals surpass talc in its multiplicity of uses. The ceramics, paint,

rubber, insecticide, roofing and paper industries consume the majority of world production; the remainder is often used in the minor markets such as in toilet preparations, in crayons, and in decorative sculptured figures.

Total world production has shown a steady increase from 3.9 million short tons in 1964 to 4.7 million short tons in 1968. Japan produces 1/3 of this total and the U.S. approximately 20%, at least 37 other countries in the world, including Argentina, Chile, Colombia and Peru, mine the mineral. Because of its general availability, it is not a major factor in world trade. French and Italian talcs, however, find a world market for cosmetic preparation because of their superior quality. U.S. prices for talc are in the range of US$ 2.00 - US$ 5.00 per short ton.

Talc is mined either by the open pit or by the underground method. There is very little mechanization of talc mines and use of explosives is kept to a minimum because of the relatively higher value of the larger block. In a successfully operated mine, recovery of talc will range from 40% to 65%.

T. GLASS MAKING RAW MATERIALS

Although the glass making materials available in many developing countries often do not have the desired amount of various constituents, there are usually alternate solutions using indigenous raw materials.

The typical composition of flat glass is:

Silica (SiO_2)	
Lime and Magnesia (CaO and MgO)	12 to 14%
Soda (Na_2O)	13 to 14%
Iron (Fe_2O_3)	less than 0.1%
Alumina (Al_2O_3)	less than 1.5%
Sulfur (as SO_3)	less than 0.5%

High quality sheet glass products should contain less than 0.1% Fe_2O_3 and 1.5% Al_2O_3. Exceeding these concentrations should not eliminate production, the solution is to produce a lower quality glass at somewhat limited production rates.

In developing countries there is most often a problem in controlling the iron and alumina content. Iron content often runs over 1% but this can be acceptable even though a more greenish colored glass will result. Alumina often runs from 2 to 3% and this adversely affects the viscosity of the melt limiting the rate at which sheet glass can be pulled. Usually in the early stages in developing a glass industry, these two problems are acceptable and often even unrecognizable. Later, increased competition and greater social awareness of glass quality will demand more technical sophistication and lower production costs. We believe, therefore, that while low iron, low alumina sand and other glass forming components are important, the immediate need for a glass industry can be justified regardless of the rigid raw material requirements demanded of glass products acceptable in world

trade. These will necessarily come later.

Specifically, a flat glass plant requires:

Silica sand

Limestone

Dolomite (or dolomitic limestone)

Feldspar

Soda Ash

Salt cake and other minor constituents such as charcoal and arsenous acid are also required but in small enough quantities that they can be imported. The raw materials should be pure, low in iron and organics and metallic components, should be fine, granular, not wet or dusty and should be free flowing.

All flat glass processes start with a large tank of melted glass constituents. Because of the cost of melting the glass and supplying energy to keep it melted in the tank, the glass-making process must be continous for a number of months: facilities must be used continually to justify initial investment and to avoid equipment damage. The molten glass in the tank is then formed into sheet glass by three types of process: a) by drawing the glass vertically from the tank -- much like candy -- and, through a series of rollers. It's cooled in the drawn form, cut and packed. Systems available are fairly limited to the Mercault process or the more expensive and more volume sensitive Pittsburgh process; b) taking molten glass and rolling it through a number of shaped

rollers to produce what is called rolled glass. These rollers can be shaped to provide contours in the glass or wire mesh can be imbedded in the rolled glass. This process is appropriate for speciality or decorative glasses but is not appropriate for high-volume window glass; c) by the recently developed float glass process in which the formed glass is floated on liquid tin until it hardens. The glass from this process is extremely flat and of high quality -- in fact too high a quality for most of the Bolivian or Andean market. Furthermore, the float glass process is extremely expensive -- at least a US$20 million investment required, and requires a minimum volume of 250 tons per day. Licenses are very difficult to obtain from the developers in the United Kingdom.

A minimum sized flat glass plant would use one furnace and one drawing machine initially because of the low sales requirement. The Forcault process is the system with minimum capital investment and least volume sensitivity. Such a total plant would cost from U.S.$ 2 million plus a 10% contingency for additional freight from the ports to the facility and higher charge for field engineering because of the costs to Bolivia.

U. CERAMICS

1. Raw Materials

Ceramic raw materials are usually classified into clay and non-clay materials. Clay materials are those fine materials usually smaller than two microns and having certain specific plasticity

qualities when wetted with water; they can also include almost all types of common soil. Specific clay types will vary from location to location, not so much by mineralogical definition but by application. For example, pottery clay in North Africa would not necessarily be regarded as such elsewhere. The application often determines the material classification.

Non-clay ceramic raw materials include:

Feldspar;

Silicas, quartz, flints, tripoli ganister, diatomite;

Nepheline syenite, an aluminum silicate rock containing sodium and potassium (usually with soda and potash feldspars);

Magnesite;

Dolomite - the mixture of calcium and magnesium carbonate usually about one to one ratio;

Gypsum - calcium sulfate;

Chromite - a spinal having the formula $FeCr_2O_4$

Aluminate silicates - many species;

Pyrophyllite - a platy, mica-like, hydrated aluminum silicate and many others such as talc, mica, graphite, and lithium minerals.

2. Products

The extent of the ceramic industry is difficult to determine because of the very many products, including those not normally considered ceramics. For example, products of the ceramics industry should include:

Glass (flat, container, pressed and fiber).

Glass (flat, container, pressed and fiber)

Cement (hydraulic -Portland)

Lime Products

Gypsum Products

Carbon and Graphite products

Refractory - of clay and non clay products

Vitreous enamels

Whitewares (floor and wall tile) structural tile pipe, Porcelain products, pottery)

Abrasives (grain coated and bonded products)

Brick

Structural Clay Pipe

Ceramic minerals

However, many of these product groups are normally considered as independent industries in their own right and not included with Ceramics below. We describe briefly the following most commonly regarded groups of ceramic products: 1) Refractories; 2) Tile; 3) Pottery or Stoneware; 4) Sanitary Ware; 5) Electrical Ceramic Products.

1. Refractories

Refractories which are heat-resisting non-metallic raw materials used in steelmaking, are frequently magnesite or native magnesium carbonate. The only large deposits of high quality magnesite in the free world today are in India and in Greece: their distance from the world's steel industry has slowed their exploitation. These are low in silica (under 6 or 8%) and low in iron

(under 0.5%). Austrian magnesite is a rich deposit but contains large quantities (4-8%) of iron. The Chapare magnesite of Bolivia is relatively low in iron (under 1.0%) but in its present state of development contains over 10% silica. Reports have indicated that this can be reduced to about 6% (which is an acceptable amount), by physical beneficiation methods; however, until extensive tests have been carried out using flotation or electrostatic techniques, the true value of Chapare magnesite relative to world requirements cannot be determined.

Magnesite for refractory use must be fired at high temperatures (above 3.000°F) in order to realize its intrinsic value as a high quality, high value refractory material. The use of fire magnesite has become increasingly important as the Basic Oxygen Furnace (B.O.F.)becomes increasingly important in steel production. Magnesite is the predominant refractory used in the B.O.F. and currently in the U.S. steel industry between 4 and 8 pounds of magnesia refractories are consumed per ton of steel produced. These refractories vary in quality and price greatly, however. For example, about one-third of this refractory consumption involves a product containing only 60% MgO which sells for about US$170/ton; 20% of the product is pitch-impregnated high purity magnesite, selling at over US$300 per ton. The criteria for selection of a refractory is quality, consistency in production and in composition, and, most important the operator's experience of its chemical compatibility with the adjacent refractory in the furnace.

2. Tiles

Tiles are used throughout the world as a high quality covering for walls and floors, and while for different types of tiles there are some slight differences in raw materials and in firing they can be considered as one product.

The raw materials used in floor tiles are feldspar (50-60%) and kaolin (10-40%), with the remainder consisting of ball clay, china clay and talc. However, compositions are largely dependent upon locally available clay or earth materials.

The quality of raw materials and ultimate fire color of the body are relatively unimportant with wall tile. Wall tile rarely contains more than 10% feldspar and many compositions omit feldspar. These tiles usually contain considerable frit (from 20.50%) as well as varying percentages of flint clay (0-35%); kaolin (0-30%) ball clay (20-40%) and talc (0-70%). They are fired to lower cone temperatures. With the exception of the glazing material for the surface (and whiting or coloring) these tiles often utilize locally available clays and materials such as talc, pyrophyllite and wollastonite.

Modern processing techniques weigh, blunge and spray dry the mix, producing tiny spheres that have adequate water content and acceptable flowability. This material is fed to a mould and the tile pressed automatically; currently, automatic screw type presses can produce from 100 to 200 tiles a minute. Well prepared feed and effectively designed feeders allow production of tiles of uniform density.

Tile is removed from the die by hand, and dresses (fettled) and dried. The tiles are then sprayed with a glaze and fired before inspection and packing. Inspection is an extremely important part of the production procedures and is obviously labor intensive. It is carried out on both a color and quality basis and emphasis on it is often the basis for success for many of the European operations.

3. Pottery or Stoneware

Pottery or stoneware is made from different types of clay than those used as the base for whitewares or refractories. The better grades of pottery are made from semirefractory grades or clay that, when burned, is quite dense and usually not white. The clays are chosen on the base of plastic properties, high green strength and low firing shrinkage. Chemical analyses are not used to describe the raw materials in this product but rather mineralogical analyses. These pottery clays usually are mixtures of naturally occurring earthy or clayey materials and contain feldspar, mica, quartz and iron oxides.

The products made from these mixtures are shaped by machine or by hand, are dried in tunnel or conveyor type dryers, and usually are then double fired. The first firing is at about 900°C to 1,000°C in a periodic or tunnel kiln. The ware is cooled, decorated and/or glazed, dried, and again fired at about 1250-1300°C. However, porduction techniques vary considerably and often they are carried out in small family operations using indigenous materials for the

underbody, which is shaped by hand. Glazes are purchased and also hand applied; firing is usually carried out in small beehive or periodic kilns.

4. Vitreous Plumbing

The production of these products differs considerably from the more usual processes previously described, and also from other processes employed in earthenware manufacture. The reason is the large size of the finished product. Raw materials required include plastic clay, kaolin, finely ground quartz, spodumene, (a fine ground nepheline), syenite, pegmatite or feldspar. Other materials required are tennin, sodium carbonate, sodium silicate. These latter minerals are used to control the workability of the slip or green clay shapes and obviously this is a very critical point when producing large, heavy products. The raw material for the glaze is most critical and requires high purity minerals since errors in formulation can cause large financial losses if products are rejected because of their quality.

Production was labor intensive when the shapes were molded entirely by hand, using plaster of paris molds. These shapes are now predominantly made by highly machanized production methods in factories throughout the world. In an average-sized plant, between 200 and 300 pieces per shift are produced, or about 50,000 to 150,000 pieces per year. The large size of the ware requires large equipment and necessitates a high investment.

The labor component for an efficient automated plant is generally low, while the raw material and operating supplies cost components are high.

5. Electrical Ceramic Products

There are four major types of these products:

a) Steatite, which uses talc, clay, barium carbonate and calcium carbonate;

b) Porcelain, using kaolinite, quartz and barium carbonate;

c) Ultra-porcelain or mullite, using alumina, clay, barium carbonate and high purity quartz;

d) Corundum, using alumina with some fusible additives.

The porcelain ceramic products are among the largest and most important of these groups.

Ceramics used for electrical insulation must exhibit certain specific properties including high mechanical and electrical strength. The raw material mix must be molded into various intricate shapes and specifications are particularly rigid, especially regarding impurities, and manufacturers invariably purchase the purest materials available. Individual specifications for each mix are proprietary; however, typical mixes for production of insulators include: 20-26% feldspar, 38-47% kaolinite, and 22-40% silica. The quality of the feldspar is carefully controlled and kaolinite is often quite pure.

The production line is similar to the production of structural clay products. The mix is carefully measured, mixed, drained

and vacuum extruded. Clay blanks are shaped by various types of presses, depending on the shape required, and then are dried and aged. The form is then dressed, cleaned and the glazing applied. Finally, they are fired either in tunnel or in periodic kilns, cooled, tested, and packed for shipment.

The insulators produced must be quite dense and nonporous and must meet rigid mechanical and dimensional tolerances. There is considerable skill required in producing insulators, as well as in design of the mix, and therefore, raw materials are accepted for use only after extensive testing procedures have been carried out. Investment in equipment is high because of the density requirements and rigid dimensional tolerances of the products. The equipment is heavy and production rates low.

III. R E S O U R C E S

III RESOURCES

A. INTRODUCTION

In the nonmetallic minerals area, resource availability is of prime importance in determining the feasibility of manufacturing, opportunities. In understanding resource availability in a country such as Bolivia, one must realize that it is impossible to estimate the exact extent of non-metallic mineral resources, given the current state of exploration. It is possible that as Bolivia becomes more fully explored new deposits of these minerals in larger quantities and of higher quality will be found In the discussion that follows, we have summarized general opinions about mineral availability based on investigations by many differing groups with differing vested interests. Exploration is continually being undertaken by the government, by international agencies, and by various existing or potential industries in the country; therefore, the knowledge about available mineral resources will improve as time goes by. We must base our present conclusions on what is known today but it should be pointed out that this may change time.

In the description of the various minerals which follows and in subsequent chapters, we have, where possible, pointed out the commercial possibilities of certain minerals whether or not they are known to be available. If certain minerals have marginal to poor potential, we so state, so that further exploration for these minerals will be avoided. For other minerals, where

information on availability is scant but encouraging, we have specifically recommended further investigation to locate or quality more fully the existing knowledge.

It should be pointed out further, that many nonmetallic minerals are high in bulk but low in value. Thus, because of the exigencies of transportation, the ultimate feasibility of ventures based on these minerals will depend not so much on the availability of the mineral as such, but rather on its location relative to the markets. For other nonmetallic minerals the potential in world markets will be a function of the quality of the mineral, the amount and proportion of the impurities, and the extent of beneficiation necessary. Present mineralogical data in many cases identfies the presence of minerals but rarely gives detailed, scientific data on its condition, with regard to impurities, grain structure and the like. Again, where opportunities seem possible, we point out the kind of information necessary before the commercial prospects of this mineral be evaluated.

In the section below, we shall discuss the principal nonmetallic minerals previously identified by the government for evaluation. On the basis of our analysis, we have classified these minerals into three groups which will be discussed sequentially according to the following breakdown:

1. STRONG PROMISE

Asbestos

Gypsum

Kaolin

Limestone

Magnesite

2. MEDIUM PROMISE

Barite

Basalt

Bentonite

Feldspar

Ocher

Quartz

3. SMALL PROMISE

Corondum

Chalk

Diatomite

Dolomite

Fuller's Earth

Granite

Marble

Mica

Realgar

Talc

These ratings are based upon the known availability and quality of Bolivian non-metallic mineral reserves: very little consideration was given at this time to commercialization possibilities. Because of the imperfect state of present information it is important that these classifications be considered in context of the above comments.

B. NON-METALLIC MINERALS REPRESENTING STRONG INTEREST

1. Asbestos

The oriental portion of the Cordillera de Cochabamba, in the upper Chapare, consists of Ordovician sediments, except in regions of large scale faulting, where some sediments of probable Cambrian age outcrop. A sequence of compact anhydrite, dark shales and calcareous siltstones is known as Limbo Formation and is unique to the South American Cordillera. According to Schneider-Scherbina, the shales were subjected to very intense dynamic metamorphism, resulting in the formation of deposits of asbestos, which are limited in occurrence to the dark shales and quartzites, subjacent to conglomerates. The dark shales near Limbo were transformed to crocidolite by metasomatism. The fibrous crocidolite fills fissures and forms stockworks.

The Filadelfia Mine near the mouth of the Cristalmayu River, where it joins the Espiritu Santo River, is the most important deposit in the region. The crocidolite here has less iron and more magnesium than comparable African ore. The San Francisco Mine at Cristalmayu and the Mirca Martha Mine at Minasmayu are other small enterprises that have operated in the upper Chapare region, where magnesite has also been mined.

Some asbestos production has been exported to Brazil and also to Argentina. Reserves have been estimated at 30,000 tons. Geobol has made recent studies for the Corporación Boliviana de Fomento and claims the feasibility of producing about 500 tons per month.

The most important unresolved question pertains to the quality of the fiber. The quality of asbestos fiber is a function of its cleanliness, openness and grading for homogeneity. Cleanliness refers to the degree to which asbestos fibers contain extraneous materials such as iron, other mineral impurities or asbestos dust; openness is the amount of separation between the fibers; and grading is a measure of the homogeneity of the goup. We have received conflicting comments about the quality of Bolivian asbestos which must be resolved before the economic feasibility of asbestos products can be determined.

2. Gypsum

Most of the gysum deposits in Bolivia were formed by the evaporation of lakes during the Cretaceous, Tertiary and Quaternary periods. The most important gypsum horizon is related to the clay-marls at the base of the Puca formation, according to Ahfeld.

In Entre Rios, Department of Tarija, gypsum occurs with salt deposits. The gypsum deposits of Orcoma and Sicaya, near Capinota, in the Department of Cochabamba, have a length of 30 kms. and a width of some 60 meters. It is claimed that this deposit has enormous reserves.

The deposit of La Union extends to the southeast from Millu-ni to Huancapampa near Palca in the Department of La Paz. This deposit belongs to the company Estuquera Bedoya.

The Chuquichambi formation described by Henry Mayer is located in the Province of Carangas, Department of Oruro. A white gypsum bed located in the axial zone of an anticline borders the oriental portion of the Huaillamarca ridges, extending from the town of Corque to the town of Huaillamarca. The constituents of this gypsum lutite are 60.4% calcium sulphate, $CaSo_4$, 6.96% calcium carbonate, $CaCo_3$, 0.50% magnesium carbonate, $MgCo_3$, and 9.17% common salt, NaCl. The gypsum contains some impurities. The deposits are chemical sediments. This same formation is found at Chacarilla, South of Corocoro, in the Department of La Paz.

Geologist Salomon Rivas has studied the Northern region of Lake Titicaca and has established the presence of thick layers of gypsum near the top of the Permian sediments, which are responsible for the tectonics of the region.

The following are the best-known companies producing gypsum:

- Estuquera Bedoya S.A.
- Estuqueria y Calera Ltda.
- Estuqueria Milluni

3. Kaolin

An outcrop of Archean rocks composed of argilleous sediments of Cretaceous age is located outside the town of Concepción in the

San Agustin area near some isolated northwest-southeast ridges at a height of about 600 meters. The region is covered by vegetation and is accessible from Santa Cruz either by air en route to Concepción or by road during the dry season--starting from Santa Cruz to Puerto Benegas on a 115-kilometer asphalt road, then crossing Rio Grande, proceeding along a path of 80 kilometers to Palmarito, and then 40 kilometers to San Agustin, where there is also a landing field near the La Bella and Palmira mines.

La Bella mine is located seven kilometers from San Agustin, and the Palmira mine is at 14 kilometers. The climate is sub-tropical and humid. The rocks consist of mica-schists and less metamorphosed quartzose sandstones and schists. At San Agustin there are outcroppings of granite and to a lesser extent orthogneisses and phyllitic schists crossed by many quartz veins, some of them up to one meter wide. The rocks are gray to red-gray and are variable in texture (fine to coarse).

The clays or kaolinitic rocks have resulted from the decomposition of granitic pegmatitic rocks, such as in the weathering of limestone. The primary clays contain alkalies as impurities. The secondary deposits were formed by the transportation and redeposition of primary clay and contain some oxide impurities. The main constituents of these deposits are kaolinite, halloysite, beidellite, montmorillonite, illite, and bentonite. The principal clay mineral is kaolinite: Al_2O_3 , $2SiO_4$, $2H_2O$. The clays must be washed to remove impurities, especially mica, which would constitute a possible by-product. The reserves have been estimated at

200,000 tons at Palmira and 65,00 tons at La Bella, with a possible recovery rate of 70%. These clays have been used for porcelain, glazed tile and sanitary artefacts.

The percentage of kaolinite particles of about 53 microns in size mined at Palmira is 90% and at La Bella, 52%. In past years the deposits were worked for mica and beryllium, not for kaolin.

Other deposits are located in Illita, Province of Tarata, Department of Cochabamba, where the clay is mainly montmorillonite associated with quartzose sandstones, dolomites and magnesites. A study for Corporación Boliviana de Fomento has been made by Ing. Blajoslav Cecil as a part of his study for the ceramic industry in 1969. Reserves have been estimated at 55,000 tons, only in the outcropping mantles.

The clays of the Altiplano have been distinguished as kaolinites, montmorillonites and illites. Kaolinites are found in the San Felipe mountain in Oruro with a content of 95% kaolinite, 3% quartz, 2% hematite and some biotite. In La Paz there are two deposits, both in Sud Yungas. The Llojeta deposit contains 89% kaolinite, 5% illite, 3% quartz, and 3% hematite. The other one has 90% kaolinite, 5% quartz, 4% goethite and some sericite, chlorite and biotite.

Montmorillonite is found in the San Martin mine, Province of Muñecas, in the Department of La Paz, with 98% montmorillonite, 1% biotite and 1% quartz. The Nancy mine, also in the Province

of Muñecas, has some plagioclase and hematite impurities and less montmorillonite. Other deposits are Calvario Norte in the Murillo Province, Callapa in the Pacajes Province, and Cotoca in the Muñecas Province, all of La Paz.

Kaolin is also found in the Province of Challapata, in Oruro and in Cochabamba at Isatta, where some 80,000 tons of reserve have been estimated. At Irpa-Irpa, in the Department of Cochabamba, a deposit is being developed for the cement industry.

In the Department of Cochabamba the deposit at Potoitaca, near Capinota, has a reserve of 1,300,000 tons; the deposit at San Antonio, near Angostura, 60 kilometers from Cochabamba, has an estimated reserve of 200,000 tons.

Near Uyuni, Province of Quijarro in the Department of Potosi, there is an important deposit. Also around the city of Santa Cruz, some ten deposits have been located. They are: Cotoca, Warnes, Paurite, Clora Chuco, Terebinto, Chorobi, Huapillo, El Gebio, Espejos, and Purgatorio.

The best kaolinite type clays are located in Buena Vista near the city of Santa Cruz and near Robore, at San Saba, 15 Kms. northeast of Aguas Calientes on the Corumba-Santa Cruz railroad, 430 kms. in length.

In some other areas the kaolinite is a product of alteration of shales by thermal waters, but because of their iron content they are not suitable for porcelain.

Geobol has recently studied the important terraces south of Capinota, in the Pocotaica mountain, where the layer of clay is 8 meters in thickness, covering an area of 92,000 square meters. The deposit is covered with recent conglomerates, d tritic material and vegetation, but there would no difficulty in cleaning this recent capping. Reserves were estimated at 1,500,000 tons. The deposit of San Antonio, located 2.5 kms from Isata, which can be reached from the Angostura bridge, is found in Silurian rocks of the Pampa formation, where argilleous sandstones and lutites predominate.

In the upper Chapare, kaolinite accompanies magnesitic clays containing 59% silica. The deposits of Orcoma and Buen Retiro, on the railroad from Oruro to Cochabamba, are important.

Small companies have been and are still working on a very small scale the most accessible deposits for local consumption by ceramics manufacturers in La Paz, Cochabamba, Oruro, and Santa Cruz, or by manufacturers of glazed tiles, pottery, enameled mosaics, sanitary artefacts, etc.

4. Limestone

Deposits of limestone are found in various formations in the Bolivian Andes, but their composition is not uniform and their occurrence is frequently associated with siliceous or dolomitic limestone, resulting in a complex and heterogeneous material.

Limestone was deposited in the following geological periods: Precambrian, Permian, Cretaceous, Tertiary, and Quaternary. The Bolaquena series, probably of Precambrian age, is a compact, fine-grained and hard limestone. It is found at Yacuses, near Puerto Suarez, in the Department of Santa Cruz, close to the Brazilian border. Reserves are estimated at 240,000,000 tons.

The Copacabana group, of the marine lower Permian is found near Lake Titicaca. The Fabrica de Cemento Hercules de Viacha is the principal consumer of the limestone from this deposit, which is located 12 kms. from Vilaque, a railroad station en route from La Paz to Oruro. The syncline is about 10kms in length and the bed of limestone is from 8 to 12 meters in thickness. Cerro Calorco, 8 kms. from Sucre, provides limestone to the Sucre Cement Plant.

The deposits in the region of Arque, in the Department of Cochabamba, are 40 meters in thickness, are considerably extensive, and are uniform in composition.

The terraces of Lago Minchin in the Department of Oruro are of organic origin. They extend from Huancané to Pazña, and the reserves are estimated at about 500,000 tons.

In several places in the Central Cordillera, the thermal springs, active or not, have deposited small layers of porous limestone (travertine). The largest deposit of this nature is located 24 kms. from Rio Mulatos on the railroad to Potosi, where another 400,000 tons of reserves have been estimated (TABLE 1).

TABLE 1

DEPOSITS OF LIMESTONE

CONTENTS (%)

Source: GEOBOL

Name	Localization	SO_2	P_2O_5	Al_2O_3	Fe_2O_3	CaO	MgO	$CaCO_3$	Si_2	Reserves (t)	Observations
Lago Mirchin	Poopó-Pazña-Huancané Prov. Abaroa-Dept. Cruro	3.99	0.86	0.76		49.42				4,950,000	
Caleras Montalvo	2 Km. S-RR station Carlos Machicado, Prov. Cuijarro Dept. Potosi	3.16		0.58	2.70		4.42	95.83		1,000,000 2,300,000(Ca_2CO_3)	There is a block easy to polish Limestones.
Central Zone	Sipe-Sipe, Santivañez Dept. Cochabamba	0.18	0.36	1.52	1.01	40.90	1.22		14.11	10.3×10^6	
Orcoma, North	Orcoma, Prov. Arque Dept. Cochabamba					37.45	3.45			4,285,000	
Orcoma, South	Dept. Cochabamba					38.56	1.01			$.10.5 \times 10^6$	
Apillapampa	Dept. Cochabamba					31.40	2.10			6×10^7	
Sayari	Sayari-Colcha, Dept. Cochabamba					46 to 49	1.8 3.8			20×10^6	
Colcha	Prov. Arque, Dept. Cochabamba					37.3	3.32			25×10^6	
Pasorapa	Pasorapa, Dept. Cochabamba			1.19	4.43	21.22	2.74			5×10^6	
Huancané	Huancané, Dept. Cruro		0.78	0.98	0.56	48.11	1.08			800,000	
Calacoto	Cerro Paschi, Dept. Cruro		1.00	0.55	0.48	50.73	1.11		3.25	700,000	
El Tunal	Comarapa, Dept. Santa Cruz			11.52	2.18	22.85	7.90		21.35	22×10^6	
Cuatro Amigos	Challa-Arque, Dept. Cochabamba			1.18	0.68	44.70	5.05		8.51	12.1×10^6	
Cerro Catavi	Dept. La Paz						1.07	86.11	6.14		Marmorifer Limestone
Abapó	Abapó Cordellera, Dpt. Santa Cruz				0.30	55.50	0.45		1.20	530,000	

5. MAGNESITE

Two kms. from Limbo, in the upper Chapare district of the Department of Cochabamba, there is a deposit of magnesite which forms part of the Limbo formation. The mineral is fine, and yellowish in color, and turns white when the mineral is dried. The deposit was formed by the alteration of calcareous (dolomitic) rocks by solutions rich in magnesium bicarbonate moved by dynamic metamorphism.

The magnesite occurs with deposits of crocidolite. The magnesite outcrops on both sides of an anticline and contains 75-85% $MgCO_3$. Impurities in the rock are quartz, dolomite, calcite and micaceous minerals. Reserves have been estimated by Geobol at 2 million tons.

Three mines have started some production intended especially for use in the fabrication of refractory bricks. The mines are San Francisco in the Cristalmayu area, the Filadelfia mine and the Mirco deposit of Minasmayu in the upper Chapare.

C. NON-METALLIC OF MEDIUM INTEREST

1. Basalts

The basaltic ortho-andesitic volcanism in Bolivia has produced basaltic and melaphyric lavas in three different stratagraphic horizons: Infra-Cretation, Ex-Tertiary and Quaternary. The basaltic volcanism was more intense during the lower Crustation period. The basalts are observed from north to south along the synclines of Ilabaya-Sorata, Yaco, Banderani, Mercachata, Torotoro, Colquechaca, Potosi and Tarabuco, according to Schneider-Scherbina. They are more abundant in the Macha-Ocurí region of the Maragua area.

Toward the east the basalts reach the sub-Andian region of Entre Rios, where the synclines of Salinas and Saururo are found along with the ridges of Mendeyapecua. They form thin layers but are distributed throughout 600 meters of vertical thickness. The composition of the basalts varies from those rich in olivine to those free from it. According to Ahfeld, the Huari-Huari basalt has abundant ilmenite.

The melaphyres of Tarabuco contain disseminations of native copper and copper minerals.

No basalts have been exploited in Bolivia.

2. Bentonite

This type of clay occurs in secondary deposits formed by the transportation of primary clay resulting from the decomposition of granitic-pegmatitic rocks. These deposits have been located at:

1. Achocalla, Province of Murillo in the Department of La Paz; claimed to contain 98% bentonite (montmorillonite), 1% biotite, and 1% illite.

2. Province of Challapata in the Department of Oruro, where the clay contains 76% bentonite and is accompanied by kaolin.

3. Fatima Mine in the Province of Muñecas, Department of La Paz, from which Geobol has made some studies not yet published.

It is said that these clays contain many impurities, especially mica. The bentonite used by YPFB is imported from Argentina.

3. Feldspar

The feldspars in Bolivia are of little importance. Large masses of pure orthoclas have been found together with deposits of kaolin in the pegmatites of the Province of Ñuflo de Chavez, in the Department of Santa Cruz, in the locality of San Agustin. The feldspars are mainly orthoclase (KNa) $AlSi_3O_8$. Loose crystals some 6 cm. in length are found in the dacites of Oruro, in the porphyritic manzonites of Quimsa Cruz and in the intrusions of the Illimani.

In the tuffs of the Condoriquina Mountain, South of the town of Macha, in the Department of Potosi, there are also some small crystals of feldspar. Geological reports on the Llallagua tin mining district indicate the presence of feldspar in the Salvadora Mountain. It can also be found in alluvial deposits of Llavisa and Santiaguillo, West of Margua, in the Department of Potosi.

4. Ocher

There are large deposits of hematite at El Motacu, south of [illegible], Province of San José de Chiquitos, Department of Santa Cruz. They consist of several isolated hills which are part of the Brazilian formations of the Jacadigo iron manganese district. There are no descriptions of these deposits.

Ocher is also found at Bavello, Province of Chayanta, Department of Potosí. In the Altiplano, or Bolivian high plateau, ocher is very common in veins, but is of no industrial importance.

5. Quartz

Large prismatic crystals or quartz are found in many hypothermal veins of wolframite, as in Chicote Grande, and in the tin mines of Atocha, Viloco, Chojnacota and Llallagua. At the Rosario Gold Mine of Araca large masses of quartz can be found, occasionally containing needles of touraline. Quartz for gem purposes, such as amethyst, is found in the geodes of the melphyres of Tarabuco, south of the Sucre. Quartz, as chalcedony, is found with cassiterite in some epithermal deposits. Epithermal quartz veins with gold are also found in Paleozoic soft shales that have been little if at all metamorphosed.

Quartz veins in the Northern Cordillera form aureoles around granitic batholiths, showing genetic relation with them. In the Center and South Cordillera of the country quartz is related to antimoniferous veins.

In the province of Velasco, West of Santa Ana, South of the road Motacu-Santa Ana, in the Department of Santa Cruz, there is a vein 4 to 6 meters in width and 100 meters in outcrop. Crystal Mountain is located in the Sansas ridges, north of San José de Chiquitos, also in the Department of Santa Cruz. No studies have been made of these deposits.

Quartzitic sands, with 95% white silica, are found as erosion products of the lava flows between Sevaruyo and Poopo. Thirty kilometers from Cochabamba there are some white and red silica deposits grading 98% SiO2, used by Simsa Refractories Factory of Cochabamba.

At Collana, in the Department of La Paz, important deposits can be found. The Fábrica Nacional de Vidrios y Cristales S.A. in La Paz is the most important consumer.

D. NON-METALLIC MINERALS REPRESENTING SMALL INTEREST

1. Chalk

This variety of calcite, white or reddish white or sometimes yellowish in color, is a soft earthy material found together with clay at Limites, Province of Sica-Sica, Department of La Paz. The banded veins were deposited as a product of thermal waters. It is said that there are other deposits scattered in several parts of Bolivia, but there are no studies or data available. Based on the currently information available, further investigation is not recommended.

2. Diatomite

Diatomite, more commonly known in Bolivia as tripolita, composed of the siliceous shells of diatoms and other microscopic species, occurs in the region of Lake Titicaca. It appears as a very fine-grained earth, similar to clay or earthy chalk, but is harsh to the touch. It is exploited by the Indians in small amounts, but the possibilities for commercial exploitation are minimal, and additional investigation is not recommended.

3. Dolomite

Some dolomite is found at the Juliana Mine in the mining district of Conde Auqui, near the city of Oruro, where it generally accompanies scheelite. The mineral is white, dry and fine grained, due probably to its colloisal origin. It usually occurs in large masses with wide fractures. Reserves are believed to be limited. The mine is accessible by road from Oruro.

During the period 1942-1943, 1,800 tons were exported to Chile, but this market has not been maintained. Another deposit is found 40 kms. from Cochabamba in Santibañez. This dolomite is accompanied by calcite which itself contains 22-24% MgO. There is no estimate of reserves. Compañía SIMSA, from Cochabamba, is currently using this mineral for refractories. The dolomite is not considered important enough to justify an industry by itself, but it could perhaps be supplied to a new refractories industry producing a broad product line. Under present circumstances, additional study is not recommended.

4. Granites

Practically all the Cordillera Oriental has an uninterrupted central granitic area which was produced by magmatic activity in the Ortho-Andean Zone of Bolivia and which culminated in extensive hypo-abyssal intrusions into segments of the lower Paleozoic. Due to the irregular extent of the epeirogenic uprising in the Ortho-Andean zone during the upper Cenozoic, the geographic distribution of the outcrops of these intrusions is erratic, but there is a certain regional symmetry.

The igneous activity produced a row of batholiths distributed northwest southwest along about 200 kms. In the northern extremity close to Peru lies the Cordillera de Apolobamba, where there is an outcrop of the granitic stock of Sunchulli.

The Cordillera Real has five igneous masses of granitic and granodioritic outcrops. These are:

1. The Sorata batholith, 50 kms in length, extending from the Illampu Mountain and the Anko Huma (6,500 meters high) to the Collana River, covering a surface area of about 350 kms.^{2}.

2. The Chucuro intrusive, in which the most conspicuous mountain is The Huaina Potosí (6,200 mts. high).

3. The Taquesi-Mururata batholith.

4. The Illimani intrusive with the Illimani mountain, the second highest peak in Bolivia.

South of the Cordillera Real is the Quimza Cruz, 5 kms. long, covering an area of 300 kms.^{2}, with practically a continuous mass of granodioritic outcrop (see map). In these Cordilleras a continuous sequence of magmatic differentiation was produced starting with a magma of granodioritic composition and continuing to a dioritic extreme and a later granitic extreme. The intrusive rocks differ from a calc-alkaline magma, with a consistent predominance of potassium over sodium.

Most of the granites in Bolivia are found between 4,500 and 6,000 meters above sea level. Because of the difficulty access to the Cordillera and the lack of roads, only a few exposures of granites have been worked on a very small scale for use in construction. The most known and exploited deposit is Comanche near the city of La Paz. Because of the general inaccessibility of the known granite deposits, and thus the impracticality of its exploitation, we do not recommend further study.

5. Fuller's Earth

Galactite, a variety of natrolite, has been identified (but not evaluated) at the Sapo Mountain, in the ridge of Palca, province of Ayopaya, Department of Cochabamba. Some studies, as to location and size of the deposit, have been made by Geobol, but have not been published. Hydrothermal veins of ankerite, barite and sodalite accompany the syenitic intrusion. Natrolite was formed by the alteration of sodalite. It is found in dense white masses with a fibrous texture. Very little detailed investigation has been made. The lack of proven reserves and quality coupled with low value/low demand suggest that the study of this material

not worth purching further.

6. Marble

There are no reported commercial qualities of marble in Bolivia, although there are scattered deposits which are important only for local consumption. The following five deposits are considered the most important:

- A calcareous rock, 6 meters thick, easy to polish, fine grained, compact and uniform, is found at the Catavi hill, North of Tambillo, near the town of Huillamarca, in the Titicaca Lake area.

- At the Laurani hills, close to Sica-Sica, on the railroad from La Paz to Oruro, there is a deposit with three calcareous veins. The rock is reddish-brown and crossed by ferruginous stringers.

- 12 kms. south of Berenguela, Province of Pacajes, in the Department of La Paz, there is the deposit of Mirazapani, consisting of a few calcareous beds from 1 to 5 meters in thickness, resting on Tertiary arkoses and sandstones. The deposit was formed by thermal waters, and the calcium carbonate was deposited in colloidal form. The rock can be cut into large blocks and can be well polished. It is called Marmol de Berenguela.

- In the area of Puerto Acosta, Department of La Paz, some deposits have been studied by Geobol. No information is available.

In the Province of San José de Chiquitos, Department of Santa Cruz, Geobol has reported the existence of a deposit of reddish marble. No reserves have been established for this so-called "Bolivian marble", which has been used only locally.

Only the finest grade marble could be exported from Bolivia, but most knowledgeable respondents have been of the opinion that the Bolivian marble is not of exportable grade. These specific sources can continue to be worked as they are today, but no further stimulation of this local industry is justified.

7. Mica

A wide and extensive belt of muscovite is located between the Quiser River and the town of San Agustin in the Ñuflo de Chavez Province, Department of Santa Cruz. The orientation of this belt is South South East.

Two mines have been operated in the belt. Mina Negra was originally worked by Casa Schweizer during the years 1926-1928, and later by Casa Hardt; both companies were from Santa Cruz. Mina Negra is located 2 kms. southeast of San Agustin. In the years 1953-1954 Mr. Dionisio Foianini worked the mine for columbite. Mica has been exploited from an irregular pegmatite occurring in mica-schists; the mineralization includes quartz, orthoclase, microcline and muscovite, which is olive green in color, and has crystals 40 cms. in diameter. The mine was worked to about 70 mts in depth. It is reported that Mr. Foianini produced a total of 20 tons of mica.

In the year 1945 Corporación Boliviana de Fomento studied the deposit in detail, but no follow-up occurred.

The other mine in this region in Mina Verde, located 5 kms. Northwest from San Agustin. The vein is 20 meters wide, and the muscovite has a fish-tail structure. It was worked between 1942 and 1943. The deposit also contains columbite and monazite, but none of these minerals, including muscovite, were considered of commercial value. It is reported that 38 tons were exported. Based on the declining world market for high-value mica (because of the replacement of electronic tubes, the major sheet mica market, by solid state components and because of the small and low value per ton of ground mica) we believe that commercialization of these questionable deposits should not be considered.

8. Realgar

Realgar is a very rare mineral in Bolivia. Some nodules are found near the Peruvian border near Candarave. In the locality of Urmiri, in the Caracato Valley, Loayza Province of La Paz, there is a small deposit of recent age, formed by thermal waters, which contains some cinnabar and sulphur. Occurrences have also been found in Mallasa, near the city of La Paz; they are also of thermal origin.

Arsenopyrite, or mispickel (AsFeS), is more common in Bolivia and is found associated with wolframite in hypothermal deposits and also accompanying cassiterite in many tin mines.

Again, we see little commercial value in these spotty, small occurrences.

9. Talc

Very little talc has been found in Bolivia. Some talc occurs with magnesite in the Limbo formation in the upper Chapare area, Department of Cochabamba. Some talc is also found in Camacho, Arce Province of the Department of Tarija. Commercialization of these marginal sources should be discouraged unless it can be accomplished in conjunction with a venture based on magnesite or another more viable material found with the talc. No specific investigation of talc is recommended.

E. MINERAL AVAILABILITIES IN OTHER ANDEAN COUNTRIES

Mining or manufacturing opportunities within the context of the Andean subregion and suggested by the above availability classification will to a large extent depend on the quantity and quality of similar minerals available in Colombia, Chile, Peru and Ecuador. In table 2 we have developed, for specific non-metallic minerals, information on the present availability of these minerals in the other Andean countries. We have attemped to provide judgements on the extent to which Bolivian resources are inferior, equal or superior to the resources of the other Andean countries. On this table an "A" indicates that Bolivian resources are considered generally superior to the resources in the other countries, a "B" indicates that Bolivian resources are comparable and a "C" that Bolivian resources are inferior.

TABLE 2

AVAILABILITY OF NON-METALLIC MINERALS IN ANDEAN COUNTRIES

	Chile	Colombia	Ecuador	Perú
Asbestos	A	A	A	A
Barite	B		A	B-C
Dolomite	B	B	B	B
Feldspar	B	B		B
Gypsum	B-C	B	B	B
Kaolin	B	B-C	B	B
Limestone	B-C	B-C	B	B-C
Magnesite		A		A
Marble	B	B-C	B	C
Quartz	B-C	B-C	B-C	B-C

The table indicates that only in the case of Asbestos and Magnesite does Bolivia have an advantage over the other Andean countries. In the remaining non-metallic minerals for which a comparison was made, the other Andean countries have similar resources.

IV. THE CONSTRUCTION INDUSTRY

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A. INTRODUCTION

The construction industry throughout the world, as in Bolivia, is the largest consumer of materials and products produced by the non-metallic minerals industry. One cannot fully evaluate opportunities in the non-metallic area without developing an understanding of the present and future construction industry within Bolivia. In the report thus far we have been dealing with available minerals and products which could be made with these minerals; in this section we will look at the non-metallic minerals area from a different perspective, i.e., from the largest ultimate end use market -- the construction industry.

The basic materials used in construction are steel, cement, sand, gravel and rock. These basic materials, in their upgraded value, represent almost 74% of the material imput to the construction sector. They are used in the foundations, frames, walls, floors and ceilings of most of the buildings in Bolivia and they are also the principal inputs to the construction of highways, dams, sewers, and the like. Not only are they used in crude form, but they are also the major constituents in floor tile, plaster, pipe, masonry, and other specialty building products. Furthermore, secondary building materials such as asbestos cement products, clay brick, gypsum, glass and sanitary ceramic ware all represent major markets for non-metallic minerals. With the exception of certain high value-added non-metallic mineral products (glass,

ceramic ware, etc.), most construction products are relatively high volume, low value products in which freight costs are a major element of final costs. This indicates that low value construction materials for the most part must look to the domestic market for their principal outlets, with export markets being incremental markets with marginal or no profits. This generalization is particularly valid in Bolivia, where freight costs out of the country are relatively high and most construction products of the low value type are readily available in neighboring countries. Therefore, we believe that it is essential to develop a brief description of the construction industry as it exists today, and as it may exist in the future, so that the non-metallic industry can be more thoroughly understood.

In Bolivia, as throughout the world, the construction industry is highly fragmented, very cost-sensitive, and poorly documented statistically. While it is beyond the scope of our present assignment to document and analyze thoroughly the construction industry, we have made a brief attempt to do this below for the purpose of developing insights into this large potential market for non-metallic minerals. It should be stressed, however, that the figures presented in TABLE 3 dealing with size and growth of the construction industry are extremely preliminary and are based principally on public data. We have augmented this by modest amounts of field work within the country and Arthur D. Little's previous experience in the construction industry in other countries throughout the

world. It is possible that the numbers submitted below are inaccurate--indeed many differences of opinion exist in the industry within Bolivia--so that all professionals will not agree with our estimates. We believe ,however, that in the first place, even order of magnitude numbers are necessary to understand the sensitivity of the industry to different factors. In the second place, order of magnitude numbers are accurate enough to express the important dynamics taking place in this industrial sector.

TABLE 3

VALUE OF CONSTRUCTION
(millions of current Bolivian Pesos)

Year	Value Added	Materials	Total
1958	122	98(45%)	220
1959	139	111(45%)	250
1960	168	136(42%)	304
1961	136	110(45%)	246
1962	181	146(45%)	327
1963	212	171(45%)	383
1964	221	177(45%)	398
1965	360	291(45%)	651
1966	291	234(45%)	525
1967	342	247(42%)	589
1968	451	304(40%)	755
1969	450	362(45%)	812

B. THE SIZE OF THE CONSTRUCTION INDUSTRY IN BOLIVIA

Table 3 shows the Ministry of Planning current estimates for the value of construction in Bolivia in current Pesos, from 1958 to 1969. This table shows separately the "value added" component of the construction industry (labor, overhead, profits) and the materials component which includes the value of the imported and domestically-manufactured materials used in this sector. These figures are certainly estimates--at best--both in terms of total value and percent materials.

It should be pointed out that great confusion exists in this industry as to whether a material is produced at the job site (i.e., part of the construction materials sector) or by the mining sector or industrial sector. For example, sand and/or gravel may be simply loaded into a truck at the gravel pit by the contractor. This value formally represents value of the mining industry rather than of the construction industry, but in practice may be included in construction. Similarly, if concrete blocks are manufactured not at the job site but by the contractor, this value should technically be included in the manufacturing sector but usually is allocated to the construction sector. We believe the estimates shown above and developed by the government are valid approximations of the true situation and are suitable for our purposes.

In reviewing this table, one can see large variations in the level of activity over this time period; furthermore, it should be pointed out that a significant portion of the growth in the bottom

line of Table 3 reflects inflation rather than a rapidly growing value of the construction.

Table 4 breaks down the value of construction for the year 1968 into six different subsectors (housing, commercial, industrial, etc., each with varying material requirements. In Column 1 of this table we show the gross value of construction; in Column 2 we have deducted 85% of the gross value represented by overhead, profits and other indirect costs to develop the net value of construction which represents the costs of direct labor and materials. In the remaining columns we have developed estimates for the net value of the construction in various trades such as concrete, masonry, finish, electrical, etc.

It is significant to note that a large portion of the total construction in Bolivia is controlled by the National Government. Such sectors include public buildings, highways, streets and civil engineering (sewers and the like). This suggests that the National Government has in the past and will in the future play a strong role in the construction industry. This provides the government with a significant opportunity to lead this industry through a healthy and planned maturity phase.

As shown in Table 4, the "other" category is large, particularly in the civil engineering portion. These "other" items can be divided into two principal types, neither of which represent major opportunities for industrial development at this point. First, it includes large sums representing labor and equipment,

TABLE 4

Value of Construction Components

Based on 1968 Construction Data

(Millions of Current Pesos)

	Gross Value	Net Value (75% Gross)	Concrete	Masonry	Finish	Elec-trical	Plumb.	Doors & Windows	Other
Housing	169	127	44	15	5	8	10	10	35
Commercial-Industrial Buildings	46	35	11	3	3	2	3	3	10
Public & Health Buildings	52	39	13	4	3	2	4	3	10
Highways & Streets	200	150	8	-	-	-	-	-	142
Public Civil Engineering	165	124	25	6	-	6	-	-	87
Misc. (40% Bldg. 60% Civil Engineering)	123	92	23	5	2	2	4	2	54
	755	567	124	33	13	20	21	18	338

Source: Arthur D. Little, Inc. Estimates

rather than materials, particularly in the highway, streets and civil engineering area. The principal materials in these sectors include stone, fill, sand, asphalt, pipe, and highly-specialized mechanical equipment. Secondly, particularly in the building portion, the "other" category includes small quantities of a large variety of different products including air conditioning, elevators, heating equipment, and other specialty products.

It is apparent from the data presented in Table 4, that the concrete portion of the construction industry, coupled with a large amount of sand, gravel and fill used in civil engineering, account for the bulk of the construction materials used in Bolivia.

In Table 5, we have taken the net value of the different trades or subsectors of construction shown in Table 4 and have attempted to separate material value from the labor content to develop the total values of material used in the construction industry. These are again order-of-magnitude estimates which are consistent both with our own understanding of these trades and also with the value of material development by the government (Table 3). Again the question arises as to what constitutes materials or labor. In the concrete sector, for example, we are counting as material costs the cost of sand, cement, gravel, reinforcing steel, and forms regardless of who buys and who mixes these materials.

TABLE 5

Value of Materials

(Millions of Current Pesos)

Sector	Net Value	Percentage Materials	Value of Materials
Concrete	124	75%	93
Masonry	33	75%	25
Finish	13	30%	4
Electrical	20	80%	16
Plumbing	21	80%	17
Doors and Windows	18	75%	14
Misc.	75	80% Bldg.	60
Total	250	30% Civil Eng.	75
			304

Source: Arthur D. Little, Inc.

C. THE TRADES OF THE CONSTRUCTION INDUSTRY

In the section below, we will review each of the six trades quantified in Table 5, with particular attention to the material usage in these trades. We will also make observations on the opportunities that may exist in these material sectors for new industrial projects.

1. Concrete

Table 5 shows that approximately 93 million pesos were expended for concrete products in 1968. These materials were broken down approximately as follows:

Cement	30 million pesos
Aggregate	12 million pesos
Reinforcing Steel	21 million pesos
Lumber	25 million pesos
Miscellaneous	5 million pesos
	93 million pesos

Despite the fact that the civil engineering portion of the industry represents 60% of the total value of construction, it only consumes approximately one-third of the poured concrete used within the country. The concrete trade is heavily tied to the building construction industry and must look to this market for future growth.

Approximately 45,000 tons of cement were used for poured concrete in 1968. This is the largest market for cement, but an

additional 25,000 tons were used for producing concrete products (floor tile, blocks, shapes, and the like), in plaster and masonry grout and for local purchases of cement for maintenance and repair of existing buildings. In the future, the total market for cement will grow at the growth rate of building construction activity or perhaps 8% a year; it will, therefore, be at least ten years before the demand for cement approaches the 200,000-ton capacity currently being installed within Bolivia. Certainly no additional capacity should be planned at present for the domestic market.

The current price for cement in Bolivia is relatively high compared to world market prices. Cement prices are currently $50 per ton or $2.00 to $2.25 per sack (including transportation); world prices (at dock side) are averaging slightly over $20 per ton. These facts, coupled with the freight costs to the West Coast of approximately $20 per ton and the large cement capacity in Chile, Perú, Brazil, and Argentina, make export markets an unlikely possibility in the short term, although small incremental sales may be possible in Western Brazil or in Northern Argentina. Hopefully, the excessive capacity currently available in the country will bring down the current high price of cement but, in all probability, not to the point which will open up significant export markets.

It appears that the current capacity for cement is adequate for the country for a number of years. Export opportunities seem

remote. The cement industry, therefore, does not represent a new opportunity for the country or a new market for the non-metallic industry for Bolivia.

The aggregate portion of the poured concrete market, coupled with the even larger market for aggregate in civil engineering projects and in manufactured concrete products, does represent opportunities for expansion of existing industries or creation of new industries. However, these industries will remain small, often under the control of highway contractors, product manufacturers, or building contractors, and do not represent an opportunity for high value-added manufacturing opportunities. Sand and gravel are readily available, are cheaply mined at $1-$2 per ton, and do not significantly benefit from large scale production or new technology. Transportation costs are paramount in the sand and gravel business, often exceeding mining costs even for delivery within 100 km. We do not believe the government should encourage expansion of the sand and gravel business, but rather let it grow naturally, undertaken for the most part by small, local industries.

2. Masonry

The 25 million pesos worth of masonry materials shown in Table 5 include many wall materials of which well over 50% are hollow tile and brick used for the interior and exterior walls of many of the buildings in Bolivia, together with the mortar used to apply these materials. In addition, it includes modest quantities of concrete blocks, special shapes, and walls technically not

masonry but such as curtain walls, precast concrete wall panels and the like meeting this end use.

The use of hollow and solid brick in Bolivian construction is well established and in all probability will be replaced by newer products very slowly if at all. Therefore, this manufacturing area is relatively secure for the long term. There are, presently, a few major and a larger number of small tile and clay products. companies in Bolivia which are currently meeting the demands of the masonry trade. There is, furthermore, no export opportunity for clay bricks since they are relatively inexpensive materials ranging from 200 to 1,000 pesos per thousand bricks with a relatively high freight rate to the coast, since the materials used in brick and block manufacture are readily available in other South American countries, and since there already exists a number of plants throughout South America to produce this product for local markets. This well established, local industry will probably expand as the market expands and does not need government stimulation or protection to insure its meeting the demands in the country.

There are also well-established industries in concrete products in Bolivia, although concrete blocks are not as accepted in Bolivia as they are in other western countries. Industries in this market sector also tend to be small, have low capitalization and are not sensitive to economies of scale or new industrial technology. While it is possible that there are opportunities for more sophisticated concrete manufacture, particularly in the areas of pre-stressed

pre-cast concrete products, the feasibility of such ventures is virtually independent of the availability of cement and aggregates. Feasibility studies should be undertaken only after a detailed analysis of the construction industry has been completed.

As stated in the concrete section above, the availability of aggregates and cement for this sector is currently more than adequate as are the existing sources of clay for the tile and brick.

3. Finish

The finish trade in the construction industry accomplishes the finishing of surfaces of buildings constructed in Bolivia, including plaster, floor tile, paint, and specialty finishes used in prestige buildings. The principal materials include gypsum, cement and lime, all readily available within the existing industry structure of the country, coupled with paints (discussed in the chemical sector) and certain wood panelings (discussed in the wood products sector). The relatively small quantities of cement and lime used in this market are not in themselves adequate to justify new facilities but rather should continue to be incremental markets for existing cement and lime operations. The gypsum industry within the country is fragmented between a number of small firms converting gypsum rock into plaster. There is little opportunity for expansion of these small industries.

The large gypsum industry occurring in the United States and Western Europe produces a wallboard product from gypsum formed between two sheets of paper. This gypsum wallboard is particularly

appropriate for woodframed construction and replaces wet gypsum plaster effectively where labor costs are high. The scale of economics of these plants makes it inefficient below levels of 1 million square meters per year; and in fact, the newer plants throughout the world are as large as 20 million square meters per year. Plant costs of such facilities are US$10-20 million. Because of the use of masonry construction in Bolivia, the relatively small building construction market, and the low labor costs in Bolivia we do not consider the installation of gypsum wallboard facilities a good opportunity at this time.

4. Electrical

The 60 million pesos expended for electrical materials (as shown in Table 3) represent on the surface a large market but in fact represent hundreds of different products including wire, cable, conduit, wiring devices, bells, outlets, junction boxes, electrical fixtures such as lights, and electrical equipment including transformers, circuit breakers and the like. This electrical value excludes the large value of major electrical equipment used in generating, distributing and regulating power but rather is limited to the electrical supplies used inside of building construction. The opportunity for these products will be discussed under the Electrical/Electronic Sector study.

The only opportunity relating to the non-metallic minerals is the very modest quantities of electrical porcelain. This will be discussed elsewhere in this report.

5. Plumbing

The $17 million of plumbing used in building construction again is represented by large numbers of products, including piping, piping fittings, fixtures (toilets, bath tubs, sinks, and bidets) and fittings such as valves, spigots, drains, and connectors. Of particular interest to the non-metallic sector are the vitreous china plumbing fixtures, which will be discussed in the next chapter.

6. Doors and Windows

Approximately 14 million pesos expended for doors and windows, most of these made from wood, steel, or aluminum. The only possible product opportunity represented by this Sector is for the local manufacture of sheet glass which will also be discussed in the next chapter.

D. THE ROLE OF THE GOVERNMENT IN THE CONSTRUCTION INDUSTRY

As discussed above, the National Government of Bolivia already plays a major role in the construction industry since it is the leading buyer of construction services in the nation. This fact alone, coupled with the government's active role in attempting to provide housing and other social benefits to people of Bolivia, puts it in an excellent position to help regulate and develop the construction industry in years ahead. Many building materials industrial projects based on non-metallic minerals will succeed or fail in the future, based on the health and maturity of the construction industry; the government indirectly can assist in making these industries viable both by its purchasing and regulatory abilities. Specific steps

which could be taken by the government to improve the climate for construction materials industries include the following:

1. Balance the volume of construction occurring from year to year

As shown in Table 3, the volume of construction activity in Bolivia has been erratic. New ventures to produce building products will require constant to modestly growing volumes; they cannot survive, however, periods of major fluctuations in construction demand. Since the government is such a large buyer of construction projects, it should be aware of the effect of its purchase on the health of the building materials industry. It should attempt to use its large buying power to level out construction activity and, where possible, defer construction purchases when the free market activity is high and accelerate its purchases when construction activity is low. Obviously, other factors will on occasion make this practice impossible. However, the government, in preparing plans for new construction purchases, should be aware of the effect of its purchases on the construction industry and, where possible, it should attempt to schedule its construction projects to level the total construction industry load.

In making such plans, the government should be aware of the different material requirements for different types of construction. For example, the highway and the building sectors are different and peaks in one sector do not balance lows in another. Cement, for example, is used heavily in the building portion of the construction activity, while labor is used extensively in civil engineering projects.

Not only will such a planned construction program assist materials producers but it will also provide assistance to contractors themselves. It is undesirable for construction companies to spring into activity for peak loads and go out of business when government spending stops. The government, through planned construction awards, can build healthy and continuing construction firms rather than creating opportunistic short-term contracting organizations.

2. Creation of standards and codes

There currently exist in Bolivia various building standards and codes, although these certainly could be modernized and more strictly enforced. While the government can encourage strengthening of the code procedure, it also has the opportunity--through its large buying power--to specify high quality construction which in itself will develop markets for high quality materials and will train contractors to a higher level of construction performance. Many of the newer production processes for making building materials produce controlled, quality products at relatively low cost. However, most of these products are more expensive than the low quality products often produced by small local industries. In many countries where new plants are installed to produce large volumes of high quality products, they are not accepted in the marketplace because they are slightly more expensive than currently used, inferior quality products. If the government increasingly insists that materials used in its purchases are of the highest

quality, this by itself will develop a market for such products which will make industrialization of building products manufacturers possible. It is possible that the government will pay slightly more for its construction products by following this approach, but it will benefit both by acquiring higher quality construction and by upgrading the materials industries and the quality of the contractors.

3. Encourage the use of domestically-produced materials

The government is currently undertaking an ambitious program of low-cost housing for the people of Bolivia. There is great interest in Bolivia as throughout the world in new forms of "prefabricated" housing made from a variety of specialty materials including plastic foam, light-weight concrete, and prefabricated wood elements. While it is possible that such techniques can modestly decrease the cost of housing, we believe that all too often the cost savings is not guaranteed and is often grossly overstated. We believe that it will be in the best interest of the government and the construction industry of Bolivia if the attempts to industrialize the housing process were based on the system which utilizes relatively conventional materials which are locally available.

E. RECOMMENDATIONS

The construction industry is a vital industry to the economy of Bolivia; indeed, according to Table 6, the GNP within Bolivia in the next decade of the construction industry will grow

TABLE 6

GROSS DOMESTIC PRODUCTIONS PROJECTIONS

BY ECONOMIC SECTORS, 1966-1980

(In millons of 1958 pesos)

Sector	1966 In millions of 1958 pesos	1966 Percentage	1980 In millions of 1958 pesos	1980 Percentage	Average Annual Rate of Growth
AGRICULTURAL	1,266.0	26.8	2,250.0	20.4	4.0
INDUSTRIAL	1,500.3	31 8	4,034.5	36.6	7.3
Manufacturing	573.4	12.1	1,535.9	13.9	7.3
Mining	427.3	9.1	903.8	8.2	5.5
Petroleum	238.6	5.1	828.2	7.5	9.3
Constructions	261.0	5.5	766.6	7.0	8.0
SERVICES	1,952.3	41.4	4,728.4	42.9	6.5
Commerce & Finance	57 .8	12.2	1,358.7	12.3	6.3
Transport	382.1	8.1	808.5	7.3	5.5
Government	453.2	9.6	1,328.8	12.1	8.0
Other services	543.2	11.5	1,232.4	11.2	6.0
TOTAL PBI	4,718.6	100.0	11,012.9	100.0	6.2

SOURCES: SEDEPLA, 1966 National Account as quoted by Human Resources in Bolivia Study, Ohio State University.

faster than all but one other sector. The construction industry in Bolivia at present only accounts for a small portion (less than 10%) of the total gross national product. If Bolivia undergoes economic growth in the next decade, it will be led by rapid growth in the construction industry. Not only does the construction industry consume significant amounts of products which could be the basis for new industries in the country, but further, the construction industry provides for commercial/industrial establishments.

The construction industry is highly complex. It certainly involves the non-metallic minerals sector, and also the forest products, steel, and chemical industrial sectors. Many of the products of construction can be made of a number of different materials (wood, steel or concrete framing; plastic, clay or steel pipe; wood or metal windows and doors). Therefore, one cannot necessarily make projections of the growth of one construction product without considering the entire spectrum of construction materials available.

The construction industry, furthermore, tends to consume large quantities of low value domestically produced materials (with the exception of some specialty products used in heating and ventilating, plumbing and electrical). The commodities, however, are generally not products of international commerce but are used close to where they are made; potential manufacturers must look to the domestic market as their principal market.

Arthur D. Little, Inc., recommends that before any manufacturing feasibility studies be undertaken for the basic construction commodities (cement, rock, gypsum, clay, block, brick, pipe) a thorough pre-feasibility study be made of the entire construction industry and its many sub-components. Feasibility studies in narrow material sectors cannot be valid until the entire materials requirements for the industry are analyzed together, considering material substitutability and technological and material trends are developed on a consistent, intra industry basis. The construction industry is so important to the future of Bolivia that to analyze it piece-meal with the narrow perspective of one product may well be to create recommendations inconsistent with the direction of the industry as a whole.

Specialty products such as flat glass, sanitary ceramics and others can be looked at separately; indeed, we so recommend in a subsequent chapter. However, with the basic commodities we strongly urge the government of Bolivia to undertake a detailed across-the-board construction industry analysis before funding specific materials feasibility studies.

This study should cover the following topics:

a) Develop the present value of construction currently taking place in Bolivia, broken down as shown earlier on Table 3, and by geographical region.

b) Project this breakdown forward for 10 years.

c) Develop materials imputs required by this industry.

d) Investigate materials substitution possibilities i.e.

steel vs. concrete vs. asbestos cement pipe

concrete vs. brick masonry

wood vs. concrete vs. steel frames

wood paneling vs. plaster walls

e) Evaluate current and future roles of government in construction in regard to government findings, code enforcement, national housing policies, etc.

f) Document number, capacity and quality of domestically made construction materials.

g) Identify specific products which could be profitably produced in the country, based on any basic material--mineral, metal, wood, plastic.

V. COMMERCIAL CONSIDERATIONS

V COMMERCIAL CONSIDERATIONS

A. INTRODUCTION

In chapter III we evaluated the quantity and quality of non-metallic mineral resources in Bolivia and classified them according to their importance. In this chapter we will consider those non-metallic minerals having strong and medium promise and further evaluate them according to such commercial factors as markets and the competitiveness of the Bolivian product in each market. We examined the relative cost structures FOB and CIF for the domestic and imported non-metallic minerals in each of the five Andean countries together with the relevant market data.

Some of these minerals are low in value and high in bulk, and transport costs are an important part of the total delivered price. We thus considered it appropriate to examine the price composition of any delivered material and to eliminate if from consideration should the difference between the delivered price of a Bolivian mineral and that currently being paid by purchasers in the other Andean countries be excessive. We also examined market volumes and other commercial considerations for those raw materials that potentially could be delivered to customers in Bolivia and in other countries at an attractive price.

We realized at an early stage that the best opportunities for Bolivian industry might not exist in the recovery and marketing of the non-metallic minerals themselves but in the manufacture in

Bolivia of products derived from them for domestic and export markets. This type of development of the non-metallic minerals industry would create a wider employment base for the Bolivian population, attract investment by new and growing industries, help in creating a demand for associated machinery and factory construction, and generally benefit the Bolivian economy in a more positive way. Consequently, in the second part of this chapter, we will examine whether opportunities exist for the manufacture of products derived from non-metallic minerals available in Bolivia in the quantity and quality required by the industry. As was the case in our evaluation of opportunities in the production and marketing of non-metallic minerals we examined the FOB and delivered prices of the various products derived from non-metallic minerals, compared them with those prevalent in existing markets, and analyzed market volumes.

The analysis takes into account our field investigations in Boliva and the other Andean countries. Members of Arthur D. Little, Inc. and Prudencio, Claros y Asociados conducted many interviews in the five Andean countries collecting market data, examining existing price structures and marketing techniques, and generally building up a picture of market requirements. We considered it extremely important, for example, to know the technical and cost requirements for refractory minerals by manufacturers utilizing these products in Peru, how Chilean ceramic producers regarded imported raw materials, to what degree the Colombian sanitary

ware market is being satisfied and other such aspects of a commercial and marketing nature.

While this approach is obviously one of the best that could be adopted in such a study, our work was made difficult on two counts: the lack of useful or reliable market statistics in all of the Andean countries and the non-existence of Bolivian industries on which to base costs of mineral recovery and product manufacture. Despite determined attempts in gathering relevant market data in each of the five Andean countries on which to base our evaluation, we met with far less than complete success and many vital gaps still exist. In fact, we occasionally were faced by a number of different sets of statistics for a particular product, each set in conflict with the others.

As part of our analysis in this chapter we classify each of the non-metallic minerals and their derivative products as to whether or not they represent an opportunity and the extent of the opportunity for those products or projects having the most promise we also recommend the next steps to be taken.

B. NON-METALLIC MINERALS

Our analysis of the opportunities for exporting non-metallic minerals focused on the following:

1. Asbestos
2. Gypsum
3. Kaolin

4. Limestone
5. Magnesite
6. Barite
7. Basalt
8. Bentonite
9. Feldspar
10. Ocher
11. Quartz

As has been noted, place value or location of deposits near large consuming centers is of vital importance in such industries as non-metallic minerals. Many non-metallic minerals are low value commodities, faily widely distributed, and it can thus be expected that transportation costs play an important part in their total cost structure. A widely distributed mineral, such as commnon building sand, or crushed stone, is not likely to be transported great distances because it would be uncompetitive beyond its local market. Of course, it is understood that proximity to important markets is always an advantage, even with such scarce commodities as asbestos and copper. However, some minerals, even of low unit value, do not have a widespread or favorable geographic distribution. We have to take them where we find them and if a more favorably located deposit was to be found in quantity the economics of the whole industry would be changed.

The relative importance of place value to the consumer is thus a vital concept. Typically, place value is of paramount importance for low grade clays, crushed stone, gypsum, ordinary grades of limestone and lime, and of course, sand and gravel. It is of lesser importance for barite, feldspar, high grade kaolin, magnesite and special silica sands. Place value is of low importance for asbestos, magnesite, special types of bentonite and high grade sheet mica.

Because place value is such an important concept for many of the non-metallic minerals, we focused on the effects of transportation costs in our evaluation process. In Table 7, we indicate railroad freight rates in dollars per ton between major cities and ports in Bolvia, Chile and Peru. These freight rates are for a number of selected minerals, as well as for products to be discussed in a later section of this chapter. In many cases, quotations were not available for certain specific products or minerals and comparisons were made with some other products in arriving at a rate. The cities that were selected represent both major centers or mining activity within Bolivia as well as typical destination points such as Pacific Ocean ports. Table 8 shows the truck rates per ton-kilometer for cities within Bolivia. Although not always explicitly stated, consideration was given to a reduced transportation cost brought about by improvement in the infrastructure.

In discussing raw material costs, some brief explanations of our assumptions are required. Non-metallic minerals that occur in

TABLE 7

RAILROAD FREIGHT RATES

DOLLARS/TON BETWEEN MAJOR CITIES AND PORTS (1)

	Arica-La Paz	La Paz-Antofagasta	La Paz-Matarani	Oruro-Arica	Oruro Antofagasta	Oruro-Matarani	Cochabamba-Arica	Cochabamba-Antofagasta	Cochabamba-Matarani
DISTANCE	448 Km.	1.164 Km.	804 Km	618 Km	930 Km.	974 Km.	824 Km.	1.136 Km.	1.180 Km.
Flat Glass	$17.63	$23.13	$20.45	$22.34	$16.31	$24.06	$31.06	$23.49	$31.24
Container Glass	21.48		19.56	26.85		23.91	36.15		32.63
Cement	12.76	19.84	17.29	15.84	14.09	20.37	21.82	20.07	26.35
Brick- Excluding glazed and refractory	15.39	19.84	17.29	19.19	14.09	20.37	26.37	20.07	26.35
Ceramic Tile	15.39	23.13	20.10	19.19	16.31	23.71	26.37	23.49	30.89
Clay Refractories	12.76	19.84	18.28	15.84	14.09	21.36	21.82	20.07	27.34
Pottery and related Products (2)	12.76	37.81 23.13	29.22 18.97	15.84	28.66 16.31	23.52 22.58	21.82	37.96 23.49	32.62 29.76
Vitrious Plumbing	17.63	27.13	28.54	22.34	19.06	24.06	31.06	27.78	32.78
Ordinary Table China	17.63	23.13	17.71	22.34	16.31	24.06	31.06	23.49	32.78
Electrical Porcelain	21.48	27.13	23.54	26.85	19.06	23.91	36.15	27.78	32.63
Lime	12.76	19.84	17.86	15.84	14.09	22.92	21.82	20.07	28.89
Asbestos Friction Metals	21.48	19.84	15.24	26.85	14.09	22.92	36.15	20.07	28.89
Asbestos Cement Prod.	12.76	19.84	15.24	15.84	14.09	22.92	21.82	20.07	28.89
Minerals and Earths, General	12.76	19.84	18.28	15.84	14.09	21.36	21.82	20.07	27.34
Non-Clay Refractories	12.76	19.84	18.28	15.84	14.09	21.36	21.82	20.07	27.34
Kaolin	15.39	19.84	18.28	19.19	14.09	21.36	26.37	20.07	27.34
Magnesite	15.39	19.84	18.28	19.19	14.09	21.36	26.37	20.07	27.34
Asbestos	12.76	19.84	18.28	15.84	14.09	21.36	21.82	20.07	27.34
Bentonite	15.39	19.84	18.28	19.19	14.09	21.36	26.37	20.07	27.34
Chalk	21.48	23.13	17.59	26.85	16.31	23.91	36.15	23.49	31.09
Feldspar	15.39	19.84	18.28	19.19	14.09	21.36	26.37	20.07	27.34
Quartz	15.39	23.13	20.10	19.19	16.31	23.71	26.37	23.49	30.89
Ocher	12.76	19.84	18.28	15.84	14.09	21.36	21.82	20.07	27.34

(1) Where Rates were unavailable estimates were made by comparison with similar materials

(2) Upper figure refers to artistic pottery; lowerfigure to ordinary pottery.

TABLE 8

PRINCIPAL FREIGHT TARIFFS BETWEEN MAJOR CITIES IN BOLIVIA

(By Truck, in U.S. Cents/ton kilometer)

	TARIFF	DISTANCE KMS.
Santa Cruz-Cochabamba	3.49	500
Santa Cruz-Oruro	3.48	728
Santa Cruz-La Paz	5.10	903
Santa Cruz-Potosí	3.22	774
Santa Cruz-Sucre	2.91	608
Cochabamba-Santa Cruz	1.27	500
Cochabamba-Oruro	5.98	206
Cochabamba-La Paz	4.19	403
Cochabamba-Sucre	2.22	366
Cochabamba-Potosí	2.35	532
Oruro-La Paz	5.75	225
Oruro-Potosí	9.77	383
Oruro-Sucre	17.6	558
Potosí-Tarija	3.79	384

their natural state usually do so in association with other materials and the process of mining and recovery must include the various stages of separation, cleaning, crushing and grinding, and beneficiation that were described in Chapter II. Some minerals require more investment in time and labor in these preparatory states than others; we had to assume a certain state of preparation at which we could compare costs on the most logical basis. We considered that the most appropriate stage would be when the mineral has been prepared for shipment, either in bags or in bulk, and is ready to leave the locality of the mine. We realize that the preparation necessary before this stage will vary from mineral to mineral: for example, kaolin may be used in its general form without much preocessing, or it may be fully calcined before shipment. We also realize that the degree of processing carried out at one location will vary from mineral to mineral: calcining may occur at the mine head or possibly at a location some few miles away. For the sake of consistency, therefore, we took the viewpoint of a prospective customer and asked ourselves the question that would be in their minds "what is the price I have to pay for your material at the product stage at which I could use it, but before it is delivered to my plant?" It is in this way that the prospective customer compares prices from various sources and is able to make a decision on allocating his custom.

Even by using this as a starting point, it was difficult to arrive at prices for the individual raw materials. In some cases, list prices for typical building materials such as cement and lime

were available and could be consulted. In other instances, our interviews in Bolivia and in other Andean countries gave us some typical price structures for materials purchased by the manufacturing industry for use in their own processes. In many cases, however, we found the required prices difficult to come by and in these instances we have either used unit prices derived from trade statistics on consumption and value for the individual minerals, or from our own experiences of world trade. Of course, the quality and quantity of the mineral has a great effect on the price, and some of the generalizations we have used are crude, at best. Where possible in our report we have indicated the degree of uncertainty associated with our figures.

Tables 9, 10, and 11 present production and trade statistics for each non-metallic mineral to be discussed. It should be stressed that these data, based on government publications are in some cases incomplete, and in some cases erroneous. They are submitted as a guide only. Before major decisions on identification of opportunities were made, further investigations of market size were undertaken.

1. Asbestos Fiber

Asbestos fiber is used almost solely in the Andean subregion to manufacture asbestos cement products. Between 1966 and 1968 total yearly consumption accounted for approximately 27,000 - 28,000 tons with a value of about US$6 million (TABLE 12). Colombia is the largest consumer accounting for 13.0-16.0 thousand tons

TABLE 9

PRODUCTION & TRADE STATISTICS FOR NON-METALLIC MINERALS
ANDEAN NATIONS - 1966

(METRIC TONS)

MINERAL	BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export
ASBESTOS	26	2	2		7442	0	1663	3533			375	0		16534	
BARITE	0	0	0	2127	9576	0	116,645	98	91,680		781	0	7400	11	
BENTONITE		1670			2636	0		805	46		467	0		3117	
CHALK		29			18	0		2070	15		520	0		19	
FELDSPAR				1193		0	473	635				0	1900	113	
QUARTZ		186		157332	820	0		26			16	0	9000	4729	29
KAOLIN		53		4[illegible]	280	0	417	1630		891	85	0	26,000	81	
MAGNESITE		11			4873	0		1270			4	0	190		
OCHER		11			211	0		11				0			
OTHER REFRACTORY EARTHS		31	19	37751	1063	14	290000	680				0	1,384,000	30	

Quantities in Metric Tons

Source: Published Data an Arthur D. Little Estimates
Where Blks Appear, Statistics were not Available

TABLE 10

PRODUCTION & TRADE STATISTICS FOR NON METALLIC MINERALS

ANDEAN NATIONS - 1967

		BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
		Prod.	Import	Export	Prod	Import	Export	Prod.	Import	Export	Prod	Import	Export	Prod	Import	Export
ASBESTOS	$000			2		1755			890	0	0	119	0		3258	0
	TONS	4	1.6			8995			4240			622			13,752	
BARITE		0	0	0	4504	1412	0	110,000	308	67,439				6007	8	0
BENTONITE	$000		43	0		164		769	129			8	0		109	4.8
	TONS		604			3153		17,000	2307	50		132			1405	102
CHALK	$000		2	0		8			54			0	0		8	0
	TONS		35			229			2090	20						
FELDSPAR	$000		0	0		5			46	0	0	.45	0		5	0
	TONS				821	32		2,500	805			5		18,500	43	
HI-SI QUARTZ	$000		18	0		,,02			18	0		.15	0		0	0
	TONS		188		159,293	.2			351			2		37,000		
KAOLIN* (VALUE)	$000		4	0		16		0	169	0		5	0			
*(QUANTITY)	TONS		57		23,424	168			3543		372	25		11.000	2255	96
MAGNESITE	$000		0	0		347			350	0		2	0		27	0
	TONS					2700			3234			7		190	70	
OTHER	$000		8	0		4			7	0		0	0			0
	TONS		24			7			17							
OTHER REFRACTORY EARTHS	$000		[illegible]	3.39		8			180			0	0		295	0
	TONS		[illegible]	45.9		29			3008	7				527,000	69	

VALUE IN THOUSAND DOLLARS- U.S.
QUANTITY IN METRIC TONS
SOURCE: PUBLISHED DATA AND ARTHUR D. LITTLE ESTIMATES
WHERE BLANKS APPEAR, STATISTICS WERE NOT AVAILABLE

TABLE 12.

PRODUCTION & STATISTICS FOR NON-METALLIC MINERALS
ANDEAN NATIONS - 1968

MINERALS		BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
		Prod.	Import	Export	Prod	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod	Import	Export
ASBESTOS (VALUE)	$000		0	.2		1734	0		701	0						
(QUANTITY)	TONS	1		.9		8660			3970							
BARITE		0	0	0	3986			66,642						7570		
BENTONITE	$000		264	0		177	0	N/A	59							
	TONS		6140			8940			1280	80.7						
CHALK	$000		0	0		.4	0		23	0						
	TONS					2			8430							
FELDSPAR	$000		0	0		2	0		52	0						
	TONS				935	12		1889	1470					22,000		
QUARTZ	$000		0	0		2	0	N/A	4	0						
	TONS				144,357	60			42					43,000		
KAOLIN	$000		3	0		18	0		113	0						
	TONS		41		25,950	202		1024	2920		642			18,000		
MAGNESITE	$000		7			252	0		76	0						
	TONS		60			7000			1020							
OCHER	$000		7	0		0	0		70	0						
	TONS		22						30							
OTHER REFRACTORY EARTHS	$000		2	0		19	0	47,914	122	0						
	TONS		25		81,992	139			2100					569,000		

VALUE IN THOUSAND DOLLARS - U.S.
QUANTITY IN METRIC TONS
SOURCE: PUBLISHED DATA & ARTHUR D. LITTLE ESTIMATES
WHERE BLANKS APPEAR STATISTICS WERE NOT AVAILABLE

TABLE 12

APPARENT CONSUMPTION ASBESTOS

ANDEAN SUBREGION

1966 -1968

	Production		Import		Export		Consumption	
	Tons	Value (US$)	Tons	Value (US$)	Tons	Value (US$)	Tons	Value (US$)
BOLIVIA								
1966	26	N.A.	2	N.A.	2	N.A.	26	N.A.
1967	4	N.A.	1.6	N.A.	4	200	1.6	N.A.
1968	1	N.A.	N.A.	N.A.	9	200	N.A.	N.A.
CHILE								
1966	N.A.	N.A.	7,442	N.A.	N.A.	N.A.	7,442	N.A.
1967	N.A.	N.A.	8,995	1,754,746	N.A.	N.A.	8,995	1,754,746
1968	N.A.	N.A.	8,660	1,733,992	N.A.	N.A.	8,660	1,733,992
PERU								
1966	N.A.	N.A.	3,533	N.A.	N.A.	N.A.	3,533	N.A.
1967	N.A.	N.A.	4,240	890,000	N.A.	N.A.	4,240	890,000
1968	N.A.	N.A.	3,970	701,000	N.A.	N.A.	3,970	701,000
ECUADOR								
1966	N.A.	N.A.	375	N.A.	N.A.	N.A.	375	N.A.
1967	N.A.	N.A.	622	119,000	N.A.	N.A.	622	119,000
1968	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
COLOMBIA								
1966	N.A.	N.A.	16,534	N.A.	N.A.	N.A.	16,534	N.A.
1967	N.A.	N.A.	13,752	3,238,000	N.A.	N.A.	13,752	3,238,000
1968	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TOTAL ANCOM								
1966	26	N.A.	27,886	N.A.	2	N.A.	27,910	N.A.
1967	4	N.A.	27,611	6,001,746	4	200	27,611	6,001,746
1968	1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

N.A.: Not Available

Source: Official Published Statistics

or roughly 50% of the market. Chile with a yearly consumption of 7.5 - 9.0 thousand tons or about 30% of the market is the second largest consumer of asbestos fiber. In third place is Peru with a yearly consumption of 3.5 - 4.5 thousand tons or about 15%. Production of asbestos fiber during the 1966 - 1968 period was insignificant and limited to Bolivia. Nearly all the asbestos fiber consumed into the subregion was imported and used mainly in asbestos cement products such as pipe and tiles. It was also used in asbestos friction materials.

Our analysis has indicated that there exists an opportunity to export asbestos fiber to the Andean subregion and to the world market, provided that the quality of the fiber meets the needs of the user industries particularly the asbestos cement industry. The relatively small and declining market for asbestos textile products makes them appropriate for serious consideration as an opportunity.

There is little or no question that Bolivia does have significant asbestos resources compared with most South American countries. The only question that remains is whether the fiber is suitable for the production of asbestos cement products. The fact that the fiber is blue and appears to resemble South African asbestos, which is well established in world markets, has led some individuals to the premature conclusion that this fiber is appropriate for asbestos cement. Our interviews with professionals in the industry indicate that the fiber available in Bolivia is low in tensile strength and not suited for asbestos cement products.

Another factor supporting our conclusion that there may be an opportunity for Bolivia to export asbestos fiber is that this product can support the high transport cost required to ship it to the Andean subregion and world markets. The current price for asbestos fiber utilized in asbestos cement products is between US$150 and US$250 depending on the exact grade. The freight cost from Bolivia to the coast is about US$20/ton and, therefore, is relatively small compared to the selling price. As a result, if the proper quality material is available the development of a large industry is quite possible.

If the fiber available in Bolivia is not of a grade appropriate for the production of asbestos cement products, the industry will continue to operate as it has in the past. Under these conditions the industry will probably be very small using hand labor for picking rocks.

2. Barite and Bentonite

One of the principal uses of these two minerals is for oil drilling muds: bentonite is used as a colloidal mud that swells, lubricates the drill, and seals the wall: barite is used to reduce the gas or sand pressures around the drill, and to give added weight to the mud solution. For these uses, a very high quality bentonite is required. A measure of its quality is the yield in barrels of water, per ton of bentonite, that is required to give the necessary suspension. Thus, Bolivian bentonite has been

tested to give a recovery of 70 barrels per ton, as compared to mineral imported from Mendoza, Argentina, which gives a higher yield of 100 barrels per ton. This imported material is at a cost of $30 per ton, f.o.b. Mendoza, with added freight of $30 a ton to Santa Cruz. While it is known that Colombia and Ecuador are essentially importing their requirements from the United Sates, it would be safe to say that a Bolivian product could not compete on the basis of freight with those suppliers. Peru has its own extensive resources, but still is unable to compete with Argentina in supplying Chile's needs. It is unlikely that Bolivia could do so, either, under those circumstances.

Production of barite in Bolivia is believed to be about 5000 tons per year. Although the capactity of the producing company, San Onofre at Cochabamba, is capable of being expanded to some 9000 tons a year, the market potential for a Bolivian product in the other Andean countries is not good. Chile produces some 4500 tons each year and Peru over 100,000 tons. Colombia is also producing some 6,000 to 7,000 tons each year and the only importation of any substance is some 1400 tons by Chile from Argentina. Further, the present price of Bolivian barite at $40 per ton f.o.b. Cochabamba, makes this an uneconomic material to market competitively outside Bolivia.

Our analysis thus indicates that barite and bentonite opportunities have minimum promise.

3. Quartz and Basalt

Basalt, a crushed stone used as an aggregate in concrete manufacture and road construction, is a low value, high-bulk, product that is extremely sensitive to transportation costs. It is a highly substitutable material, with other alternative minerals frequently being found at locations close to the required construction site. Its price of approximately $1 per ton at the quarry can be easily doubled by truck transportation rates of 4.5c per ton kilometer. As a result, it is unlikely that an opportunity exists for the export of basalt to the Andean subregion.

The commercial environment for quartz, or common sand, is similar. Industries, such as glass manufacturing, that use quartz are generally established close to the source of a good raw material as transportation costs must be minimized for such a low value commodity. In the case of building sand, local pits and quarries are frequently available to supply current requirements. While markets might exist for high silica quartz, there are no indications at present that such a material, having a silica content of 98% and higher, is available in Bolivia and we believe that such a level of quality must exist to create an opportunity in export market.

4. Feldspar

Our market analysis has indicated that a large part of the total market in the Andean subregion is supplied from local sources at prices averaging US$20 - US$40 a ton delivered to the customer;

small quantities of high grade feldspar mineral are also imported into the Andean group at US$100 to US$140 per ton.

The figures below are indicative of the market situation for feldspar in Colombia, Chile and Peru (all figures are in metric tons).

COUNTRY	PRODUCTION	IMPORTS	APPARENT CONSUMPTION
CHILE			
1967	871	32	903
1968	935	12	947
PERU			
1967	2500	805	3305
1968	1889	1470	3359
COLOMBIA			
1967	18500	43	18543
1968	22000	--	22000
TOTAL			
1967	21,871	880	22,751
1968	24,824	1,482	26,306

Apparent consumption for the three contries was 27,751 tons in 1967 and 26,306 tons in 1968; Colombia was the largest consumer, accounting for about 80 - 85% of the total. Peru was the second largest consumer of feldspar.

The data also indicate that about 95% of total requirements were supplied by domestic production. Colombia and Chile supplied virtually all their needs locally. Peru imported nearly 25% of its needs in 1967 and 45% in 1968, primarily from the U.S. Our field work indicated, however, that Peru has located and started the recovery of an excellent quality feldspar which will reduce the price to about US$70 per ton delivered to the plants versus the US$100 per ton CIF Lima they currently pay for the imported high grade feldspar. Another factor tending to minimize opportunities for exporting feldspar to Peru is that as with kaolin and other clays used in the ceramic industries, manufacturers of ceramics products in Peru are attempting to minimize the quantity of minerals they import and there appear to be adequate resources in Peru to meet their immediate needs.

In Bolivia the establishment of a creramics industry would encourage the development of feldspar resources for domestic use. If this does not occur opportunities for further development are very limited.

5. Gypsum

Crude uncalcined gypsum is used as a cement retarder or as an agricultural product and is generally valued at US$3-5 per ton when it is ground screened and packaged. Calcined gypsum is used in relatively small quantities for industrial molding, plate glass and the like, and is valued at US$20-30 per ton. As a plaster, gypsum is valued at US$20 per ton, and as a

prefabricated product -- usually gypsum wallboard at US$40 per ton.

Gypsum wallboard production does not represent a promising opportunity for Bolivia at this time because of the infrequent use of woodframe construction -- the principal market for such gypsum board -- coupled with the relatively low cost for plastering in Bolivia. Gypsum board is essentially prefabricated wet plastering, and is only economical where labor costs are high.

The speciality calcined gypsum often represents less than 1% of the total gypsum market, probably less in Bolivia, and is usually an incremental business. Therefore, the Bolivian gypsum industry would have to look to plasters as the principal product for domestic markets.

There currently exist in Bolivia a number of small gypsum facilities calcining gypsum and making plaster. These industries are relatively small and are meeting the needs of the market. Furthermore, becuase of world prices of US$3-5 per ton for the raw gypsum, because of the high freight rates up to approximately US$20 per ton, and because of the readily available gypsum in neighboring countries, the opportunities for exporting crude gypsum are not attractive.

Gypsum plaster currently sells for US$18-20 per ton in Bolivia and in the neighboring Andean countries. Therfore, it is wholly unrealistic to consider promoting domestic gypsum in Andean

countries, let alone the world market when the freight rate outside of the country would doble the delivery price over the current price.

The gypsum industry in Bolivia, thus will remain domestically oriented and at present does not represent an opportunity for expansion or consolidation, pending a detailed analysis of the technological, economic and growth trends in the domestic construction industry.

6. Kaolin

Kaolin prices vary depending on the stage of processing, and range from about US$15 per ton for a general purpose kaolin to US$60 per ton for a newly calcined product. Prices of locally produced kaolin in the Andean countries that we visited were about US$20 per ton F.O.B., the plant, while imports varied from US$40 per ton to US$90 per ton at the port of entry for high grade kaolins. Bolivian kaolin is mostly available in the department of Oruro and transportation costs from there to a coastal port such as Arica would be US$19 per ton. Thus,on the basis of price, a kaolin material of the required quality coud be competitive in Peruvian and Chilean markets with kaolin imported from other countries, but not with the domestic production of those countries.

An examination of trade and production statistics indicates, however, that relatively small amounts are imported into the Andean subregion and that most of their local demand is supplied by domestic sources.

In Chile, for example, 200 tons were imported in 1968 as compared to 26,000 tons of domestic production. In Perú nearly 3,000 tons of kaolin were imported in 1968 versus 1,000 tons of domestic production. The relationship between imports and production in 1968, however, is significantly higher than in either 1966 or 1967 and the high imports may be due to a statistical error. Our interviews with kaolin users in Peru indicated that they are very satisfied with the quality of domestic kaolin and that they are making conscious efforts to purchase all their requirements locally as the output of suppliers increases to satisfy demand. Similarly in Colombia almost all the domestic requirements of kaolin are satisfied locally.

In summary, based upon current and expected future requirements of kaolin by Andean countries outside Bolivia, opportunities for export are very limited. In the event that a refractory and/or ceramic business is established in Bolivia, there would probably exist some opportunities for locally produced kaolin, as current average prices of the imported mineral are US$75 per ton.

7. Limestone

Limestone, a naturally occuring mineral, is used in practically its pure form by various construction industries without much initial processing. Its use in these construction markets, including the cement industry, has been referred to in a previous chapter. As a calcined lime, the product is used in addition in many chemicsl

and refractory industry applications and opportunities for it will be considered in a subsequent section of this report.

8. Magnesite

The magnesite deposit in Bolivia presently under consideration for development and utilization in the SIMSA plant is in the upper Chapare district of Cochabamba. The deposit is a replacement in a dolomite - limestone ore body. It occurs close to, and at times with, deposits of blue crocidolite asbestos. Reserves have been estimated at 2 million tons by GEOBOL. The rock contains a high content of quartz as well as some dolomite, calcite and various micas. We indicate below the chemical analysis of some samples of magnesite from the Chapare region, which, although not necessarily typical, are indicative of the quality available.

SiO_2	6.2%
Al_2O_3	0.7%
Fe_2O_3	0.9%
CaO	1.7%
MgO	44.4%
Na_2O+K_2O	1.2%
CO_2	46.7%
SO_3	0.3%

Because of the high silica content and other impurities in the above analysis, the relation between the value of the processed magnesite in the form of brick or calcined grain, and the type of

magnesite available at Chapare is largely unknown. There is, for example, a beneficiation problem that needs to be solved. This problem involves the removal of silica and other impurities from the magnesite ore so that the magnesite concentrate can be calcined and then converted into a valuable and desirable commercial product.

As discussed in Chapter II, calcination burns off the impurities with a consequent doubling of the percentage of MgO magnesia content in the resulting product. In the above analysis the MgO percentage would increase from 44.4% to 84%. Unfortunately, silica is not burned off in the calcining process and it would increase from 6.2% in the unburned basis to 11.7% of the burned magnesia grain. As mentioned previously, the optimum $CaO:SiO_2$ ratio is 1.86:1, while the ratio in this particular analysis is 0.274:1, thus emphasizing the high silica impurities in this analysis.

As far as is known, requirements of magnesite by the other four Andean countries are almost entirely imported and amount to about 9,000 tons each year. Both, Chile and Peru import about 3,000 tons of magnesite, and are the major importers. One company in Lima, Refractarios Peruanos (REPSA) imports 1,500 tons a year of a 93.5% MgO and claim that their requirements are increasing year by year as the demand for their refractory bricks increases. They are presently paying US$94 per ton, importing from the US into the port of Callao.

In Santiago, Refractarios Chilenos (RECSA) is currently in the process of putting onstream a new plant to produce basic

refractories. This plant will have an initial capacity of 20,000 tons per year and raw materials are to be imported from Brazil, Japan, Mexico and the United States. It is anticipated that some 8,000 tons of magnesite will be required and this company is anxious and ready to consider Andean countries as alternatives to their presently planned sources of supply. They stress, however, that the quality of the materials they are seeking should be of high purity and magnesium oxide content, The major competitor to this company in Santiago, Refractarios Lota-Green, is watching RECSA's new facitity with interest and they may consider the expansion of their present clay refractories plant to include the production of special refractories; they, too, presently import their magnesite requirements.

In general, the refractory industry of the world is expected to require increasing quantities of higher-purity magnesium oxide, such as that which can be made from sea-water, dolomite and various brine solutions, because of the increasingly stringent requirements for the brick. Coupled with this demand for a higher quality product is an increased knowledge of the advantages of high-purity magnesium oxide used for basic refractories. This will lead to increased production of magnesium and the consumption of magnesia for refractories is expected to increase at some 7-8% per year.

We understand that the proposed SIMSA plant will have a capacity of at least 30,000 tons per year and it is apparent that the markets at which they are aiming extend beyond the Andean countries. The planned capacity is only just equivalent to the minimum

economic scale of plant that could be considered for such a facility. It is likely that the costs of production of the magnesite grain will be approximately US$70 per ton. In the world market, magnesite prices range from US$50 to US$80 per metric ton depending upon quality, and US$90 to US$125 for the premium material.

Table 13 presents the order of magnitude of the costs for producing magnesite grain. The data indicate that a large plant of 40,000 tons per year could produce magnesite grain at US$65 per ton or a price competitive for quality magnesite grain in world markets. Table 13 also indicates the sensitivity of prices to volume of calcining magnesite. The costs of producing a ton of magnesite in a 1,200 ton plant are US$200 or nearly three times as much as in a 40,000 ton plant.

Whether Bolivian magnesite can compete successfully in both the Andean and world markets will depend very largely on the MgO content of the grain and on the elimination of the silica in the process. In summary our analysis has indicated that there is an excellent opportunity for the production and export of magnesite grain to the Andean and world markets, provided Bolivia can produce the grain of the quality required.

9. Ocher

As indicated in Chapter II, the use of ocher is declining rapidly and Peruvian ocher is one of the better known in the world. As far as can be ascertained, the imports of ocher into the Andean countries total no more than 50 to 60 tons per year

TABLE 13

ORDER OF MAGNITUDE COSTS FOR PRODUCING MAGNESITE GRAIN

(VALUE IN THOUSANDS OF U.S. DOLLARS)

ASSUMPTIONS:		
Annual Production	1,200 tons	40,000 tons
Investment	700	1,800
COSTS:		
Raw Materials	12	400
Operating Supplies	14	80
Labor	50	200
Maintenance	42	80
Utilities	50	1,300
Depreciation-Insurance	77	530
Total Costs	245	2,590
Cost per Ton	200	65

On this basis, market opportunities, especially with a reduced rate of growth expected, are not very promising.

C. PRODUCTS DERIVED FROM NON-METALLIC MINERALS

As was stated earlier, the true potential opportunities for Bolivian industry will not be in the development and marketing of essentially low value, non-metallic mineral resources, but in the manufacture and distribution of selected products derived from these minerals. In this section, we repeat the process gone through in the last section of this chapter, only this time with emphasis on the products themselves rather than on the minerals. These products represent the type that can be manufactured from those minerals that appear to be available in sufficient quantity and quality in Bolivia for the required industry. They fall into seven major groups:

1. flat and container glass
2. cement
3. common brick
4. ceramics
5. refractories
6. lime
7. asbestos products

Within each group a number of different opportunities exist. For example, the ceramics group includes pottery and related products, vitreous plumbing, vitreous table china, ceramic tile and electrical porcelain products.

The market for non-metallic mineral products is summarized in tables 14,15 and 16 which present production, import and export statistics for each of the five Andean countries in value and in tonnage for the years 1966 through 1968.

In the discussions that follow, we will be considering each market by individual products rather than by product groups as it can generally be stated that little inter-product synergism exists at the production level. One plant is not likely to be producing all types of ceramic products, for example, as the technology, skills and equipment are very different. (An exception is the refractory plant in which both clay and non-clay products can be manufactured interchangeably in the same facility; the only differences occur in raw materials and not in the products or process). During our work we have examined a number of reports that refer to feasibility studies or investment decisions that have been made or considered by the Bolivian Government and other Bolivian agencies for the establishment of plants within the next few years. Specifically these reports include one by the Bolivian Development Corporation (CBF) that deals with the establishment of the various factories for the production of cement, window-glass, ceramics, etc. A second report is in the form of a Memorandum to the Commission of Non-metallic Minerals for the Operative Secretariat of the Union of ALALC, and deals with various projects concerning asbestos, diatomite, flat glass, ceramics, cement, bentonite, barium sulfate, etc. The third, the National Plan for Bolivia, itemizes a number of industrial projects in the area of construction

TABLE 14

MARKET FOR PRODUCTS DERIVED FROM NON METALLIC MINERALS

(Metric tons)

	ANDEAN SUBREGION 1966														
	BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
	Prod.	Import	Export	Prod	Import	Export	Prod	Import	Export	Prod	Import	Export	Prod	Import	Export
FLAT GLASS		1770	0		863			5750			2778			2000	
CONTAINER GLASS	500	199	0		267			1370			7430			650	
CEMENT	60,000	1240	0	1.364,000	6495	2555		157,300			2210		2,074,000	435	181,325
BRICK, EXCL. GLAZED & REFRACTORY		22	0		46	0		1			0			100	
CERAMIC TILE		295	0		50	0		7			26			0	
CLAY REFACTORIES		24	0		19,200	216		57			7			60	
POTTERY & RELATED PRODUCTS		222	0		179	5		1180			796			15	
VITREOUS PLUMBING		436	0		37	0		128			758				
VITREOUS TABLE CHINA		247	0		28			273			48			35	
ELECTRICAL PORCELAIN		152	0		606	2		60			135				
LIME	612	167	0		26	0		1.5			0		50,000	27	
ASBESTOS FRICTION MATERIALS		86	0		0	0		409			74			300	

continued.....

TABLE 14 (CONT.)

	BOLIVI			CHILE			PERU			ECUADOR			COLOMBIA		
	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod	Import	Export	Prod.	Import	Export
ASBESTOS CEMENT PRODUCTS		1.4	0		40	0		68			3220			0	
NON CLAY REFRACTORIES		591	0		0	0		2650			657			230	

QUANTITY IN METRIC TONS
SOURCE: PUBLISHED DATA AND ARTHUR D. LITTLE ESTIMATES
WHERE BLANKS APPEAR, STATISTICS WERE NOT AVAILABLE

TABLE 15

MARKET FOR PRODUCTS DERIVED FROM NON METALLIC MINERALS
ANDEAN SUBREGION 1967

		BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
		Prod.	Import	Export	Prod	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export
FLAT GLASS	$000		378	.1		510	0	2253	2420		0		0	2738	718	731
	TONS		2450	.06		786			6650	1		3100			2349	5569
CONTAINER GLASS	$000	640	222			55	0	6350	705		0		0	11,157	200	455
	TONS		62			101			778	51		6100			523	3227
CEMENT	$000		29384	4		354	14	33,800	2050		8160		0	32,686	246	2664
	TONS	62,000	5330	44	1,235,000	12800	500	1,087,000	99,877	15,900	382400	2300		2,169,200	202	229,687
BRICK, EXCL. GLAZED & REFRACTORY	$000	157				0		4300	2,3		48		0	5841	0	0
	TONS								18	3		.001				
CERAMIC TILE	$000		104			39	2		226		415		0	3277	0	37
	TONS		509	0		179	10		664	52		1.7				178
CLAY REFRACTORIES	$000	35	5			145		1600	26	0	5	-	0	2192	3	0
	TONS		19	0		826			55						14	
POTTERY & RELATED PRODUCTS	$000		67			93	.4		559	0	85.6		0	438	55	17
	TONS		162			92	.1		941			696			47	31
VITREOUS PLUMBING	$000		374			34		752	668	0	0		0	2334	3	174
	TONS		634	0	800	39	0	3400	34			890			3	483
VITREOUS TABLE CHINA	$000		130			44	0	10,5	368	0	0		0	200	57	0
	TONS		222	0		27			390			54			24	

Continued.....

TABLE 15 (CONT.)

		BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
		Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod	Import	Export	Prod	Import	Export
ELECTRICAL PORCELAIN	$000		84			39	0		580	0			0		109	0
	TONS		174	0		42			709			216			179	
LIME	$000	41	2			4.3	0	400	-	0	58	-	0	687.7	12	0
	TONS	1512	41	0	1,920,000	23		14,763			3285			51,033	182	
ASBESTOS FRICTION MATERIALS	$000		153			171	0		490	0	0		0		153	14
	TONS		103	0		45			291			92			166	27
ASBESTOS CEMENT PRODUCTS	$000		1.4		3280	33	0	1086	142		109		0	14,171	0	613
	TONS		2			470			101	15		3700				4835
NON CLAY REFRACTORIES	$000		44			3121	1.6		820		0		0	355	118	2,4
	TONS			0		17,000	19		3100	61		984			143	25

VALUE IN THOUSAND DOLLARS - U.S.
QUANTITY IN METRIC TONS
SOURCE: PUBLISHED DATA AND ARTHUR D. LITTLE ESTIMATES
WHERE BLANKS APPEAR, STATISTICS WERE NOT AVAILABLE

TABLE 16

MARKET FOR PRODUCTS DERIVED FROM NON-METALLIC MINERALS

ANDEAN SUBREGION

(1968)

		BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA	
		Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod	Import	Export	Prod	Import	Export
FLAT GLASS	$000		433			693	133		1310	1.20						
	TONS		2300			1200	79		4900	.03						
CONTAINER GLASS	$000		7			47	0		480	45						
	TONS		14			72			894	26						
CEMENT	$000		1538			490	84		426	.60						
	TONS		46,000		1,251,000	1600	5000	1,098,000	7870	28	434,000			2,307,000		
BRICK, EXCL GLAZED & REFRACTORY	$000		.7			3	8		0	1						
	TONS		.5			14				11						
CERAMIC TILE	$000		159			26	0		70	.5						
	TONS		730			106			254	1.5						
CLAY REFRACTORIES	$000		.1			197	0		20	0						
	TONS		4			673			85							
POTTERY & RELATED PRODUCTS	$000		72			116	.6		175	0						
	TONS		170			69	.3		350							
VITREOUS PLUMBING	$000		301			33	0		150	0						
	TONS		566			48			8							
VITREOUS TABLE CHINA	$000		130			87	11		69	0						
	TONS		224			830	35		277							
ELECTRICAL PORCELAIN	$000		73			78	0		122	0						
	TONS		182			64			193							
LIME	$000		4			3	0		0	0						
	TONS		88		2,038,000	34							4,852,000			

continued.....

TABLE 16 (CONT.)

		BOLIVIA			CHILE			PERU			ECUADOR			COLOMBIA		
		Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export	Prod.	Import	Export
ASBESTOS CEMENT PRODUCTS	$000		394			27	0		30							
	TONS		1600			59			97	4						
ASBESTOS FRICTION MATERIALS	$000		158			241	0		363	0						
	TONS		98			71			147							
NON CLAY REFRACTORIES	$000		150			2	0		656							
	TONS		580			9700			2240	69						

VALUE IN THOUSAND DOLLARS - U.S.
QUANTITY IN METRIC TONS

SOURCE: PUBLISHED DATA AND ARTHUR D, LITTLE ESTIMATES
WHERE BLANKS APPEAR, STATISTICS WERE NOT AVAILABLE

materials and non-metallic minerals, and defines the location, investment, production capacity and products, and markets expected to be served, together with the expected date of completion. Where relevant in this section, we have obviously taken these proposed facilities, into account in our discussions. Essentially, however, our approach is similar to that adopted in the last section: We examined the markets and cost structures for the various products and evaluated the opportunities for them.

1. Glass

On Table 17 we present data[1] on imports, exports, and production of flat glass in the Andean subregion. Imports of flat glass in 1966 were 13,161 tons, in 1967 they amounted to 15,335 tons with a value of about US$5 million. Perú is by far the largest importer with 5,750 tons in 1966, 6,650 tons in 1967 and 4,900 in 1968. Ecuador is the next largest importer with 2,778 tons in 1966 and 3,100 tons in 1967, followed by Colombia with 2,000 tons in 1966 and 2,349 tons in 1967. Bolivia imported 1,770 in 1966, 2,450 tons in 1967 and 2,300 tons in 1968. Chile was the least important importer of flat glass in the subregion with 863 tons in 1966, 786 tons in 1967 and 1,200 tons in 1968.

Colombia is a major producer of flat glass in the Andean subregion. One company we interviewed has a capacity of 24,000 tons per year. The majority of its production remains in Colombia, but its products are also exported to the Caribbean, Venezuela, Ecuador and the United States. This company is presently entering into an

(1) Where blanks appear on the table it signifies that we were not able to obtain statistics.

TABLE 17

IMPORTS, EXPORTS AND PRODUCTION OF FLAT GLASS

ANDEAN SUBREGION

1966-1968

	Production		Import		Export	
	Tons	Value (US$)	Tons	Value (US$)	Tons	Value (US$)
BOLIVIA						
1966	N.A.	N.A.	1,770	N.A.	N.A.	N.A.
1967	N.A.	N.A.	2,450	378	N.A.	N.A.
1968	N.A.	N.A.	2,300	433	N.A.	N.A.
CHILE						
1966	2,404[a]	N.A.	863	N.A.	N.A.	N.A.
1967	1,770[a]	N.A.	786	510	N.A.	N.A.
1968	N.A.	N.A.	1,200	693	N.A.	N.A.
PERU						
1966	N.A.	N.A.	5,750	N.A.	N.A.	N.A.
1967	N.A.	2,253	6,650	2,420	N.A.	N.A.
1968	N.A.	N.A.	4,900	1,310	N.A.	N.A.
ECUADOR						
1966	N.A.	N.A.	2,778	N.A.	N.A.	N.A.
1967	N.A.	N.A.	3,100	1,000[E]	N.A.	N.A.
1968	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
COLOMBIA						
1966	N.A.	N.A.	2,000	N.A.	N.A.	N.A.
1967	N.A.	2,738	2,349	718	5,569	731
1968	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

N.A.: Not available

a: Thousand meters^2

E: Estimate

expansion phase by which it is planning to double its capacity within five years.

Ecuador which currently imports approximately 3,000 tons of flat glass annually, purchases 40-50% of its requirements from Colombia. Our interviews, however, indicated that two companies are planning to establish a flat glass manufacturing plant to begin operations in 1972, using locally available raw materials which will supply all the requirements of the domestic market and eliminate imports.

Perú is a large producer of flat glass; in 1967 they produced approximately US$2.3 million he industry is currently in a position of overcapacity and is capable of exporting a part of their production. The glass they produce is of low quality.

Chile has two flat glass companies; one is relatively small and another is quite large.

Production statistics indicated that Chile in 1966 produced 2.4 million square meters of flat glass and in 1967 nearly 1.8 million square meters.

All existing facilities in the subregion utilize the Forcault process. However, our interviews indicated that a large company in Chile which is associated with a foreign glass manufacturer is considering the possibility of a new plant using the Pittsburg process. If these plans are realized Chile would be in a good position to supply the Andean subregion with some of its requirements for glass not now

supplied by the existing industry.

The above analysis indicates that it is unlikely that Bolivia has a very promising opportunity to produce flat glass by the Forcault process with the aim of exporting to the subregion. On the other hand, there is an opportunity for Bolivia to establish a flat glass plant oriented to its internal market.

Bolivia's demand for flat glass is presently about 2,500 tons per year. On the basis of the estimated growth rate of the construction industry (the primary market for flat glass) we have projected a demand of 4,000 tons by 1974. This volume is sufficient to justify a minimum economic scale of plant. Given the requirements of the market, the Forcault process would probably be the best alternative for Bolivian consideration at this time.

In Table 18 we indicate order of magnitude costs for the operation of such a plant. The data suggests that assuming a 60% yield, the plant could produce glass at U. S. $0.13 per square foot which, with appropriate profits and distribution costs, could compete with imported glass.

We could not estimate, at this time, the market for specialty glasses and for glass manufactured by the Pittsburg process since trade statistics were not sufficiently broken down in the required detail for this analysis. Our interviews, however, indicated that at present Pittsburg glass and specialty glasses are not produced in the subregion, but are imported from third countries. It is possible

TABLE 18

ORDER OF MAGNITUDE COSTS FOR PRODUCING FLAT GLASS

(VALUE IN THOUSANDS OF U.S. DOLLARS)

ASSUMPTIONS: Operation -- 365 days per year -- 60% yield at 3,700 tons or 80,000 cases 2 mm equivalent thickness

INVESTMENT: 2.25 million

COSTS:

Raw Materials	140
Labor	165
Utilities	175
Maintenance	225
Operating Supplies	31
Packing	80
Insurance & Depreciation	225
Total	1,041
Cost per Case	$13.30

MATERIALS:

Sand	39
Dolomite	8
Limestone	1
Feldspar	2
Soda Ash	70
Salt Cake	2
Sodium Nitrate	5
Miscellaneous Firing Agents	13
Total	140

that there might be an opportunity to install facilities in Bolivia to produce both Pittsburg glass and specialty glasses and supply both the domestic and export markets. Before this opportunity is confirmed, however, a detailed analysis of the economics underlying the manufacture of Pittsburg glass and specialty glasses would be required.

2. Glass Containers

The glass container industry is relatively well established in all of the Andean countries. In Colombia, one manufacturer, with a combined capacity of 8,400 tons from 3 plants, supplies about 90% of the country's requirements. He is currently in the process of doubling his capacity by 1975. In contrast to this, Colombian exports are a modest 2,500 tons per year, mainly to neighboring countries such as Ecuador, Perú and Chile which also have manufacturing facilities.

At present, Bolivian operations produce some 5 million glass containers each year, or about 2,500 tons. The capacity of this hand forming operation is reported to be about 9 million containers, and this under utilization would suggest sufficient capacity for increases in demand within the next few years.

3. Cement and Common Building Brick

These basic products are referred to in a previous chapter dealing with the construction industry and should be considered along with our recommendations for that industry.

4. Vitreous Plumbing

At present, Bolivia imports 600 tons of vitreous plumbing each year, at an average price of US$590 per ton. This volume represents approximately 30,000 sanitary ware pieces 1/ assuming that each ton consists of 50 pieces. Demand for vitreous plumbing products is closely related to activity in the construction sector which is expected to grow in Bolivia at a rate of 10% per year. On this basis we have projected total consumption at 925 tons by 1973 and 2,500 tons by 1985.

With those projections in mind, the plant proposed by the Bolivian Strategy for Development, and in various reports of CBF, which has a planned annual capacity of 1,000 tons by 1973 appears to have a domestic market sufficient to absorb its output. Our experience, however, has indicated that the minimum required capacity for a sanitary ware plant is about 2,000-5,000 tons annually, depending on the kiln 2/On this basis the Bolivian market would not be capable of supporting an economic plant for some years. Consequently the viability of this project would in part depend on exporting the excess capacity to the other Andean countries, at least until Bolivian demand rises to meet production capacity.

1/ For purposes of our discussion we have defined a sanitary ware piece as being a hand basin, bidet or toilet bowl; each piece obviously has a different unit weight but on the average consist of about 40-45 pounds of ceramic per piece.

2/ The kiln is the most crucial portion of a vitreous plumbing plant, since it determines the plant's capacity. The kiln should be heated up and operated continuously.

Our investigations of the vitreous plumbing industry in Colombia, Chile, Perú and Ecuador indicate that a shortage of supply does not exist at present, nor is it likely to exist in the near future. In Perú, the two major manufacturers each have an estimated capacity of 300,000 units a year, for a total of 600,000 units, while demand at present is only 180,000 units. It must be noted however, that Peruvian demand of 180,000 units a year is not indicative of the actual market inasmuch as construction activity has been at low levels recently; in past years total demand has been as high as 400,000 units a year. This demand, however, still only represents two thirds of Peruvian capacity. As a result, even though Perú exports small quantities of their excess capacity to Ecuador the existing industry is still operating at a severe undercapacity level.

Chilean demand for vitreous plumbing products is about 8,000 tons (420,000 pieces) a year and is about equal to total production. As the Chilean market expands, there will be a need for additional domestic production, or imports.

Our field work indicated that the American-Standard Company of the United States has been considering the possibility of establishing a production facility in Chile to supply that market. Whether they implement their plants or not at this stage is difficult to say; it would appear more likely that Peruvian manufacturers would be able to export to Chile as demand there increases.

In Colombia, two manufacturers meet the country's annual needs of about 14,000 tons a year, and are able to export a further 400 to 500 tons to other countries. The major importer of Colombian products is Ecuador, where there are currently no production facilities, although one potential user is currently planning to establish a plant. It is likely that vitreous plumbing products will be manufactured in Ecuadorian factories in about one year. Current Ecuador imports are from Colombia, Czechoslovakia and the United States, at an annual rate of about 900 tons.

In the table below we show the balance of production capacity, demand and excess capacity for the Andean countries.

	Production Capacity (Tons)	Estimated Demand	Excess Capacity
Bolivia	--	650	(650)
Colombia	14,500	14,000	500
Perú	10,000	3,500	6,500
Chile	8,000	8,000	--
Ecuador	--	900	(900)
TOTAL	32,500	27,050	5,450

This data indicates that there is presently an excess capacity of 5,500 tons in the Andean subregion. At projected growth rates of about 7% per year for the area, the present production capacity, excluding the planned plant in Ecuador, will begin to be totally

utilized by about 1973-1974 and show a demand gap thereafter. It would seem that opportunities may then exist for a Bolivian facility to meet the excess demand situation. Transportation costs would not present a serious problem since they are US$30 per ton from Cochabamba to Arica and only represent 12% to 15% of total FOB prices. On the other hand, and more likely, the existing industry in each country is in a good position to expand its capacity to meet rising demand.

Our analysis, therefore, has indicated that opportunities for export of sanitary ware to the other Andean countries are limited and a plant in Bolivia would need to sell its product on the domestic market. It was earlier determined that the Bolivian market at present is 650 tons and that it would grow to 2,500 tons by 1985 and since the minimum economic scale of plant is 2,000-5,000 tons the establishment of vitreous plumbing facilities will not represent an opportunity for a number of years.

5. Ceramic Tiles

Largely because the other Andean countries are meeting their demand from domestic production, the opportunities for a ceramic tile facility in Bolivia must be considered solely in the light of domestic demand. The products referred to in this category are generally used for wall and floor coverings; the weight of these tiles averages 11.4 kg. per square meter. Generally, these tiles are 10 centimeters square, and average 88 square meters to the ton.

The market growth rate of ceramic tiles will closely resemble that of the construction industry, assuming a constant penetration into the available market. Total Bolivian demand is currently about 750 tons a year, and is projected to reach 1,100 tons by 1972 and 3,750 tons by 1985. Presently the average price of tile in La Paz is about $600 per ton. The manufacturing operations for a tile plant are largely labor intensive and require a relatively low investment.

Our investigations indicate that there are plans for the establishment of a ceramic tile plant in Bolivia for 1972, to be located in Cochabamba. The capacity of this plant is projected at 1,000 tons and the investment at $0.9 million. However, the operating costs of a plant with such an output would mean that the selling prices of the tiles would not be reduced much below the $600 per ton level. As the capacity of such a plant would be fully utilized by the time it was constructed, we suggest that the Bolivian Government consider the possibility of installing a larger facility, perhaps with an output of 1,500 tons per year. Table 19 presents order of magnitude costs for a plant producing 750 tons and 1,500 tons of ceramic tile per year. The data indicates that substantial economies of scale exist in operating the plant on one shift producing 750 tons or two shifts producing 1,500 tons; in the former case the cost per ton of output is US$580 while in the latter case it is US$490 per ton.

TABLE 19

ORDER OF MAGNITUDE COSTS FOR PRODUCING CERAMIC TILE

(VALUE IN THOUSANDS OF U.S. DOLLARS)

ASSUMPTIONS:		
Annual Production	750 Tons	1,500 Tons
Investment	825,000	825,000
Operation	1 Shift	2 Shifts
COSTS:		
Materials	60	120
Labor	115	200
Utilities	70	140
Operation Supplies	20	35
Maintenance	75	125
Packing	10	20
Depreciation, Insurance & Taxes	82	100
Total Cost	432	740
Cost per Ton	580	490

6. Pottery and Related Products

We note with interest the proposed establishment of an artisan workshop in Bolivia for the training and instruction of personnel in the production of pottery products. We consider this low investment approach a worthwhile one for Bolivia and one that should enable the country to produce on a small scale the high value items that can frequently be exported to many parts of the world. Such items as urns, vases, and fired earthenware are popular purchases by tourists and the artisan workshop could eventually form the basis for a small, but profitable industry. This area of production should be considered on the basis of low investment and local industry and not as one geared to meet the demands of a mass market.

7. Electrical Porcelain Products

The manufacture of products for use in electrical installations requires a great deal of sophistication and product knowledge. Certain specifications and requirements must be met with accuracy and it appears premature that a facility for the production of these products should be considered before the establishment of a more basic ceramic industry in Bolivia. Such a basic industry would commence with the production of ceramic tiles, vitreous sanitary ware and, possibly, table china, and could proceed at a later date (at least five years after initial production of the more basic products) to the consideration of electrical porcelain products. Although there are no production economies possible by an intergrated ceramic products plant, Bolivian industry

would, over the course of time, accumulate a great deal of expertise and knowledge of the quality of Bolivian minerals, and the production processes involved before a commitment to sophisticated process. Further, the markets for these products would have increased greatly as the rising standard of living of the Andean countries produces a greater demand for the supply of electricity. At present, domestic demand of some 200 tons per year, together with the limited imports of other countries, does not make this a recommended project.

8. Asbestos Products

Products included in this section are asbestos friction materials and various asbestos cement products such as pipe and tiles. In part, opportunities for these products depend on the quality of asbestos available in Bolivia and the conclusions of the earlier section dealing with the evaluation of this mineral are applicable. A second, major, consideration must be the market potential for these products should the asbestos itself be of the required quality.

Examination of the market data presented earlier and the result of our interviews in other Andean countries would indicate that markets available for Bolivian asbestos cement are limited. Manufacturing facilities exist in all of the Andean countries including Bolivia and imports are modest. At least one plant in Colombia, Chile, Perú, and Ecuador is controlled by Eternit, a large European company which holds the licenses of many asbestos cement products.

In Colombia there are a number of manufacturers, in addition to Eternit, and existing capacity is capable of fulfilling domestic demand, even though in the past some imports have been recorded. Moreover the start of operations by Asbestos Colombianos next year will increase available capacity.

In Ecuador, the one major manufacturer has excess capacity and is endeavoring to expand local penetration for its products.

In Chile and Perú existing capacity is also sufficient to meet their local needs.

It is unlikely, therefore, that Bolivia could find a market for asbestos cement products to the Andean subregion. The establishment of facilities to manufacture asbestos cement products would have to be oriented towards the domestic market. Our field work, however, indicated that there exists in Bolivia (Cochabamba) a cement asbestos factory with a capacity of 13,000 tons and there are plans to increase it to 22,000 tons. This plant is using asbestos imported from Canada and mixing it with a limited amount of Bolivian asbestos. We consider it totally adequate to meet all increases in demand over the next few years.

9. Vitreous Table China

Market data on this product area is very sparse and it was difficult to assess whether any opportunities existed for Bolivian industry. It would appear, however, that imports by most countries are at a fairly low level and that there is at least one domestic

manufacturer in each of the Andean countries. The indicated annual demand in Bolivia of about 235 metric tons (600,000 pieces) in Bolivia also implies that only a small percentage of the capacity of a new plant, operating at minimum economic scale, would be utilized. This demand compares with 9,000 tons each in Colombia and in Chile, all supplied by local production.

10. Refractories

Three manufacturing plants for refractory bricks exist in Bolivia, but they are not equipped with modern machinery and the quality of their output is generally not satisfactory for metallurgic uses due to poor heat shock and corrosion resistance characteristics. The combined capacity of the Barbato and SIMSA plants in Cochabamba is reportedly 2,000 bricks per day, or about 2,300 tons a year. However, actual production only reaches about 1,500 tons. The national consumption is presently estimated at about 2,800 tons per year (600,000 bricks), mostly used by Comibol, CBF, YPFB, the railroad companies, and the glass, lime, cement and beer industries. The national demand for refractory bricks is projected at about 3,300 tons in 1971, at about 4,300 tons in 1975, and 5,000 in 1977 assuming a 7.3% growth rate for user industries. The existing industry in Bolivia has sufficient capacity to meet current requirements. If additional facilities for the production of magnesite refractory brick are established in Bolivia, the excess production would have to be sold in external markets.

The market in Perú for refractory bricks is presently about 12,000 tons, mostly supplied by REPSA, who also export to Bolivia. They are part of the Harbison-Walker company and manufacture a wide range of refractories including high alumina, basic magnesite, and chrome bricks. The market in Chile totals about 50,000 tons and is represented by ordinary clay refractories that are presently being imported into Chile but will soon be supplied by a new plant being completed by RECSA. Magnesite and other special refractory producers include Leta-Green (20,000 tons) and RECSA (7,000 tons). Colombian manufacturers currently cannot meet all the country's needs and some imports are taking place. However, a major manufacturer, EREGO, with a current capacity of about 20,000 tons per year is extending facilities and plans to meet domestic demands, and to begin exporting, within three years. The refractories industry in Ecuador is very small and some refractory bricks are being imported. The analysis thus indicates that Chile and Perú have existing industries adequate to supply their local needs. Colombia and Ecuador, on the other hand, are importing from other countries, although the former has plans to expand their existing industry to meet their requirements. It is unlikely that given their market conditions Bolivia could export refractory bricks to the Andean subregion.

It is also not probable that Bolivia has a promising opportunity for the manufacture of magnesite refractory brick for the world market. The biggest and most sophisticated users of this product

around the world prefer to purchase magnesite brick from forms such as Harbeson-Walker and Lota-Green who provide highly technical services as part of their sales effort.

In conclusion, we do not consider the production of refractory bricks in Bolivia for export to the Andean and world markets to be a promising opportunity, at this time.

11. Lime

Bolivian domestic demand for lime is at a low level as the types of industries using lime are not established in the country. For Bolivia to consider this as a potential industry it would have to rely almost entirely on export markets. An examination of market data for other countries shows that the production in each of these is at a high level and that imports are relatively low. A further examination on transportation rates indicates that the f.o.b. plant price of about US$20 per ton would be more than doubled before the lime reaches the Pacific Coast and even consideration of any potential reduction in these freight rates does not make this an economic possibility. Consequently, we do not recognize any potential opportunities for Bolivia in lime production.

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