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Marketing Study of British Columbia's Gypsum in the Pacific Rim Area of North America

Study

Queenstake Resources Ltd.
Vancouver, BC

KING, MURPHY LAVALIN
87-03 51098

Lavalin

FOREWORD

There has been a strong demand for gypsum products throughout 1985/86 and in previous years. There is every indication that this upward trend will continue with the improved economies in the United States and Canada.

Queenstake Resources Ltd. believes that industrial minerals can provide a solid base for future mine development in the Province of British Columbia. An industrial mineral such as gypsum, for which there is a strong demand in the building and construction industry, can provide a growing cash flow for a mining company with numerous benefits to the Province in the areas of employment opportunities, as well as industrial and marketing expansion potential.

In view of this philosophy, and the potential for British Columbia's gypsum in the markets for gypsumboard, cement, agriculture, extenders and fillers, pulp and paper, and other specialty products, Queenstake Resources Ltd. has initiated a study with financial support from the Canada/British Columbia Mineral Development Agreement's participation, on gypsum markets, uses and occurrences with special emphasis on the Pacific Northwest area and British Columbia.

The study was financed by Queenstake Resources Ltd. and the Canada/British Columbia Mineral Development Agreement on a 50:50 basis and was carried out by King, Murphy, Lavalin, Consultants, and Queenstake Resources Ltd., both of Vancouver, British Columbia.

The purpose of this study is to create an in-depth document on gypsum and its role in today's industrial world, and is intended for a newcomer to the industrial mineral business in the Province of British Columbia.

The focus of the study is to research and document the markets for gypsum in the "Pacific Rim" of North America, more specifically, the North American "Pacific Northwest" area, including British Columbia, and to outline the marketing opportunities for British Columbia's gypsum in such market place.

ACKNOWLEDGEMENTS

This study was made possible through financial assistance from the Mineral Resources Division of the British Columbia Ministry of Energy, Mines and Petroleum Resources under the Canada/British Columbia Mineral Development Agreement.

The Mineral Development Agreement provides a mechanism by which the governments of British Columbia and Canada co-ordinate scientific, technological, and market development resources. The objective of the Agreement is to stimulate and diversify exploration, mining, mineral processing and marketing efforts by the private sector, to increase the mineral industry's contribution to the Province's economy.

The cost of this study was borne equally by the Mineral Resources Division, under the Canada/British Columbia Mineral Development Agreement, and Queenstake Resources Ltd.

The study was carried out in joint co-operation with Queenstake Resources Ltd., a publicly-owned Canadian mining company with its Corporate Office in Vancouver, British Columbia, and King, Murphy, Lavalin, Consultants, also with its office in Vancouver, British Columbia.

The authors wish to acknowledge the undivided support of the Mineral Resources Division Geological Branch, especially the helpful guidance of Mr. Greg McKillop, Manager of the Mineral Development Agreement, and the great, enthusiastic support from Mr. Don Sharp, Vice-President, Finance, of Queenstake Resources Ltd., who was instrumental in getting the study started.

SUMMARY

Gypsum is a relatively low-cost, high bulk mineral commodity, generally produced from deposits in close proximity to areas where markets for gypsum exist. Exceptions to this rule occur when crude gypsum is of unusually high quality and when it can be mined and transported at low cost. Such is the case of Mexican and Spanish gypsum currently imported to plants along the North American Pacific Seaboard, including British Columbia.

Gypsum markets experienced exceptionally strong growth in 1983 through 1986, reaching a plateau of high levels, which are forecast to grow steadily between 1.9% to 3.2% well into the 1990's and to the year 2000 respectively.

On a global scale, North America is the major area of consumption and production due to high levels of gypsum products used by the construction industry. The most widespread use of gypsum is in the manufacture of wallboard and other plaster products used in the construction industry.

Gypsum production in Canada is in direct response to demand from the wallboard industries in the United States and domestically. The wallboard industry in both countries is, in turn, tied to demand from the construction industry for residential, commercial, and institutional building projects.

Canadian production of crude gypsum is predominantly from Atlantic provinces, where major deposits have been mined for many years by Canadian firms and Canadian subsidiaries of United States gypsum products manufacturers. The Atlantic region accounts for 75% of the total Canadian gypsum production, and for the majority of exported gypsum, usually over or about 80%.

The producers and consumers of gypsum in British Columbia mine, in part, crude gypsum in the Province but also import crude gypsum for their wallboard and cement plants from Mexico and Spain.

Gypsum production in British Columbia generally accounts for 5.3% of the total Canadian production.

Any future producers of crude gypsum in British Columbia will have to capture a marketshare by being highly competitive in price and gypsum quality, together with a guaranteed long-term supply.

The best opportunity for British Columbia's gypsum is in the supply of crude gypsum to the wallboard and cement plants located in the Vancouver port area and those in Seattle and Tacoma, in Washington State.

It is recommended that potential developers of gypsum deposits in British Columbia undertake an extensive strategic survey of the Pacific Northwest market area. Developers should consider primarily the wallboard and, secondly, the cement market. Efforts should be directed at capturing a part, if not a whole, sector of the imported gypsum supply.

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1. INTRODUCTION

The objective of this study is to develop a marketing scenario for gypsum of British Columbia regarding the existing markets on the Pacific westcoast of the North American continent.

Thorough research preceded examination of markets for gypsum including wallboard, portland cement, agriculture, pulp and paper, extender and fillers, and other specialty markets. The geographical market area or 'Pacific Rim' covered by this study extends from Alaska in the north, to California in the south, and includes non-coastal provinces of Alberta, the Yukon Territory, and the State of Nevada (refer Figure 1).

The study begins with an overview of gypsum providing general knowledge on history, properties, mining and processing, and end-use.

World, North American and domestic production and trade provide a preview to markets for gypsum and factors that affect marketability.

All known occurrences of gypsum in the Pacific Rim of North America are identified. This includes the market area represented in Figure 1 plus the States of Idaho and Montana.

The quality of British Columbia's gypsum deposits is given following a thorough review of specification requirements for end-uses.

Events, trends, and issues in the North American gypsum industry are discussed at length in Section 7. Included is an in depth review of the construction industry and discussions regarding gypsum in agriculture, pulp and paper, and extender and filler markets. Forecasts for construction activities and the total United States and Canadian demands are also provided.

Following a review of the price structure of gypsum, a review of current producers and suppliers of gypsum is detailed to provide a complete picture of supply and demand in the Pacific Rim of North America.

A forecast of the gypsum industry in the Pacific Rim of North America, presented in Section 10, is based on historical trends and industry feed-back. Finally, this study concludes with an assessment of the market opportunities for British Columbia's gypsum in the Pacific Rim of North America. This section provides conclusions to the findings and recommendations for prospective producers.

FIGURE 1

GEOGRAPHICAL MARKET AREA COVERED BY STUDY

2. AN OVERVIEW OF GYPSUM

2.1 HISTORY

Gypsum was used by the earliest civilizations for artistic and ornamental purposes, both as carvings of alabaster and as plaster coats.

Chinese, Assyrians and Greeks used gypsum in carvings and decorations.

It was utilized as mortar by the Egyptians in the construction of pyramids about 3,000 B.C., and later by Romans who consumed small quantities for plaster.

In early Greek times, Theophrastus described the burning of gypsum and the preparation of gypsum plaster.

Gypsum plaster became known as "plaster of paris" after the famous gypsum deposits at Montmartre, a section of Paris, France. It was known in England by its name in the 13th century, but the first record of the manufacture of gypsum plaster in England was during the time of James II (1633 - 1701).

Such early uses of gypsum continued through the middle ages and, late in the 18th century, its use as a fertilizer and soil conditioner became important in France and Germany.

Benjamin Franklin, on a trip through Europe in 1776, observed the practice of using gypsum for soil conditioning and promoted its use as fertilizer in the United States. The growth in demand for agricultural use in the United States was rapid, with supplies coming from France and Nova Scotia in the form of ship ballast.

Calcining of gypsum for use as a plaster in North America began in 1835 in New York. Demand was small until 1885 when a commercial method to retard the setting rate of gypsum plaster was developed and gypsum was used in the portland cement industry as a retarder, controlling the "set" of the cement. Thus, the construction industry became the dominant consumer of gypsum.

The first production of plasterboard was reported in the United States in 1918.

Large-scale use in the construction industry was attained in 1929 when over 92.9 million square meters of lath and wallboard was produced.

In 1968, the United States gypsum industry had 43 firms producing 9.1 million tonnes of crude gypsum.

In 1983, 72% of the gypsum marketed was in the form of prefabricated products.

In the gypsum industry, companies have always integrated their activities from mining, grinding, calcining and manufacturing into vertically structured industrial complex.

2.2 GENERAL PROPERTIES

Gypsum is the most common, naturally occurring, sulphate mineral. It occurs extensively in sedimentary deposits all over the world and is commonly associated with limestone, dolomite, shale, sandstone, marl and clay.

It is normally formed as a chemical precipitate from marine waters of high salinity, may be hydrothermal in origin or may be formed by the natural hydration of anhydrite.

Descriptive properties of gypsum include perfect cleavage in one direction, a hardness of two on the Moh's scale, a specific gravity of 2.3. It is readily soluble in hot hydrochloric acid, slightly soluble in water, and its colour ranges from white, gray, yellowish, and brownish. Such colour variations are due to contained impurities.

Most gypsum used commercially is massive fine to medium-grained material known as rock gypsum.

A chemical property of particular importance for gypsum use, is the loss of three-fourths of the combined water of hydration when heated to 160 deg.C to form a hemihydrate ($CaSO_4 \cdot 1/2\ H_2O$), a process known as calcination. The calcined material, when mixed with water, assumes a plastic state which can be readily molded to designed shapes and then "sets" to a rigid condition due to a recombination of water with the hemihydrate to produce original ($CaSO_4 \cdot 2H_2O$) gypsum.

Gypsum calcined to the hemihydrate is synonymously referred to as calcined gypsum, plaster of paris, or gypsum hemihydrate.

Calcination at a higher temperature (482 deg.C - 704 deg.C) results in a product called dead-burned gypsum or sometimes anhydrite since its chemical composition is the same as that of the mineral anhydrite, which does not react readily with water like the hemidydrate.

2.3 GYPSUM ROCK CHARACTERISTICS

2.3.1 Chemistry

Gypsum is the dihydrate form of calcium sulphate with the chemical formula $CaSO_4 \cdot 2H_2O$. It is usually found in close association with anhydrite ($CaSO_4$) and very seldom does a calcium sulphate deposit consist exclusively of one mineral or the other. However, anhydrite has very minor economic use.

Calcium sulphate is one of the principal constituents of evaporate deposits and, when pure, has the following composition.

	Lime (CaO)	Sulfur Trioxide (SO_3)	Combined Water (H_2O)
Gypsum	32.6%	46.5%	20.9%
Anhydrite	41.2%	58.8%	0.0%

Deposits of pure gypsum or of pure anhydrite which are large enough to be commercially mined have never been discovered because of the metastable relationship between the two minerals and the presence of impurities such as calcium or magnesium carbonates, chlorides, other sulphate minerals, clay minerals, or silica. Most mine production of gypsum will range between 85% and 95% pure. It is often used as mined, although in certain cases some form of mineral beneficiation is deployed to upgrade the product.

2.3.2 Mineralogy

Gypsum ($CaSO_4 \cdot 2H_2O$) is the common calcium sulphate mineral in rock outcrops. It is easily distinguished from anhydrite by its inferior hardness (2.0 vs. 3.0 to 3.5) and lower specific gravity (2.2 to 2.4 vs. 2.7 to 3.0).

Most gypsum is white to grayish white, although the impurities frequently determine the colour. Petrographically, most gypsum rock is granoblastic. In commercial deposits, there is usually a correlation between grain size and calcium sulphate content. This is due to secondary crystallization around impurities, resulting in coarser texture than in deposits having no impurities and a resulting higher sulphate content.

Bassonite ($CaSO_4 \cdot 1/2H_2O$) is a distinct intermediate phase between gypsum and anhydrite, identifiable only by X-ray diffraction or petrographic techniques. It is metastable under ordinary conditions, its occurrence in amounts of under 1% is thought to be widespread in calcium sulphate deposits.

Anhydrite ($CaSO_4$) is not often found in outcrops because of rapid conversion to gypsum and relatively high solubility (0.2 g per 100 g H_2O), especially in wet climates. It can be found outcropping on steep dipping slopes where hydrated material is continuously removed. Anhydrite is mostly light to bluish-grey in colour. Its texture varies from granoblastic to feltylath crystal aggregate.

Alabaster is a compact, very fine-grained variety of gypsum rock, prized by sculptors for its uniform workability and it is occasionally found within commercial deposits.

Satin Spar is fibrous gypsum composed of needle shaped crystals in orientation to the c-axis. It occurs widely as a fracture filling.

Selenite is composed of large euhedral gypsum crystals with large cleavages. It is formed in fluid-filled spaces or in deformed host material, sometimes mistakenly identified as mica.

Satin Spar and Selenite are of little or no economic importance.

Gypsite is a mixture of clay, sand and other earthy materials and small gypsum crystals.

2.4 GYPSUM SUBSTITUTES

Other construction materials may be substituted for gypsum, especially lime, lumber, cement, steel or masonry.

However, there is no practical substitute for gypsum in portland cement.

By-product gypsum is presently substituting for crude gypsum in special agricultural applications and may, in time, be utilized in place of crude gypsum for cement set-retarding and in the manufacture of wallboard.

2.4.1 By-Product Gypsum

By-product gypsum or synthetic gypsum is generated in flue gas desulphurization and by a variety of chemical processes such as manufacturing of phosphoric acid, hydrofluoric acid, citric acid, and titanium dioxide from ilmenite.

It is a relatively fine wet material which comes out of chemical processes as a filter cake or sludge settled in tanks or ponds after desulphurization in thermal power plants. Such by-product gypsum has both higher impurity and moisture levels than crude gypsum.

Because of its chemical and physical characteristics, by-product gypsum needs further beneficiation in order to make it a useful product.

Only small amounts of by-product gypsum are reclaimed for limited uses in agricultural and wallboard purposes. An operating wallboard plant in northeast Texas uses by-product gypsum for a portion of its raw material requirements in wallboard manufacturing. A widespread use of by-product gypsum in wallboard may have a long-term impact on the crude gypsum supply to a wallboard manufacturing industry. Some phosphogypsum, derived from phosphoric acid production, is used in the manufacture of cement and sulphuric acid using OSW-Krupp process. In 1983, two plants were operating, one in Austria and one in the Republic of South Africa.

FCS apparently has a process to use by-product gypsum from phosphoric acid manufacture, which would produce sulphuric acid. FCS would have another product from its process, co-generated energy, that it can sell to local power companies. Also, there is a ready market for sulphuric acid in Florida. This may result in an increase in the use of by-product gypsum without affecting the existing markets for primary mined gypsum.

An estimated 25% of world gypsum consumption is reclaimed from by-product gypsum, mainly in Japan, and the Federal Republic of Germany.

Recent experiments in France have produced paper with 20% phosphogypsum content as filler.

In Canada and the United States, vast quantities of by-product gypsum are produced but are not reclaimed in any significant portion that would upset the market of crude gypsum.

It is not yet economical to subject by-product gypsum to the treatment required to make it suitable for major uses such as plaster or wallboard in spite of limited use in a Texas wallboard plant.

However, minor quantities of by-product gypsum, in the form of phosphogypsum, are being sold as a soil conditioner in California, and the southeastern States. Such phosphogypsum is used because the type and amount of impurities are not detrimental to soils and a low-cost processing treatment makes it economical to put by-product gypsum into a useful form.

By-product gypsum is used in Japan for both portland cement retarder and wallboard. It is a unique situation applicable to Japan only, because of Japan's well developed industry and a shortage of natural gypsum. The high cost of importing crude gypsum, in this case, makes it more economical to utilize treated by-product gypsum.

Additional use of by-product gypsum has been started in Australia and some European countries where economics favour its use.

By-product gypsum produced from the acidulation of phosphate rock in phosphate fertilizer manufacture, has not been utilized in Canada despite available technology from Europe and Japan.

Studies conducted on phosphogypsum indicate that a potential hazard exists in the use of phosphogypsum produced from sedimentary phosphate rock which contains appreciable amounts of uranium and radium.

Co-operative research programs have been conducted to determine the suitability of fluorogypsum, derived from the manufacture of hydrofluoric acid, from Allied Chemical Canada Ltd.'s Amherstburg, Ontario cement plant and at St. Lawrence Cement Inc.'s plant in Clarkson, Ontario.

Those uses do not have any affect on the North American natural crude gypsum marketplace.

2.5 EXPLORATION, MINING AND PROCESSING OF GYPSUM

2.5.1 Exploration

Gypsum deposits are found in many but not all geological era, but they are most common in the Permian era.

By exploring sedimentary rocks, stratigraphic sequence and lithology, evaporite environments conducive to gypsum formation can be delineated by geologists. Once the evaporite rocks are indicated, outcrops and geological formations are examined through available historical data, sampling and assaying. Gypsum extent in lateral and vertical extensions is mapped and followed up by core drilling.

Core drilling is usually carried out by BX (65 mm) or larger size core in order to provide an adequate amount of material for sampling and permit good core recovery.

In some instances, geophysical methods can be used to determine the depth of overburden.

Geochemical methods are rarely applicable to calcium sulphate, although heavy concentrations of sulphate may serve as a useful clue. In a few instances, differences in plant species may indicate changes in rock types that can aid in surface mapping.

Most massive gypsum deposits are found as large lenticular, stratified ore bodies that were formed by evaporation of sea water in basins that have one or more restricted openings to the sea. Such basins may range in size from tens to hundreds of kilometers.

Gypsum deposits are explored in order to determine the physical and chemical nature of the ore body. It is also necessary to determine a minable thickness and the ratio of gypsum to anhydrite. The depth of hydration is important in mining because the presence of a few percent of anhydrite may render gypsum unusable for manufacture of plaster. Thus, samples are always obtained from drill cores and outcrops for analysis of anhydrite content.

2.5.2 Mining

Deposits near the surface are mined by open pit mining methods, developing multiple benches, stripping the overburden and constructing access and transportation routes.

Underground ore bodies are developed by sinking shafts or driving adits with room and pillar mining methods.

Most of the gypsum production comes from open pit mines. Mining is mechanized with large capacity equipment and the stripping ratio is normally 1.6 to 1.

Equipment employed consists of cable or hydraulic shovels and/or front-end loaders. Rotary or auger drills are used for drilling and explosives are used in rock breaking. Haulage is carried out by off-highway trucks.

Quality control is most important in the mining sequence and may often result in a higher unit cost of mining.

In underground mines, room and pillar design is based upon the rock conditions and strata control of each mine. Recovery of total gypsum rock from underground mining is only 65% to 80% versus open pit mining of 95% to 100%. Auger drilling is standard practice and loading is done with gathering arm type loaders, front-end loaders or load-haul dump units. Underground haulage is done by rail or by diesel-powered trucks. In some cases, conveyor belts are used.

In general, mining of gypsum is highly mechanized, although the limited volume of production, in some cases (500 to 1500 tonnes per day), restricts the size of equipment which can be utilized economically. The physical environment of most gypsum deposits favours good working and safety conditions which is the major factor contributing to low cost gypsum mining.

2.5.3 Processing

The processing of crude gypsum, like most natural resources, depends on the end-use. Most crude gypsum mined is used as run-of-mine material, but some low grade ore is upgraded by log-washing, sink-float process, and selective crushing and screening, both dry and wet. In such beneficiations, dolomite, limestone, clay, shale, and even anhydrite, are removed to produce a commercial and salable gypsum product of 80% or more purity.

Gypsum, for use in cement, is crushed to minus 1-1/2 inch plus 3/8 inch fractions.

For agricultural or filler use, the gypsum is pulverized to 100 mesh or finer.

Typical gypsum rock processing is shown on the generalized flow sheet (Figure 2) and can be divided into three basic steps:

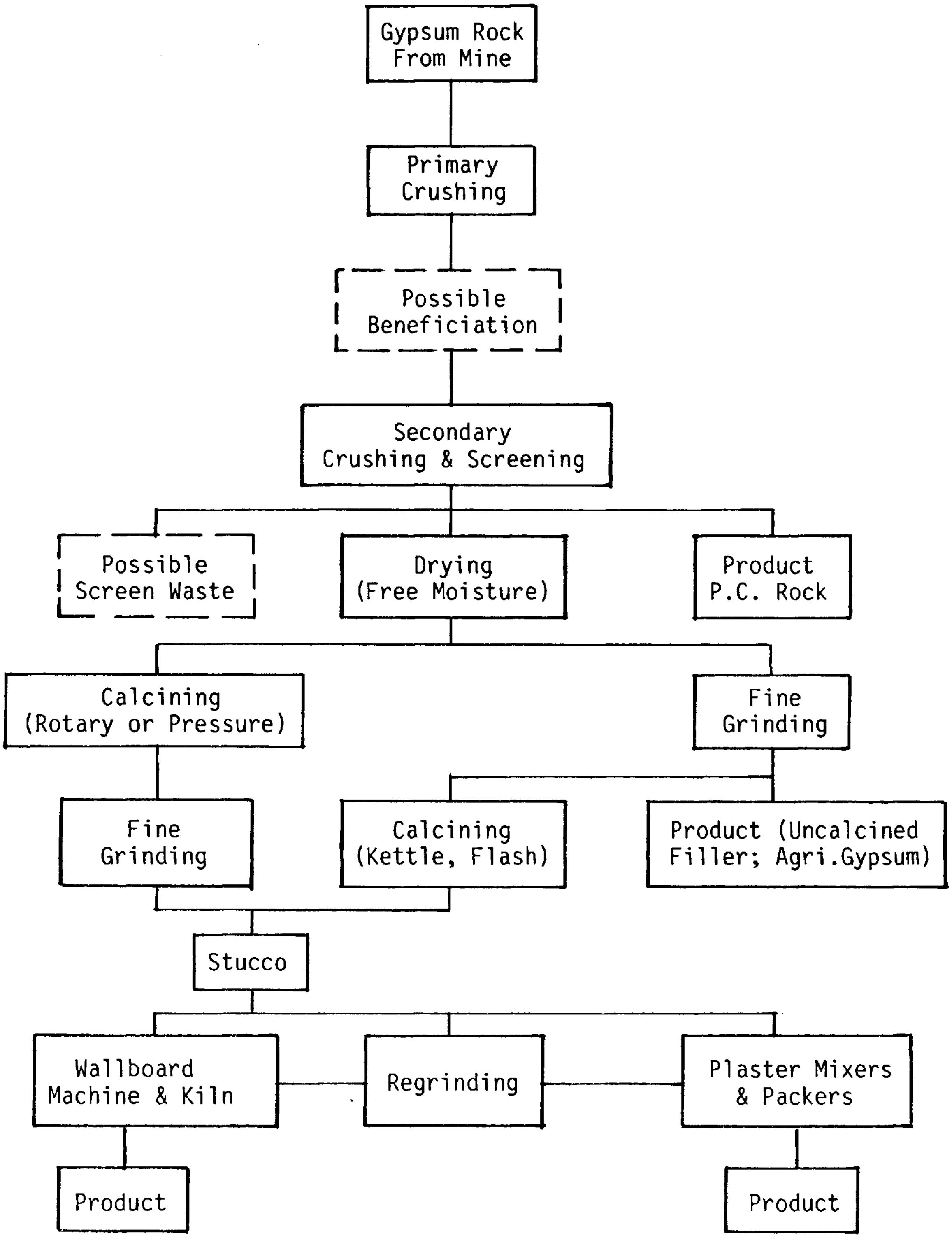
1. Rock preparation, which starts with gypsum rock coming from the mine for primary crushing. Primary crushing is accomplished by jaw, gyratory or impact crushers. Secondary crushing further comminutes the rock through hammer mills, or cone-type crushers.

   Fine grinding of both uncalcined and calcined gypsum is generally accomplished by air-swept roller mills or high energy impact mills plus air classifiers.

   Both primary and secondary crushing are usually conducted with vibrating screens in order to reduce the generation of ultra-fines.

   Depending on the amount of free moisture in the rock, drying may or may not be used either before or after the secondary crushing stage. However, a drying step is often added to increase free-flowing characteristics of crushed gypsum which is difficult to handle at minus 4 inches if wet.

FIGURE 2
GENERALIZED FLOW DIAGRAM OF GYPSUM PROCESSING



Source: Industrial Minerals and Rocks, 1983

The use of the beneficiation techniques is becoming more common as the quality of final product is greatly improved to meet the stringent specifications of the marketplace.

The most common form of beneficiation is classification of particle size by screening and/or air separation.

Washing is used in cases where the need for a white colour exists.

The use of heavy media sink-float separation is used at only one operation in Canada and one in the United States.

2. Calcining is the processing step applied to gypsum in order to transform it into hemihydrate or anhydrous forms. Calcining produces four calcined products on a commercial basis: the two forms of hemihydrate (alpha and beta): soluble anhydrite; and an insoluble (dead-burned) anhydrite. All hemihydrates are known as "stucco" within the industry, although the form "plaster of paris" is often used too. The alpha form of hemihydrate is more stable than the beta form and has a slower rate of strength development. This is a disadvantage in uses for stucco, but rehydrated alpha hemihydrate produces denser and stronger plaster which is advantageous in other uses.

   A soluble anhydrite in the calcining process is produced after the "first boil", as a "second boil" known as "second settle" at about 204 deg.C, at which point, almost all of the water of crystallization is removed. The "first boil" is achieved at a temperature of 177 deg.C, called "first settle" stucco.

   Second settle stucco (soluble anhydrite) differs from first settle stucco in that it has less plasticity. After rehydration, second settle stucco will make a product with greater density and strength.

Calcining is accomplished in a vessel called a kettle, of which the basic design originated in 1870. It is a cylindrical steel vessel with a height greater than its diameter which is enclosed in a refractory shell. For kettle calcining, gypsum is usually ground to a fineness of 90% minus 100 mesh.

The largest utilization of calcined gypsum is in the manufacture of wallboard and the formation of plasters for building markets.

Insoluble anhydrite or dead-burned gypsum is produced in beehive kilns, rotary calciners or flash calciners using higher temperatures (up to 482 deg.C), than is required for the other calcining method described before.

The resulting product is anhydrous calcium sulphate which does not rehydrate and is the least soluble of calcium sulphate forms.

3. Formulation and manufacturing follows calcining because the direct product of gypsum calcining is almost never used without further processing such as grinding, blending with additives, rehydrating and casting it into blocks or wallboard.

The earliest attempts at formulating calcined gypsum to improve its utility were the addition of fibres and/or aggregates.

Today, retarders are made from organic compounds and several different materials can be used. These are formulated and manufactured by the major gypsum producing companies for their own use. Retarders are usually glue and starch. Accelerators used in the process are metal or synthetic salts, such as potassium sulphate or gypsum itself.

Finely ground raw gypsum or rehydrated stucco are both used to accelerate the "set" of stucco for the manufacture of wallboard.

The type of stucco and the characteristics of the plaster being formulated can be controlled by other additives mixed in precise proportions prior to bagging. Much research has been carried out by companies to determine proper formulas to be used.

Plasters premixed with sand, expanded perlite, or exfoliated vermiculite aggregates are offered for the building trades, and a wide range of formulated plasters for industrial use are also available on the marketplace.

2.6 END-USES OF GYPSUM

Gypsum is one of the most common non-structural building materials largely used for interior walls, partitions, ceilings, either as plaster or in prefabricated products.

The development of wallboard revolutionized the building industry. Type-X gypsum wallboard, in the 1950's, became the most commonly sought construction material for high rise apartments and office buildings because of its lesser unit weight and excellent fire resistant characteristics.

Crude gypsum is marketed for use in cement, agriculture, and occasionally as a filler.

In portland cement, gypsum is used to retard the setting of concrete.

In agriculture gypsum is used to neutralize alkaline and saline soil and provide sulphur for maximum fertilizer utilization.

Plaster is reground calcined gypsum modified with retarders or accelerators, containing various binders. The plaster is packed in bags and sold under various trade names.

Prefabricated products include lath, veneer base, tile, sheathing and wallboard.

Keenes cement is made by converting crushed gypsum to insoluble anhydrite by calcining at temperature of 700 deg.C in rotary kilns. The ground calcined gypsum, mixed with a set accelerator, makes a harder and stronger plaster product than ordinary gypsum plaster.

Crude gypsum is also used, to a limited extent, as a filler in paint and paper manufacture and as a substitute for salt cake in glass manufacture; however, those uses are not yet wide-spread in the North American marketplace.

The largest end-use for gypsum today is in the manufacture of wallboard. Some 75% of the gypsum consumed in Canada and the United States is used for wallboard. Wallboard, in its simplest form, is a thin slab of gypsum made by casting a water slurry of stucco in a paper "envelope" which consists of a gypsum core with specially prepared paper bonded to both sides and the edges. This product is made on high speed, highly automated machines to a wide range of precise specifications.

The bond between the paper and the gypsum core is produced by the growth of gypsum crystals locking themselves into the fibre of the paper as the stucco is rehydrated, instead of the use of adhesives. Extensive research and development work was spent on the proper formulation of gypsum slurry used in wallboard, but, basically, it consists of beta hemihydrate, an accelerator, fibres, starch and a framing agent with stucco making up 95% of the materials used prior to mixing with water. Figure 3 shows a general process flow diagram from a wallboard plant.

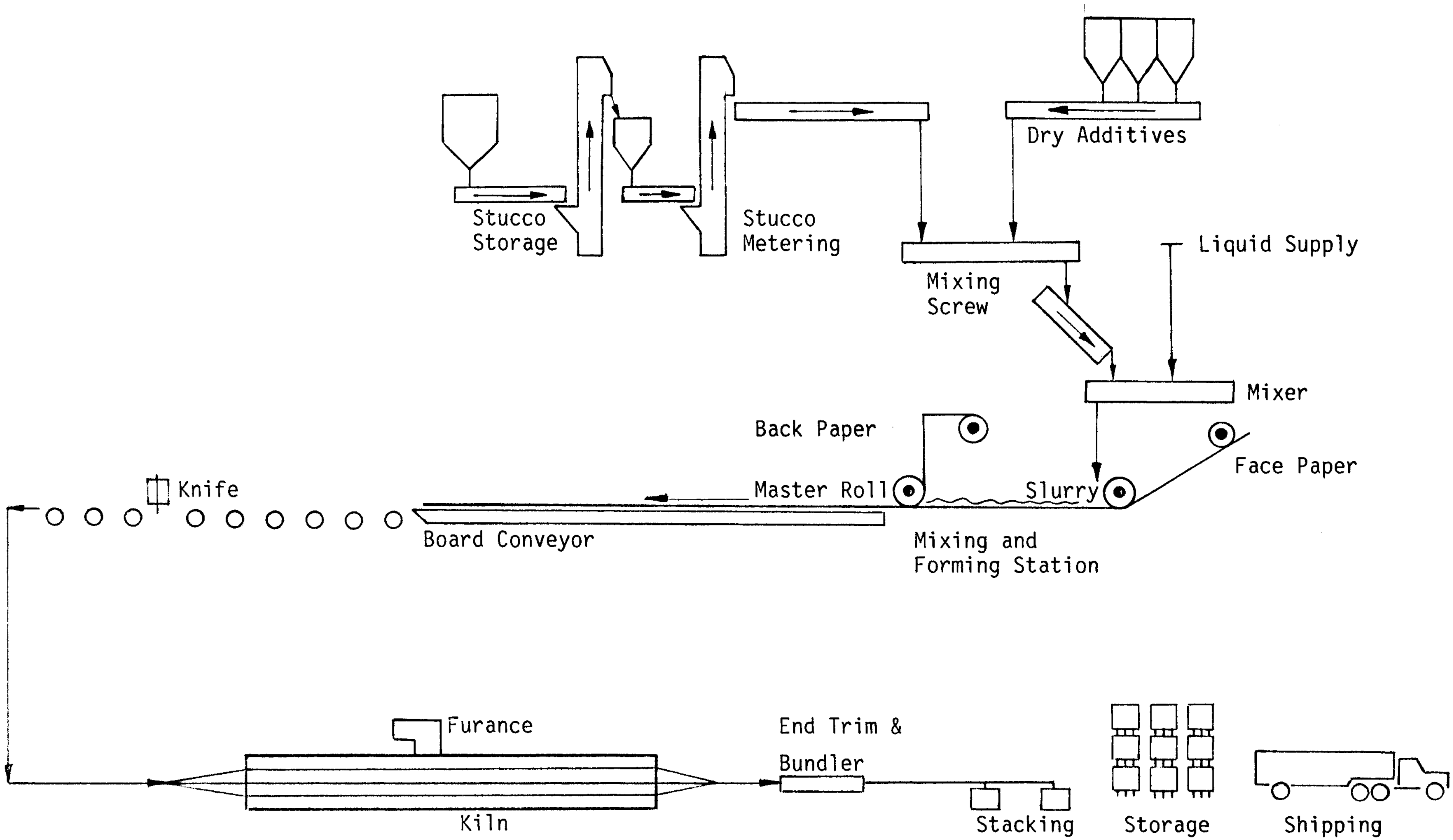
The boards are cut with a revolving knife into appropriate lengths and slowly pass through a drying kiln.

The most popular size of wallboard is 1.2 m x 2.4 m x 12.77 mm (4 ft. x 8 ft. x 1/2 in.) thick, but a wide variety is produced and made available on the market.

Gypsum sheathing is made in the same basic way as wallboard except that asphalt-impregnated paper is used.

FIGURE 3

SIMPLIFIED FLOW DIAGRAM FOR COMPLETE SMALL GYPSUM PLANT



Source: Industrial Minerals and Rocks, 1983

3. GYPSUM PRODUCTION AND TRADE

3.1 WORLD PRODUCTION AND TRADE

Gypsum is known to be produced in some 72 countries in the world with over 80% of recorded production coming from 15 of those countries. They are located in Europe, North America, the Middle East, and Australia. Table 1 provides a picture of the world production of gypsum for the years 1984, 1985, and 1986.

The production and use of gypsum in any particular country is usually a function of the methods of construction rather than the frequency of gypsum deposits. For instance, in countries where masonry products dominate in construction use, the need for gypsum-based building materials is low. The calcining of gypsum for wallboard, building plaster, and industrial plasters, is almost exclusively limited to Europe, U.S.S.R., Canada, U.S.A., and Japan.

In the North American gypsum industry, the United States is both the largest producer and the largest importer of gypsum rock. In 1985, the United States imported 9.2 million tonnes of gypsum, chiefly from three sources: Canada (70%), Mexico (20%), and Spain (8%).

Canada is the second-largest producer of gypsum and is the largest exporter with the majority going to the United States in crude gypsum form.

In Europe, France is both the largest producer and exporter of gypsum and, like Canadian exports, the gypsum is in crude rock form. Other leading exporters in Europe include Spain, Poland, and West Germany.

TABLE 1

ESTIMATES OF THE WORLD PRODUCTION OF GYPSUM

Producer	Quantity (000's Tonnes)		
	1984	1985	1986E
United States	12,990	13,359	14,787
Australia	1,996	998	1,179
Canada	8,709	8,437	8,891
France	5,443	5,443	5,534
Germany, Federal Republic of	2,177	1,996	2,268
Iran	4,990	4,990	4,808
Italy	1,270	1,270	1,361
Japan	6,078	6,260	6,169
Mexico	2,994	2,812	3,175
Spain	5,625	5,262	5,443
United Kingdom	2,994	3,075	3,084
Other Market Economy Countries	12,060	12,440	12,610
China	4,808	4,990	4,990
Poland	1,297	1,352	1,270
Romania	1,814	1,542	1,633
U.S.S.R.	4,899	4,899	4,899
Other Centrally Planned Economies	1,777	1,816	1,814
World Total[1]	81,922	80,940	83,916

1. Data may not add to totals shown because of independent rounding

E. Estimated

Source: United States Bureau of Mines, Mineral Commodity Summary, 1986 and 1987

It can be said that the world trade in gypsum is limited due to the cost of transportation from the mine to the market areas. Although deposits local to the market may not be as pure, or as easily accessible as remote deposits, the cost of freight negates cost effectiveness.

3.2 UNITED STATES PRODUCTION AND TRADE

Available data on crude gypsum output in the United States for 1985 was 13.1 million tonnes, valued at $ 120 million U.S. This was an increase of 1% in tonnage compared with that of 1984.

Leading States in crude gypsum production were Texas, Oklahoma, Michigan, Iowa, California, and Nevada, which together accounted for 65% of the total. 42 companies mined crude gypsum at 69 mine sites in 22 States. Gypsum was calcined by 14 companies at 71 plants in 30 States, producing 15.2 million tonnes of calcined gypsum. Also, 725,760 tonnes of by-product gypsum were produced. Some 8.4 million tonnes were imported. Thus, a total 1985 consumption of crude gypsum totalled 22.2 million tonnes.

Available capacity of operating gypsum board plants in the United States at year-end 1985, was 2.0 billion square meters per year. Sales of wallboard were 1.8 billion square meters, representing a capacity utilization of 89%.

3.3 CANADIAN PRODUCTION AND TRADE

Gypsum mining in Canada is active in six of the ten provinces and the gypsum industry contributes to the economy of nine provinces. Therefore, it can be said that the gypsum industry is one of the most important industrial mineral industries in the country. Presently, Canada ranks as the second-largest gypsum producer in the world and, at the same time, holds the position of being the largest exporter of crude gypsum.

TABLE 2

UNITED STATES GYPSUM PRODUCTION/CONSUMPTION AND WALLBOARD PRODUCTION 1981-1985

	1981	1982	1983	1984	1985
			(000's Tonnes)		
Production					
. Crude Gypsum	10,430	9,560	11,688	12,990	13,064
. By-Product Gypsum	631	632	689	708	726
. Calcined Gypsum	10,602	10,200	12,612	14,016	15,150
Imports of Crude Gypsum	7,215	6,095	7,286	8,078	8,437
Consumption of Crude Gypsum	17,634	15,874	20,603	21,973	22,226
Prefabricated Products (Wallboard)	1,278	1,216	1,557	1,701	1,774

Source: United States Bureau of Mines

Table 3 gives an indication of the distribution of gypsum production by province for the years 1978 through 1986.

It shows a decline of gypsum production in British Columbia from 1980 to 1982 by almost 50%. Thereafter, the production is maintained at about the same level accounting for 5.3% of the total Canadian gypsum production in the period from 1984 to 1986.

From Table 3, it is also obvious that gypsum production in Ontario is on the steady increase accounting for some 13% to 15% of the total Canadian production.

Nova Scotia is the leading producer of gypsum accounting for 73% of the total Canadian production.

Rating the provinces according to production, British Columbia comes fourth after Nova Scotia, Ontario, and Newfoundland. Manitoba and New Brunswick come after British Columbia.

Table 4 provides a complete picture of gypsum movement in and out of Canada for the years 1982 through 1985.

It is quite apparent that the majority of Canadian crude gypsum exports are to the United States. Table 5 summarizes statistics on United States-bound gypsum from Canada from 1983 through 1985.

3.4 BRITISH COLUMBIA PRODUCTION AND TRADE

In British Columbia, gypsum is presently produced from three mines, two are located in the southeastern part of the Province and a third is located in the Okanagan District. Domtar Construction Materials produces an estimated 120,000 tonnes annually from its Lussier River deposit, which is railed to the company's wallboard plant in Alberta. The other producer in the southeast is Westroc Industries which annually mines between 300,000 and

TABLE 3

CANADIAN GYPSUM PRODUCTION BY PROVINCE, 1978 - 1986

Province	Quantity (000's Tonnes)								
	1978	1979	1980	1981[1]	1982	1983	1984	1985	1986P
Nova Scotia	5,935	6,031	5,273		4,480	5,397	5,476	6,165	6,164
Ontario	793	820	918		574	907	1,183	1,114	1,309
British Columbia	795	766	800		415	460	412	454	459
Newfoundland	865	858	711		409	553	531	518	449
Manitoba	195	137	145		109	190	173	216	162
New Brunswick	53	55	46		-	-	-	-	-
Total	8,636	8,667	7,893	7,025	5,987	7,507	7,775	8,447	8,542

1. Distribution for 1981 not found

P. Preliminary

Sources: Energy Mines and Resources Canada; Statistics Canada

TABLE 4

CANADIAN GYPSUM PRODUCTION AND TRADE, 1982 - 1985

	1982		1983		1984		1985	
	(Tonnes)	($000)	(Tonnes)	($000)	(Tonnes)	($000)	(Tonnes)	($000)
Production[1] (Shipment) Crude Gypsum								
. Nova Scotia	4,480,000	30,500	5,397,000	37,064	5,476,643	38,373	6,165,000	47,268
. Ontario	574,000	5,350	907,000	11,354	1,183,193	12,712	1,114,000	15,056
. British Columbia	415,000	5,468	460,000	4,917	411,829	4,076	454,000	4,695
. Newfoundland	409,000	3,284	553,000	3,731	530,761	4,549	518,000	6,096
. Manitoba	109,000	2,006	190,000	2,231	172,656	1,848	196,000	1,997
Total[2]	5,987,000	46,608	7,507,000	59,297	7,775,082	61,562	8,447,000	75,076
Imports, Crude Gypsum							(Jan.-Sept)	
. Spain	-	-	-	-	83,914	2,876	10,839	362
. Mexico	83,102	2,806	97,444	2,949	43,449	1,385	65,270	2,162
. United States	10,742	264	3,479	128	4,357	110	13,582	412
. Hong Kong	-	-	16	1	89	3	57	2
Total[2]	93,844	3,069	100,939	3,078	131,809	4,374	89,748	2,937
Plaster of Paris and Wall Plaster								
. United States	18,627	3,654	24,717	4,630	21,383	4,529	19,386	4,609
. France	175	34	-	-	2-	4	-	-
. United Kingdom	15	3	-	-	6	2	-	-
. Italy	16	3	-	-	4	2	-	-
. Other Countries	93	30	11	3	12	1	5	2
Total[2]	18,926	3,724	24,728	4,633	21,427	4,538	19,391	4,611
Gypsum Lath, Wallboard and Basic Products	(Square Meters)		(Square Meters)		(Square Meters)		(Square Meters)	
. United States	349,862	643	485,614	722	276,466	649	1,298,573	2,047
. Other Countries	-	-	5,942	8	-	-	14,238	40
Total[2]	349,862	643	491,556	730	276,466	649	1,312,811	2,087
Total Imports Gypsum and Gypsum Products		7,436		8,441		9,561		9,635
Export, Crude Gypsum	(Tonnes)		(Tonnes)		(Tonnes)		(Tonnes)	
. United States	4,775,780	28,716	5,186,529	33,331	6,195,225	48,579	4,349,531	36,334
. Other Countries	-	-	503	6	29,349	217	12,416	78
Total[2]	4,775,780	28,716	5,187,032	33,337	6,224,574	48,796	4,361,947	36,412
Gypsum Lath, Wallboard and Basic Products	(Square Meters)		(Square Meters)		(Square Meters)		(Square Meters)	
. United States	13,808,620	12,898	25,836,909	28,435	71,692,814	104,978	33,645,225	62,708
. Saudi Arabia	224,507	576	195,192	189	171,165	341	44,592	121
. Algeria	31,639	46	45,970	65	140,050	230	51,971	68
. Bermuda	111,219	139	154,418	485	60,853	189	50,091	74
. Other Countries	209,016	261	247,445	345	218,724	366	290,569	640
Total[2]	14,385,001	13,920	26,479,934	29,519	72,283,606	106,104	34,082,448	63,611
Total Exports of Gypsum and Gypsum Products		42,636		62,856		154,900		100,023

1. Totals do not include gypsum produced by or shipped for use by Canadian portland cement producers
2. Totals may not add due to rounding

Sources: Energy, Mines & Resources, Canada; Statistics Canada

TABLE 5

CANADIAN GYPSUM PRODUCTION AND EXPORTS TO THE UNITED STATES

	Quantity (000,000's Tonnes)		
	1983	1984	1985
Production	7.51	7.78	8.45
Export to United States	4.97	5.45	5.90
% Export	66.20	70.10	69.60

Sources: United States Bureau of Mines; and Statistics Canada

500,000 tonnes of gypsum from the company's Windermere operation. This product is then railed to the company's wallboard manufacturing plant located on Annacis Island in New Westminster and other users such as Trurock and Genstar Cement plant.

In Falkland, Canada Cement Lafarge operates a mine from June to September each year, shipping crude gypsum/anhydrite mixture to its cement plant in Kamloops.

The O'Connor River gypsum deposit in the northwestern part of the province, close to the Alaska border is presently being evaluated as a possible source of crude gypsum for the markets in the Vancouver and Tacoma areas. Part of this market is presently supplied by gypsum imports from Mexico and Spain.

4. MARKETS FOR GYPSUM

4.1 PRODUCT GROUPS

Gypsum products, depending on their processing method and/or end-use, are generally divided into several categories and groups.

The market for gypsum is mainly contained in three major groups:

1. Construction - gypsum used directly as a construction or building material;
2. Industrial - gypsum used in the manufacture or processing of other materials;
3. Agricultural - gypsum used as a soil conditioner.

4.1.1 Construction Group

Gypsum products used in the building and construction industry do not constitute structural components, but are used as covering and finishing material.

The largest market for gypsum in this group is in wood frame buildings.

The most valuable characteristic of gypsum in the manufacture of construction materials is its fire-proofing quality. Gypsum is noncombustible, a property that has its basis in the combined water content of the product. When stucco is rehydrated to make covering material, it reverts back to dihydrate form and when the heat of fire hits a plaster wall, it begins to lose its combined water which retards the transmission of heat and fire. This aspect is especially important when wood framing is used in buildings.

Another major advantage of gypsum for the construction industry is its versatility and its economy of application. Plaster can be used in many forms as well as wallboard, cast block or tile. Utilizing different calcining methods and additives, physical properties of finished gypsum products can be varied widely to meet different and often stringent specifications.

The use of gypsum partition and roof tile has declined in recent years, but these products are still preferred for some applications.

Poured gypsum roof decks are usually specified for industrial buildings. In such applications, a specially formulated plaster slurry is pumped in place over a wallboard base to provide a completely fire-proof roof. Other construction applications include water resistant sheathing, plaster baseboard and fire-proofing building steel.

4.1.2 Industrial Group

Gypsum, in this category, can be divided into calcined, anhydrous and an uncalcined gypsum product.

The industrial segment of the gypsum industry is well developed in the United States, but markets are widely scattered geographically over the continent. The industrial group contains segments with many product lines being specialized, and customers demand tens or hundreds of tonnes of a product rather than thousands of tonnes.

The largest use for calcined gypsum by industry groups is in the manufacture of sanitary ware, pottery, metal casting and decorative objects.

Molding plaster is produced of high purity 95% gypsum and is marketed on the basis of its water demand, strength, white colour, setting time and tightly controlled expansion and contraction qualities. It can be made from either alpha or beta hemihydrate or a combination of the two.

Casting plaster is used by many industries. A highly specialized material producing a setting time in only three to four minutes is used in dental and orthopedic work.

Another industrial use is as a cementing agent in the well drilling industry, particularly oil and gas. A cementing agent is made of low consistency alpha hemihydrate and is an effective sealant for porous and cavernous rock strata. Gypsum, in such application, may be mixed with other cement-base materials.

A small, but seemingly growing, use of high density and high strength plasters is in the maintenance of floors for quick patching, and high-use surfaces such as highways and airport runways, because they do not have to be closed down for conventional repairs. In such applications, gypsum can be mixed with other cementitious materials.

Anhydrous gypsum, made from "second settle" stucco without water of crystallization often called "soluble anhydrite", is used as a desiccant in commercial applications, due to its ability to attract water.

A finely ground soluble anhydrite is also used as a carrier for certain insecticides which must remain dry to maintain their effectiveness.

A dead-burned gypsum is used for industrial filler applications and for the manufacture of Keenes cement. Keenes cement is a generic name for dead-burned gypsum which, by the use of additives, can be made to set and harden after being mixed with water.

Uncalcined industrial gypsum is raw or crude gypsum sometimes intermixed with anhydrite which is used in the cement industry as a retarder, because calcium sulphate controls the setting time of portland cement.

Terra alba, a high purity finely ground gypsum at 95% gypsum and minus 325 mesh size, with very white colour, is used as an inert filler or diluent and a source of soluble and biologically available calcium.

Glass batch gypsum is uncalcined gypsum ground and sized to the fineness of sand and is used in the manufacture of container glass.

4.1.3 Agricultural Group

The oldest use of gypsum on the North American continent is as a soil conditioner.

Land plaster can be produced from gypsum or anhydrite in an air-swept mill to a required fineness of 75% to 95% passing 100 mesh.

In a few western states, particularly California, gypsite is sold in large quantities for soil fertilizer.

When gypsum is applied to soil, it is for these purposes:

- o breaking up compacted clays, increasing porosity and aiding in drainage;
- o supplying soluble calcium for crops and quickly available sulphate sulphur:
- o neutralizing sodium compounds in alkali soils and connecting high sodium irrigation waters;
- o improving availability and utilization of nitrogen;
- o cleaning up muddy farm ponds and stimulating soil micro organisms.

In other agricultural-related applications, apart from soil, ground gypsum is added as an ingredient in formulating feed for beef cattle, dairy cows, and sheep.

Today, however, gypsum application in agriculture has a lesser use. It is basically substituted by calcium carbonate and limestone and used in applications where a source of calcium is needed.

A phosphogypsum is used as agricultural fertilizer in California.

4.2 NORTH AMERICAN MARKET REVIEW

4.2.1 United States Market

In 1986, output of crude gypsum was 14.7 million tonnes valued at $ 126 million U.S., an increase of 11% compared to 1985 output.

Leading states in gypsum production are Texas, Michigan, Iowa, Oklahoma, California, and Nevada. They account for 85% of the total crude gypsum production output.

By-product gypsum, generated in flue gas desulphurization, phosphate rock acidulation and other chemical processes, is not reclaimed, except for a minor amount for agricultural and wallboard purposes.

Imports of crude gypsum to the United States in 1986 came from Canada (69%), Mexico (20%); Spain (10%); and Others (1%).

During 1986, the gypsum industry followed the high activity of the construction and housing industry. The housing industry experienced 1.8 million housing starts in 1986 compared to 1.7 million in 1985. The sales of gypsum wallboard in 1986 increased by 8%

from 1985 reported sales. Total wallboard shipments for 1986 were 2.0 million square metres.

A new wallboard plant in Oklahoma made several expansions and improvements to the existing line operation, which brought the gypsum board capacity in the states up to 2.1 billion square metres per year.

This increased capacity was sufficient to meet increased demand without developing shortages.

The average price of wallboard in twenty cities increased slightly from the beginning of 1986 to year-end.

Shipments of imported wallboard from Italy and Spain increased, while the imports of wallboard from Canada were 82.7 million square metres, an increase of 13% over imports in 1985.

Wallboard exports from the United States to 33 different countries were 3.4 million square metres.

Current wallboard production capacity in the United States is roughly equal to demand.

The major firms manufacturing gypsum wallboard in the United States are United States Gypsum with 22 plants, National Gypsum with 18 plants, Georgia Pacific with 9 plants, and Genstar Building Materials with 5 plants.

The United States consumes 26% of the world's production of crude gypsum to produce calcined gypsum in prefabricated products at 96%, and industrial and building plaster at 4%.

Leading sales region for prefabricated products are the South Atlantic, West South Central, Pacific, and East North Central.

Table 6 indicates the distribution of gypsum products sold or used in the United States by preduct greup and use in 1985.

4.2.2 Canadian Market

The United States is the only export market for Canadian crude gypsum and gypsum wallboard production. Thus, gypsum production and sales in Canada are in direct response to demand from the wallboard industries domestically and in the United States.

There are four large wallboard manufacturers in Canada. Two are Canadian-owned, Domtar and Genstar, while the other two are foreign-owned, Canadian Gypsum, owned by U.S. Gypsum, and Westroc Industries, owned by British Plaster Boards Ltd.

Canadian production and markets are mainly concentrated in Atlantic Canada, principally in Nova Scotia and Newfoundland, where major deposits have been mined for many years. The Atlantic region accounts for more than 75% of Canadian gypsum production and for approximately 70% of exported gypsum. In 1984, 80% of the total Canadian crude gypsum production was exported from the Atlantic region, mainly to the United States.

Shipments of crude gypsum from the gypsum quarries in the Atlantic region are delivered to wallboard plants and portland cement plants in Quebec, Ontario, and the United States. New Brunswick gypsum production is used locally by a cement producer.

Gypsum production in Ontario is used on-site, except that of the Westroc Ihdustries Limited mine in Dumbar which ships gypsum to a wallboard plant in Mississauga.

The prairie markets are served by gypsum production in Manitoba and British Columbia.

TABLE 6

GYPSUM PRODUCTS[1] SOLD OR USED IN THE UNITED STATES, 1985

	Quantity (000's Tonnes)	%	Value ($000 U.S.)	%
Construction				
. Building Plaster	279	1.2	35,075	1.5
. Prefabricated Products[2]	17,774	74.2	2,266,348	93.7
Sub-Total	18,053	75.4	2,301,423	95.2
Industrial				
. Portland Cement	4,129	17.2	38,623	1.6
. Industrial Plaster	495	2.1	55,426	2.3
. Fillers and Miscellaneous	128	0.5	6,448	0.3
Sub-Total	4,752	19.8	100,497	4.2
Agriculture[3]	1,145	4.8	16,377	0.6
TOTAL	**23,950**	**100.0**	**2,418,296**	**100.0**

1. Includes domestic, imported and by-product gypsum.
2. Includes weight of paper, metal and other materials and some by-product gypsum.
3. Includes most of 755,315 tonnes of by-product gypsum.

Source: United States Bureau of Mines, Mineral Yearbook, 1985

Imports from Mexico, Spain, and the United States, are used by wallboard and cement plants situated in the British Columbia Pacific coastal region.

The Canada-United States trade, including gypsum wallboard, is usually in truck loads of 18 to 23 tonnes for delivery to warehousing or job-sites.

Recently, due to high demand requiring larger shipments, transportation by rail has become quite common.

The present structure of the Canadian gypsum industry is not likely to change. Building materials plants have sufficient capacities to meet the short-term regional demands for gypsum production and also to supply some of the high demand from the United States.

4.2.3 Pacific Northwest Market

Most of British Columbia's products are supplied by gypsum from the province and imports from Mexico and Spain.

Gypsum production from Windermere, Lussier River, and Falkland, are used by wallboard and cement manufacturers.

Imports from Mexico and Spain have been made feasible because of high demand, stringent quality specifications which are met by Mexican and Spanish gypsum, and a low cost bulk shipping.

Low production costs and competitive shipping arrangements play a major role in placing such imported gypsum on Canadian markets. Some of the Spanish gypsum, due to its competitiveness, is backhauled to the United States ports.

Table 7 gives an overview of gypsum board products for 1986 in the United States Pacific market, excluding British Columbia.

4.3 FACTORS AFFECTING MARKETABILITY

The objective of this section is to give the reader an introduction to the major factors that hinder the marketing of gypsum in the industrial world. Each factor listed below is dealt with in greater detail in subsequent sections as it would apply to British Columbia.

1. Transportation

   The most important factor that will determine the value of one gypsum deposit against another is the cost of transportation from the mine to the market area. "Place Value" is the term used to describe the market potential of a deposit based on its relative market location.

   A good example of "place value" is witnessed in the United States where, historically, over one-third of its gypsum needs are imported to coastal markets because exporting countries have deposits near deep water and, therefore, shipping costs to consumers are lower than from inland United States sites.

2. Grade

   An assessment of the grade of a gypsum deposit is required to compete with a deposit serving the same market. More specifically, impurities must be analyzed to determine if beneficiation is required and, if so, if it is economically feasible.

TABLE 7

GYPSUM BOARD PRODUCTS IN THE UNITED STATES PACIFIC REGION, 1986

	Quantity (000's Square Meters)	%
Lath	830	0.26
Veneer Base	2,211	0.69
Sheathing	2,800	0.87
Regular Gypsum Board	164,145	51.08
Type-X Gypsum Board	133,183	41.44
Predecorated Board	1,335	0.41
5/16 Mobile Home Board	7,103	2.21
Water/Moisture Resistant Board	9,752	3.03
Total[1]	321,361	100.00

1. Data may not add to totals shown due to independent rounding

Source: United States Department of Interior, Bureau of Mines

3. Construction Industry

In the recent past, the production of gypsum has related closely to the building construction industry. Wallboard is used extensively in both residential and non-residential buildings and cement consumption is substantial in commercial building developments.

Although housing starts are a good indicator of demand for gypsum wallboard, the increasing use in retrofit applications must be taken into account as well.

4. Captive Market

Because crude gypsum is a relatively low-cost commodity, it is economical to be a vertically-integrated mine and manufacturing company. The manufacturing facilities of these integrated companies are usually located near the particular market. These large, well-financed companies, have captivated a market.

Vertical integration has caused strong competition in the technologically advanced countries including the United States, Canada, Western Europe and Japan.

5. By-Product Gypsum

The threat of synthetic or by-product gypsum being used in substantial quantities as a substitute for natural gypsum has existed for some time. By-product gypsum is used in Japan for both portland cement retarder and wallboard. Closer to home, synthetic gypsum is being used as a soil conditioner in California, while a wallboard plant in Texas uses minor quantities in its manufacturing process.

By-product gypsum has not yet made a significant impact on the gypsum industry, mainly because of added costs to remove or reduce impurities to make it acceptable. However, it should be noted that increasing volumes of by-product gypsum are being stockpiled in the United States and quantities produced each year are enough to cover annual imports.

6. Seasonal Operations

Climatic conditions or seasonal changes, existing at a gypsum deposit, may hinder or halt mining for significant periods of time and deprive intended markets. Being unable to deliver could cause unfavourable consequences.

7. Currency Exchange Rates

Like many commodities destined for foreign markets, the volume of gypsum product exports are highly dependent upon the currency exchange rate. This is of particular importance to Canadians where, historically, exports of gypsum to the United States have far exceeded internal consumption. For example, shipments of gypsum wallboard to the United States rose from 26 million square metres in 1983 to 723 million square metres in 1984. The 1984 shipments represent approximately 35% of the total Canadian capacity.

5. OCCURRENCES OF GYPSUM IN THE PACIFIC RIM OF NORTH AMERICA

The common geological origin of economic gypsum deposits is from evaporation and concentration of marine deposits in dry climates, where the calcium sulphate minerals are deposited by precipitation from aqueous solutions.

Most commercial gypsum deposits were formed by the action of surface and ground water on anhydrite. Hydration of anhydrite into gypsum is found at depths ranging from 0 to some 61 meters below the surface.

Many gypsum deposits are Quaternary in age, although gypsum, as found, is produced from rock of different ages. The abundance of gypsum of Quaternary age is due to the recent and continuing conversion of anhydrite to gypsum.

Gypsum that is utilized in commercial applications contains some 10% to 15% of impurities. Some deposits may be 80% to 95% pure gypsum.

The impurities that are tolerated depend on: the type of impurity, the product being manufactured, and the competitive situation.

Details of occurrences and minable deposits within the North American Pacific Rim including Idaho and Montana follow.

5.1 UNITED STATES OCCURRENCES

5.1.1 Alaska

There are three notable occurrences of gypsum in Alaska. Two have seen production in the past. The Iyoukeen Cove property on eastern Chichagof Island, 96 km west of Juneau, was discovered in 1902. By 1926, some 454,000 tonnes of gypsum were mined from underground by the Pacific Coast Gypsum Company. Gypsum mined was high quality "blue gypsum", but technical and economic factors forced the mine closure.

Another deposit, known as Sheep Mountain, lies some 160 km northeast of Anchorage. The Sheep Mountain property consists of irregular pods of gypsum and anhydrite in hydrothermal zones associated with porphyry copper-type mineralization. A small quantity of gypsum with kaolin clay was exploited for production of bricks in the Anchorage area during the 1950's. A third notable gypsum occurrence in Alaska is a deposit in the northern Wrangell Mountains at Baultoff Mountain. This deposit consists of pods of high-grade gypsum associated with a high temperature alteration zone in a porphyry copper system.

Locations of these deposits are noted on the accompanying map.

5.1.2 Washington

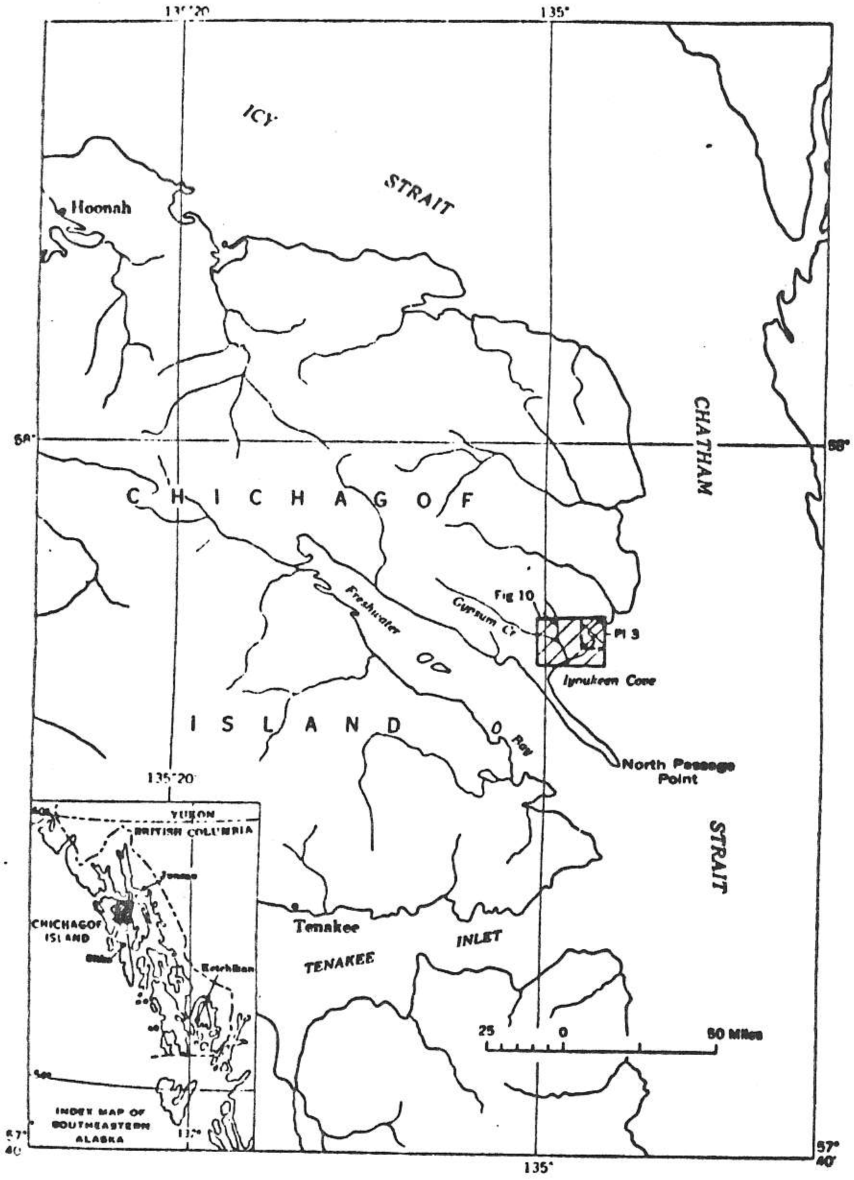
Crude gypsum is mined by Agro Minerals Inc. at Poison Lake, Okanogan County, the only gypsum mine in the State of Washington. Agro Minerals Inc. has been mining gypsum at Poison Lake since 1948. The granulated gypsum product is used mainly as a soil conditioner.

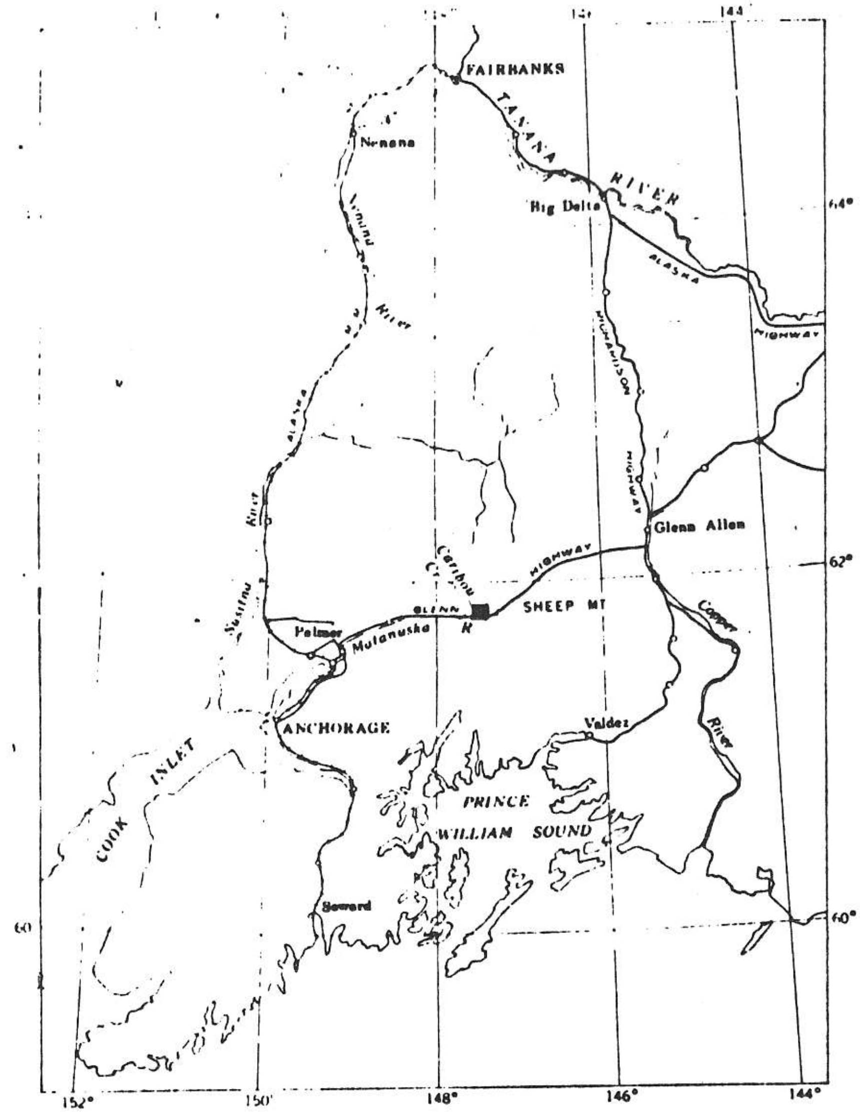
Calcined gypsum is produced by Norwest Gypsum Inc. in Seattle, and by Domtar Gypsum America Inc. at Tacoma, in Pierce County. Gypsum for calcining in these plants is shipped from other deposits outside the State of Washington. Other noted occurrences of gypsum in the state are:

1. Orting, Pierce County - Grade too low for current economic use.

2. Tacoma, Pierce County - Gypsum showing a short distance from Tacoma, near Orting.

GYPSUM OCCURRENCES IN ALASKA





Source: U.S. Bureau of Mines

3. Mount Adams, Yakima County - Small quantity, inaccessible.

4. Ahtanum Creek, Yakima County - Unknown reserves.

5. Squaw Saddle, Yakima County - Sub-economic grade of gypsum.

6. Minnie Prospect, Okanogan County - Noncommercial quality.

7. Lenton Flat, Okanogan County - Sufficient quality and quantity to warrant market investigation.

8. Bitter Lake, Okanogan County - Small amount mined in the past.

9. Jenny Prospect, Ferry County - Commercial extraction impractical.

Locations of these deposits are noted on the accompanying map.

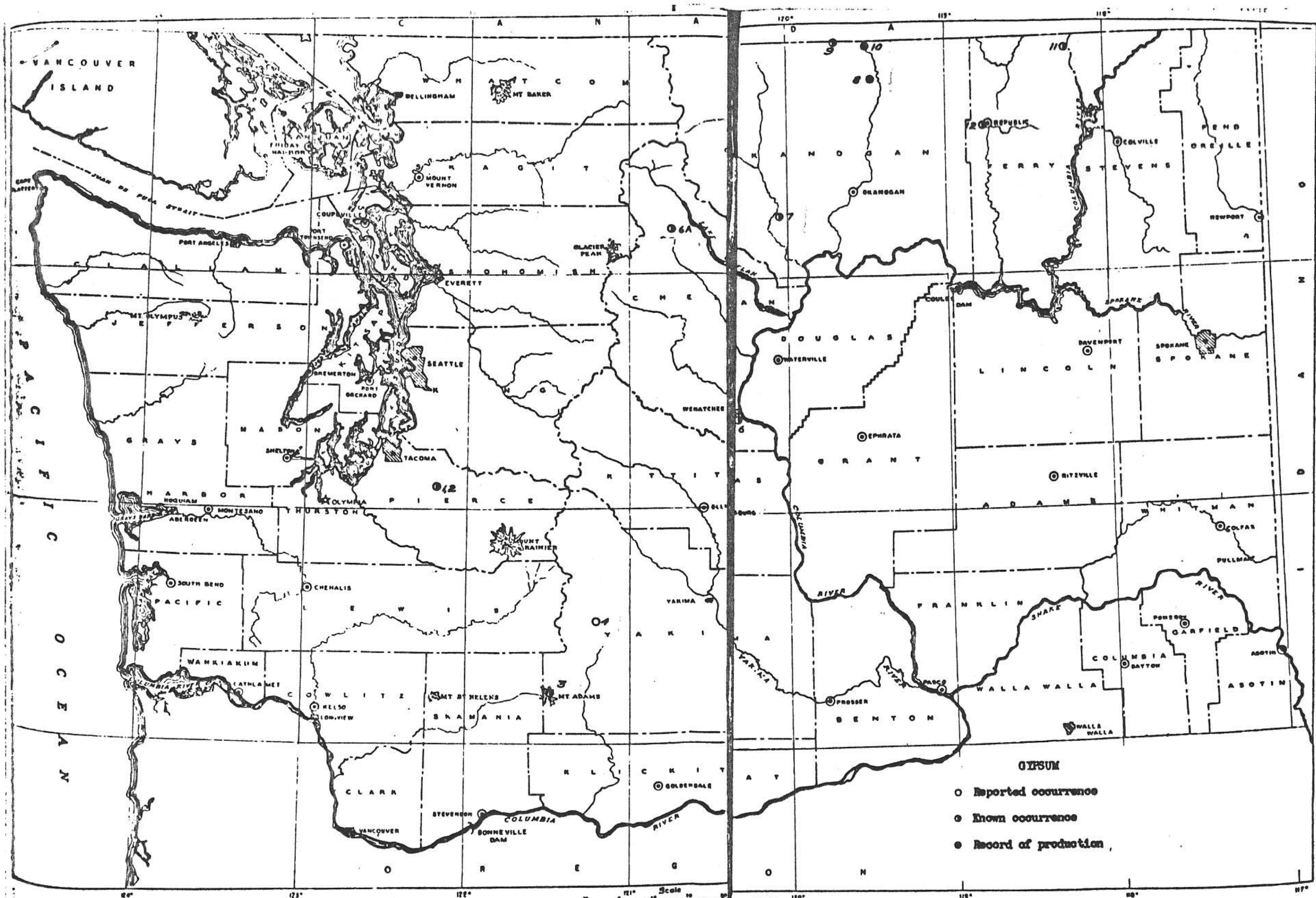
5.1.3 Oregon

Gypsum stringers and clusters of gypsum crystals are known through many localities in Oregon. Gypsum also occurs as a gangue material in many of the vein-type deposits. Some of these localities provide specimens of selenite and satin spar, but none of these occurrences appear to be of any commercial value for development. These localities are found in western and southwestern Oregon, as shown on the accompanying map.

The only gypsum deposit where gypsum was mined between 1896 to 1926, is located near the Snake River, a few kilometers north of Huntington, Baker County. This deposit is not currently mined and future exploitation seems unlikely for this deposit.

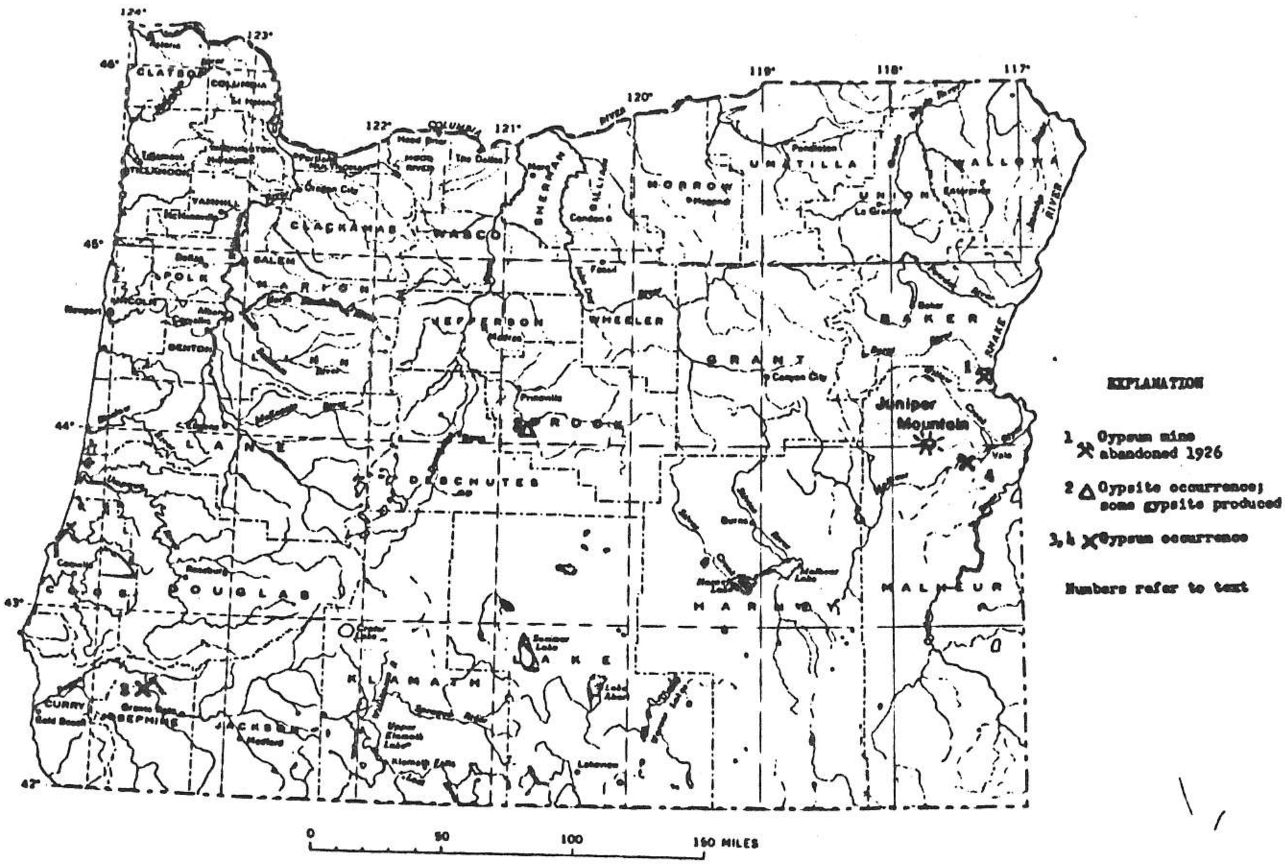
The locations are noted on the accompanying map.

GYPSUM OCCURRENCES IN WASHINGTON



Source: U.S. Bureau of Mines

GYPSUM OCCURRENCES IN OREGON



Gypsum, gypsite and anhydrite in Oregon.

Source: U.S. Bureau of Mines

5.1.4 California

Potentially minable deposits of gypsum in California are known to exist in only one geological environment, lake beds resulting from the total evaporation of inland bodies of water.

A substantial part of finished gypsum products, manufactured in California, use imported gypsum mined elsewhere. Crude gypsum is imported to California from Nevada, San Marcos Island, Baja California, and Mexico.

Noted occurrences of gypsum in California can be listed as follows:

1. Fish Creek Mountain Deposit, Imperial and San Diego Counties - This is the largest gypsum mine in the United States. The mined gypsum rock is hauled by narrow-gauge railway some 40 km to the United States Gypsum plant at Plaster City.

2. Quatal Canyon, Ventura County - Gypsum occurs in the eastern part of Cuyama Valley. The quarry is located in the northwest flank of a northwest-trending anticline. The gypsum here is a brown-coloured aggregate of grains which does not affect quality of the gypsum.

3. Little Maria Mountains Deposits, Riverside County - The gypsum occurs with crystalline limestone, quartzite and green schistose rocks. Only one deposit is being worked at the present time. The quarry, formerly operated by Utah Construction Company, was acquired by the Fannin interests to form the Fannin Superior Gypsum Co., Inc. The mill is located at Inco Siding on the Santa Fe Railway.

4. Palen Mountains Deposit, Riverside County - A large deposit of gypsum is known to exist in the Palen Mountains, including marble, quartz, and their thermally metamorphosed derivatives. In spite of exploration and development activities in the region, no mining of gypsum has been attempted.

5. Riverside Mountains Deposit, Riverside County - A large deposit of pre-Tertiary gypsum occurs on the east face of the Riverside Mountains, 6.4 km south of Vidal. Development work has been done for an underground mine consisting of short tunnels and test pits. Relief in the region is extreme and road construction is difficult.

6. Clark Mountain Area, San Bernardino County - Undeveloped deposits of gypsum occur north of Clark Mountain.

7. China Ranch Deposit, Inyo County - Gypsum is exposed along China Ranch Road. Underground mining methods have been used on this deposit.

8. Cuddy Canyon Deposit, Kern County - A gypsum deposit 3.2 km west of Frasier Park, on the south-side of Cuddy Canyon, has been developed by an inclined shaft.

9. Avawatz Mountains Deposit, San Bernardino County - Gypsum, salt and selenite beds occur here in a belt of folded and faulted Tertiary beds that are exposed in the northern foothills of the Avawatz Mountains.

10. Bristol Lake, San Bernardino County - This is the most important source of playa gypsum. The playa is filled with brine saturated fine sediments covered by a hard, salt-crusted surface.

11. Danby Lake, San Bernardino County - Another playa gypsum deposit along the northeastern margin of the lake.

Locations of these deposits are noted on the accompanying map.

5.1.5 Nevada

In 1984, Nevada produced 1,081,400 tonnes of crude gypsum from the Empire, Adams, Apex, and Blue Diamond deposits. Three of these operations produced calcined gypsum which was used in the manufacture of wallboard. The output of the fourth mine was used in the manufacture of cement.

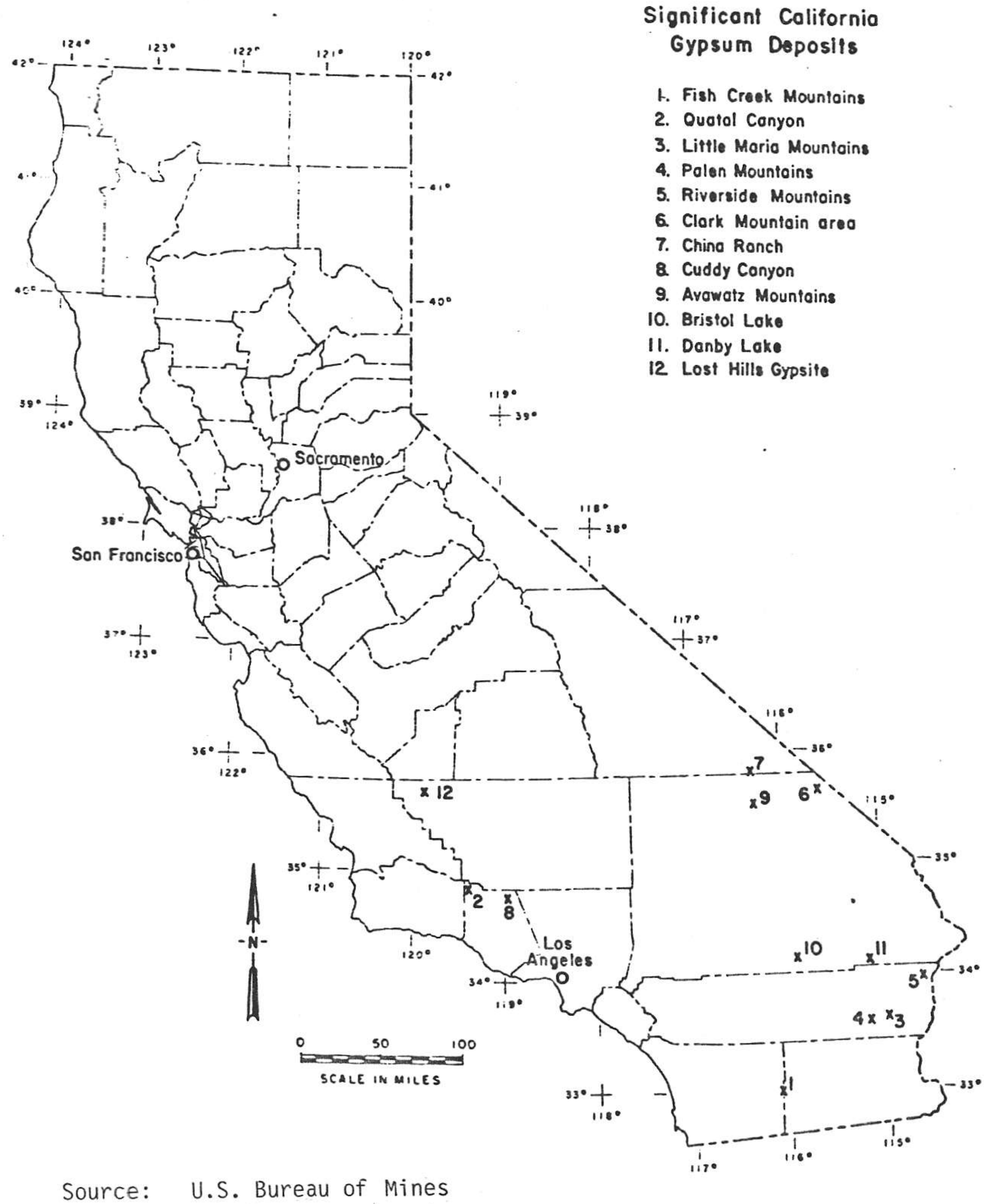
There are 26 listed gypsum deposits in Nevada and a total of 20 occurrences of bedded gypsum. Of the known deposits, 10 are in the western one-third of the state, and the other 16 are in Clark and southern Lincoln Counties.

Nevada ranked as the sixth largest producer of gypsum in 1984 and has an important role in gypsum supply to California.

Deposits and occurrences of gypsum in Nevada are listed as follows:

1. Empire, Pershing County - Most of the gypsum is white, fine grained, and non-friable, purity of gypsum content varies from 25% to 95%. Mining is carried out by open pit methods. The deposit is located in the western part of the Selenite Range. The crushed gypsum is hauled to the plant at Empire, in Weshoe County, some 10 km away. The property is developed by United States Gypsum Co. Most of the mine output is calcined and used for the manufacture of wallboard at Empire and Fremont, California. Patented claims in the area are owned by United States Gypsum Co., Domtar Gypsum Inc., and National Gypsum Co.

GYPSUM OCCURRENCES IN CALIFORNIA



Source: U.S. Bureau of Mines

2. North Lovelock, Pershing County - Located on the west side of the West Humboldt Range, gypsum is white, friable to firm, with minor impurities of quartz, mica, and montmorillonite. Gypsum was mined by a small open pit, several adits and a few test pits. Three patented claims owned by United States Gypsum Co. cover the area of the deposit.

3. Lovelock, Pershing County - Gypsum consists of a medium grey crust, several centimeters thick, and is devoid of vegetation. The gypsum material is white, friable, in the variable amounts of light-grey harder rock.

   It is situtated on the west side of the West Humboldt Range. Some adits, trenching and road building were carried out on the property. The claims are owned by Pacific Coast Building Products Inc., and the United States Gypsum Co. United States Gypsum Co. drilled in 1940 and the area owned by Pacific Building Products was drilled in 1984. Small production was carried out in the past.

4. Crystal Placer, Pershing County - Gypsum is indistinctly bedded, white to grey in colour, friable and locally iron stained. It is located in the West Humboldt Range east of Lovelock. The deposit is inactive today. Some production was carried out by open pit mining in the past few years.

5. Muttlebury Canyon, Pershing County - Gypsum is white to light olive-grey, fine grained, friable, and fairly uniform. The deposit is located in West Humboldt Range east of Lovelock. Minor past production totalled less than 1,810 tonnes. The land is owned by South Pacific Co.

6. Corn Beef, Pershing County - Gypsum is snow-white, sugary and friable. It is located in the northwestern part of the

Stillwater Range. It was explored by a few shallow trenches and cuts. There was no past production.

7. Adams, Lyon County - Gypsum with anhydrite bedded deposit was developed by open pit mining. Gypsum supply is shipped to two California cement plants and one cement plant in Nevada. It is located on the southwestern flank of the Virginia Range about 2 km northwest of Mound House.

8. Ludwig, Lyon County - Gypsum is white to light olive-grey, sugary to compact, and fairly pure. It was developed by an irregular open pit. The mine operated from 1911 to 1930. Gypsum was shipped to a plaster mill at Reno. Later, plaster was produced on the property. The mine is located on the west edge of the Singatse Range.

9. Regan, Mineral County - Gypsum is uniform, white to light grey, fine-grained to sugary and of good quality. The area was mined in the 1930's to 1940's. It was briefly active in 1983. It is located on the West Wassuk Range.

10. White Queen, Lincoln County - Gypsum is fine grained, friable and porous. The area was explored by shallow cuts and drill holes. There has been no production. It is located in the southern part of Tule Springs Hill.

11. Bunkerville Ridge, Clark County - Gypsum is white, massive, fine-grained, and friable. There has not been any past production. Minor exploration was done by trenching. The deposit is located near the edge of the Virgin Mountains.

12. White Star No. 2, Clark County - Gypsum is laminated to thin-bedded, white to greyish orange-pink in colour. Surface workings consist of three open pits. Underground work was

done by inclined open stopes. The deposit is located on the west flank of Weiser Ridge.

13. Anderson, Clark County - Gypsum is of good quality, white, fine-grained, and friable. The site was explored by a few shallow prospects, pits, and an adit. There has been no past production. It is located in the North Muddy Mountains, northwest of Overton.

14. Apex (PABCO), Clark County - Gypsum was formed in a marine environment and is of coarse grain size. The area has been continuously mined since 1959 when PABCO Products Inc. built a washing plant. The washed product was shipped to plants in the Los Angeles and San Francisco Bay areas. A wallboard plant was completed on the property in 1965. In 1984, the operation began supplying the Bay area with calcined gypsum. Gypsum of 92% to 95% purity is produced through the washing plant. The location is east of Sunrise Mountain, about 24 km east of Las Vegas.

15. Blue Diamond, Clark County - Gypsum is of good quality, white, fine-grained, and non-friable. The crude gypsum is produced by Genstar Building Materials Co. All production is by open pit. Reserves are large. The location is in the vicinity of Blue Diamond Hill, southwest of Las Vegas.

16. Wechech Basin, Clark County - Gypsum is impure, crudely bedded, and yellowish-grey to pale orange in colour. This site was explored by a few shallow trenches and test pits. There has been no past production. It is located in the Wechech Basin, south of the Virgin Mountains.

17. White Eagle, Clark County - Gypsum occurs with dolomite and dark reddish-brown claystone. Gypsum is abundant in this rock and is estimated to be 30 m thick. This site was mined

by open pit methods between 1938 and 1956. The location is in the Rainbow Gardens, east of Las Vegas.

The State of Nevada has an abundance of known and mined deposits, as well as numerous occurrences as shown on the accompanying maps. Table 8A shows chemical analyses of gypsum in some deposits throughout the State of Nevada.

5.1.5 Idaho

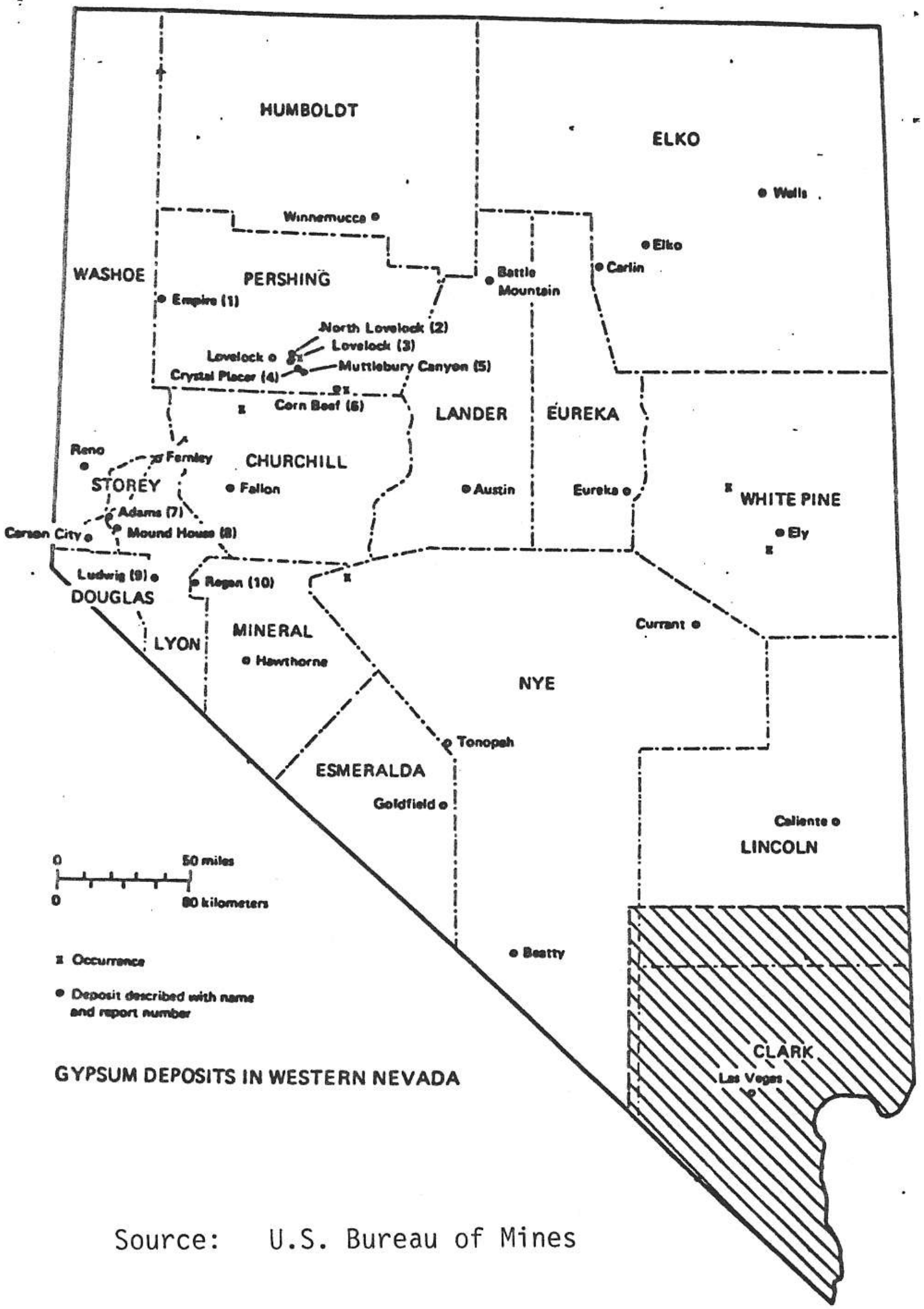
Gypsum is found in three widely scattered areas, Bear Lake County, Lemhi County, and Washington County. None of these deposits are large and the only ones that have been worked are in Washington County, where no more than 4,850 tonnes of gypsum have been produced.

Because of their small size and the impurities contained in the gypsum, small amounts of gypsum are expected to be produced from these deposits for local use as an agricultural mineral.

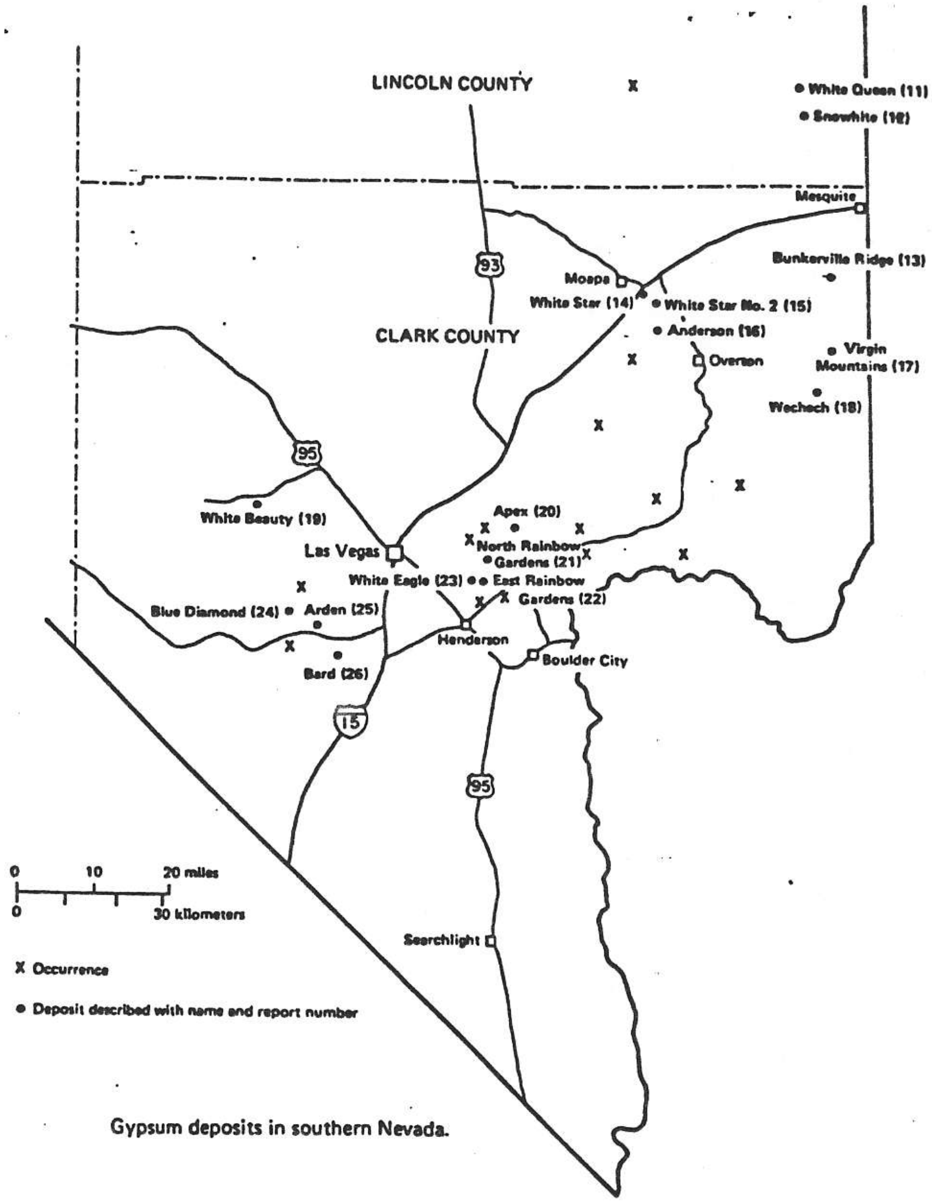
Gypsum occurs some 5.6 km east of Montpelier, Bear Lake County in rocks of the Wells Formation of Pennsylvanian age. The gypsum is in bedded deposits about 305 metres above U.S. Highway 89. The gypsum ranges in thickness of 1.2 metres to 6 metres. It is white, sugary and, in places, pure. An analysis shows 88% gypsum content, although the majority of the deposit is less pure. The deposit is not readily accessible and is too small, except for a soil conditioner used locally.

Small gypsum deposits are reported in Lemhi County. These deposits are each less than 30 metres in length and vary from 1.5 metres to 4.6 metres in width. The gypsum appears to be deposited by hot springs in a fault zone that cuts limestone rock. This gypsum is mixed with calcarious fault gouge and breccia and is too impure to be used commercially.

GYPSUM OCCURRENCES IN NEVADA



GYPSUM DEPOSITS IN WESTERN NEVADA



Gypsum deposits in southern Nevada.

Source: U.S. Bureau of Mines

TABLE 8A

CHEMICAL ANALYSIS OF SOME NEVADA GYPSUM

%	Lovelock	North Lovelock	Corn Beef	Regan	Apex	Blue Diamond	Wechech Basin	White Queen	White Eagle
SiO_2	1.54	1.13	1.43	0.38	9.43	0.33	5.35	0.87	1.53
Al_2O_3	0.37	0.21	0.30	0.02	3.94	0.03	0.63	0.03	0.15
Fe_2O_3	0.14	0.06	0.53	0.03	0.22	0.01	0.16	0.02	0.08
CaO	38.0	34.7	32.8	31.8	27.7	33.4	30.5	32.3	31.6
MgO	0.18	0.12	0.54	0.26	5.47	0.03	0.77	0.19	4.92
Na_2O	0.10	0.16	0.23	0.12	0.69	0.02	0.18	0.06	0.05
K_2O	0.13	0.08	0.08	0.06	0.68	0.02	0.45	0.04	0.15
SO_3	33.5	41.1	44.6	46.4	29.4	48.1	43.2	46.3	36.5
CO_2	12.2	5.30	2.28	0.88	9.20	0.02	0.62	0.99	10.4
H_2O+	10.4	13.3	12.7	17.6	8.90	10.8	13.1	16.2	10.7
H_2O-	3.59	3.15	5.34	2.05	4.30	7.59	4.67	3.40	4.11
Total	100.15	99.31	100.83	99.60	99.93	100.35	99.63	100.40	100.19
Gypsum[1]	72	88	96	100	63	103	93	99	78

1. Calculated by formula SO_3 x 2.146

Source: Nevada Bureau of Mines and Geology 1986

The most extensive and accessible gypsum deposits are in Washington County. These include deposits along the Snake River about 48 km north of Weiser, a deposit of unknown extent near Mineral and a reported occurrence at Iron Mountain.

In the Snake deposits, gypsum is just above river level at the bottom of a steep canyon. It occurs in beds of 3.6 metres to 4.6 metres in thickness in a sequence of 305 metres of yellowish-gray and green shales of Triassiac age. The gypsum is yellow to buff, thin-bedded and medium crystalline. Analysis of this deposit shows 83.7% gypsum, 4.8% anhydrite, 2.1% calcite, and 9.4% insoluble and other constituents.

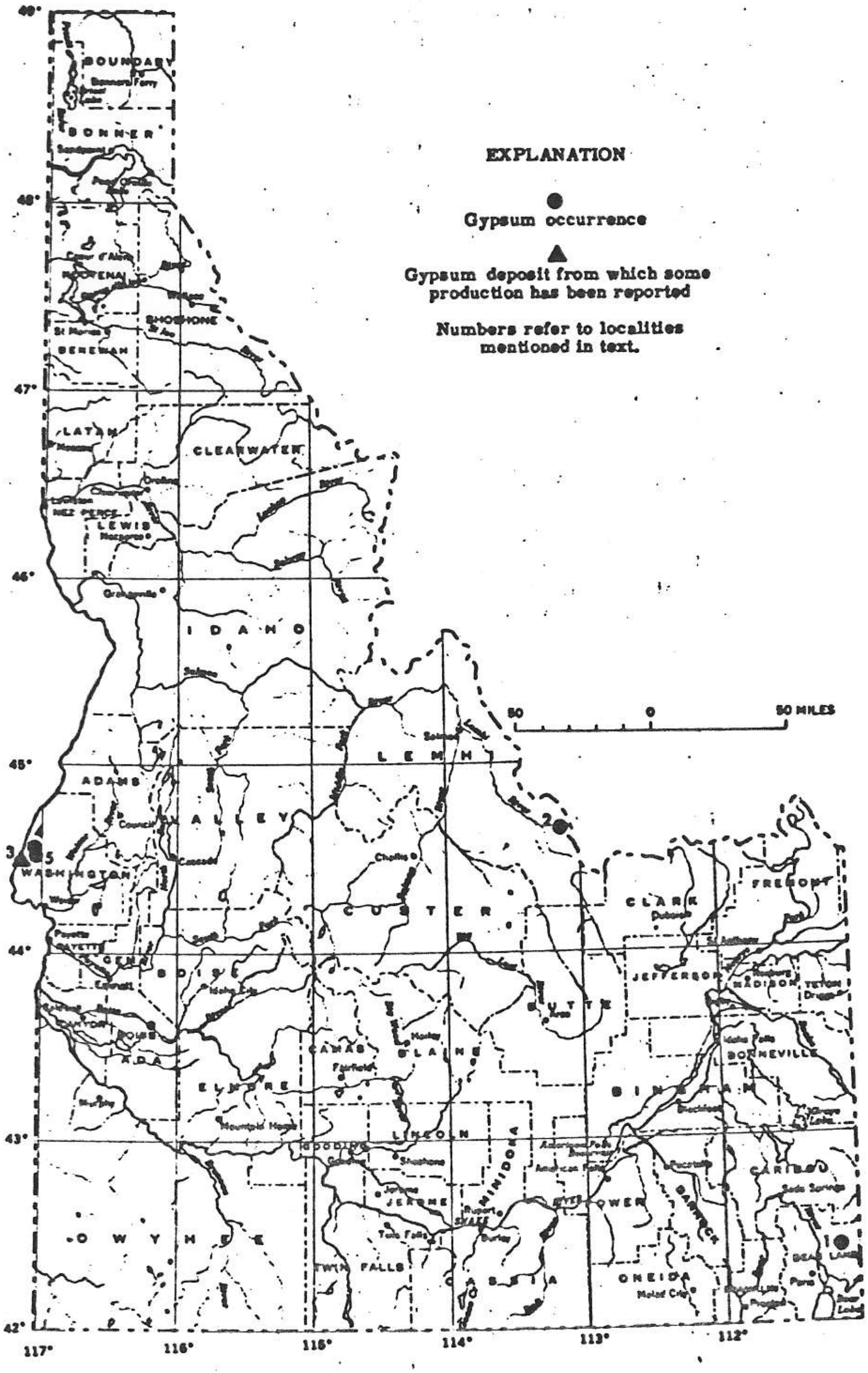
A deposit south of Mineral is reported to be in two or more beds in an outcrop of limestone 30 metres wide. These beds, although faulted, can be traced for 4 km along the outcrop.

Additional gypsum has been reported at Iron Mountain, east of Mineral. Nothing else is known of this occurrence.

Gypsum of mineralogical interest only has been reported by Shannon (1926). These include selenite crystals associated with massive bornite in the south Peacock mine in the Seven Devils District, Adams County; small crystals of gypsum found with native sulphur east of Soda Springs, Caribou County; thin veinlets of satin spar in the oxidized ore and the adjacent wall rock in the Alder Creek area, Custer County; selenite in clay near Mountain Home, Elmore County; and gypsum associated with soluble sulphates and nitrates in small amounts in the soils southeast of Homedale, Owyhee County.

The locations of these deposits are shown on the accompanying map.

GYPSUM OCCURRENCES IN IDAHO



Source: U.S. Bureau of Mines

5.1.7 Montana

U.S. Gypsum has been mining gypsum from their underground Shoemaker Mine for the manufacture of wallboard in their adjacent plant. This mine has been producing for forty years and is presently closed due to non-competitive underground mining and transportation. The wallboard market in Montana did not experience significant growth and was in 1986 at about the same level as in 1985.

Maronic Construction, Inc., has been mining gypsum at a site in the Raynesford area for use by the cement industry. The two Montana cement producers, Ideal Basic Industries and Kaiser Cement, report that demand for cement in Montana has remained flat.

Three gypsum occurrences are mapped in Montana; the Peterson deposit, the McCarthy deposit, and the Talent deposit.

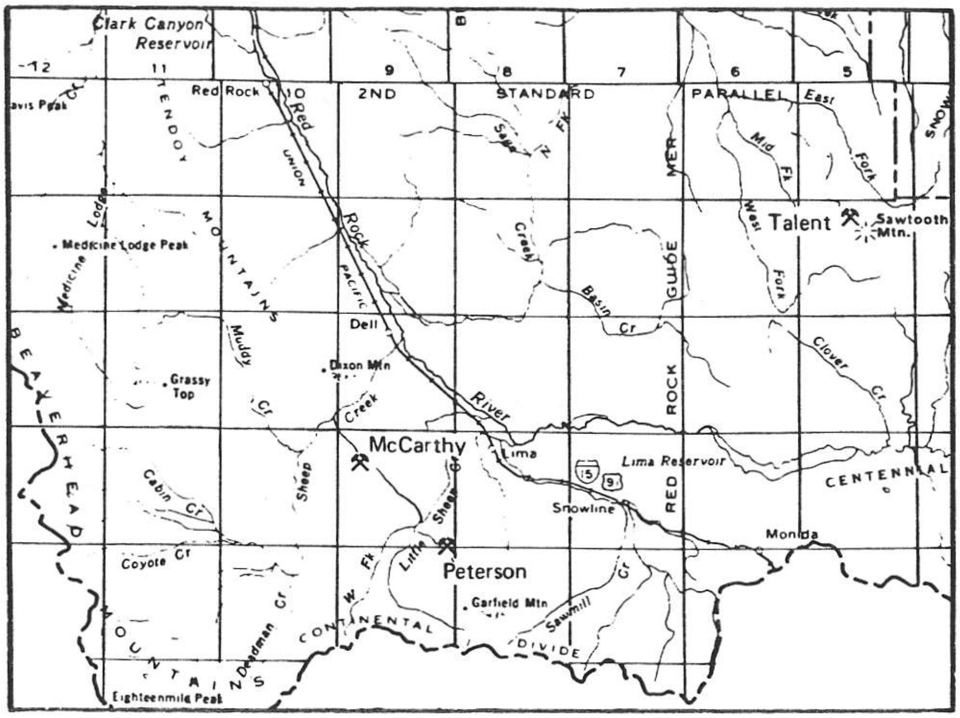
The Peterson and McCarthy deposits are located west of Lima in the southern Tenday Range, and the Talent deposit is located southeast of Dillon in the Snowcrest Range.

These deposits are currently inactive except for annual assessment work at the Peterson property. Past production has been recorded only from the Peterson deposit. No recent work has been done at the McCarthy and Talent deposits.

The locations of these deposits are shown on the accompanying map.

1. Peterson deposit - Gypsum was reported prior to 1908 on the East Fork of Little Sheep Creek about 9 km southwest of Lemhi, Beaverhead County. Gypsum at the Peterson deposit is

GYPSUM OCCURRENCES IN MONTANA



Source: U.S. Bureau of Mines

a dense to fine-grained, white to light-gray soft material, which is tinted yellow, red and brown when weathered. Massive gypsum exposed at the surface is fractured or jointed.

At the Peterson deposit, indicated reserves are determined for beds A and B. Horizontal widths of gypsum beds are 4 metres to 7 metres wide. Estimated (indicated) reserves are about 544,000 tonnes. About 5,442 tonnes of gypsum ranging in grade from 89% to 94% pure gypsum were mined and shipped to the Idaho Portland Cement Company at Inkom, Idaho between 1940 and 1960. Gypsum has been produced from three adits and a glory hole.

The geological structure of the property is complicated by superimposed folds and poorly exposed faults. This complexity will certainly increase the cost of exploration and production.

Sampling results taken at the Paterson mine are shown in Table 8B.

2. McCarthy deposit - Gypsum was located in 1939 near the head of Deadwood Gulch in the Tenday Range, Beaverhead County. Gypsum in this deposit is similar in physical appearance to gypsum at the Peterson deposit. It consists of white, fine-grained or saccharoidal soft material that contains vugs and cavities in the outcrop produced by weathering and solution at the surface. Some surface gypsum exposure weather to pale reddish-orange and light brownish-gray.

   Scattered through some of the gypsum are grains of transparent colourless selenite 1.5 mm in diameter. The McCarthy deposit contains some 127,000 tonnes of gypsum. Minimum mineable thickness of 1.5 metres was considered in reserves

TABLE 8B

ANALYTICAL RESULTS FROM SAMPLES TAKEN AT PETERSON MINE, MONTANA

Sample No.	% Acid Insol.	% Fe_2O_3	% MgO	% CaO	% CO_2	% SO^3	% H_2O (350°C)	% $CaSO_4 2H_2O$	Description
NP-3*	3.35	0.24	0.73	31.0	3.85	40.0	21.3	86.0	Bed A, lower adit 2-1/2 m white gypsum against footwall.
NP-4*	1.78	0.25	0.74	33.2	8.95	33.0	23.4	71.0	Bed A, lower adit 1-1/4 m impure gypsum against hanging wall.
NP-5*	1.83	0.17	2.98	29.9	8.00	35.0	18.1	75.2	Bed A, 2-1/2 m white gypsum - impregnated limestone.
NP-6	1.78	0.28	1.56	30.9	7.25	41.2	21.2	88.6	Bed A, 2-1/2 m exposed white massive gypsum.

* Samples NP-3 and NP-4 were taken across a +3-1/4 m gypsum bed. The hanging wall was not exposed.

Source: Montana Bureau of Mines & Geology

calculation. The thickness of gypsum beds ranges from 1.5 metres to 4.0 metres in bed A, and 0.6 metres to 4.0 metres in bed B. Analysis of gypsum indicates the grade from 47% to 91% pure gypsum.

Sampling results from five horizontal channel samples, taken from bulldozer cuts, are shown in Table 8C.

3. Talent deposit - Gypsum was first discovered in 1930 near the head of Alkah Gulch in Snowcrest Range. It lies about 64 km southeast of Dillon, Beaverhead County. Gypsum from the Talent deposit is a fine-grained or saccharoidal white soft material; a dense fine-grained light-gray alabasterlike material; and a colourless selenite yielding transparent cleavage folia. The major type is the white saccharoidal variety. Indicated reserves of 1,270,000 tonnes of gypsum were determined for the deposit.

   Sampling results from four surface samples (T1 - T4) and one sinkhole sample (T-5) are shown in Table 8D.

5.2 CANADIAN OCCURRENCES

5.2.1 Alberta

Several occurrences of gypsum are known in the Province. The known deposits have not been developed due to their remoteness, inaccessibility, and the locations within National Parks boundaries.

Two areas in the northeastern part of the Province may be developed in the future.

Presently, wallboard and cement plants in Alberta use crude gypsum mined in British Columbia and Manitoba.

TABLE 8C

ANALYTICAL RESULTS FROM SAMPLES TAKEN AT McCARTHY MINE, MONTANA

Sample No.	% Acid Insol.	% Fe_2O_3	% MgO	% CaO	% CO_2	% SO^3	% H_2O (350°C)	% $CaSO_4 2H_2O$	Description
TM-1	2.40	0.76	0.52	31.3	6.20	39.2	21.3	84.3	2-1/2 m white massive gypsum in gulldozer cut.
TM-2	28.4	0.19	0.35	26.1	10.9	21.8	14.7	46.9	3-1/2 m mixed gypsum and limestone.
TM-7	0.88	0.16	0.07	32.3	3.57	38.0	21.2	81.7	2 m white massive gypsum 60 ft.
TM-8	0.52	0.28	0.11	32.0	3.34	42.3	21.6	90.0	3-1/2 m white massive gypsum in bulldozer cut.
TM-9	1.36	0.16	0.08	31.9	3.28	41.9	21.2	90.1	2-1/3 m white massive gypsum in bulldozer cut.

Source: Montana Bureau of Mines & Geology

TABLE 8D

ANALYTICAL RESULTS FROM SAMPLES TAKEN AT TALENT PROPERTY, MONTANA

Sample No.	% Acid Insol.	% Fe_2O_3	% MgO	% CaO	% CO_2	% SO^3	% H_2O (350°C)	% Min.	% $CaSO_4 2H_2O$	Description
T-1	0.63	0.76	0.18	30.7	44.4	0.77	21.0	none	90.6	25 m horizontal sample of gypsum, east limb. Two interbedded red siltstone beds and 2 and 1-1/2 m thick not included in sample.
T-2	1.67	0.21	0.78	31.0	40.8	2.86	21.4	none	87.7	56 m horizontal sample. Interbedded limestone beds 2/3 and 1-1/4 m thick not sampled.
T-3	0.42	0.14	0.23	31.7	43.0	3.27	21.1	none	92.4	17 m horizontal sample, west limb.
T-4	0.90	0.14	0.52	31.2	41.8	1.25	21.5	none	89.9	51 m horizontal sample, west limb. Interbedded buff-yellow dolomite and gray limestone not sampled.
T-5	9.75	0.42	3.62	29.1	29.7	12.45	22.5	0.15	63.8	10-1/2 m horizontal chip sample. Interbedded gypsum, limestone and siltstone

Source: Montana Bureau of Mines & Geology

The Peace Point deposit has excellent qualities, running to 95% gypsum content over thicknesses of 5 to 10 metres.

The Fort McMurray deposit grades 84% gypsum, but requires underground mining. This deposit is located on Athabasca River near the rail head at the City of Fort McMurray.

Phosphogypsum, a by-product gypsum, is produced at four fertilizer plants in Alberta. In spite of research programs to determine its use in the manufacture of wallboard, it is not commercially used.

Other gypsum occurrences are found at:

1. Mowitch Creek, Triassic age gypsum occurrence in Western Alberta.

2. Fetherstonehaugh Creek, Triassic age gypsum occurrence in Central Alberta - British Columbia border.

3. Head Creek, Late Devonian age gypsum occurrence in Southwestern Alberta.

4. Salt River, Middle Devonian age gypsum occurrence in Northwestern Alberta.

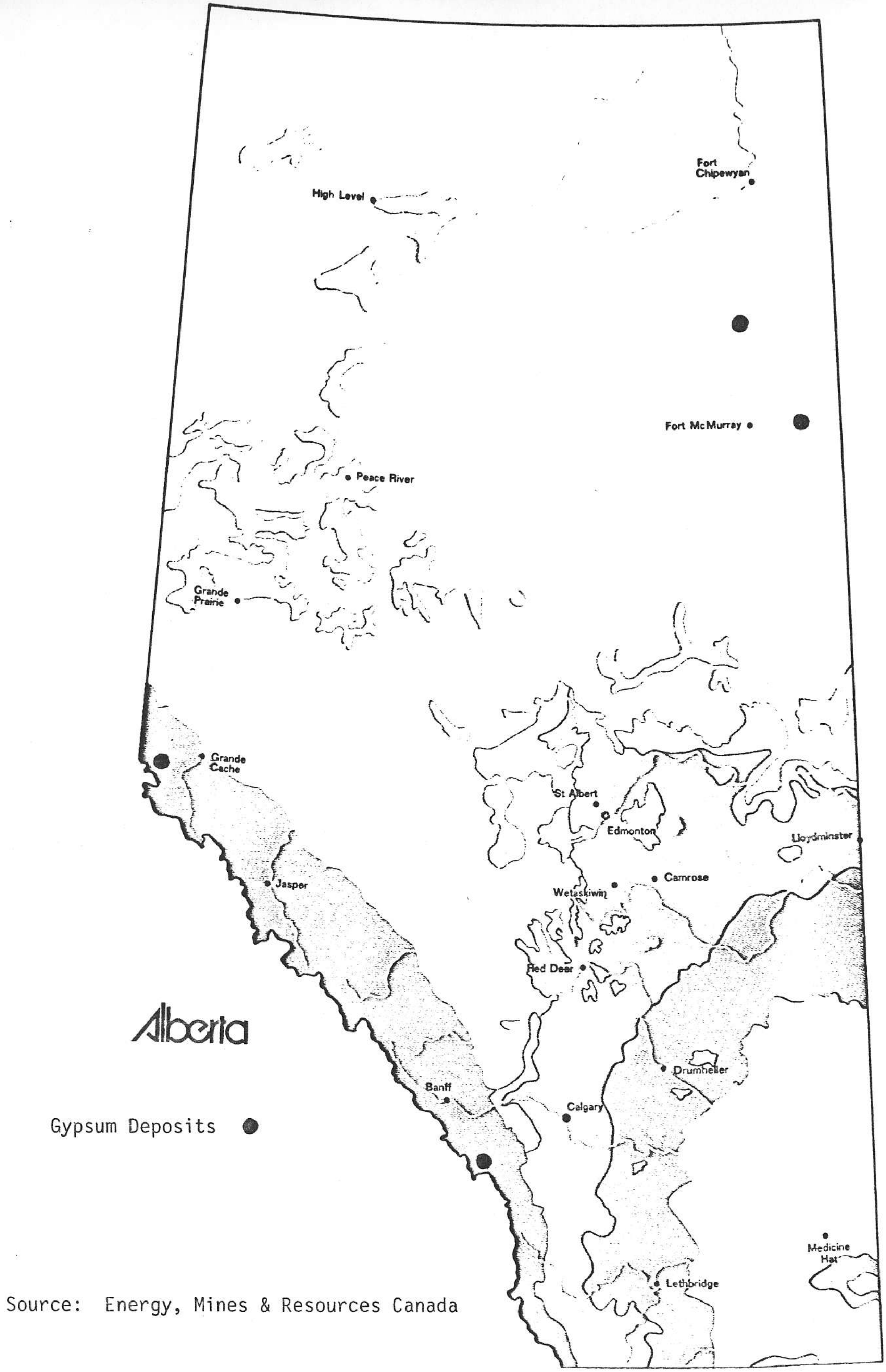
5. Kananaskis, Middle Devonian age gypsum occurrence in Southwestern Alberta.

These locations are noted on the accompanying map.

5.2.2 British Columbia

In British Columbia, the Ministry of Energy, Mines and Petroleum Resources lists 21 gypsum occurrences in the Province. Most of the occurrences are located in the southwestern part of the province, where mining of gypsum is a well-established industry.

GYPSUM OCCURRENCES IN ALBERTA



Source: Energy, Mines & Resources Canada

Gypsum quarries are in operation at Lussier River, Windermere, and Falkland.

The Lussier River and Windermere deposits are situated in the Stenford Range of the Rocky Mountains in the Kootenay District of southeastern British Columbia.

These deposits are located within the foreland thurst zone of the Western Cordillera. The Beaverfoot Brisce formation stratigraphically underlies the Burnais formation. The Beaverfoot Brisce formation consists of up to 600 metres of carbonate rock with limestone at the top and dolomite at the bottom. It is thought to be Ordouician to middle Silurian in age.

The Burnais formation contains the gypsum deposits. It is composed principally of well-bedded and finely laminated gypsum. The gypsum weathers light to dark gray, black, fetid, well breciated limestone comprises a small percentage of this unit. It is thought to be middle Silurian to middle Devonian age.

The Burnais formation is mostly covered by glacial drift. Sinkholes and "gypsite" are most reliable indicators of covered gypsum.

The Burnais formation has been traced for over 140 km from Windermere to Wardner.

The Lussier River deposit is presently operated by Domtar Construction Materials which ships crude gypsum to its wallboard plant in Edmonton.

Westroc Industries Limited operates a mine at Windermere, from which it ships crude gypsum to a wallboard plant in Vancouver, a distance of 800 km by rail. It also ships gypsum to cement plants in Alberta and the United States.

The Falkland gypsum deposit, southeast of Kamloops, is mined by Canada Cement Lafarge for the cement plant in Kamloops.

A deposit on the O'Connor River in northwest British Columbia is presently under evaluation by two Canadian companies and may be brought to a development and production stage if satisfactory markets are found.

The following is a list of other gypsum occurrences in British Columbia.

1. Bluebell Mine - Secondary gypsum occurrence is reported.

2. Mayoak - Beside Highway No. 3, at Mayook Siding, 26 km east of Cranbrook. Canada Cement Company quarried some 91,000 tonnes of gypsum for cement retarder. Western Gypsum Company mined here from 1945 to 1946.

3. Chipka Creek - This site is located at the mouth of Chipka Creek, atributary that flows east into Kootenay River, 1.6 km south of Wardner. A deposit is 20 to 60 m thick, with steep dipping beds of grey to black gypsum outcrops for 1 km along the creek. Some trenching, drilling and tunnelling was carried out but no production followed.

4. Bull River - This site is located on the banks of Bull River, 4 km above the bridge on the Fort Steele Road. Folded and faulted grey to black gypsum, running 75% pure, is present in undetermined amounts. A trench and a few exploration pits were dug and a 336 tonne shipment was made in 1937.

5. Martin - This site is located on the north-side of Nine Mile Creek, 2.5 km east of the Kootenay River, 15 km northeast of Canal Flats. Gypsum deposits are overlain by 35 metres of till.

6. Kootenay River - The location is along Kootenay River, 8 to 16 km northwest of Canal Flats. The area of 1,813 square meters is underlain by gypsum formation. Exposure on the east bank reveals 3 to 73 m high gypsum cliffs. Trenching and drilling was done and only one trial shipment was recorded in 1950.

7. Joffre Creek - Location of gypsum occurrence is noted on the east side of Joffre Creek, just west of the British Columbia-Alberta boundary, 56 km east of Invermere.

8. Stoddard Creek - Gypsum is exposed in sinkholes on the Stoddart Creek-Shuswap Creek Divide, 8 km north of Windermere.

9. Sweetsbridge - Gypsum is located some 300 m north of Highway 97, some 6.4 km southeast of Falkland. White brown and grey gypsum is exposed across 200 metres along the hillside.

10. Britannia Mine - Lenses of grey-white gypsum, 3 to 10 m wide, were found in the underground workings on the Fairview Claim at Britannia Beach, 48 km north of Vancouver.

11. Foregetmenot Creek - Massive white and grey gypsum is exposed on the Forgetmenot-Fetherstonehaugh Divide, astride the British Columbia-Alberta boundary.

12. Morning Group - Gypsum is noted on the hanging wall of a dyke on the east side of the Coquihalla River.

14. Spatsum - Gypsum is found as lumps and crystals in disintegrated schist, just west of Highway 1, at Spatsum, 19 km south of Ashcroft.

15. Len - Gypsum veins are reported with copper molybdenum mineralization on Huckleberry Mountain, 10 km east of Tahtsa Lake.

16. Alice - Gypsum is found in the gangue of molybdenite mineralization on the southeast fork of Lime Creek, 8 km from Alice Arm.

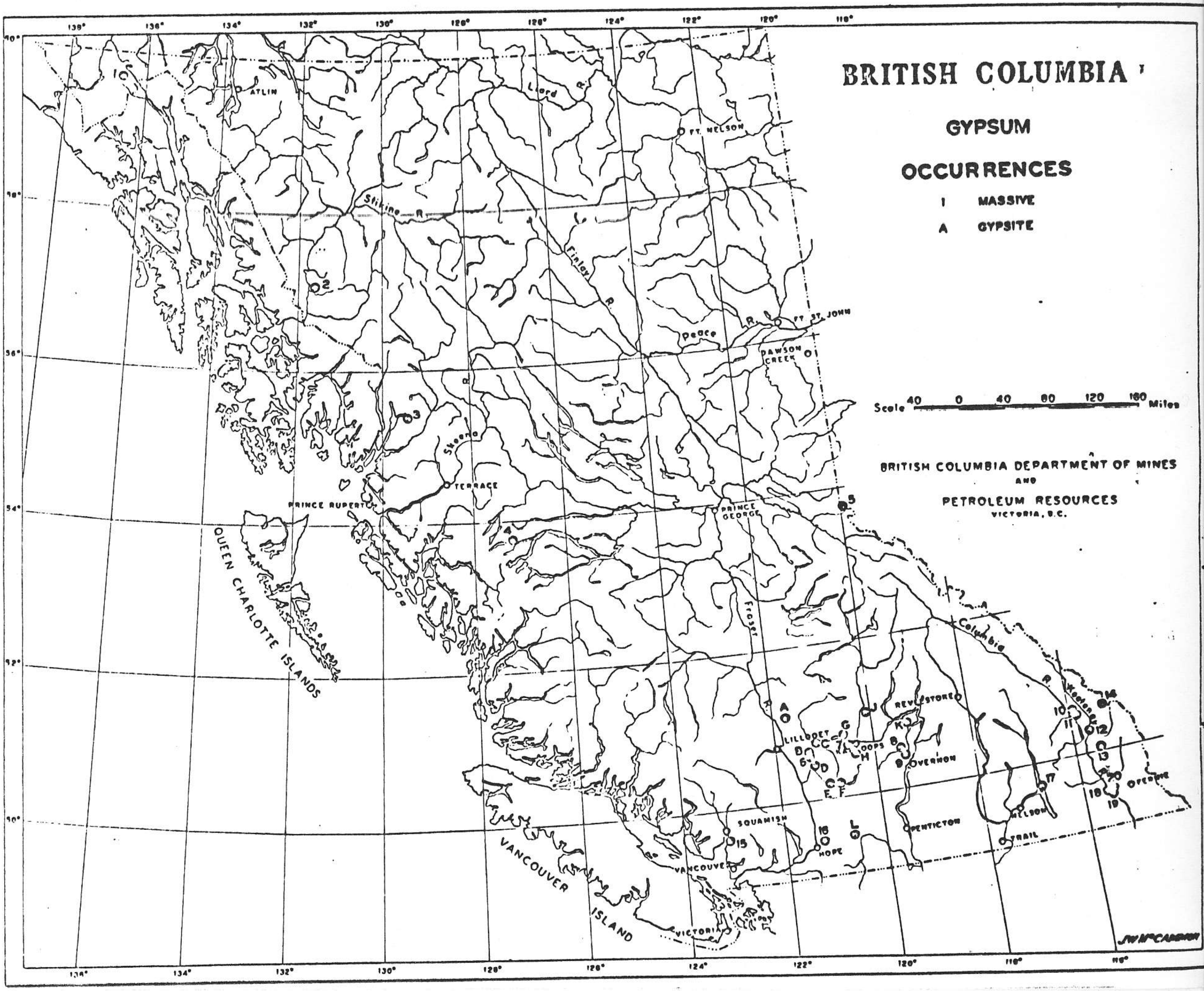
17. Galore Creek - Gypsum is reported with anhydrite in veins with copper mineralization at the Galore Creek and Copper Canyon properties, 32 km southeast of the junction of the Scud and Stikine Rivers.

18. O'Connor River - Gypsum occurs 10 km west of Haines Road at Kusawak Lake. The deposit is situated within the Alexander Terraine of the Insular Tectonic Belt. The gypsum is white, finely crystalline, with few foreign inclusions, assaying to 88% gypsum, 7% anhydrite, and 5% carbonates. The deposit consists of three separate gypsum zones.

Occurrences of gypsum in British Columbia are shown on the accompanying map.

5.2.3 Yukon

No occurrences of gypsum are reported in Yukon Territory at present.



BRITISH COLUMBIA
GYPSUM
OCCURRENCES
1 MASSIVE
A GYPSITE
Scale 40 0 40 80 120 160 Miles
BRITISH COLUMBIA DEPARTMENT OF MINES
AND
PETROLEUM RESOURCES
VICTORIA, B.C.
ATLIN
FT. NELSON
Liard R.
Stikine R.
Finlay R.
Peace R.
FT. ST. JOHN
DAWSON CREEK
Skeena
TERRACE
PRINCE RUPERT
PRINCE GEORGE
QUEEN CHARLOTTE ISLANDS
Fraser
Columbia R.
Kootenay
REVELSTOKE
LILLOOET
VERNON
PENTICTON
NELSON
TRAIL
SQUAMISH
HOPE
VANCOUVER
VANCOUVER ISLAND
VICTORIA

6. QUALITY OF GYPSUM

6.1 QUALITY VERSUS END-USE

The quality of gypsum is a measure of purity. Most crude gypsum contains impurities in the range of 10% to 15%, but some deposits may contain less than 5% or as much as 20%. Often times, gypsum can be used as mined where purity is sufficiently high that no upgrading is required.

The amount of impurity acceptable is mostly dependent upon the product being manufactured. Other considerations, regarding acceptable impurity levels, include the type of impurity and market competition.

Industries using gypsum as a raw material have categorized impurities into three main types as follows.

1. Insolubles or relatively insolubles (e.g., limestone, dolomite, anhydrite, anhydrous clays and silica);

2. Soluble chlorides (e.g., halite and sylvite);

3. Hydrous (e.g., sulphate salts and hydrous clays).

The following sections give an indication of specified requirements of raw gypsum, including acceptable impurity levels, for the wallboard, cement, paper, extender and filler, and specialty markets.

6.1.1 Wallboard Industry

Approximately 70% of all gypsum consumed in North America is for the purpose of manufacturing wallboard. Wallboard manufacturers calcine raw gypsum to a hemihydrate of calcium sulphate to produce the end product - gypsum wallboard. Wallboard manufacturers require the following specifications to be met:

1. Insoluble or relatively insoluble minerals such as limestone, dolomite, anhydrite, anhydrous clays, and silica minerals, are required to be consistent and generally less than 20%.

2. Soluble chloride mineral - less than 0.03%.

3. Hydrous minerals (excluding hydrous clays) - less than 0.02% to 0.03%; hydrous clays - less than 1.0% to 2.0%.

4. Colour - prefer white gypsum.

6.1.2 Cement Industry

Cement is formed by the blending of ground raw gypsum and clinker. Gypsum acts as a retarder for portland cement, controlling the setting time. The use of calcium sulphate compounds in cement products has been under extensive research. The SO_3 content of the gypsum, the type of cement being manufactured, and the mix of raw materials used to make the cement clinker, are all factors governing the amount of gypsum used. 4% to 6% by weight of finished cement is the amount of gypsum generally found in any portland cement product.

The research carried out on setting time and strength development of portland cement has resulted in tighter specifications on raw materials including gypsum.

Gypsum for cement may be mixed (or contaminated) with anhydrite. Cement manufacturers prefer to have gypsum with the following quality specifications:

1. Insolubles - less than 2%;
2. SO_3 - greater than 41%;
3. Moisture - less than 4%;
4. Size: Maximum 100% - less than 2-1/2" to 3-1/2"
   Minimum - less than 10% finer than 1/4".

6.1.3 Pulp and Paper Industry

Mineral fillers are finely ground minerals which can be incorporated with various compounds into the manufacture of paper. Mineral fillers provide paper with greater opacity, strength, surface texture, ink receptivity, and whiteness, to mention a few characteristics that can be modified by the addition of fillers. The prime objective of filler usage is the reduction of cost of the end paper product.

The key areas and relative properties which these industrial mineral fillers are incorporated into the manufacture of paper are as follows:

Filler: Finely ground minerals which are incorporated into the manufacture of paper products to provide some beneficial property such as ink receptivity, surface smoothness, colour, impact strength, and opacity.

Coaters: Finely ground minerals that are combined with binders and additives and spread on the surface of paper for the purpose of improving printing properties and appearance. Key properties of mineral coaters are brightness and whiteness, easy dispersability and disintegration, low abrasion, opacity, and high flow properties.

Extenders: Finely ground minerals that, when incorporated into a composition that contains a base pigment, the mineral extender will not inhibit the optical, physical, or chemical properties of the extender.

The principal industrial mineral used as a substance in the manufacture of paper products is kaolin. Talc and calcium carbonate are occasionally used in special circumstances. The following identifies the functions, applications and characteristics of these principal industrial minerals used in the production of pulp and paper.

Kaolin
- Major filler in the manufacture of acid-printing paper.
- Used as a filler, coater and extender in fine papers to reduce production costs by covering wood fibre content, enhance opacity and whiteness, and improve printing quality.
- Key properties include: chemical inertness, whiteness, low abrasive particle content and fine particle size.

Talc
- Primarily used as a pitch control agent.
- Key properties include: smoothness, chemical inertness, and high reflectance.

Calcium Carbonate
- Used in the manufacture of alkaline papers.
- Used as a coating agent to brighten paper, improve ink receptivity, and produce a smooth surface.
- Key properties include: whiteness, chemical purity, and low abrasiveness.

There are numerous other minerals which can substitute these principal mineral substances, including gypsum, all of which are outlined in Table 9.

It is evident from Table 9 that gypsum has many common physical properties as compared to kaolin, calcite and talc. The main physical property in which kaolin and gypsum differ is the chemical stability whereas kaolin is chemically inert between a pH of 4 to 9 and gypsum is acid soluble. Kaolin also tends to have a higher refractive index, which basically represents brightness, a higher oil absorption and platy particle shapes, all of which are regarded as favourable factors by the pulp and paper industry.

TABLE 9

PROPERTIES OF MINERAL FILLERS

	Mohs' Hardness	% Brightness	[1]Shape*	Specific Gravity	cc per 100 g Oil Absorption	Refractive Index	[2]Chemical Stability	[3]Cost
Anatase	5.0-6.0	98.99	EQ	3.9	18-30	2.55	IN	H
Aplite	6	80-85	EQ	2.62	10-30	1.53	IN	L
Aragonite	3.5	75-90	EL	2.95	15-40	1.68	AS	L
Asbestos	2.5-4.0		EL	2.5-2.6	40-90	1.51-1.55	IN	L,M
Attapulgite	4.0	50-70	EL	2.2-2.6	30-50	1.50	IN	L,M
Barite	2.5-3.5	80-97	EQ	4.3-4.6	6-10	1.64	IN	L,M
Bentonite	1.5	50-90	PL	2.3-2.6	20-60	1.55-1.56	AS,BS	L,M
Calcite	3.0	82-96	EQ	2.7	12-30	1.63-1.66	AS	L,M
Diatomite	4.5-6.0	65-90	PL	2.0-2.35	100-300	1.42-1.49	I	L,M
Dolomite	3.5-4.0	80-90	EQ	2.85	10-30	1.68	AS	L
Feldspar	6.0		EQ	2.57	10-30	1.52	IN	L,M
Gypsum-anhydrite	1.5-2.0	75-90	EQ	2.3	20-25	1.52	AS	L
Hematite	3.8-5.1		EQ	4.5-5.1	10-35	2.94-3.22	IN	M
Kaolin	2.0-2.5	78-92	PL	2.6	25-50	1.56-1.58	IN	L,M
Mica	2.0-3.0	70-80	PL	2.7-3.0	25-50	1.59	IN	L,M
Nepheline syenite	5.5-6.0	70-85	EQ	2.6-2.65	10-30	1.54	IN	L,M
Perlite	5.0	70-85	EQ	2.5-2.6	50-275	1.48-1.49	IN	M
Pyrophyllite	1.0-2.0	75-85	PL	2.8-2.9	40-70	1.57-1.59	IN	L,M
Rutile	6.0-7.0	97-98	EQ	4.2	16-45	2.76	IN	H
Sepiolite	4.0	60-75	EL	2.5	30-50	1.49	IN	L,M
Silica	6.5-7.0	78-92	EQ	2.6-2.65	20-50	1.53-1.54	IN	L,M
Talc	1.0-1.5	85-96	PL	2.6-3.0	20-50	1.57-1.59	IN	L,M
Vermiculite	1.5		PL	2.2-2.7	25-60	1.56	IN	M
Wollastonite	4.5	85-95	EL	2.9	25-30	1.63	IN	L,M
Zeolite	3.5-4.0	75-90	EQ	2.1-2.2	30-100	1.48	AS	L,M

* [1]EQ - Equidimensional
EL - Elongate
PL - Platy

* [2]IN - Chemically inert pH - 4 to 9
AS - Acid soluble
BS - Base soluble

[3]L - Low cost - 5¢/lb. or less
M - Moderate cost - 5¢/lb. to 20¢/lb.
H - High cost - over 20¢/lb.

Source: Pigment, Filler, Coater and Extender Minerals
Haydn M. Murray

6.2 QUALITY OF BRITISH COLUMBIA GYPSUM

The quality of British Columbia gypsum was analyzed under the methods outlined in ASTM C471-66, "Standard Methods for Chemical Analysis of Gypsum and Gypsum Products".

Samples were obtained from deposits located in the Interior and Coastal regions of the Province.

Table 10 tabulates the quality of collected gypsum from samples.

TABLE 10

CHEMICAL ANALYSIS OF SOME BRITISH COLUMBIA GYPSUM

	Interior Deposit Crude Gypsum %	Interior Deposit Crushed Gypsum %	Interior Deposit Screened Gypsum %	Bulk Mined Coastal Deposit Crude Gypsum %	Selectively Mined Coastal Deposit Crude Gypsum %
Free Water	0.10	0.13	0.08	0.35	0.01
Combined Water (H_2O)	16.86	17.11	17.24	16.40	16.97
Sodium Chloride (NaCl)	0.03	0.03	0.03	0.03	0.03
Calcium Oxide (CaO)	30.8	31.7	31.4	31.7	31.48
Sulphur Trioxide (SO_3)	39.5	42.7	41.3	39.9	39.41
Silica & Insol	1.90	1.52	3.91	5.86	3.46
Iron & Aluminium Oxides (R_2O_3)	0.19	0.18	0.24	0.31	0.30
Magnesium Oxide (MgO)	3.15	1.99	2.11	1.66	1.77
Gypsum Content	80.56	81.75	82.37	78.36	81.12

7. EVENTS, TRENDS AND ISSUES IN THE NORTH AMERICAN GYPSUM INDUSTRY

Research has made it clear (see Section 3. Gypsum Production and Trade), backed by historical evidence, that the North American gypsum market is dominated by the United States demand. Any contemplated mining of gypsum in any area of North America, including the North American Pacific Rim, should be based on satisfying a particular demand in the United States market. This section is devoted to identifying and quantifying factors affecting the demand for gypsum primarily in the United States. It will provide a statistical base upon which a credible forecast of gypsum activity in the North American Pacific Rim can be made in a subsequent section.

7.1 INDUSTRY STRUCTURE

The gypsum industry is highly integrated with several companies commanding dominant position. These integrated companies operate wallboard plants with captive mines scattered throughout North America at strategic locations close to the markets. The same companies sell gypsum for use in the cement industry and agriculture and serve other specialty markets, while the majority of crude gypsum is consumed in the manufacture of wallboard. Leading gypsum companies are United States Gypsum Co., with 12 mines, National Gypsum Company, with 7 mines; Georgia Pacific Corporation, with 6 mines; Celatex Corp., a subsidiary of Jim Welter Corp., and Genstar Building Materials Corporation, with 3 mines each; and Weyerhaeuser Co., with 1 mine. These six companies, with 32 mines, produce some 80% of the total crude gypsum in the United States.

Fourteen companies calcine gypsum at 70 plants and market the gypsum products. Leading producers are United States Gypsum Co., 22 plants, National Gypsum Co., 18 plants; Georgia Pacific Corp., 9 plants, Genstar Building Materials Co., 5 plants: and Celatex

Corp., 4 plants. These five companies operate 58 plants and produce 85% of the total gypsum products output in the United States. Another nine companies make up for 15% of the output.

In Canada, the Province of Saskatchewan has one wallboard plant at Saskatoon. This plant is owned by Domtar and crude gypsum for the plant comes from the Domtar Quarry at Gypsumville, Manitoba.

The Province of Alberta has no gypsum production of its own and relies on sources in British Columbia and Manitoba to supply three wallboard plants and three cement plants. Domtar and Westroc each own a wallboard plant in or near Calgary while Domtar also operates a wallboard plant in Edmonton. Canada Cement Lafarge operates cement plants in Exshaw and Edmonton. Genstar also operates a cement plant in Edmonton.

In British Columbia, Westroc Industries operates a mine in Windermere primarily supplying crude gypsum to its wallboard plants in Calgary, Alberta and New Westminster, British Columbia. Domtar also operates a mine in the East Kootenays and ships crude gypsum to its wallboard plant in Calgary.

The two cement plants near Vancouver operated by Canada Cement Lafarge and Genstar both import crude gypsum from Spain. The Canada Cement Lafarge plant in Kamloops receives its gypsum from its local mine in Falkland.

In the Province of Ontario, Westroc Industries Limited operates an underground mine at Drumbo, west of Hamilton. The crude gypsum is shipped 110 km by rail to Westroc's wallboard plant in Mississauga. Canadian Gypsum Company, a subsidiary of United States Gypsum, mines crude gypsum from underground operations at Hagersville, south of Hamilton. All gypsum is processed in its wallboard plant at the mine site. Domtar Construction Materials Limited mines underground gypsum deposits at Caledonia, north of Hagersville. The gypsum is trucked to its two wallboard plants less than 2 km from the mine.

In the Province of Quebec, there are four wallboard plants in the Montreal area. The Domtar Construction Materials Limited plant at Montreal is presently idle, Westroc has a plant located at Ste. Catherine d'Alexadrie, and Canadian Gypsum Company has two wallboard plants, one in Montreal and another in St. Jerome. Crude gypsum for these plants is brought in by ship from the gypsum mines in Nova Scotia. Finished gypsum products are transported to markets in Quebec, Ontario, and the United States, by tractor-trailer and rail.

In the Province of New Brunswick, Canada Cement Lafarge is the only company mining gypsum. The quarry is located at Intervale, in the southern part of New Brunswick, and supplies the company's cement plant at Havelock, located 10 km to the northwest. Production is over 100,000 tonnes per year.

In the Province of Newfoundland, Flintkote Holdings Limited (Genstar) operates an open pit mine at Flat Bay in southwestern Newfoundland. Atlantic Gypsum Limited has a small wallboard plant located at Corner Brook, some 100 km northeast of the Flat Bay area. The Flat Bay quarry supplies gypsum to Atlantic Gypsum's wallboard plant. At Flat Bay, Flintkote is producing about 550,000 tonnes per year, moving crude gypsum to a dock facility at St. George's Bay where it is loaded on ships destined for the east coast of the United States.

In the Province of Nova Scotia, six companies have gypsum quarries producing 73% of the total gypsum mined in Canada and exporting over 90% of the crude gypsum to the United States. The largest gypsum producer in Nova Scotia is National Gypsum (Canada) Limited. National Gypsum produced 7.7 million tonnes of crude gypsum in 1985 from a single open pit mine, making it the largest gypsum mine in the western world. The mine is located at East Milford, Halifax County. This gypsum is shipped to markets in central Canada and the eastern United States.

In Nova Scotia, Fundy Gypsum, a subsidiary of United States Gypsum, produced 1.5 million tonnes of crude gypsum in 1985 from two quarries near Windsor, Hants County. Most of the gypsum is wallboard grade, and is transported by unit train to shipping facilities at Hantsport. Ocean-going vessels transport this gypsum from Hantsport to Boston, Massachusetts, and to Galena Park, Texas.

Little Narrows Gypsum is another subsidiary of United States Gypsum, and is located on tide water at Little Narrows, Victoria County on Cape Breton Island. This gypsum is shipped to central Canada and along the eastern seaboard from Boston, Massachusetts, to Houston, Texas. In 1985, the mine produced 1 million tonnes.

Georgia Pacific operates a quarry at River Denys in Inverness County on Cape Breton Island which produced just under 1 million tonnes of crude gypsum in 1985. The gypsum product is moved by unit train to a port facility at Port Hawkesbury and is then shipped to Georgia Pacific's plants along the eastern seaboard.

Domtar Construction Materials Limited operates a quarry and calcining plant in Windsor, Hants County.

Canada Cement Lafarge also operates a small gypsum quarry in Brookfield, Calchester County, which supplies the needs of its cement plant.

From analyzing the structure of gypsum companies in Canada, it is obvious that the pattern is the same as in the United States; well integrated with captive mines, transportation systems, and markets. In Canada, Domtar Construction Materials, Westroc Industries Limited, Canada Cement Lafarge, National Gypsum (Canada), and three other United States subsidiaries are the main producers of crude gypsum and gypsum finished products with captive mines and market share divided amongst them.

7.2 LEADING INDICATORS OF GYPSUM DEMAND

The total demand for gypsum over the past sixty years has very much been a function of the health of the building/construction industry. Moreover, the demand for the prefabricated products (wallboard) industry, has consistently dominated the gypsum demand pattern. Table 11 provides historical evidence to support this statement.

More recent statistics continue to support the relationship between gypsum consumption and construction activities, according to the United States Bureau of Mines, Mineral Yearbook, 1985 (Reference Table 12). Building plaster, portland cement, and prefabricated products constitute 92.6% of the gypsum products sold or used in the United States in 1985.

In Canada, all crude gypsum remaining in the country (30% of the total production) goes into wallboard manufacture or portland cement production.

Without doubt, the leading indicator of gypsum demand in North America is the level of construction activity. In the following section, details are provided on various types of construction, its relation to wallboard and cement production, and forecasts of activities.

7.3 CONSTRUCTION INDUSTRY

For discussion purposes, the construction industry has been divided into two product demands: wallboard and cement.

7.3.1 Wallboard Demand

Crude gypsum requirements for wallboard manufacture account for over 70% of the total gypsum consumed in North America.

TABLE 11

UNITED STATES GYPSUM DEMAND PATTERN, 1973 - 1983

(000's Tonnes)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Prefabricated Products	12,510	10,781	8,938	10,747	12,658	13,423	13,790	11,815	11,726	11,085	14,215
Plaster, Industrial and Building	1,019	866	752	721	712	824	708	717	688	623	643
Cement Retarder	3,762	3,681	2,942	3,099	3,583	3,818	3,650	3,524	3,296	2,782	3,587
Agriculture	1,318	1,516	1,344	1,555	1,519	1,368	1,542	1,504	1,383	1,180	1,187
Fillers and Miscellaneous	106	112	161	221	161	148	112	122	102	112	179
Total Demand[1]	18,717	16,955	14,138	16,343	18,633	19,581	19,803	17,681	17,195	15,782	19,812

1. Data may not add totals shown due to independent rounding.

Source: Mineral Facts and problems, 1985

TABLE 12

CALCINED AND UNCALCINED GYPSUM PRODUCTS[1] SOLD OR USED IN THE UNITED STATES, 1985

Gypsum Type/Use	Quantity (000's Tonnes)	%
Uncalcined		
. Portland cement	4,129	17.2
. Agriculture[2]	1,145	4.8
. Fillers and Miscellaneous	128	0.5
Sub-Total	5,402	22.5
Calcined		
. Building Plaster	279	1.2
. Industrial Plaster	495	2.1
. Prefabricated Products[3]	17,774	74.2
Sub-Total	18,548	77.5
TOTAL	**23,950**	**100.0**

1. Includes domestic, imported and by-product gypsum.
2. Includes most of 755,315 tonnes of by-product gypsum.
3. Includes weight of paper, metal and other materials and some by-product gypsum.

Source: United States Bureau of Mines, Mineral Yearbook, 1985

The current annual North American market for crude gypsum used in wallboard manufacturing is about 1.8 billion square meters. Approximately 1.65 billion square metres of this total is in the United States and the remaining 150 million square meters is in Canada. Production capacity in Canada exceeds annual domestic market demand by approximately 30% and in the United States, production capacity roughly matches demand.

The traditional measure used to predict gypsum demand has been new housing starts. However, the emergence of significant housing repair and remodelling and increased use of gypsum wallboard in non-residential buildings are influencing the size and structure of the current market.

7.3.1.1 United States Housing Starts

The health of the gypsum wallboard industry in North America has always been closely tied to the United States housing starts. Levels of housing starts have historically fluctuated and coincide with peaks and valleys in interest rates, inflation rates and unemployment rates.

Since 1982, when the recession was at its lowest and following a 60% increase in housing in 1983, housing starts have climbed gradually from 1.7 million in 1983 to 1.8 million in 1986.

Economic factors accounting for the increase include a drop in interest rates, increasing employment, and a relatively low inflation rate of approximately 3% per year.

It should be noted that there were major regional shifts in housing starts in the United States in 1986. Table 13 shows the changes from 1985 to 1986 in housing starts by region.

TABLE 13

UNITED STATES HOUSING STARTS BY REGION, 1985 - 1986

Region	% of National Total	
	1985	1986
Northeast	12.9	14.3
Midwest	12.8	14.7
South	46.7	43.5
West	27.5	27.3

Source: Markets 87-90, Widman Management Limited

It is known that other factors must now be considered to predict wallboard consumption. Figure 5 attempts to correlate the United States consumption of wallboard and the United States private housing starts for the years 1976 to 1986.

7.3.1.2 Repair and Remodelling in United States Housing

Widman Management Limited[1] reported, in their market study on Canadian lumber (Markets 87-90), that of the total lumber production in the United States in 1986, the repair and remodelling market accounted for 28% compared to 16.3% in 1972. Similarly, a 1984 United States Gypsum Company publication reports the total annual expenditure on housing repairs and renovations in the United States as $ 60 billion U.S. and an annual growth rate in this market of 12%.

Approximately one-third, or 30 million, of the existing housing units in the United States are over 45 years old; therefore, the demand for repair and remodelling products, including wallboard, should increase substantially.

7.3.1.3 United States Non-Residential Construction

Manufacturers of wallboard have confirmed that because of its fire retardant characteristics, the use of gypsum wallboard in commercial and institutional buildings is increasing. However, non-residential construction of high rise condominiums and commercial office buildings in which large quantities of type-x wallboard is used, is subject to great fluctuations.

7.3.1.4 United States Lumber Consumption Versus Wallboard Demand

With reference to Figure 6, the correlation made between lumber consumption in the United States for residential, non-residential,

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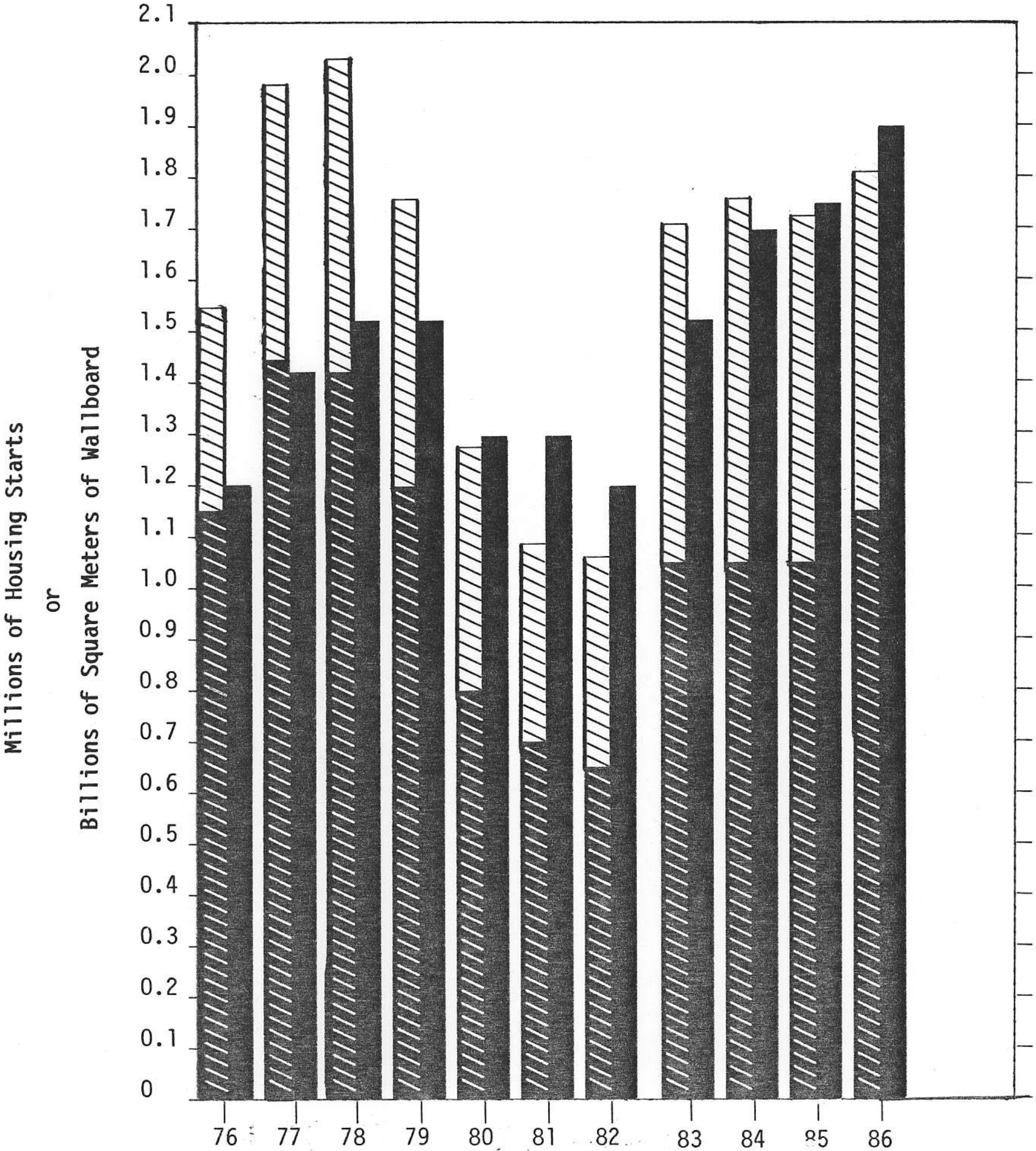
[1] A Vancouver-based Management consulting firm

FIGURE 5

UNITED STATES WALLBOARD CONSUMPTION AND PRIVATE HOUSING STARTS, 1976 - 1986

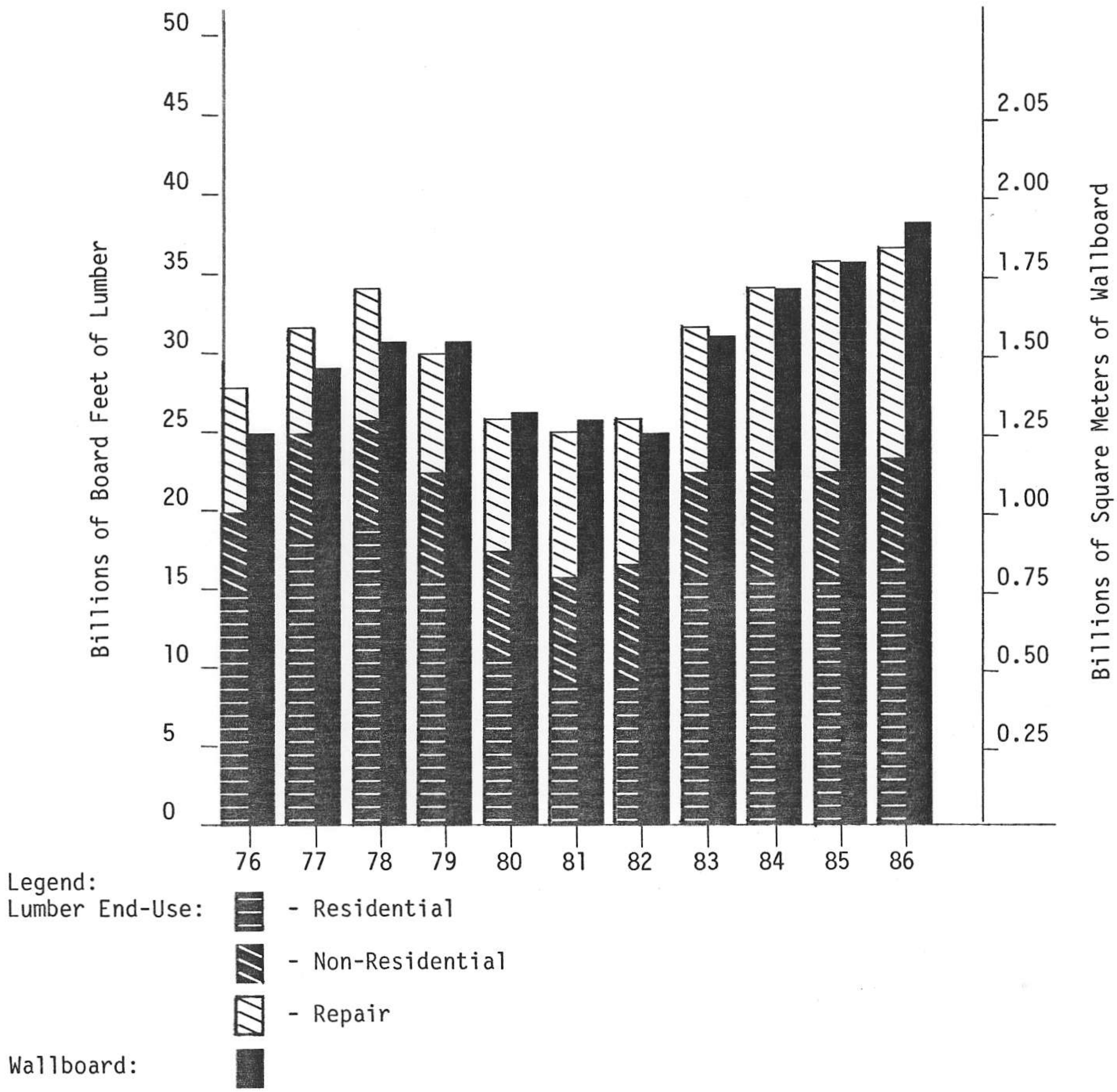


Legend:
- Single Units
- Wallboard
- Multiple Units

FIGURE 6

TOTAL UNITED STATES WALLBOARD CONSUMPTION

AND UNITED STATES LUMBER CONSUMPTION BY END-USE, 1976 - 1986



and repair sectors of construction and wallboard demand, is much more realistic than a comparison between private housing starts and wallboard consumption. This confirms that repair and remodelling activities are a factor in influencing the size of the wallboard market.

7.3.1.5 Canadian Housing Starts

Housing starts in Canada parallel trends in the United States because of response to the same economic factors. Widman Management Limited reports an 11% increase in housing starts in Canada for 1986 over 1985. 1985 starts totalled 165,826 and estimates for 1986 are at 183,000.

Regionally, Ontario and Quebec housing starts have remained stable while starts in British Columbia have risen significantly over 1985 totals. In the prairies, Alberta housing starts have decreased due to a recession in the oil industry while Saskatchewan and Manitoba report increased levels over 1985.

Table 14 provides details on housing starts by province from 1984 to 1986.

7.3.1.6 Specialty Wallboard

Recent United States statistics reveal an increase in specialty wallboard production. Gypsum has taken over more of the mobile-home market where 5/16 inch products are in increasing demand.

Of all wallboard products consumed in the Pacific Region of the United States in 1986 (Refer to Section 4, Table 7), type-X wallboard, predecorated board, 5/16 inch board and water/ moisture resistant board made up 47.1%.

TABLE 14

CANADIAN HOUSING STARTS BY PROVINCE, 1984 - 1986

Province	1984 Units	1984 %	1985 Units	1985 %	1986 Units	1986 %
Newfoundland	2,720	2.0	2,854	1.7	2,883	1.4
Prince Edward Island	643	0.5	788	0.5	1,110	0.6
Nova Scotia	4,598	3.4	6,923	4.2	7,571	3.8
New Brunswick	2,873	2.1	4,142	2.5	4,045	2.0
Quebec	41,902	31.1	48,031	29.0	60,348	30.2
Ontario	48,171	35.7	64,871	39.1	81,470	40.8
Manitoba	5,308	3.9	6,557	4.0	7,699	3.9
Saskatchewan	5,221	3.9	5,354	3.2	5,510	2.8
Alberta	7,295	5.4	8,337	5.0	8,462	4.2
British Columbia	16,169	12.0	17,969	10.8	20,687	10.3
Canada	134,900	100.0	165,826	100.0	199,785	100.0

Source: Canada Mortgage and Housing

7.3.2 Cement Demand

7.3.2.1 United States Scene

Table 15 provides statistics on cement production and consumption in the United States for the years 1982 to 1986.

Production came from one state agency and forty-eight companies operating 144 plants in 40 states. Quantities produced in 1986 included 69.1 million tonnes of portland cement and 3.3 million tonnes of masonry cement. 50% of the portland cement came from six states: California, Texas, Pennsylvania, Michigan, Missouri, and Alabama.

Distribution by end-use was as follows:

. Ready-mix concrete	70.0%
. Concrete Products (block, pipe and precast)	12.0%
. Building Material Dealers	6.0%
. Highway Contractors	5.0%
. Other Contractors	7.0%

Table 16 provides details on capacities by states.

Cement consumption hit a record high in the United States in 1986 and was 5% above 1985 levels. Regionally, the northeast and north central regions experienced the largest gains with 11% each, followed by the west with 3%.

7.3.2.2 Canadian Scene

Statistics on Canadian consumption were not readily available at the time of this writing. However, the Portland Cement Association, of the United States, reported a consumption figure for Canada during November 1986 of 569,800 tonnes, more than 2% above

TABLE 15

UNITED STATES CEMENT SALIENT STATISTICS, 1982 - 1986

(000's Tonnes)

	1982	1983	1984	1985	1986E
Production (Portland, Masonry & Other)	57,463	63,871	70,474	70,651	72,379
Shipments from Mills (Includes Masonry Cement	58,108	64,336	72,711	75,310	77,004
Imports[1]	2,640	3,828	7,880	12,807	15,419
Exports	182	107	73	89	63
Apparent Consumption	59,520	66,606	76,472	79,323	83,263

1. Import Sources (1982 - 1985): Canada 40%
Spain 23%
Mexico 21%
Other 16%

E - Estimate

Source: United States Bureau of Mines

TABLE 16

UNITED STATES CEMENT PLANT CAPACITIES BY STATES, 1985

Rank	Finish Grinding (000's Tonnes)	State
1	11,668	Texas
2	11,618	California
3	6,911	Pennsylvania
4	6,606	Michigan
5	5,053	Alabama
6	4,718	Florida
7	4,600	Missouri
8	3,171	New York
9	3,039	Iowa
10	2,927	South Carolina
11	2,692	Indiana
12	2,177	Kansas
13	2,097	Ohio
14	2,026	Colorado
15	1,887	Oklahoma
16	1,842	Maryland
17	1,755	Washington
18	1,672	South Dakota
19	1,630	Arizona
20	1,590	Georgia
21	1,438	Arkansas
22	1,429	Nebraska
23	1,307	Illinois
24	1,286	Utah
25	1,089	Virginia
26	932	Tennessee
27	765	West Virginia
28	726	Kentucky
29	691	Maine
30	680	Louisiana
31	617	Montana
32	599	New Mexico
33	544	Oregon
34	499	Wyoming
35	489	Nevada
36	476	Mississippi
37	318	Idaho
38	263	Hawaii
39	195	Wisconsin
40	145	Alaska
	94,157	Total

There are no cement-producing plants in the following states:

Connecticut	Delaware	District of Columbia
Massachusetts	Minnesota	New Hampshire
New Jersey	North Carolina	North Dakota
Rhode Island	Vermont	

Source: Portland Cement Association Market and Economic Research, December 31, 1985 the year earlier level. Regionally, Ontario registered a sizeable increase, but other provinces declined. Portland Cement Association also reported shipments for the first eleven months of 1986 to be 6.8 million tonnes, which was 4.5% more than the year earlier period.

Statistics on Canadian production of cement for 1985 and 1986, by province, are given in Table 17; Table 18 provides details on capacities by province.

7.3.3 Construction Forecasts

7.3.3.1 United States Housing Starts and Lumber Consumption

Widman Management Ltd. has made predictions on United States housing starts for the period 1987 through 1990. Table 19 indicates those predictions which were based on predicted moderate levels of interest rates.

The 1987 level of 1.7 million starts is considered unusual and a cyclical downturn is likely to occur in the next year. In 1989 and 1990, a strong climb is anticipated.

The corresponding forecast for lumber consumption in the United States for residential, non-residential, and repair and remodelling is provided in Table 20 along with a forecast of wallboard use based on a direct proportion. The growth in wallboard use for the years 1987 through 1990 averages at 3.2%. Research done by Pressler[1] indicates a similar pattern.

7.3.3.2 Canadian Housing Starts

Based on the same economic factors present in the United States, Widman Management has predicted housing starts in Canada to follow that indicated in Table 21.

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1 Minerals Facts and Problems, 1985

TABLE 17

CEMENT PRODUCTION IN CANADA, 1985 - 1986

Province	1985		1986	
	Quantity (000's Tonnes)	Value ($000)	Quantity (000's Tonnes)	Value ($000)
Newfoundland	X	8,779	X	9,300
Nova Scotia	X	21,079	X	20,449
New Brunswick	X	12,366	X	8,406
Quebec	3,094	183,794	3,231	200,700
Ontario	4,093	283,677	3,965	282,189
Manitoba	343	35,725	431	46,104
Saskatchewan	X	19,237	X	20,007
Alberta	1,143	148,882	934	124,951
British Columbia	988	74,818	1,013	78,740
Canada	10,192	788,357	10,058	790,846

X - Too small to report

Source: Energy, Mines and Resources, Canada

TABLE 18

CANADIAN CEMENT PLANT CAPACITIES BY PROVINCE, 1985

Rank	Finish Grinding (000's Tonnes)	Provinces
1	5,567	Ontario
2	4,095	Quebec
3	3,491	Alberta
4	1,744	British Columbia
5	890	Manitoba
6	485	Nova Scotia
7	376	Saskatchewan
8	315	New Brunswick
9	250	Newfoundland
	17,214	Total

There are no cement producing plants in the following provinces:

Prince Edward Island

Source: Portland Cement Association Market and Economic Research, December 31, 1985

TABLE 19

UNITED STATES HOUSING FORECAST, 1987 - 1990

Year	Number of Units (000's)
1987	1,500
1988	1,575
1989	1,675
1990	1,775

TABLE 20

UNITED STATES SOFTWOOD LUMBER AND WALLBOARD CONSUMPTION FORECAST, 1987 - 1990

	Lumber (Millions Board Feet)				Wallboard (Millions Square Meters)
Year	Residential	Non-Residential	Repair & Remodelling	Total	
1987	15,330	6,600	12,700	34,630	1,750
1988	16,065	6,675	12,975	35,715	1,810
1989	16,855	6,725	13,200	36,780	1,860
1990	17,745	6,850	13,300	37,895	1,920

TABLE 21

CANADIAN HOUSING FORECAST, 1987 - 1990

Year	Number of Units
1987	180,000
1988	165,000
1989	175,000
1990	185,000

7.3.3.3 Heavy Construction and Non-Residential Building

Engineering News Record proved to be the best source on market trends in heavy construction and non-residential building in the United States. Table 22 indicates Engineering News Record's prediction for contracts in the United States for 1986 and 1987.

The Canadian Construction Association is forecasting increases in the non-residential contract construction industry constant dollar expenditure of 4.5% through to 1995, based on the differences of Western Accord and the May 1985 federal budget. The construction industry has expressed a concern that Canada's infrastructure network needs serious attention, leading to major renovations and upkeep projects similar to those begun in the United States on their highway systems. An implemented program in such a context would allow the construction and the mining industry to plan five to ten years ahead, rather than to invest in short-term survival projects as the main incentive.

7.4 AGRICULTURE

Uncalcined and by-product gypsum are commonly used for agricultural purposes in the United States, while only occasionally used in Canada. In 1983, gypsum demand for agricultural purposes was 1.2 million tonnes, or 6% of the total United States gypsum demand. Approximately 60% of this amount of gypsum used (689,000 tonnes) was by-product gypsum, while the balance was uncalcined. The value of by-product gypsum sold for agricultural uses in 1983 was $ 7.1 million U.S.; representing an average unit value of $ 10.30 U.S. per tonne.

An estimated 90% of gypsum used for agricultural purposes are within the South Atlantic States, and in California. In these locations, certain leguminous crops require a significant amount of soluble calcium. Gypsum is also used to neutralize alkaline

TABLE 22

UNITED STATES CONSTRUCTION CONTRACTS FORECAST (MILLIONS U.S. DOLLARS)

Type of Work	1985	Estimate 1986*	Forecast 1987	% Chg. '85-86	% Chg. '86-87
Total Construction**	**160,046**	**153,923**	**143,552**	**-4**	**-7**
Heavy Construction, Total	**40,405**	**41,225**	**40,025**	**+2**	**-3**
Water Use and Control	**12,941**	**13,400**	**13,850**	**+4**	**+3**
Waterworks	3,219	3,550	3,700	+10	+4
Sewerage	6,463	6,250	6,400	-3	+2
Dams, Reservoirs, Waterways	3,259	3,600	3,750	+10	+4
Transportation	**19,597**	**20,700**	**19,425**	**+6**	**-6**
Highways, Streets	15,042	15,750	14,750	+5	-6
Bridges	4,555	4,950	4,675	+9	-6
Electricity, Gas, Communications	**2,462**	**2,000**	**2,000**	**-19**	**0**
Other Heavy Construction	**5,405**	**5,125**	**4,750**	**-5**	**-7**
Non-Residential Buildings	**82,740**	**78,173**	**74,840**	**-6**	**-4**
Manufacturing	**7,561**	**6,700**	**7,300**	**-11**	**+9**
Commercial	**47,623**	**42,794**	**38,206**	**-10**	**-11**
Offices, Banks	24,739	20,200	16,450	-18	-19
Stores, Mercantile	13,044	12,872	12,268	-1	-5
Warehouses	6,967	6,873	6,958	-1	+1
Garages, Services Stations	2,873	2,849	2,530	-1	-11
Educational	**8,805**	**9,775**	**9,925**	**+11**	**+2**
Hospitals, Health Treatment	**7,743**	**7,525**	**7,775**	**-3**	**+3**
Government Service	**2,994**	**2,885**	**2,677**	**-4**	**-7**
Other (Leisure, Religious, Miscellaneous)	**8,014**	**8,494**	**8,957**	**+6**	**+5**
Multi-Unit Residential	**36,901**	**34,525**	**28,687**	**-6**	**-17**
Apartments	**29,875**	**27,514**	**22,450**	**-8**	**-18**
Hotels, Motels, Dormitories	**7,026**	**7,011**	**6,237**	**0**	**-11**

* Preliminary
** Excludes 1-2 Family Houses

Source: ENR-Dodge/DRI

and saline soil conditions, softening of clayey soils, soil stability and providing the basic nutrients of calcium and sulphur.

Salient statistics for the United States demand for agricultural purposes are provided in Table 23.

7.5 PULP AND PAPER INDUSTRY

World consumption of paper and paperboard products increased an estimated 3.0% in 1986 and is expected to increase a further 4.0% in 1987. It is anticipated that in the next four years, pulp prices will increase significantly from $ 500 U.S. per tonne to $ 620 U.S. per tonne by the year 1990. This significant price increase of pulp prices should have a positive effect on the filler and extender markets as pulp and paper manufacturers seek less expensive partial substitutes other than pulp as a filler for specialty paper products.

Gypsum may as well, due to its characteristics and cost advantage over kaolin, become an acceptable filler to be used in pulp and paper manufacture.

With apparently modest levels of economic growth, one can expect continued demand growth in paper and paperboard products through the balance of the 1980's. An annual growth rate of 3.5% to 4.5% in consumption of paper and paperboard products over the next four years would be consistent with the past two years growth rates.

This growth rate should reflect westcoast (North American) pulp and paper manufacturers current consumption of 272,160 tonnes of mineral filler increasing to 317,500 tonnes by the year 1990.

TABLE 23

DEMAND FOR GYPSUM IN UNITED STATES AGRICULTURE, 1973 - 1983

(000's Tonnes)

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1,318	1,516	1,344	1,555	1,520	1,368	1,542	1,504	1,383	1,180	1,188

7.6 EXTENDER, FILLER AND SPECIALTY MARKETS

Mineral fillers and extenders are materials that can be incorporated with other compounds to achieve a variety of different results. The primary reasons for industries to utilize mineral fillers are to reduce production costs; increase hardness, brittleness, impact strength; and modify fire resistance, surface texture, flow characteristics, heat conductivity, thermal expansion, physical characteristics, deformity, viscosity and softening point.

Gypsum is known to be incorporated in limited amounts as a mineral filler in the manufacture of plastics, paper, cotton goods, paint, rubber, pesticides, foods, pharmaceutical and ceramics. The greatest potential for gypsum, within the filler markets, is within the manufacture of paint, paper and plastics.

Salient statistics for the United States demand of gypsum for mineral filler and extender purposes are unavailable for specific geographic areas, though total demand between the years 1973 and 1983 is outlined in Table 24.

In the United States, mineral filler demand is for 60% calcined gypsum and 40% uncalcined gypsum. Recent statistics (Mineral Industry Surveys, 1986) indicate that in 1985, 104,872 tonnes of uncalcined gypsum was sold or used by United States producers for mineral filler and miscellaneous uses.

In British Columbia, 1985: 8,800 tonnes of kaolin and 9,600 tonnes of talc were imported for the manufacture of plastics and rubber products; while in 1983, 2,900 tonnes of calcium carbonate, kaolin and talc were consumed by paint manufacturers. Though this is not a significant amount, it provides an insight as to the potential of mineral filler applications within British Columbia's marketplace.

TABLE 24

DEMAND FOR GYPSUM IN UNITED STATES FILLER AND MISCELLANEOUS MARKETS, 1973 - 1983

(000's Tonnes)

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
106	112	161	221	161	148	112	122	103	112	179

Source: J.W. Pressler (1985)

Overall, in the mineral filler and extender markets, the specific mineral filler is chosen by the user balancing costs versus performance. Factors taken into consideration include: geographic location and associated transportation costs, physical characteristics and purity of product, along with associated handling and processing costs. The filler market is very competitive among the established fillers (kaolin, calcium carbonate, and talc) and, therefore, it would be difficult for a new product to penetrate a significant portion of the current market.

In British Columbia, the salient statistics, as per Mineral Policy Sector Internal Report MRI 86/2, on the consumption of kaolin, calcium carbonate and talc by pulp and paper plants between the years 1980 and 1985 are outlined in Table 25.

The estimated value of kaolin clay consumed in 1985 by British Columbia pulp and paper manufacturers is $ 1.7 million. This represents only a small fraction of the value of kaolin clay consumed by the rest of Canadian pulp and paper manufacturers, primarily located in eastern Canada, of $ 17 million. The prime reason for this occurrence is that most fine papers, which require a significant portion of mineral filler, are located within Ontario and Quebec.

The demand for gypsum within the specialty markets is less than 1% of the total demand and significantly less than 1% of the total product value. Calcined gypsum is used as a casting plaster or dental plaster, as a cementing agent in oil and gas well drilling, ceramics, and as a maintenance compound for quick patching of high-use surfaces. Anhydrous gypsum, when heated to 204 deg.C, creates a "soluble anhydrite" which is sold in various particle sizes as desiccant in laboratory and commercial applications and as a carrier of certain insecticides. When heated to 482 deg.C, a dead-burned or insoluble anhydrite is formed which can be used in the manufacture of Keenes cement or as an industrial filler.

TABLE 25

MINERAL FILLER CONSUMPTION IN BRITISH COLUMBIA PULP AND PAPER PLANTS, 1980-1985

(Tonnes)

	1980	1981	1982	1983	1984*	1985*
Kaolin	3,760	3,544	3,664	4,601	6,275	8,830
Calcium Carbonate	-	28,925	4,776	3,611	16	38
Talc	-	1,699	1,293	1,783	3,614	9,566

* Partial use by pulp and paper industries

Source: Energy, Mines & Petroleum Resources, Canada, Mineral Policy Sector

7.7 BY-PRODUCT GYPSUM

By-product gypsum generated in flue gas desulphurization, phosphate rock acidulation, and other chemical processes in the United States and Canada in not reclaimed, except for the small amount sold for agricultural and wallboard purposes.

The recovery of by-product gypsum from phosphoric acid and other acid manufacturing, including thermal power plant stack desulphurization, could alter some minor local supply situations, but the integration of the gypsum industry plus certain technical problems seem likely to prevent a major shift to widespread usage of by-product gypsum.

Phosphogypsum, a by-product of the phosphate fertilizer industry, is produced at four fertilizer plants in Alberta. Research programs have been conducted to determine if phosphogypsum could be used in the manufacture of wallboard, but no commercial use is made of Alberta's phosphogypsum at present.

Phosphate producers in Florida have always had problems with phosphogypsum. For every tonne of phosphoric acid manufactured, five tonnes of phosphogypsum are produced and stockpiled next to the phosphate chemical plants.

According to "Chemical Week", the researches have found a way to process phosphogypsum making sulphuric acid and aggregate for roads. The phosphogypsum is fed to a rotating circular grate with petroleum coke, waste phosphatic clays and pyrites. The mixture is burned in a series of sealed zones on the grate. The new gas produced is high SO_2 and is collected for use as a feed gas in a conventional, metallurgical-type sulphuric acid plant. The solid by-product which remains on the grate after the reaction is discharged in a dry form. According to the technical experts, the mixture yields more than 90% sulphur recovery and a road aggregate that looks promising.

A research conducted at C-E Raymond's Neperville, Illinois, laboratory facilities, has resulted in the development of an innovative commercial calcining process which allows high-quality wallboard to be produced from by-product gypsum of flue gas desulphurization at coal-fired power plants.

Possible utilization of by-product gypsum from the manufacture of phosphoric acid, hydrofluoric acid, citric acid, titanium oxide, and refinery flue gas desulphurization, would provide some relief for environmental problems and augment the mitigation process of these industries. The recycling and utilization of by-product gypsum, resulting from desulphurization of stack gases from coal-burning power plants, would provide some benefit to the utilities industry. Storage of the waste sludge will become more critical as the cost of land increases and the public concern for solid waste pollution intensifies. However, as long as the cost for solid waste disposal continues to be economical and solid waste pollution remains non-critical, only a small amount of the potentially useful by-product gypsum will be used.

7.8 UNITED STATES GYPSUM DEMAND FORECAST

Minerals, Facts and Problems, 1985, presents projections and forecasts for the United States gypsum demand for the year 2000.

The predictions presented (Refer Tables 26 and 27) are considered credible and realistic based on analytical procedures used.

With permission from the proper authorities, the analysis and discussion are repeated here, word-for-word, except the tonnage has been converted to metric.

End-use-demand data for gypsum were correlated with various economic indicators. A statistical projection for each end-use was derived from an independent forecast of the indicator that

TABLE 26

PROJECTIONS AND FORECASTS FOR UNITED STATES GYPSUM BY END-USE - 2000

(000's Tonnes)

		2000			
			Contingency Forecasts for United States		
			Forecast Range		
End-Use	1983	Statistical Projections[1]	Low	High	Probable
Construction:					
. Prefabricated Products	14,219	25,946	19,958	26,309	24,494
. Plaster, Industrial and Building	643	0	544	635	544
. Cement Set Regarder	3,588	4,717	4,355	4,717	4,355
Agriculture	1,187	1,542*	1,452	1,542	1,542
Fillers and Miscellaneous	179	236*	181	245	236
Total[2]	19,816	-	26,309	33,566	30,845

1. Statistical projections, provided by the Branch of Economics Analysis, are derived from regression analysis based on historical time series data and from forecasts of economic indicators such as GNP and FRB index. A statistical projection of zero indicates that demand will vanish at or before year 2000, based on the historical relationship. Projection equations with a coefficient of determination (R-squared) less than 0.70 are indicated by an asterisk(*).

2. Data may not add to totals shown because of independent rounding

TABLE 27

SUMMARY OF FORECASTS OF UNITED STATES AND REST-OF-WORLD GYPSUM DEMAND, 1990-2000

(000's Tonnes)

	1983	2000 Forecast Range Low	2000 Forecast Range High	Probable 1990	Probable 2000	Probable Average Annual Growth Rate 1983-2000 (percent)
United States						
Total	19,816	26,309	33,566	23,587	30,845	2.6
Cumulative	-	390,096	453,600	154,224	426,384	-
Rest-Of-World						
Total	58,044	77,112	96,163	68,947	87,091	2.4
Cumulative	-	1,179,360	1,270,080	444,528	1,179,360	-
World:						
Total	77,859	103,421	129,730	92,534	117,936	2.5
Cumulative	-	1,542,240	1,723,680	598,752	1,632,960	-

showed the best correlation. A forecast of each end-use considered the impacts of technologic and social contingencies on the demand for gypsum.

Prefabricated Products. - The use of wallboard has grown faster than that of almost any other building material, with an annual growth rate of 3.2% over the last 21 years. Use of prefabricated products, primarily gypsum wallboard for housing and buildings relates to growth in new construction activity and housing starts. The statistical projection of 25.9 million tonnes for the year 2000 was obtained from the regression equation with Gross Private Domestic Investment as an explanatory variable. The high side of the 2000 forecast demand range is established at 26.3 million tonnes on the assumption that the historical pattern will continue into the future, notwithstanding the recent depressed years of 1981 and 1982 of low housing and building starts. The low demand forecast of 19.9 million tonnes was obtained by assuming a strong competitive market from plywood and other manufactured wooden board, and that demand will be slowed by continuing high mortgage interest rates and construction costs, higher density condominiums and high rise apartments, and decreased population growth. The near-high position of 24.5 million tonnes was selected for the probable demand.

Building and Industrial Plaster. - The labour-intensive nature of plaster use in the United States has caused a long-term decline in its use in the last 21 years. Regression analysis indicates a 15% negative growth rate for building plaster, and a 1.4% growth rate for industrial plaster. These trends are expected to continue although building plaster is predicted to approach an irreducible minimum of 181,440 tonnes per year. Industrial plaster, principally used for casting and molding has had a modest growth rate in the last 21 years and correlates well with the United States population. Combining both types of plaster, the statistical projection of zero for 2000 was obtained by an excellent correlation with the United States population as an independent variable. The high side of the 2000 forecast demand range is established at 635,040 tonnes, an optimistic no-growth situation from the present, and the low demand forecast of 544,320 tonnes was obtained by assuming continuing economic pressures on housing costs in which more prefabrication and unit construction procedures will be practiced. The low of 544,320 tonnes was selected for the probable demand.

Cement Retarder. - New construction activity was used in the regression equation as an explanatory variable to obtain the statistical projection of 4.7 million tonnes for cement set retarder in the manufacture of cement in the year 2000. The high side of the 2000 forecast demand range is established at 4.7 million tonnes on the contingency that this historical pattern will continue to 2000 unabated. The low side of the 2000 forecast demand range of 4.4 million tonnes was obtained by assuming constraints on the construction industry, including housing because of continuing high interest rates, and low population growth. The probable annual demand in 2000 for gypsum use as a cement set retarder is selected at 4.4 million tonnes, which coincides with a 5% average gypsum requirement of the probable cement consumption in 2000.

Agriculture. - There was no good correlation of this end-use with any of the available economic indicators. The statistical projection of 1.5 million tonnes of gypsum for agricultural use in 2000 was obtained from the regression equation with the Federal Reserve Board (FRB) Agricultural Chemicals index as an independent variable. This projection was selected as a probable demand forecast. The probable demand forecast of 1.5 million tonnes was also obtained by extrapolating the result of a regression equation of 21 years' data using time as the explanatory variable. The harvested crop acreage in the South Atlantic States and California, the areas that use over 90% of the agricultural gypsum, was used in the regression equation as an additional explanatory variable to obtain 1.5 million tonnes of gypsum used in 2000. This was selected as a low demand forecast, because little increase in crop acreage is expected through 2000. Better utilization of crop acreage, the improving technology of obtaining maximum crop productivity including fertilizer utilization, and the need to promote nitrogen fixation in leguminous crops, indicate the continued use of gypsum in the future, but no optimistic projection can exceed the probable demand forecast of 1.5 million tonnes, so that was also selected as the high demand forecast.

Fillers and Miscellaneous. - The statistical projection of 235,872 tonnes of gypsum for fillers and miscellaneous uses in the year 2000 was obtained from the regression equation with the United States population as the independent variable. The 21-year historical time series indicates an average 4.5% growth rate per year. An optimistic high side of the 2000 forecast demand range was established at 244,944 tonnes on the assumption of a continuation of this healthy growth rate. The low demand forecast of 181,440 tonnes was obtained by assuming a slowing of demand for these specialty uses by strong competition with other materials such as kaolin, pulverized calcium carbonate, and talc. The near high of 235,872 tonnes was selected for the probable demand.

8. PRICE STRUCTURE OF GYPSUM

8.1 PRICE VERSUS END-USE

Wallboard and other gypsum products are priced to yield a satisfactory return on investment for a manufacturer and at the same time to compete with alternative products.

There are no market quotations for wallboard and crude gypsum. Captive production receives an 'assigned value' which reflects production costs only, so that the true value of gypsum, the main component in the manufacture of wallboard, is not revealed.

When crude gypsum is supplied to wallboard and cement manufacturers or other unrelated gypsum products producers, a contract price, which is influenced by the price from the next available source, is always negotiated between the seller and the buyer.

The average price in U.S. dollars per tonne of crude gypsum priced FOB mine and calcined gypsum priced FOB plant during the period from 1981 to 1986 is shown in Table 28.

This tabulation shows that a price of crude gypsum actually fell 7.8% from its 1982 level. It has been constant for the last three years, averaging $ 8.69 U.S. per tonne.

On the contrary, a price of calcined gypsum shows a wider fluctuation during the same period with an upward trend of 37.3% from 1982 to 1986 price level.

The primary reason for the constant price level of crude gypsum is the large-scale integrated operations, dominated by a small number of large companies.

TABLE 28

AVERAGE PRICE IN U.S. DOLLARS PER TONNE[1] OF CRUDE GYPSUM, 1981 - 1986

	1982	1982	1983	1984	1985	1986
Crude Gypsum	9.48	9.40	8.64	8.82	8.62	8.67
Calcined Gypsum	23.11	19.42	21.59	23.05	26.14	26.67

1. F.O.B. Mine

Source: Mineral Commodity Summaries 1986 and 1987

Although the market is dominated by a small number of large companies, there is a high degree of competition. Distribution patterns vary with sales being direct from plant to large building contractors, and through building product wholesalers to retail outlets.

The larger contractors, building supply chain stores, or purchasing associations, normally go to tender on large wallboard purchases. Once a chain or association negotiates a price for wallboard, individual retail outlets are able to place orders directly with the manufacturer.

Price information on the margin structure used by individual firms is difficult to obtain. Some indications on average values can be summarized from available trade information statistics and current selling price.

Average total cost of manufacturing gypsum board, as reported to Statistics Canada, per hundred square meters, is in the order of $ 118.41 CDN. Current selling price to large contractors and chain stores in Canada are in the order of $ 156.08 CDN per hundred square meters. Current prices for smaller customers buying from building material suppliers in central Canada are in the order of $ 193.76 to $ 204.52 CDN. per hundred square meters in truck load lots delivered to the job site.

Sales to the United States are more profitable, the current prices being in the order of $ 209.90 U.S. per hundred square meters in truck load lots delivered to the job site. The United States market appears to be more profitable than does the Canadian market.

Data compiled for the Pacific Northwest market reveals that a price of crude gypsum delivered to the customer's wallboard plant site ranges from $ 23.00 U.S. to $ 26.00 U.S. per tonne.

The price of crude gypsum for the cement industry delivered to the plant site is quoted between $ 30.00 CDN to $ 33.00 CDN per tonne in the Vancouver and Seattle market areas.

A future crude gypsum producer in British Columbia will have to compete in the gypsum market in the Pacific Northwest area. An outline of the price structure of gypsum delivered to the Pacific Northwest market area is given in Table 29.

Therefore, a producer of crude gypsum in British Columbia will have to undercut the price of either Spanish or Mexican gypsum for at least $ 1.00 U.S. per tonne, in order to be competitive in the cement or wallboard market area.

According to Data Resources Inc., of Lexington, Massachussets, material prices forecast for 1989 for gypsum board and portland cement will follow the trend which is outlined in Table 30.

A drop of 0.5% in gypsum board prices is predicted for 1987, and, thereafter, an increase of 2.2% and 3.1% in 1988 and 1989 respectively.

Forecast for portland cement price for 1987 is 0.3% drop with sharp increases of 2.8% and 5.0% in 1988 and 1989 respectively.

TABLE 29

PRICE OF CRUDE GYPSUM DELIVERED TO THE PACIFIC NORTHWEST

Gypsum Source	Purchase Price FOB Nearest Port $U.S./Tonne	Freight $U.S./Tonne	Other Costs $U.S./Tonne	Total Cost $U.S./Tonne
Spain	5.00 - 6.00	10.00 - 11.00 (40,000 Tonne) 13.00 - 14.00 (25,000 Tonne)	2.50+	$ 25.00 Vancouver
Mexico	-	Domtar	-	$ 26.00 Seattle
Windermere, B.C.	-	Westroc	-	$ 23.00 Vancouver

TABLE 30

PRICE FORECASTS FOR GYPSUM BOARD AND PORTLAND CEMENT, 1985 - 1989

	1985 (%)	1986 (%)	1987 (%)	1988 (%)	1989 (%)
Gypsum Board	-2.3	2.9	-0.5	2.2	3.1
Portland Cement	2.0	-1.6	-0.3	2.8	5.0

Source: Data Resources Inc.

9. GYPSUM SUPPLY AND DEMAND IN THE PACIFIC RIM OF NORTH AMERICA

In the Pacific Rim of North America, commercial gypsum deposits are in three major areas which are not evenly distributed through the region. Due to high land transportation costs relative to the base cost of the gypsum, the gypsum in these areas is converted to the end-use product in relatively local plants.

Other areas, principally on the coast, utilize gypsum imported mainly from Mexico and Spain. The costs of gypsum from these sources is competitive due to the ability to ship in bulk by sea and the lower mining costs at these locations.

9.1 SUMMARY

Figures 7 and 8 graphically depict the movement of crude gypsum and the estimated supply and demand in the Pacific Rim of North America.

In the following sections, details of supply and usage of gypsum in the Pacific Rim of North America have been quantitied.

9.2 PRODUCERS

The three main mining areas of gypsum in the Pacific Rim of North America, as depicted in Figure 9, are:

a) Southern California and Southern Nevada;
b) Northwestern Nevada; and
c) British Columbia.

Other producing areas are Washington State and Central California. The gypsum deposits in these areas are generally of a lower purity and used principally in agriculture.

FIGURE 7

CRUDE GYPSUM FLOW IN THE PACIFIC RIM OF NORTH AMERICA

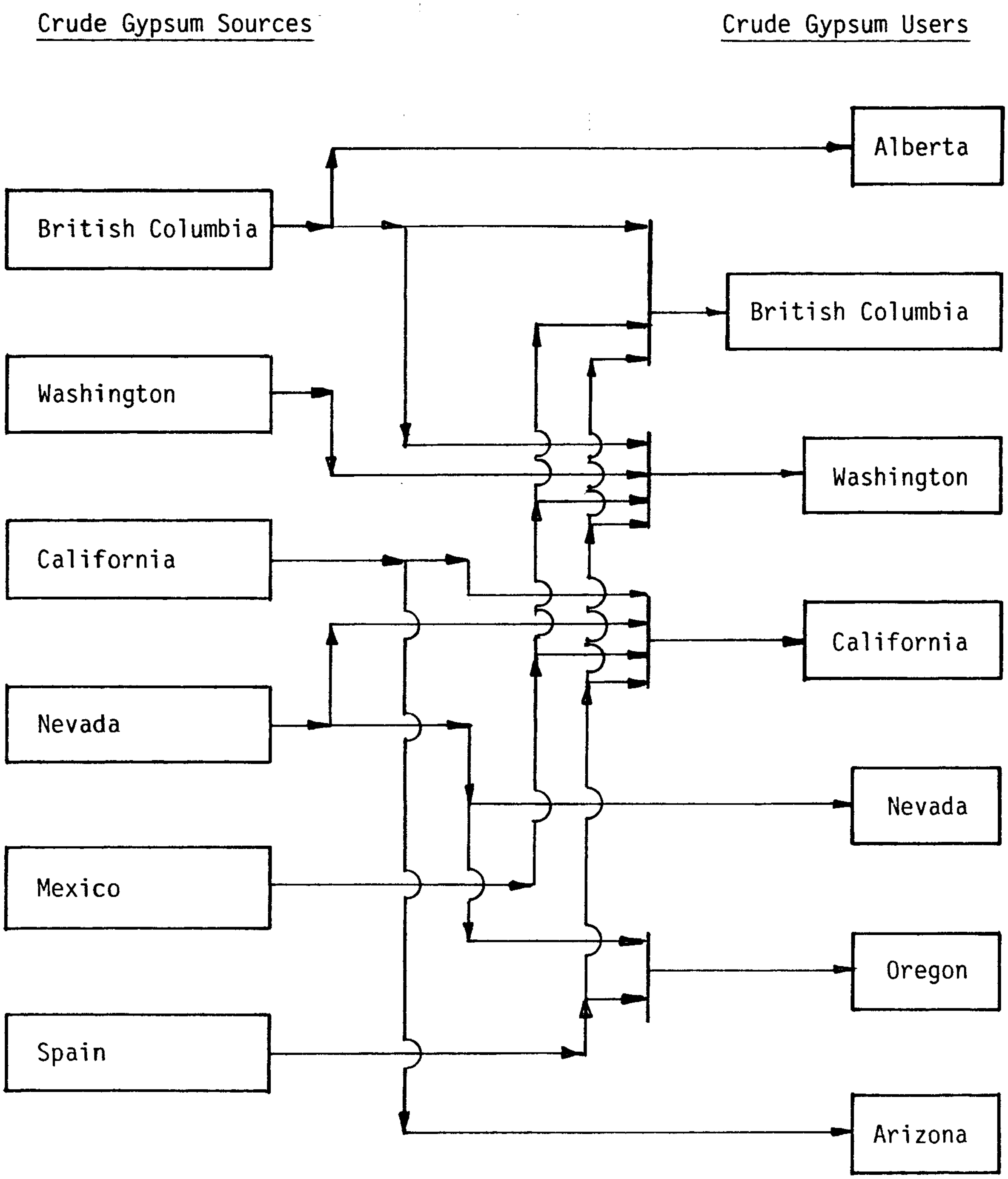


FIGURE 8

ESTIMATED SUPPLY/DEMAND OF GYPSUM IN THE PACIFIC RIM OF NORTH AMERICA

(Tonnes)

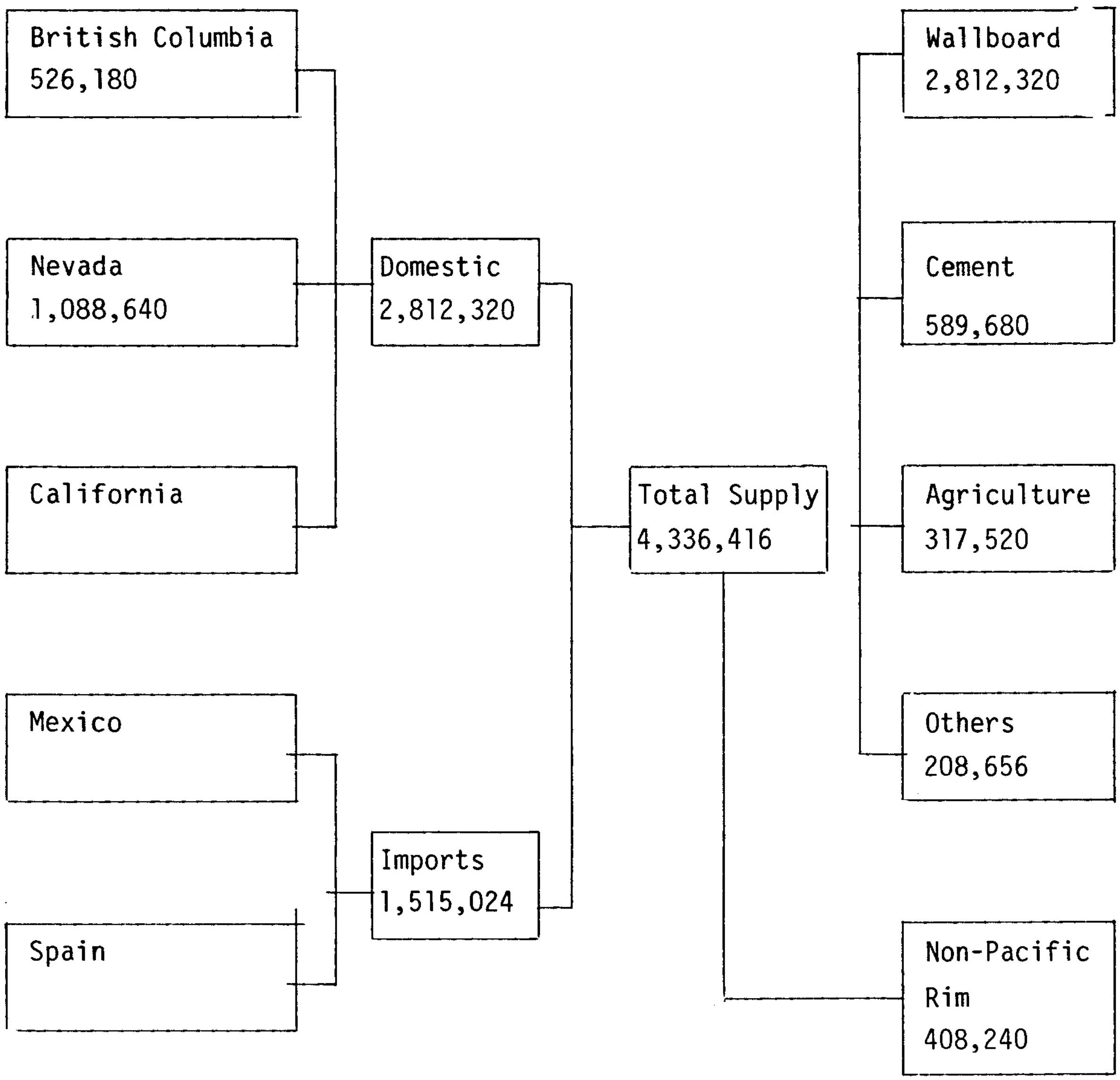
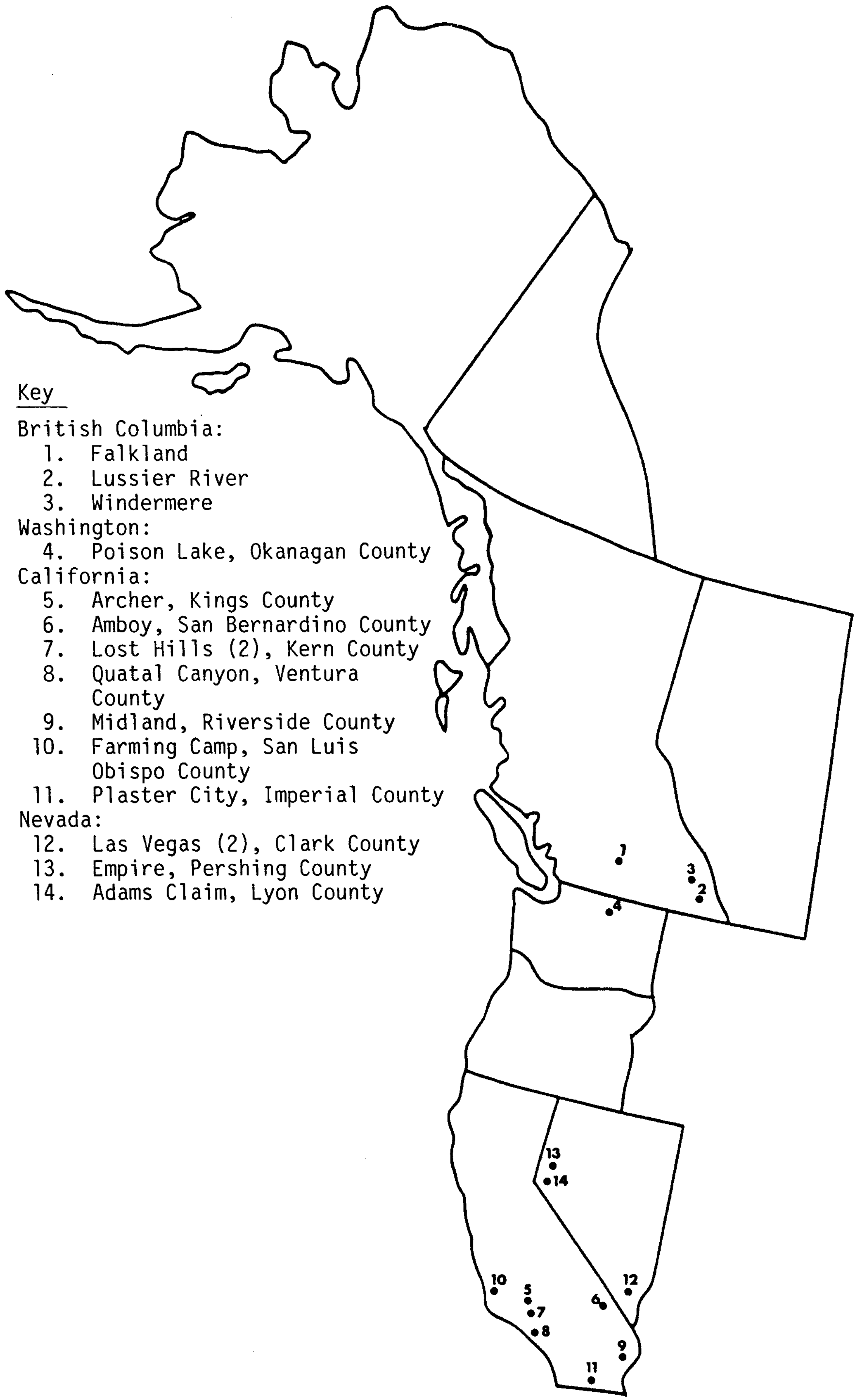


FIGURE 9

LOCATION OF ACTIVE GYPSUM MINES IN THE PACIFIC RIM OF NORTH AMERICA (1985)



Key

British Columbia:
1. Falkland
2. Lussier River
3. Windermere

Washington:
4. Poison Lake, Okanagan County

California:
5. Archer, Kings County
6. Amboy, San Bernardino County
7. Lost Hills (2), Kern County
8. Quatal Canyon, Ventura County
9. Midland, Riverside County
10. Farming Camp, San Luis Obispo County
11. Plaster City, Imperial County

Nevada:
12. Las Vegas (2), Clark County
13. Empire, Pershing County
14. Adams Claim, Lyon County

By-product gypsum is manufactured in Northern California. This is a small percentage of the total gypsum produced in the Pacific Rim of North America and is utilized almost exclusively in the agricultural area.

Table 31 lists the production of gypsum by Province and state.

9.2.1 British Columbia

Gypsum is mined in British Columbia primarily at two locations, both in the East Kootenays.

The Westroc Industries mine at Windermere, is currently producing approximately 454,000 tonnes per year. Approximately 80% of this production is used in its own wallboard plants in Calgary, Alberta and Vancouver, British Columbia. The remaining 20% is sold for both the cement industry and agricultural uses. Shipping of the gypsum is both by truck and rail, with slightly more rail than truck.

Domtar utilizes all its production of approximately 118,000 tonnes per year from its Lussier River mine in its own wallboard plant in Edmonton, Alberta. The gypsum is all shipped by rail.

The mine at Falkland is owned by Canada Cement Lafarge and operates only three months of the year. Its total output is consumed by its cement plant in Kamloops.

9.2.2 Washington

The only mine in Washington is at present producing a negligible amount. The entire output is sold locally for use as a soil conditioner in agriculture.

TABLE 31

PACIFIC RIM GYPSUM PRODUCTION BY PROVINCE AND STATE

Quantities Mined (000's Tonnes)

State/Province	1980	1981	1982	983	1984	1985
British Columbia	784	685	415	460	412	
Washington	(1)	(1)	(1)	(1)	(1)	(1)
California	1,491	1,321	987	1,100	1,254	1,208
Nevada	773	706	595	905	1,081	1,095
Totals	3,048	2,666	1,942	2,466	2,747	

(1) Reported quantities are included with other non-metalic minerals as the volume is minimal.

9.2.3 California

The mines producing gypsum in California for the calcining plants and cement industry are located in Southern California. The largest producing mine in the United States is at Plaster City in Imperial County, which produces in excess of 1.5 million tonnes per year. The gypsum rock from this mine is used principally in the owner's (U.S. Gypsum) local wallboard and plaster manufacturing plant.

Riverside County is a second large producer of gypsum. Superior Gypsum, at Blythe, mines approximately 544,320 tonnes per year. Approximately 80% of its production is used in the cement industry, mainly in southern California with a small amount being shipped to Arizona. The balance of its production is sold for agricultural use.

Other smaller deposits of lower grade gypsum and gypsite are mined in the San Joaguin Valley. Although these deposits are too low in percent gypsum to be utilized in the plaster and cement industry, they are used extensively to treat the alkaline soils which predominate in the agricultural areas of the state.

By-product gypsum is also manufactured in California. The amount produced as a percentage of the total gypsum used is minimal. This product is used almost entirely as a soil conditioner as are the low grade gypsite deposits.

9.2.4 Nevada

The producing areas of Nevada are the south of Clark County, and the northwest of Lyon and Pershing Counties.

The two mines in Clark County, owned by PABCO and United States Gypsum, utilize the gypsum in their own plants locally to produce wallboard and plaster. The United States Gypsum mine in Pershing County produces approximately 1.22 million tonnes per year for use in its own plant. 96% to 97% is calcined to produce wallboard, with the balance sold for agriculture.

Art Wilson Co. markets approximately 80% of the 90,720 tonnes per year output from its mine in Carson City to the cement industry in Northern California and Northern Nevada. The balance is used for agricultural purposes.

9.3 CONSUMERS

9.3.1 Wallboard Industry

The wallboard industry consumes approximately 70% of the gypsum used in North America.

Wallboard plants are generally located relatively close to the source of supply of crude gypsum due to the high transportation costs.

In the Pacific Rim of North America, the majority of plants are located either:

a) at the site of the mine which supplies it;

b) along the coast, where there is easy access to bulk unloading facilities for imported gypsum.

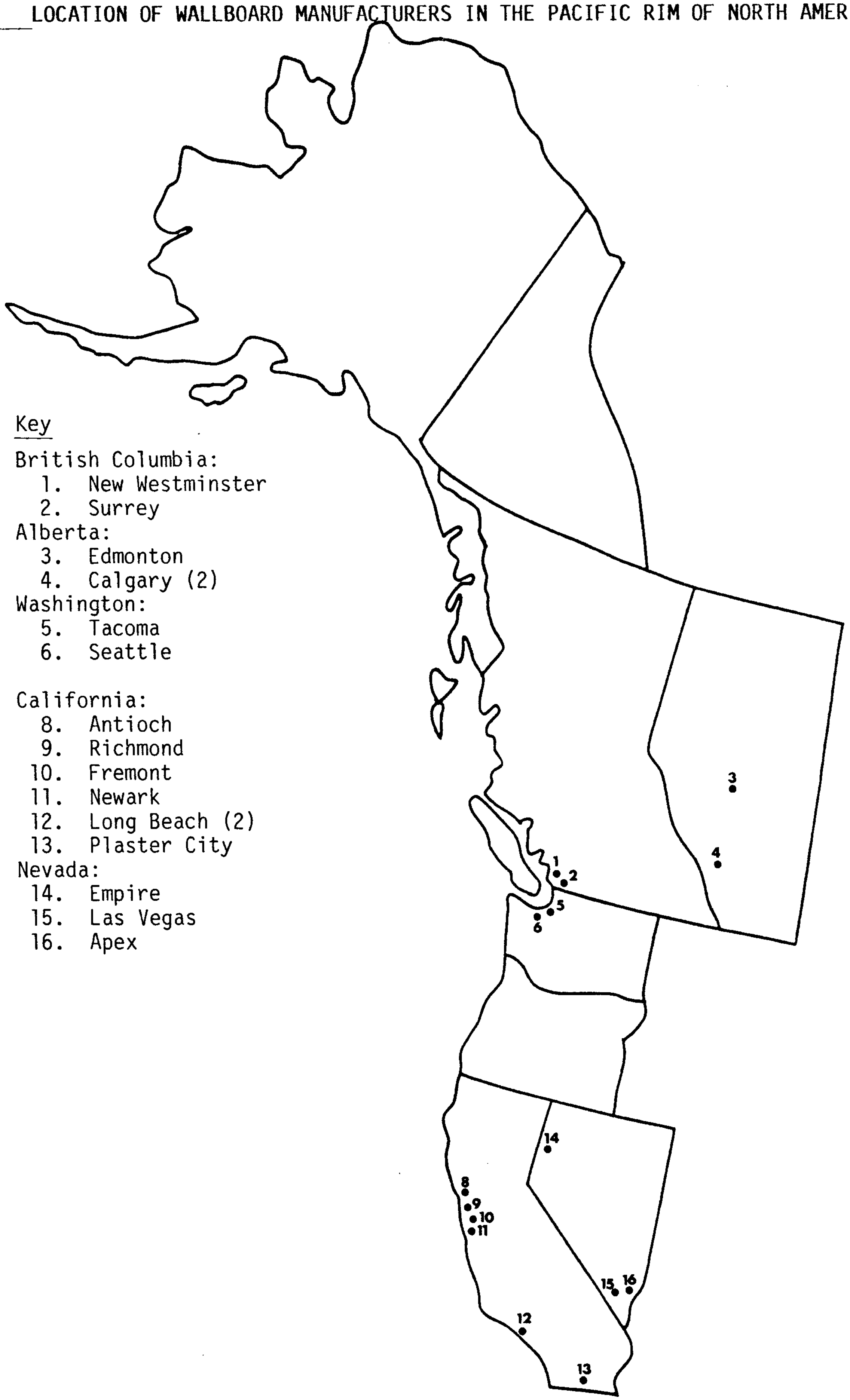
See Figure 10 for locations of wallboard plants.

9.3.1.1 British Columbia

The two plants in British Columbia, Westroc Industries and Domtar Construction, are located within easy access of waterborne bulk shipments in the Greater Vancouver area.

FIGURE 10

LOCATION OF WALLBOARD MANUFACTURERS IN THE PACIFIC RIM OF NORTH AMERICA



Key

British Columbia:
1. New Westminster
2. Surrey

Alberta:
3. Edmonton
4. Calgary (2)

Washington:
5. Tacoma
6. Seattle

California:
8. Antioch
9. Richmond
10. Fremont
11. Newark
12. Long Beach (2)
13. Plaster City

Nevada:
14. Empire
15. Las Vegas
16. Apex

Domtar imports all its gypsum, principally from their own mine in San Marcos.

Westroc Industries' mine at Windermere, British Columbia, supplies all the gypsum for its wallboard plant in New Westminster. Current consumption averages 131,544 tonnes per year.

9.3.1.2 Alberta

All three wallboard plants in Alberta receive crude gypsum from outside the province.

Westroc Industries operates a wallboard plant in Calgary with gypsum arriving from Westroc's mines in eastern British Columbia and Manitoba.

Domtar's wallboard plant in Calgary is presently closed, while its plant in Edmonton receives its crude gypsum supply from Domtar s mine at Lussier River in the East Kootenays of British Columbia.

9.3.1.3 Washington

Domtar and Northwest Gypsum are the two wallboard plants on the coast of Washington. Their total requirements of approximately 508,032 tonnes per year are provided by imported material from both Mexico and Spain. Domtar's supply is totally from its own mine in San Marcos and Northwest Gypsum being supplied by both San Marcos and Spain.

9.3.1.4 California

There are seven wallboard manufacturing plants in California, six of which are located on the coast, and one in Imperial County.

In 1986, an estimated 1,814,400 tonnes of gypsum were used to manufacture wallboard. The six coastal plants were supplied by imported gypsum, while the U.S. Gypsum plant in Imperial County was supplied entirely from its own local mine.

9.3.1.5 Nevada

The three wallboard manufacturing plants in Nevada are all located within short hauling distance of the mines supplying them. The plants, with their respective mines, are each owned and operated by its own parent company.

9.3.2 Cement Industry

The cement producing plants in the Pacific Rim of North America are more widely distributed than the wallboard plants. They are generally located closer to the supply of lime, as this is the main ingredient in the making of cement (Refer to Figure 11).

The gypsum component of the cement varies from 3% to 6% so the higher transportation costs do not have a significant bearing on the locations of the plants.

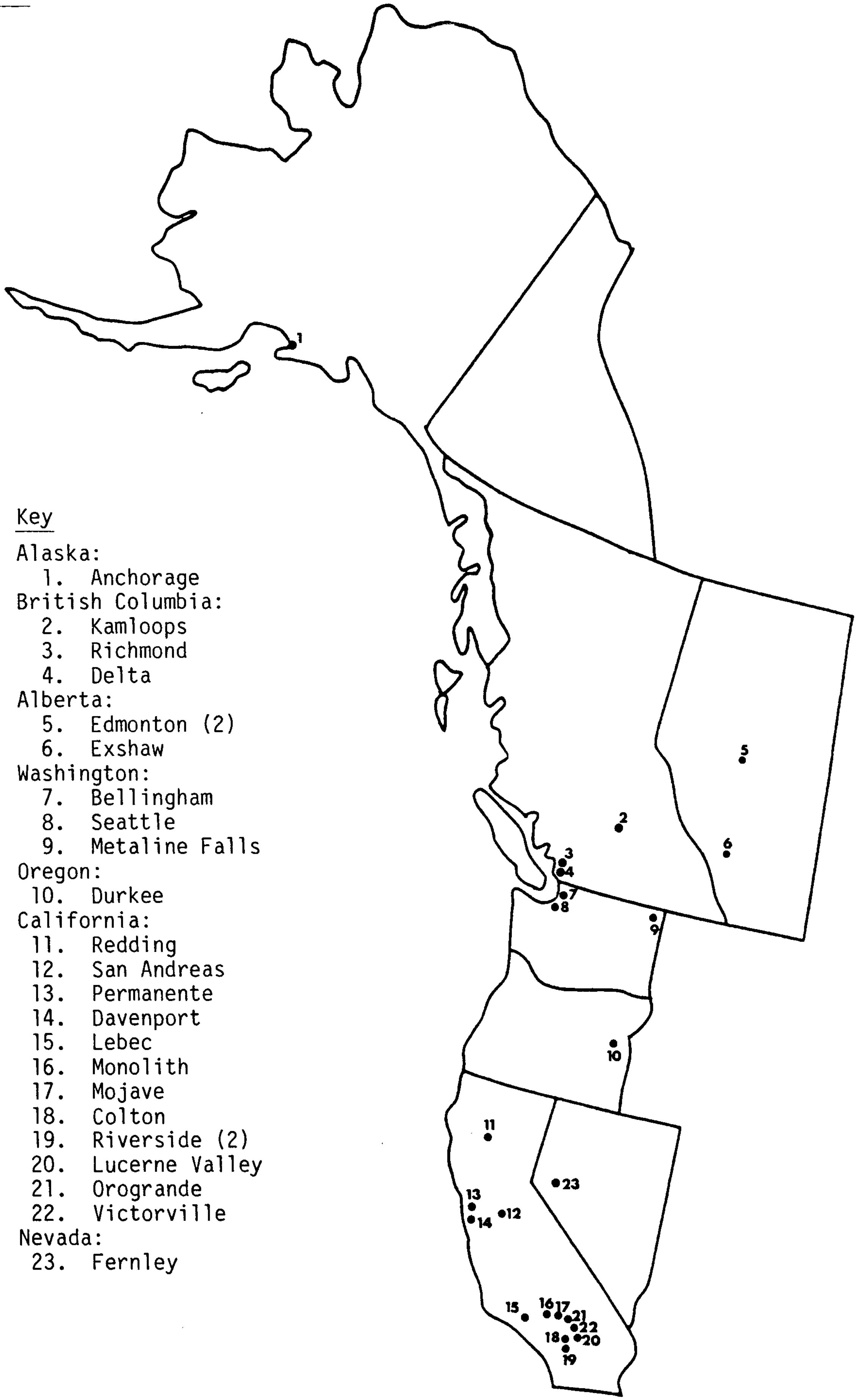
The cement plants on the coast utilize both domestic and imported gypsum. Imports are principally from Spain.

The mines of southern Nevada and southern California supply gypsum to the cement plants in central California and western Arizona as well as their own local markets.

The northwestern Nevada mines ship gypsum into Oregon and northern California for the cement industry.

FIGURE 11

LOCATION OF CEMENT PRODUCING PLANTS IN THE PACIFIC RIM OF NORTH AMERICA



Key

Alaska:
1. Anchorage

British Columbia:
2. Kamloops
3. Richmond
4. Delta

Alberta:
5. Edmonton (2)
6. Exshaw

Washington:
7. Bellingham
8. Seattle
9. Metaline Falls

Oregon:
10. Durkee

California:
11. Redding
12. San Andreas
13. Permanente
14. Davenport
15. Lebec
16. Monolith
17. Mojave
18. Colton
19. Riverside (2)
20. Lucerne Valley
21. Orogrande
22. Victorville

Nevada:
23. Fernley

In British Columbia, the cement plant at Kamloops receives its gypsum from the local mines at Falkland. The plants in the Vancouver area utilize gypsum from both British Columbia and foreign sources.

The Alberta cement plants rely primarily on sources of crude gypsum in British Columbia and to a lesser extent in Manitoba.

9.3.3 Pulp and Paper Industry

Currently, there are no pulp and paper manufacturers on the West Coast utilizing gypsum as a mineral filler or extender in the manufacture of paper or pulp. The paper industry heavily favours the use of kaolin as a mineral filler and also uses calcium carbonate for special coating applications. West Coast pulp and paper manufacturers annually consume 275,000 tonnes of kaolin and 160,000 tonnes of calcium carbonate. The kaolin is almost wholly produced in Georgia and South Carolina and is transported by rail to various consumers on the West Coast at an average cost of U.S. $70 per tonne.

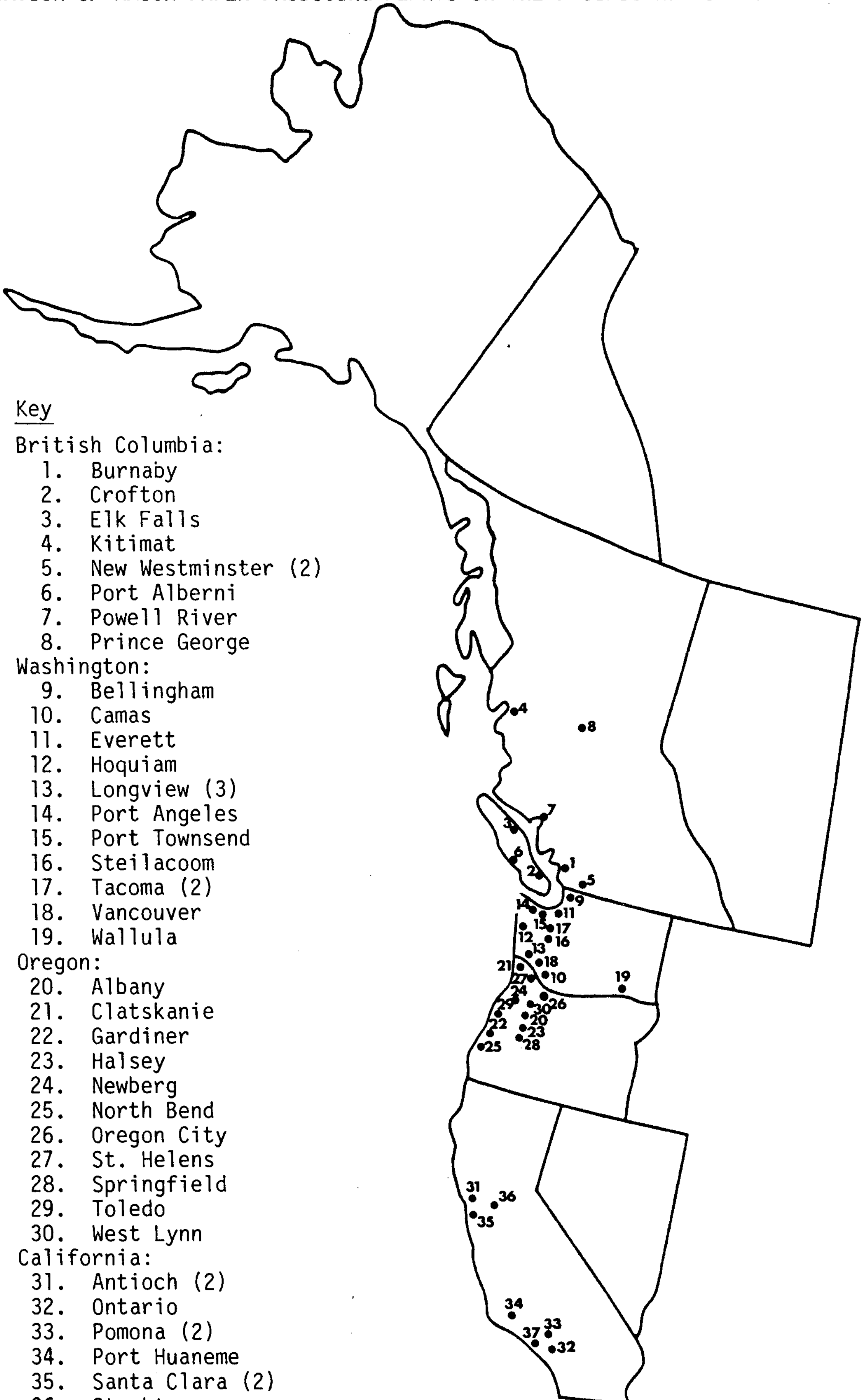
Pulp and paper manufacturers presently have a good supply of both kaolin and carbonate from within the United States and would be reluctant to convert their present capital intensive plant facilities to the use of gypsum as a mineral filler or extender in the near future. Locations of major paper producing plants in the Pacific Rim of North America are shown on Figure 12.

9.3.4 Fillers, Extenders, and Specialty Markets

Gypsum is only used to a limited extent as a mineral filler in the manufacture of plastics, rubber, paint, foods, pharmaceutical and ceramics. In 1983, 199,000 tonnes of gypsum were used for these purposes, a significant increase over the past five years (1979 112,000 tonnes). There are no statistics available as to the

FIGURE 12

LOCATION OF MAJOR PAPER PRODUCING PLANTS IN THE PACIFIC RIM OF NORTH AMERICA



Key

British Columbia:
1. Burnaby
2. Crofton
3. Elk Falls
4. Kitimat
5. New Westminster (2)
6. Port Alberni
7. Powell River
8. Prince George

Washington:
9. Bellingham
10. Camas
11. Everett
12. Hoquiam
13. Longview (3)
14. Port Angeles
15. Port Townsend
16. Steilacoom
17. Tacoma (2)
18. Vancouver
19. Wallula

Oregon:
20. Albany
21. Clatskanie
22. Gardiner
23. Halsey
24. Newberg
25. North Bend
26. Oregon City
27. St. Helens
28. Springfield
29. Toledo
30. West Lynn

California:
31. Antioch (2)
32. Ontario
33. Pomona (2)
34. Port Huaneme
35. Santa Clara (2)
36. Stockton
37. Vernon

distribution of gypsum used in the manufacture of these goods, though it is understood that United States Gypsum Company, including its nine subsidiary companies, is one of the prime producers of refined gypsum for specialized gypsum end-uses.

Table 32 compiles mineral filler and extender requirements by West Coast pulp and paper manufacturers.

9.3.5 Agriculture

Statistics for the Pacific Rim on the amount of gypsum used for fertilizer and soil conditioner are almost unattainable. However, it is known that besides the small mine at Poison Lake, Washington, producing for agriculture, Greenacres Gypsum and Lime Co. operates a plant in Spokane, Washington processing crude gypsum from the East Kootenays of British Columbia for agricultural use. The annual crude gypsum consumption for this plant is approximately 10,000 tonnes.

TABLE 32

MINERAL FILLER AND EXTENDER REQUIREMENTS BY WESTCOAST PULP AND PAPER MANUFACTURERS

Mill	Location	Paper Production (Tonnes Per Day)	Filler Requirements (Tonnes Per Year)	Type
Island Paper Mills	New Westminster, British Columbia	372	8,618	
Belkin Paper	Burnaby, British Columbia	454	816	Coating Clay
MacMillan Bloedel Ltd.	Port Alberni, and Powell River, British Columbia	3,348	1,361 - 2,722	
James River Corporation (Crown Zellerbach)	Camas, Washington	970	36,288	Filler Clay
			2,722	Coating Clay
Grays Harbour Paper Co.	Hoquiam, Washington	340	10,886	Filler Clay
			11,794	$CaCO_3$ Filler
R.W. Paper Co. (Weyerhaeuser)	Longview, Washington	1,111	10,886	Filler Clay
Boise Cascade	Vancouver, and Wallula, Washington		18,144	Filler Clay
			14,515	Coating Clay
			7,258	Filler Clay
	St. Helen, Oregon		29,030	Filler Clay
James River Corporation (Crown Zellerbach)	Portland, Oregon	245	907	Coating Clay
			544	$CaCO_3$ Filler
	Clatskanie, Oregon	821	10,886	Filler Clay
	West Lynn, Oregon	454	36,288	Coating Clay
Island Paper Mill	Antioch, California	-	227	Filler Clay
Simpson Paper Co.	Pomona, California	-	7,258	Filler Clay
	Ripon, California	-	816	Filler Clay
		-	15,422	Coating Clay
	Anderson, California	-	9,072	Filler Clay
		-	1,361	Coating Clay
Federal Paperboard	Commerce, California	-	1,814	Coating Clay
Container Corporation of America	Santa Clara, California	-	3,629	Coating Clay
National Gypsum	Stockton, California	-	544	Coating Clay
	Long Beach, California	-	19,051	$CaCO_3$ Filler
U.S. Gypsum	Torrance, California	-	27,216	$CaCO_3$ Filler
Supro Products	Pomona, California	-	9,072	$CaCO_3$ Filler
Hamilton Materials	Orange, California	-	77,112	$CaCO_3$ Filler
Marshall/Filtral	Los Angeles, California	-	18,144	Filler Clay

Summary: Total Kaoline used per annum: 249,480 tonnes
Total carbonate used per annum: 145,152 tonnes

10. FORECAST OF THE GYPSUM INDUSTRY IN THE PACIFIC RIM OF NORTH AMERICA

10.1 DEMAND FORECAST

The gypsum industry, at present, is directly dependent on the construction industry and housing starts in the United States. The two main products from gypsum are for wallboard and as a set retarder in portland cement, accounting for approximately 90% of the usage.

The responses from manufacturers on these products related to short-term supply and demand are that there will be little or no increase in production over the next year.

The projection for the Pacific Rim is that this area will maintain its normal average percentage of total United States housing starts.

The anticipated 1987 housing starts are expected to be down to 1.5 million from the estimated 1.8 million in 1986. The projected trend is then for a gradual increase back to the 1.8 million by 1990.

As many of the existing housing units are older, the demand for repair and remodelling products is expected to increase substantially. This trend will offset some of the lower demand for products used in new housing starts.

The projected demand for gypsum in the United States is expected to increase to a consumption rate of between 26 and 34 million tonnes by the year 2000 (Refer Table 24, Section 7). This represents an increase of between 20% and 48% over the 1985 quantity of almost 25 million tonnes.

Through this period, the Pacific Rim area of North America is expected to maintain approximately 27% of the total United States usage in construction and fillers, and approximately 60% of the agriculture demand. This will represent an increase of between 7 million and 9 million tonnes per year by 2000.

Table 33 depicts the forecast of North America's Pacific Rim gypsum by end-use.

TABLE 33

FORECAST FOR NORTH AMERICA'S PACIFIC RIM GYPSUM BY END-USE - 2000

(000's Tonnes)

	2000		
	Contingency Forecasts for Pacific Rim of North America		
	Forecast Range		
End-Use	Low	High	Probable
Construction:			
. Prefabricated Products	5,389	7,103	6,613
. Plaster, Industrial and Building	147	171	147
. Cement Set Retarder	1,176	1,274	1,176
Agriculture	871	925	925
Fillers and Miscellaneous	49	66	63
Total[1]	7,632	9,539	8,924

1. Data may not add to totals shown because of independent rounding

11. MARKET OPPORTUNITIES FOR BRITISH COLUMBIA GYPSUM

11.1 CONCLUSIONS

Gypsum is an abundant industrial mineral commodity throughout the world. Its use, however, is dependent on the building construction industry, therefore, developments are generally limited to industrialized countries.

After the United States, Canada is the world's second largest producer of crude gypsum. The two countries, combined, produce about 24% of the world output.

Over 70% of the gypsum consumed in North America is destined for wallboard, while other principal uses of gypsum are as a set retarder in cement, accounting for 18%, and as a soil conditioner in agriculture, accounting for 6% of the total crude gypsum production.

Approximately 72% of the gypsum consumed in Canada goes to the production of wallboard and related products, 26% is used as a set retarder in the manufacture of cement, while the remainder is used for other applications.

Although new construction materials are constantly being introduced, gypsum wallboard remains popular due to its low price, ease of installation, and proven insulating and fire retarding properties. Presently, Canadian wallboard manufacturing capacity exceeds national consumption by over 30%.

The markets for gypsum and gypsum products are dominated by a small number of large manufacturers. These large manufacturers are highly integrated, with their own gypsum mines, transportation equipment, manufacturing facilities including paper and wallboard, and a distribution network. In the North American market scene, this industry is highly competitive.

In the Canadian context, Westroc and Domtar are the two large wallboard manufacturers with whom a future producer will have to negotiate the sales of crude gypsum. If these integrated companies require additional supplies of crude gypsum or are willing to substitute imported gypsum with British Columbia gypsum, then there is the possibility of developing a new gypsum mine in British Columbia.

The success or failure of a potential crude gypsum producer, will depend on the willingness of these companies to consider a different supplier or curb the imports of gypsum to British Columbia.

Witn regard to the cement industry, a future producer of gypsum will have to approach Canada Cement Lafarge and Genstar Cement, as well as the other cement plants on the west coast, in order to obtain a contract for supply.

A potential producer of crude gypsum in British Columbia will have to be highly motivated in order to penetrate this vertically integrated industry, develop a mine and sell crude gypsum to a wallboard or cement manufacturer.

Any future producer of crude gypsum in British Columbia will have to capture a market share by being highly competitive in price and gypsum quality, together with guaranteed long-term supply.

The best opportunity for British Columbia's gypsum is in the supply of crude gypsum to the wallboard and cement plants located in the Vancouver port area and in Seattle and Tacoma in Washington State. These areas can be supplied by barge transportation from the coastal gypsum deposits in British Columbia.

The North American market is dominated by the United States demand and any contemplated development of gypsum resource in British Columbia will depend on the crude gypsum demand in the Pacific Northwest market area.

It is important to secure a long-term supply contract of gypsum to a customer before attempting to develop and operate a gypsum mine.

Tables 34 and 35 depict the opportunity for British Columbia's gypsum in the Pacific Northwest market regarding wallboard and cement.

11.2 RECOMMENDATIONS

It is recommended that a potential developer of a gypsum deposit in British Columbia, on the basis of this document and prior to mine development, undertake an extensive strategic survey of the Pacific Northwest market area.

Within such a strategic survey, the transportation aspect must be well understood and analyzed. Gypsum, as any other industrial mineral, is sensitive to transportation cost from the mine to the manufacturer's plant. The cost of transportation either by land or by sea is the major cost item in gypsum development and mining, which, if not manageable, can make the project uneconomical.

Any future producer of crude gypsum is advised to establish ongoing, meaningful discussions with the companies in British Columbia such as Westroc, Domtar, Genstar and Canada Cement Lafarge. With their support and willingness to buy gypsum from a new supplier, a potential producer has a chance to place British Columbia's crude gypsum on the market for these companies, or through tbem to some other consumers in the United States.

TABLE 34

PACIFIC NORTHWEST WALLBOARD MARKET

Company	Location	Estimated Annual Requirements (Tonnes)	Current Supplier	Means of Transportation	Point of Origin
Westroc Industries	Vancouver	131,500+	Own	Rail	British Columbia
Domtar Construction Materials	Vancouver	190,000	Own	Ship	Mexico
Norwest Gypsum	Seattle	200,000	Domtar	Ship	Mexico
			Dwight Prehime	Ship	Spain
			Mineral Resource Trading Co.		
Domtar Construction Materials	Tacoma	326,600	Own	Ship	Mexico
Total		848,100			

Note: The total gypsum usage of 848,100 tonnes by the wallboard industry in the Pacific Northwest is not confirmed

Regarding a market for cement, the plants outside British Columbia are in Bellingham, Seattle, and Anchorage, and are operated by Columbia Cement, Ash Grove Cement West, Inc., Ideal Basic Industries, and Anchorage Sand/Gravel, respectively.

These wallboard and cement companies should be contacted by a future British Columbia-based crude gypsum producer to discuss the possibility of supply from gypsum deposits located in British Columbia.

11.3. OPPORTUNITY FOR BRITISH COLUMBIA'S GYPSUM

11.3.1 Summary

It appears that the best opportunity for a new gypsum producer in British Columbia is in the area of crude gypsum supply to the wallboard industry.

The successful marketing of crude gypsum can be accomplished through substituting the foreign supply of gypsum presently used by the Westroc and Domtar plants in Vancouver, with gypsum from British Columbia. It is envisaged that a producer of crude gypsum in the vicinity of 200,000 tonnes annual production from a deposit in the coastal region of British Columbia could come on stream, providing that a successful long-term contract is negotiated with either Westroc and/or Domtar, preferably both.

Another market area for crude gypsum in the wallboard industry may be with Norwest Gypsum in Seattle, Washington. Norwest Gypsum presently imports its gypsum supply from Mexico through Domtar and from Spain through Mineral Resource Trading Corp. However, in trying to supply Norwest Gypsum, any future producer must be careful not to undermine Domtar's supply position, since Domtar may be a candidate for large shipments from British Columbia.

TABLE 35

PACIFIC NORTHWEST CEMENT MARKET

Company	Location	Estimated Annual Requirements (Tonnes)	Current Supplier	Means of Transportation	Point of Origin
Canada Cement Lafarge Ltd.	Vancouver	13,610	Pacific Basin Coal and Carbon	Ship	Spain
Genstar Cement	Vancouver	30,000	Pacific Basin Coal and Carbon	Ship	Spain
Columbia Cement	Bellingham	22,680	Pacific Basin Coal and Carbon	Ship/Rail	Spain
Ashgrove Cement West Inc.	Seattle	9,100	Pacific Basin Coal and Carbon	Ship	Spain
Ideal Basic Industries	Seattle	30,000	Pacific Basin Coal and Carbon	Ship	Spain
Anchorage Sand/Gravel	Anchorage	15,000	Korea (Cement) or Norwest Gypsum, Seattle	Ship/Barge	-
Total		120,390			

Because these companies, as well as those in the United States, are vertically integrated, it is not likely that they will shut down some of their mining operations in order to accommodate a newcomer on the supply market scene. A newcomer will have to be extremely competitive, selling a superior product and must be willing to cut the ongoing price of crude gypsum in order to gain a foothold in the marketplace.

It is recommended that primarily the wallboard and secondly the cement markets be considered by a future gypsum developer in British Columbia, because these markets can sustain economics for a new gypsum mine, due to high consumption demand. Other specialty markets and the agricultural sector do not demand enough volume on which a future producer can plan a commercial mine operation.

A future gypsum producer in British Columbia should consider coastal gypsum deposits which could economically compete with imported gypsum from Mexico and Spain.

It is highly recommended that an effort to capture a part or the entire sector of the imported supply be seriously considered in an effort to expand British Columbia's gypsum industrial mineral base.

Once the market for either wallboard or cement is captured, it is easier to spin off production of crude gypsum for minor quantities as demanded by agriculture and specialty markets. However, as mentioned before, these markets alone cannot sustain any gypsum development in the province if the wallboard and cement markets are not secured.

Outside British Columbia, the available crude gypsum markets for wallboard are in Seattle and Tacoma, where Norwest Gypsum and Domtar presently supply the wallboard plants with gypsum from Mexico and Spain.

Basically, Domtar and Westroc have a dominant position on the west coast and it is unlikely that a crude gypsum supplier can wage a trade/ marketing war with the two.

The potential market locations for British Columbia's gypsum are highly sensitive to distance and mode of transportation from the source.

A preliminary high-low scenario of operating costs to mine a gypsum deposit in the coastal region of British Columbia, assuming demand production of 200,000 tonnes and transporting the crude gypsum to the Pacific Northwest, is summarized in Table 36.

This cost comparison gives a direction for future planning and consideraton for opening up a gypsum deposit near the coastline in British Columbia. It gives a range of operating and transportation costs, showing a tight profit margin for the operator.

It will be up to a future operator to determine at what cost and profit margin to operate once the market is secured.

It is, however, apparent that the cost of transportation must be controlled and if not brought to a reasonable level in comparison with the final price of crude gypsum, the project development may not be feasible in spite of secured market niche for sales of crude gypsum.

In general, if future producers of British Columbia's gypsum resources can control transportation cost, maintain a premium quality product, compete with imported gypsum, guarantee a long term supply and obtain a reasonable market share, they can successfully penetrate the currently captive market controlled by vertically-integrated companies.

TABLE 36

OPERATING COSTS[1] FOR A COASTAL BRITISH COLUMBIAN GYPSUM PRODUCER

Activity	1986 $CDN/Tonne High	Low
1. Mining	7.25	5.50
2. Crushing and Dock Facility	4.35	3.50
3. Land Transportation	10.00	8.25
4. Marine Transportation	9.50	8.50
5. Management and Market	1.75	1.25
Total, F.O.B. Customer's Dock	$ 32.85	$ 27.00

1. Assuming a demand of 200,000 tonnes and delivery to the Pacific Northwest

A comparison of British Columbia gypsum and imported gypsum regarding competition facing crude gypsum producers in the province are depicted in Table 37.

11.3.2 Market Share for British Columbia's Gypsum Producers

The two immediate market targets on which a future gypsum producer in British Columbia must concentrate are the wallboard and cement industries.

The greatest potential for a future gypsum producer in the province is within the wallboard industry with annual crude gypsum demand in the Pacific Northwest area exceeding 800,000 tonnes per annum. This market is captive and hard to capture because of vertical integration of gypsum-wallboard manufacturing companies and the industry's reluctance to adopt new untested gypsum sources and suppliers. However, if a future producer of crude gypsum could meet the industry's standards for reliability, quality and price, then the market could be secured. Initial potential in this market could be with Westroc and Norwest Gypsum. There is also an excellent growth potential in this sector with Domtar and its well-established markets.

The cement industry is most concerned with the price of gypsum per tonne delivered to dock at the plant site, rather than the purity of gypsum content. As long as a potential future producer of crude gypsum can demonstrate a reliable source and specified quality of gypsum at a price advantage over a company's own gypsum source or Spanish gypsum, he should be able to capture most of the annual demand of crude gypsum in the Pacific Northwest area, which is estimated to exceed 100,000 tonnes per annum.

When one of these market sectors is established, there is a potential for secondary markets. These secondary markets, such as agriculture, extenders and fillers, and specialty markets, cannot

TABLE 37

BRITISH COLUMBIA GYPSUM VERSUS IMPORTED GYPSUM

Item	B.C. Coastal Gypsum Deposit	B.C. Interior Gypsum Deposit	Mexican Gypsum	Spanish Gypsum
Quality:				
Combined H_2O	16.97%	16.68%		20.0%
Nacl	0.03%	0.03%	Data	0.03%
CaO	31.48%	30.8%	N/A	33.5%
SO_3	39.41%	39.5%	High Quality (similar to	45.1%
Insolubles	3.46%	1.90%	Spanish gypsum)	0.74%
R_2O_3	0.30%	0.19%		0.32%
MgO	1.77%	3.15%		0.04%
Gypsum	81.12%	80.56%		95.6%
Transportation	Sea Barging	Railroad	Sea Shipping	Trans-Ocean Shipping
Supply	Reliable	Reliable	Unreliable	Unreliable
Source	Free	Captive	Captive	Free
Currency Exchange	Depends on U.S. & CDN $ Exchange Rates			

be considered as a primary market because the crude gypsum consumption by these markets is not high enough to justify mine development with associated capital and operating cost. A typical coastal gypsum deposit would have to be developed at 200,000 tonnes per annum in order to be cost competitive (see Chapter 12).

A long-term market potential for British Columbia's crude gypsum may be in the pulp and paper industry, once this industry adopts gypsum instead of kaolin for paper filler. Such a transition will be a slow process and is not anticipated in the near future.

Overall, a future crude gypsum producer in British Columbia should be able to capture almost 100% of the cement industry demand and some 30% of the wallboard industry demand in the Pacific Northwest market area.

11.3.3 Distribution Channels for British Columbia's Gypsum Producer

It is recommended that a future producer of crude gypsum who lacks in-house expertise, should use a one-level channel to market and distribute the product to manufacturing markets. However, once the markets and distribution channels have been firmly established and the gypsum producer has control over reliable production and quality specifications, then the marketing at a zero-level channel or directly to wallboard and/or cement manufacturers should be considered.

Also, if the gypsum producer's market research indicates a good secondary market for specialized gypsum products, then the recommended distribution channel would be to control the manufacturing of such products, instead of just selling minor quantities of gypsum to secondary markets. Examples of the different level channels that a future crude gypsum producer may consider are outlined below.

Wallboard:	(Year 1-2)	Producer - Market/Distribution Agent - Manufacturer - Retailer - Consumer
	(Year 3+)	Producer - Manufacturer - Wholesaler - Retailer - Consumer
Cement:	(Year 1-2)	Producer - Market/Distribution Agent - Manufacturer - Consumer
	(Year 3+)	Producer - Manufacturer - Consumer
Secondary:	(Year 1+)	Producer - Manufacturer/Producer - Wholesaler - Retailer - Consumer

11.3.4 Marketing Concerns for British Columbia's Gypsum Producer

A future producer of crude gypsum in British Columbia must have a thorough knowledge of crude gypsum supply and demand, markets, transportation and development costs. Some of the concerns to be dealt with are listed below:

1. Future demand for gypsum is totally dependent on construction/housing activity.

2. Control over transportation costs.

3. Low profit margin per unit cost.

4. Captive markets.

5. Dealing with vertically integrated companies.

6. Assurance of reliable supply to consumer.

7. Quality control to meet market specifications.

8. Long-term contracts to be secured prior to mining.

9. Market is locally defined, therefore, increased risk to external factors.

10. Ability to undercut competition.

11. Financial resources to explore, bulk sample, mine on trial basis, develop and produce.

12. Geographic and climatic drawbacks.

13. Distance to consumer's centre.

Any future producers would have to address these concerns together with others that may occur before making a decision to develop a gypsum deposit.

12. CASE STUDY FOR THE DEVELOPMENT OF A COASTAL GYPSUM DEPOSIT IN BRITISH COLUMBIA

12.1 INTRODUCTION

During the course of market research and survey, it became apparent that the gypsum market is a "captive market" dominated by vertically integrated gypsum producing companies who control mining, transpertation, processing and products distribution. In other words, those large companies are producers and consumers of crude gypsum.

It is also clear that any future developer of crude gypsum in British Columbia must have a clear perception of the costs involved in the development of a gypsum deposit, paying special attention to transportation.

Since the future gypsum development in British Columbia will depend on securing the market position, maintaining low transportation cost and being price competitive, it was felt prudent to develop as close as possible case study for the benefit of the uninitiated.

The case study described in detail on the following pages, addresses capital and operating oests with in-depth rationale of a typical coastal gypsum deposit producing 200,000 tonnes of crude gypsum per year.

It is conservative and accurate within the bounds of its assumptions and, together with market opportunities for British Columbia gypsum, it creates a full picture of what a future gypsum producer may expect and at what cost a gypsum deposit can be developed.

12.2 ENGINEERING

Mining Method:

It is planned to proceed with mining of the hillside-type gypsum deposit located in the coastal region of British Columbia by open pit method. The plan calls for terraces to be developed on the hillside, forming benches at different elevations. The mining can proceed at the upper elevation advancing from the footwall to the hanging wall and into the hillside. It can then continue to the lower elevations towards the bottom of the ore body by terracing the ore body in 6 metre high benches. The upper pit limit is enveloping 1,130 metres topographic contour and the lower pit limit is lying on 980 metres elevation. The hillside is sloping at different angles according to terrain landscape ranging from 20 degrees to 37 degrees.

The final pit limits of the working faces and on the footwall and hanging wall sides are projected at a 60 degree slope. The working slopes on bench faces of 6 metres in height will be steeper and drilled vertically. They will slope down to a safe angle of repose after the blast.

The final bench limits on each bench will be drilled with angled holes in order to assure safety and stability of the final pit walls. The width of the working bench will not be less than 10 metres. The safety berm will be left on every third bench or every 18 metres and will be 3 metres wide. Each year, a mining block of some 100,000 cubic metres of gypsum will be mined out in one or two benches depending on the production schedule and overburden stripping.

It is planned to remove overburden which consists mainly of top soil and clay by bulldozer and/or backhoe. The overburden layer is 3 metres to 5 metres in thickness. When feasible, this overburden will be pushed by bulldozer down the hill to the flat area, or it will be loaded into a truck with a backhoe and hauled to the flat area in order to prevent its rolling into the river.

The waste rock will be removed by loader and hauled by truck to a designated waste dump for stockpiling. The waste rock will be drilled and blasted prior to digging.

The gypsum rock will be drilled and blasted, the muck pile will be loaded by loader onto a truck and hauled away to a crusher. The jaw crusher will crush the ore to a size of minus five inches, as required by the wallboard manufacturer. The crushed gypsum will be stockpiled and immediately loaded onto the highway trucks for shipment to the designated dock facility. It will be stockpiled there for loading onto barges and shipping to customers.

12.3 MINING PARAMETERS

The mine operation is based on one 12-hour shift per day with 8.5 effective working hours.

The loading of crushed gypsum onto highway trucks is based on two 12-hour shifts per day.

The operation is seasonal, one operating year is 150 days, or five months, (June to October inclusive).

The following parameters are used in the mining plan and conceptual engineering cost estimate study.

Production of gypsum salable wallboard product	200,000 tonnes/year

Losses of gypsum rock during crushing transportation and handling 5%	10,000 tonnes/year
Gypsum rock production from the mine	210,000 tonnes/year
Waste rock removal from the mine	126,000 tonnes/year
Waste to ore ratio	0.6:1.0 (tonne:tonne)
Operating season	150 days
Productive hours	8.5 hours/shift/day
Daily production of gypsum rock	1,400 tonnes/day
Hourly production of gypsum rock	165 tonnes/hour
Daily waste rock removal	840 tonnes/day
Hourly waste rock removal	99 tonnes/hour
Bank (in-situ) density of gypsum and waste rock	2.1 tonnes/cubic metre
Loose (blasted) density of gypsum and waste rock	1.7 tonnes/cubic metre
Loose density of crushed gypsum(-5" size)	1.4 tonnes/cubic metre
Jaw crusher capacity (maximum)	210 tonnes/hour
Jaw crusher size	30" x 42"
Jaw crusher setting	5"
Mining bench height	6 metres
Working bench width (minimum)	10 metres
Drilling pattern in gypsum rock	3 metres x 3 metres
Drilling pattern in waste rock	4 metres x 4 metres
Drilling subgrade	0.5 metres
Primary loader bucket capacity	5.4 cubic metres
Secondary loader bucket capacity	4.4 cubic metres
Rock truck box capacity	23.5 cubic metres.

Reserves

Drill indicated gypsum reserves	2.50 million tonnes
Minable gypsum reserves	2.25 million tonnes
Mining recovery	90%
Mine life at 210,000 tonnes/year production	10.7 years
Average gypsum content in gypsum rock (ore)	83%

Production Volumes

Gypsum Rock Production

210,000 tonnes/150 days, 1,400 tonnes/day; 165 tonnes/hour 123,529 cubic metres/150 days; 823 cubic metres/day, 97 cubic metres/hour.

Waste Rock Removal

126,000 tonnes/150 days, 840 tonnes/day; 99 tonnes/hour 74,118 cubic metres/150 days., 494 cubic metres/day; 58 cubic metres/ hour.

Total Production from the Mine (gypsum and waste rock)

336,600 tonnes/150 days; 2,244 tonnes/day; 264 tonnes/hour; 198,000 cubic metres/150 days, 1,320 cubic metres/day; 155 cubic metres/hour.

The density for both gypsum and waste rock after blasting in its loose state is 1.7 tonnes/cubic metre.

Crusher Production

Crusher feed is 210,000 tonnes/150 days; 1,400 tonnes/day; or 165 tonnes/hour.

Crusher output is 206,000 tonnes/150 days; 1,373 tonnes/day; or 165 tonnes/hour.

Estimated crusher recovery is 98% accounting for 2% loss of gypsum during crushing.

The density of gypsum rock after crushing in its loose crushed state is 1.4 tonnes/cubic metre.

Shift Working Hours

The 12-hour shift is broken down into the following increments:

- 1-hour lunch (not paid)
- 1/2-hour morning coffee break (paid)
- 1/2-hour afternoon coffee break (paid)
- 1-1/2-hour lost in delays and preventative maintenance. Accounts for 51 minutes productive hour in the 10-hour working period per day excluding lunch and coffee breaks.
- 10-hours (total working hours) x 60 min. = 600 min./day
- 1-1/2-hours lost (delays and maintenance) x 60 min. = 90 min./day
- 8-1/2-hours (effective working hours) x 60 min. = 510 min./day

Therefore, 10 working hours/day x 51 minute productive hour equals 510 minutes/day or 8.5 hours, that is a 51 minute-hour dedicated to production instead of one full 60 minute-hour.

12.4 COST ESTIMATES SUMMARY

Cost estimates consisting of the capital and operating cost projections are presented on the cost summary sheets. All dollars are in Canadian dollars.

The operating cost reflects the typical production year, and is incurred at full production of 200,000 tonnes of crushed gypsum to a minus 5" size.

The operating cost does not include depreciation and replacement of equipment since all equipment is in a used state and maintenance is part of the overall operating cost.

The capital cost estimates point to a high capital expenditure profile in the order of $ 3.5 million, requiring a prolonged payback period of up to six years.

However, the capital expenditures with contract mining can be reduced substantially if a suitable mining contractor is found at \$ 5.00/tonne or less.

Assuming that a tonne of gypsum can be sold for an average price of \$ 32.00, the operating cost of \$ 27.04 makes the project financially viable with a \$ 4.96/tonne gross profit margin.

This profit margin can be significantly increased if the cost of transportation, both trucking and barging, could be reduced by \$ 1.50 and \$ 1.00, respectively. This would have an immediate impact on capital expenditure narrowing its payback to three years, thereby reducing the risk and making the project more attractive for immediate development with a \$ 7.46/tonne gross profit margin instead of the present \$ 4.96/tonne gross profit margin.

An exchange rate of Canadian dollar versus American dollar will have an impact on any economics because of crude gypsum exported to the United States, and the price set in American dollars. This cost estimate is based on the value of the Canadian dollar in the fourth quarter of 1986 at an exchange rate of 40%.

12.5 COST SUMMARY

British Columbia Coastal Gypsum Deposit

Capital Cost

Case Study: Gypsum rock is crushed at the mine site and transported to designated dock facility, a distance of some 120 km by land.

1. Mine Site Preparation and Construction.

	1986 $ CDN.
Permitting	8,000
Environmental Impact Study	45,000
Additional In-Fill Drilling	26,000
Surveying and Topographic Maps	38,000
Mine Preproduction Stripping	45,000
Mine Preproduction Bench Development	20,000
Mine Access Roads Development	17,000
Sub-Total	199,000

2. Mine Equipment (Used)

1 Rubber-Tired Loader (5.4 cubic metre bucket for gypsum and waste rock)	160,000
2 Rock Trucks (32 tonnes for gypsum and waste rock)	310,000
1 Bulldozer	215,000
1 Drill and Compressor	120,000
1 Backhoe Excavator	125,000
1 Service Truck	16,000
2 Pick-Up Trucks (4x4)	24,000
1 Crushing Plant	180,000
1 Rubber-Tired Loader (4.4 cubic metre bucket for crushed gypsum	80,000
1 Diesel Fuel Tank (12,000 Gallons)	12,000
1 Gasoline Fuel Tank (3,000 Gallons)	3,000
2 Light Plants	12,000
1 Truck Scale	27,000
Sub-Total	1,284,000

3. Equipment Mobilization and Installation

Mine Equipment Mobilization	50,000
Crushing Plant Installation	12,000
Truck Scale Installation	6,000
Crane Rental (assisting assembly at the mine, crusher and camp)	15,000
Sub-Total	83,000

4. Camp Site Preparation and Construction

Site Levelling and Aggregate Spreading	12,000
Garbage Dump Excavation and Preparation	3,000
Sewage Excavation and Installation	4,000
Sewage Treatment	10,000
Sub-Total	29,000

5. Buildings (Used)

Camp Trailers, Fully Equipped	60,000
T.V. Dish and Camp Recreational Equipment	12,000
Maintenance Shop and Warehouse	42,000
Generator Set	17,000
Water Supply System	18,000
Explosives Magazine	13,000
Mobilization	25,000
Installation (electrical and plumbing)	17,500
Materials and Supplies	10,000
Sub-Total	214,500

6. Access Road Preparation and Construction

Borrow Pit Development	3,000
Access Road Engineering Design	17,000
Access Road Field Testing	15,000
Access Road Construction	285,000
Bailey Bridge	35,000
Culverts	20,000
Sub-Total	375,000

7. Access Road Equipment

Gravel Screening Plant	45,000
Gravel Truck	35,000
Grader	60,000
Equipment Mobilization and Installation	15,000
Sub-Total	155,000

8. Port Facility Preparation and Construction

Dock Site Preparation and Modifications	8,000
Sub-Total	8,000

9. Dock Site Equipment and Buildings

Office Trailer	6,000
Yard Fence and Gate	4,000
Stockpile Stacker	30,000
Barge Loading Stacker	50,000
Rubber-Tired Loader	60,000
Stockpile Tarpaulin Covers	30,000
Power Supply Station	35,000
Rubber-Tired Dozer	60,000

Equipment and Warehouse Shed	12,000
Equipment Mobilization	20,000
Materials and Installation	8,000
Sub-Total	315,000
10. Construction Manpower and Supplies	
Construction Camp Operations	4,336
Construction Manpower	17,954
Construction Management Overhead	12,000
Spare Tools and Materials for Construction	5,000
Transportation of Supplies, Materials, People	10,000
Sub-Total	49,290
TOTAL (1-10)	2,711,790
11. Contingency at 10%	271,179
12. Working Capital at 20%	542,358
OVERALL TOTAL (1-12)	3,525,327

12.6 CAPITAL COST ESTIMATES DISCUSSION

1. Mine Site Preparation and Construction ($ 199,000)

Permitting ($ 8,000):

It is presumed that this money will be spent during the permitting stage. This cost will cover acquisition of necessary land and environmental documents such as forestry, wildlife, fisheries, archaeologic, climatic, soil, and highway information maps. It will also cover other regulatory filing and registration of permits as required, as well as incurred travel expenses to Victoria.

Environmental Impact Study ($ 45,000):

This cost will cover some 900 manhours by a consultant during approval and permitting stages of the project. The environmental impact study will have to cover water, flora and fauna in the immediate region impacted by the mine development. It will propose mitigative measures to be undertaken by a developer regarding water quality, geotechnical/hydrology problems, and fish habitat preservation.

Additional (In-Fill) Drilling ($ 26,010):

This sum is allocated for extra drilling inside currently projected pit limit boundaries, in order to better define the final mining limits, recoverable ore, and gypsum anhydrite contact. It will allow for the additional drilling of 210 metres consisting of 5 core holes, approximate 42 metres deep at $ 87.00/metre for a total of $ 18,270 with mobilization and demobilization of $ 2,000. The sampling of each 1.5 metre interval and laboratory assaying of 140 samples at $ 35.00/ sample is included in the overall cost for a total of $ 4,900. The camp cost for four drillers for six days at $ 35.00/man/ day is in the order of $ 840.00.

Drilling of 210 metres at $ 87.00/metre	$ 18,270
Mobilization and Demobilization of Drilling	2,000
Laboratory Sampling and Analysis,	
140 Samples at $ 35.00/sample	4,900

Camp Cost 4 Drillers for 6 Days at $ 35.00/man/day	840
	$ 26,010

Surveying and Topographic Maps ($ 38,000):

It is estimated that some 760 manhours at $ 50.00/hour will be spent on topographic maps and surveying, in order to accurately map the terrain within a 3 km radius of the mine area. The topography will be projected within 2 metre to 5 metre contours, which will facilitate detailed mine planning on 1:100 scale. The claim boundaries will also be surveyed by a qualified legal surveyor and will be drawn on a topographic map. A combination of aerial photographs, government maps and field surveys will be utilized to accomplish this task.

Mine Preproduction Stripping ($ 45,000):

It is estimated that initially an area of 50 metres x 85 metres, or 4,250 square metres, will have to be stripped of 3 metre thick overburden in order to expose gypsum rock. Thus, 12,750 cubic metres of overburden will be moved at an estimated cost of $ 3.53/cubic metre, or 321 bulldozer hours at $ 140.00/hour.

Mine Preproduction Bench Development ($ 20,020):

It is estimated that drilling, blasting and bulldozer pushing will have to be carried out in order to establish the first working bench in the gypsum rock. Some 140 hours of bulldozer work and drill work, including explosives, is estimated at $ 20,020 in total. This includes 70 hours of bulldozer work at $ 140.00/hour and 70 hours of drilling and blasting work at $ 146.00/hour.

Mine Access Roads Development ($ 17,000):

This sum will cover some 120 hours (at $ 140.00/hour) of bulldozer and backhoe work needed to cut mine access roads on the hanging wall and footwall side of the deposit. These access roads are necessary for the rock trucks which will haul the gypsum and waste rock to their designated locations, i.e., crushing plant and waste dump. The backhoe excavator hours will be spent in conjunction with the bulldozer, cutting drainage and diversion ditches to prevent the run-off water entering and flooding the mine benches.

2. Mine Equipment - Used ($ 1,284,000):

1 Rubber-Tired Loader (5.4 cubic metre bucket gypsum and waste rock loading at $ 160,000)

This money is allocated for the purchase of one loader with V-edge rock bucket with teeth, such as Caterpillar 988B, or equivalent. The loader will be used as a primary digging and loading machine for gypsum mining and waste rock removal.

The general specifications for a 988B loader are:

Bucket size = 5.4 cubic metre (heaped capacity)
Bucket struck capacity = 4.6 cubic metres
Bucket fill factor = 85%

The effective bucket load in one cycle loading a 32 tonne truck with rock box volume of 23.5 cubic metres heaped capacity is 3.9 cubic metres (4.6 x 0.85). Therefore, to fill a truck with 32 tonnes of gypsum rock, approximately five loader buckets are needed. It is estimated that one loading cycle takes approximately 1 minute, in five minutes or less, the loader loads one truck with a volume of 19.5 cubic metres, or approximately 33.2 tonnes assuming blasted gypsum rock density of 1.7 tonnes/cubic metre.

2 Rock Trucks (32 tonnes gypsum and waste rock hauling at $ 310,000):

It is estimated that each off-highway rock haulage truck, used and in good working condition, will cost about $ 155,000. This estimate is based on a reliable Caterpillar 769C off-highway haulage truck. One loader will load both trucks, one truck always carrying the waste rock as scheduled. The loader will move from the gypsum rock to the waste rock area on the same bench and load the trucks as scheduled in a daily production routine.

The specifications for the Caterpillar 769C off-highway hauler are:

Heaped truck box capacity = 23.5 cubic metres
Struck truck box capacity = 17.4 cubic metres
Top speed = 69 km/hour

Because of the light gypsum rock density when blasted (1.7 tonnes/cubic metre), the struck box capacity of 17.4 cubic metres is not sufficient for a needed volume of 19.5 cubic metres. The truck can, therefore, be loaded near its heaped capacity, but it is preferable to modify the truck box with vertically extended sideboards. Such sideboards will allow for expanded volume capacity and will also prevent spillage of gypsum which would occur during haulage if loaded to a heaped capacity.

In estimating the truck haulage cycle, it is presumed that each truck will cover a distance of 2 km from the mine, either to a dump site or to a crushing site. Such a distance will be travelled in 10 minutes including the return trip to the mine, so the total distance to and fro is 4 km. Fully loaded truck travels downhill, empty truck travels uphill on a slope not exceeding 8%.

The following gives a breakdown of such cycle:

Truck speed fully loaded = 30.0 km/hour (from the mine)
2 km distance travelled 4.0 min. (to the crusher or waste dump)
Truck positioning and unleading = 2.5 minutes (at the crusher or waste dump)
Truck speed empty = 40.0 km/hour (from the crusher or waste dump)
2 km distance travelled = 3 minutes (to the mine loading site)
Truck positioning for loading = 0.5 minutes (at the loader)

Thus total truck cycle time is 10 minutes.

Loader and Truck Production Cycle

Load cycle to load one truck = 5 minutes
Truck cycle haulage = 10 minutes
Complete cycle = 15 minutes

Therefore, in 15 minutes, 33 tonnes of gypsum rock are removed. Within one hour, four hauls are complete, or 4 x 33 = 132 tonnes. During one shift operation, 34 hauls are completed by one truck (4 x 8.5 = 34).

Daily production with one truck is 34 x 33 = 1,122 tonnes, or 132 tonnes/hour x 8.5 hours = 1,122 tonnes.

The total production requirement per day call for:

Gypsum Rock = 1,400 tonnes
Waste Rock 840 tonnes
Total = 2,240 tonnes, or 264 tonnes/hour.

Therefore, to meet this requirement, two trucks are needed.

Since one loader can produce 3.9 cubic metres, or 6.6 tonnes per one-minute cycle, it will produce 396 tonnes per hour. This is 132 tonnes per hour above the required production of 264 tonnes per hour. Therefore, the loader has enough capacity and capability to serve two trucks with enough spare time to travel from the gypsum muck pile to the waste rock muck pile, as required by the production schedule.

The loader needs 40 minutes in an hour to load eight truck loads in order to achieve the hourly production target. Thus, within 40 minutes of a 51 minute hour, it will accomplish its task and still have enough time left for bench cleanup, or selective digging through the gypsum rock muck pile.

1 Bulldozer ($ 215,000):

The bulldozer will be equipped with a tilting rock push blade and single shank ripper. The cost estimate is based on a Caterpillar D8L machine or equivalent. The bulldozer will be used for stripping and pushing the overburden, road development, bench development, access road repairs, cut-and-fill construction, levelling and spreading materials on waste dumps and pads. It will also assist the loader in muck pile loading operations when called for.

1 Drill and Compressor ($ 120,000):

An air track drill or hydraulic type drill self-propelled on crawlers capable of drilling 3-1/2" to 4.0" hole, will be used for blast-hole drilling. The blast-hole pattern in gypsum rock will be 3 metres x 3 metres, while in the waste rock, it can be increased to 4 metres x 4 metres, or wider, depending on the nature of the rock. The increased spacing is possible because no fragmentation control, except one for the loader bucket, is necessary.

1 Backhoe Excavator ($ 125,000):

A backhoe equipped with a 1.0 cubic metre or 2.1 cubic metre bucket will be employed on a variety of jobs such as ditching, drainage control, stockpiling, selective digging, overburden stripping, gravel pit digging, clean-up work, and truck loading when needed in emergency situations when the loader is down. It will be used in sorting the waste rock out of the gypsum muok pile and it will laad a gravel truck with aggregate when needed for road maintenance.

1 Service Truck ($ 16,000):

The service truck will be equipped with a welding unit and boom derrick. The truck will provide service to equipment in the field such as lubrication, oil change, tire change, preventative maintenance and small repairs. The boom derrick will serve as a light crane, lifting tires and other heavier pieces of machinery.

2 Pick-Up Trucks (4x4 at $ 24,000):

Two 4x4 units will be provided for personnel transportation, small parts and supplies handling, explosive transportation during the loading of the blast, and for the supervisor's use.

Both vehicles will be equipped as required by the mine safety regulations for explosives, so that either one can accommodate explosives haulage from the magazine area to the blast site.

1 Crushing Plant ($ 180,000):

A 30" x 42" jaw crusher, with the jaw setting of 5" and the capacity of up to 210 tonnes per hour, will be employed to reduce run-of-mine gypsum rock to a minus 5" size fraction.

The crusher will be stationary, equipped with its own power plant and capable of running the jaw, apron feeder, and portable radial stacker. It will be equipped with a hopper (dumping chute) capable of receiving a direct load from the truck. The plant will be located on a suitable pad as close as possible to the mine operating benches. The required product size for wallboard is minus 6", therefore, the crusher setting of 5" will assure that particles no bigger than 6" are discharged from the jaws.

The following is a breakdown of the crushing plant components:

Jaw Crusher with Power Plant (Double Toggle Black Type)	$ 85,000
Apron Feeder and Grizzly	20,000
Portable Radial Stacker 36" x 100'	40,000
Hopper-Dumping Chute	25,000
Conveyor Extension 36" x 40' at $ 250.00/foot	10,000
TOTAL	$ 180,000

1 Rubber-Tired Loader (4.4 cubic metre bucket) Crushed Gypsum Loading ($ 80,000):

One rubber-tired loader with general purpose bucket will be employed in loading the highway trucks with crushed gypsum. This is based on a Caterpillar 980C wheel loader with the following specifications..

Bucket heaped capacity = 4.4 cubic metres (loose material)
Bucket struck capacity = 3.8 cubic metres
Bucket fill factor = 90%
Effective bucket load = 3.8 x 0.90 = 3.4 cubic metres, or 4.8 tonnes based on crushed gypsum density of 1.4 tonnes/cubic metre
Assume one loading cycle = 1 minute

To load one 30 tonne highway truck with a box capacity of 20.4 cubic metres, six loader buckets must be dumped into a truck box.

One cycle takes 1 minute, therefore, 6 minutes are needed to load one highway truck.

6 cycles x 3.4 cubic metres 20.4 cubic metres x 1.4 tonnes/cubic metre = 28.6 tonnes.

Thus, one 30-tonne highway truck would carry 28.6 tonnes of crushed gypsum. The daily production of gypsum to be hauled to a dock facility is 1,373 tonnes, or 48 truck loads. Presuming that the trucks can travel at an average speed of 60 km/hour, and that it will take 6 hours turnaround time for one truck (allowing for lunch and unscheduled delays), then one truck can make four trips during a 24-hour period on a haul distance of 120 km to and from dock facility - mine site. Therefore, it is estimated that a fleet of 12 highway trucks must be deployed on a 24-hour basis for 150 days to achieve a production goal of 206,000 tonnes of crushed gypsum delivery to the designated dock facility. Since it takes one loader 6 minutes to load one truck, the loader can load 12 trucks in 1 hour and 12 minutes, say 1.5 hours. Assuming that all 12 trucks arrive for loading at approximately the same time, it will take 1.5 hours on every sixth hour for the loader to load all 12 trucks, thus, the loader will be utilized 1.5 x 4 = 6 hours. Presumably, the trucks will be spaced out during the haulage and will not arrive at the loading and unloading points at the same time. On this premise, one loader is sufficient to be employed during two shifts with one operator on each shift. The operators on this job will work shift hours from 12 noon to 12 midnight so that no spare operator is needed for the shift change from graveyard to day shift and vice versa.

The haulage truck drivers should also change every 8 or 12 hour shift. Since the trucking will be contracted, the logistics of schedule and number of drivers is not discussed here. The trucks will be covered by tarpaulins during transport when inclement weather conditions are forecast.

The travelled highway will also have to be evaluated regarding bridge crossings and allowable loads, road width, curves and slopes, and if any upgrading of the highway is needed. The possibility of investigating the permit for heavier loads should be addressed as well.

The estimate in this study is based on the assumption that loads up to 30 tonnes are allowed on the highway and that no upgrading of the highway is needed.

1 Diesel Fuel Tank (12,000 Gallons at $ 12,000):

One 12,000 gallon (48,000 litres) diesel fuel tank will be installed at the mine site supplying fuel for the mine equipment, the crushing plant and the camp.

1 Gasoline Fuel Tank (3,000 Gallons at $ 3,000):

One 3,000 gallon (12,000 litre) gasoline fuel tank will be installed at the mine site for light-duty vehicles and other light-duty equipment powered by gasoline.

2 Light Plants ($ 12,000):

These light plants will supply additional lighting at the crushed gypsum loading site during the night shift operation.

1 Truck Scale ($ 27,000):

One truck scale will be erected at the mine site to weigh gypsum-loaded highway trucks prior to their leaving for a designated dock facility.

3. Equipment Mobilization and Installation ($ 83,000)

Mine Equipment Mobilization ($ 50,000):

This cost is allocated to equipment transportation charges for heavy-duty mining and crushing equipment to the mine site. It is estimated that approximately $ 1.10/km or some $ 2,000 to $ 5,500 per load, depending on its weight, will be charged for individual pieces of equipment. It is also presumed that equipment will be purchased within a distance of 2,000 km from the mine development staging area. There will be at least 8 heavy loads and 3 lighter loads of equipment shipped to the site.

Crushing Plant Installation ($ 12,000):

It is estimated that some $ 12,000 will be spent on crushing plant installation and assembly. This cost includes all necessary welding, wiring, base pad cement work, cladding and power plant-control board connection and start-up.

Truck Scale Installation ($ 6,000):

It is estimated that this money will be spent on proper installation, assembly and wiring of the scale, including base preparation and switch board by a qualified contractor.

Crane Rental ($ 15,000):

This money is allocated to rental of the crane that will assist assembly and installation of the crushing plant mine shop, truck scale, and other heavy-duty pieces of machinery. It is assumed that a crane can be rented at some $ 200.00 per hour plus operator for 8 hours per day for 7 days. In this estimate, some $ 3,000 is allocated to mobilization and demobilization of the crane.

4. Campsite Preparation and Construction ($ 29,000)

Site Levelling and Aggregate Spread ($ 12,000):

It is estimated that some 85 hours of bulldozer and grader time will be needed to level and prepare a pad with gravel topping and proper drainage for the camp location at $ 140.00 per hour.

Garbage Dump Excavation and Preparation ($ 3,000):

It is estimated that this money will be spent on proper garbage dump construction for disposal of camp garbage and also for disposal of waste materials from the mine equipment shop maintenance area. Spent oils and lubes will be collected in barrels and stored separately. Such waste can be destroyed at the designated site by burning.

Sewage Excavation and Installation ($ 4,000):

A sewage lagoon will be excavated and properly dyked by using heavy-duty equipment for some 50 hours at a rate of $ 140.00 per hour. A lagoon of dimensions 20 metres x 10 metres x 5 metres can be excavated providing a volume of 1,000 cubic metres for sewage disposal.

Sewage Treatment ($ 10,000):

It is estimated that this money will be spent on proper sewage treatment complying with all necessary government regulations and guidelines.

5. Buildings - Used ($ 214,500)

Camp Trailer Fully Equipped ($ 60,000):

The trailer will consist of sleeping quarters to accommodate 13 permanent employees plus 3 spare quarters for visitors, contractors, and inspection officials from the government. The sleeping quarters will be of a single type "Atco Trailers". The kitchen trailer, wash car trailer, office trailer, and recreational trailer will be tied into the same complex with the sleeping trailers. All trailers will be fully equipped with necessary equipment, furniture, plumbing and utensils which are included in the above cost estimate.

T.V. Dish and Camp Recreational Equipment ($ 12,000):

This capital expenditure will allow for the purchase of appropriate recreational equipment and installation of the T.V. dish antenna. It will also cover the cost of additional supplies for the trailers, such as furniture, extra heaters, curtains and bedding.

Maintenance Shop and Warehouse ($ 42,000):

This cost is allocated for the shop facility. A building of 8 metres x 12 metres x 8 metres dimensions will be erected at the site which will be equipped with a small overhead crane of 2 tonne capacity. Electrical wiring without heating is included with the building.

Generator Set ($ 17,000):

This money is allocated for a generator of up to 150 kw to supply power to the camp and the maintenance shop.

Water Supply System ($ 18,000):

It is estimated that a proper water supply system with pumps, pipes, water tank, power supply, and water treatment will cost some $ 18,000.

Explosives Magazine ($ 13,000):

A storage for explosives and caps, boosters and primacords will be needed on-site. One building will be used for explosives and a separate smaller building will be provided for storage of caps, boosters and primacords. The buildings will conform to safety regulations.

Mobilization ($ 25,000):

This money is allocated for transportation of the camp trailers, shop and other buildings to the site.

Materials and Supplies ($ 10,000):

Materials such as maintenance tools, propane bottles, first-aid station, safety equipment, kitchen utensils and supplies, will be purchased for a capital expenditure of $ 10,000. These materials and supplies are needed in addition to other equipment during the camp set-up.

6. Access Road Preparation and Construction ($ 375,000)

Borrow Pit Development ($ 3,000):

It is estimated that this money will be needed for borrow pit excavation and preparation of aggregate material. Some 21 hours of bulldozer time are allocated in this cost at a rate of $ 140.00 per hour.

Access Road Engineering Design ($ 17,000):

This cost will cover engineering design, field survey and mapping of the road alignment, rock and soil types, profiles and volume calculations, and constructioh requirements regarding geotechnical and hydrogeology aspects. Some 340 manhours are allocated to this cost centre.

Access Road Field Testing ($ 15,000):

It is estimated that this money will be spent on excavation of drainage ditches along the road alignment, testing the depth of muskeg in the swampy areas and checking the site for a borrow pit. Such testing will allow for accurate estimate of the road construction cost through different sections of road alignment.

Access Road Construction ($ 285,000):

It is estimated that this capital expenditure is required for some 14 km of access road construction from a turn-off at the Highway to the mine site. The access road alignment is broken down into five different sections according to terrain features. Section I lies on a good ground for 3 km and can be built by conventional methods at a cost of $ 14,000/km for a total of $ 43,500. Section II is traversing muskeg and a swampy ground for a distance of 6 km. It is estimated that this section can be built at a cost of $ 33,000/km for a total of $ 198,000. Section III, traversing the alluvial fan, does not have to be built because of its hard gravel surface. This section, with a length of 2 km, will not incur any capital expenditure. Sections IV and V, of 3 km in length, can be built at conventional cost as experienced in class 4 standard forestry type roads at a cost of $ 14,500/km for a total of $ 43,500.

Section I	- 3 km at $ 14,500/km =	$ 43,500
Section II	- 6 km at $ 33,000/km =	198,000
Section III	- 2 km - nil	will be graded only
Section IV	- 1 km at $ 14,500/km =	14,500
Section V	- 2 km at $ 14,500/km =	29,000
	TOTAL	$ 285,000

Average cost for a 12 km access is $ 23,750/km of road.

Bailey Bridge ($ 35,000):

It is estimated that one bridge will be needed for river crossing. A used Bailey bridge, 5 metres wide with the span of some 15 - 20 metres, is estimated to be available at $ 35,000.

Culverts ($ 20,000):

This money is allocated to purchasing numerous culverts of 600 mm in diameter to be used in drainage control and stream crossings.

7. Access Road Equipment ($ 155,000)

Gravel Screening Plant ($ 45,000):

It is planned to install a small portable screening plant for aggregate material classification to obtain properly sized material for access road maintenance, mine road maintenance, crushing plant, and camp pads.

Gravel Truck ($ 35,000):

One gravel truck is considered necessary for a continuous and properly scheduled aggregate haulage along the access road and other areas of the mine site.

Grader ($ 60,000):

One grader will be constantly employed on the access road and around the mine site, keeping and maintaining the roads in good condition on a daily basis. Cat 14G grader or equivalent is sufficient.

Equipment Mobilization and Installation ($ 15,000):

This money is allocated to transportation of the gravel screening plant and the grader to the mine site.

8. Dock Facility Preparation and Construction ($ 8,000)

Dock Site Preparation and Modifications ($ 8,000):

This money is estimated to be spent for minor ground preparation and modifications at the dock facility in order to accommodate gypsum stockpiling and shop/warehouse erection, as well as the loading of two barges simultaneously.

9. Dock Site Equipment and Building ($ 315,000)

Office Trailer ($ 6,000):

An office trailer is needed for administrative and supervising functions, monitoring and co-ordinating the work activities at the dock site.

Yard Fence and Gate ($ 4,000):

It is assumed that a fence and gate will be erected around the yard where equipment, shop and office trailers are located. This will be done for security reasons. About 400 metres of fence, at a cost of $ 9.80 per metre, is estimated for this work including installation.

Stockpile Stacker ($ 30,000):

A stockpile stacker with a hopper at its bottom to receive the load from the highway (rear-end) dump trucks will convey crushed gypsum to the stockpile. It is assumed that a portable stacker with a 36" belt conveyor about 40 metres long at an angle of 35 degrees with a dumping height of 20 metres will be used for crushed gypsum stockpiling. It is estimated that such a system would cost $ 750.00/metres x 40 metres = $ 30,000.

Barge Loading Stacker ($ 50,000):

Here again, a portable stacker of the same origin as a stockpile stacker is estimated at $ 750.00/metres and some 60 metres in length. This stacker will be positioned at the very edge of the dock extruding its length across to the barge. It will be loaded by a loader that will dump the gypsum in the hopper at the bottom of the stacker.

Rubber-Tired Dozer ($ 60,000):

A rubber-tired wheel dozer will be used constantly around the gypsum stockpile, levelling the piles made by the stacker and will assist in piling up gypsum for loader operation during barge loading. This machine is based on the Caterpillar 814B wheel-type tractor or equivalent.

Rubber-Tired Loader ($ 60,000):

A loader will be used at the dock facility to feed the stockpile stacker when the trucks cannot load directly into the hopper. It will help build the stockpile and will act as a spare machine when the stacker is not operating. This machine is based on the Caterpillar wheel loader 966D or equivalent with a bucket size of 3.0 cubic metres, general purpose, loose material loading.

Stockpile Tarpaulin Covers ($ 30,000):

Since the stockpiling of gypsum will be carried out in the open, the tarpaulin covers will be used to protect stockpiled gypsum from precipitation. It is planned that at any one time some 42,000 tonnes of gypsum will be stockpiled waiting for shipment. It is estimated that an area of 50 metres x 30 metres x 20 metres will always be occupied by a gypsum stockpile of 42,000 tonnes. The cost estimate assumes a price of $ 10.00/square metre for the tarpaulin covers for the total area of 3,000 square metres.

In order to enhance the drainage and the porosity within the stockpile, traffic on the pile and compaction of the pile will be avoided.

The drainage around the pile will divert the water shed from the tarpaulin covers away from the pile.

Power Supply Station ($ 35,000):

This money is provided for a power station (motor-generator set) capable of producing 350 kw to run electrical equipment such as the stacker and provide lighting and heat. This can be achieved by an independent diesel-fueled station or the money can be allocated to the installation of a transformer that can take the power from the existing grid (overhead power lines).

Equipment and Warehouse Shed ($ 12,000):

It is planned to equip the dock facility with a modular-prefabricated type building for the storage of equipment, tools, and parts which are essential to operate the facility.

Equipment Mobilization ($ 20,000):

This cost is allocated for the transportation of equipment to the dock site.

Materials and Installation ($ 8,000):

This money will cover the cost of additional materials and installation not covered elsewhere, but necessary during the construction phase.

10. Construction Manpower and Supplies ($ 49,290)

Construction Camp Operations ($ 4,336):

It is estimated that during the construction phase, the camp will operate for 14 days with 5 people who will be solely engaged in the installation and assemblage of equipment. It is therefore estimated that.

5 men x 14 days x $ 35.00	=	$	2,450
Fuel at 13 l/hour x 24 hours x 14 days x $ 0.36/l	=		1,572
Oil and lube at 20% of fuel cost	=		314
Total construction camp operating cost = 2,450 + 1,572 + 314	=	$	4,336

Construction Manpower ($ 17,954):

It is assumed that 3 tradesmen and 2 helpers will be engaged in 14 days construction work installing equipment at any one time. Therefore, the following is estimated:

3 tradesmen at $ 24.00/hour straight time x 8 hours x 10 days	=	$	5,760
3 tradesmen at $ 36.00/hour overtime x 3 hours x 10 days	=		3,240
3 tradesmen at $ 36.00/hour Saturdays, and Sundays x 11 hours x 4 days	=		4,752
Sub-Total	=	$	13,752
2 helpers at $ 11.00/hour straight time x 8 hours x 10 days	=		1,760
2 helpers at $ 16.50/hour overtime x 3 hours x 10 days	=		990
2 helpers at $ 16.50/hour Saturdays, and Sundays x 11 hours x 4 days	=		1,452
Sub-Total	=	$	4,202

Total construction manpower = $ 13,752 + $ 4,202 = $ 17,954.

This estimation is based on one 12-hour working shift with 11 paid hours, 8 hours at straight time and 3 hours at time and a half for each hour. It is also assumed that during a 14 day duration, 4 days will be Saturdays and Sundays being paid as overtime hours; for 11 working hours each Saturday and Sunday.

Construction Management Overhead ($ 12,000):

This money will cover management, supervision, and administrative costs during the 14-day construction period when equipment is being assembled and installed.

Spare Tools and Materials for Construction ($ 5,000):

This money is allocated for tools and materials which may be damaged or lost during construction and must be replaced.

Transportation of Supplies, Materials, People ($ 10,000):

During construction activities, it will often be necessary to transport people between the nearest supply centre and the site, and to bring in supplies and materials. It is estimated that a truck load of approximately $ 2,000 worth of materials and supplies will be shipped to the construction site every third day during the 14 day construction activity. It is also assumed that during this construction period, all major equipment, shop facility and crushing plant will be installed.

11. Contingency ($ 271,179):

A contingency of 10% of the capital cost is contained in this capital cost estimate. It is felt that a contingency of only 10% is sufficient since the capital cost estimate is broken down into detailed cost centres, and no new technology is used in the process.

12. Working Capital ($ 542,358):

Working capital of 20% of the total capital expenditure is estimated to suffice for the first operating season. This working capital will carry the operation for the first three months before the gypsum shipments can commence. In the first operating year, only the last two months out of the five month operating season will produce gypsum at the rate of 40,000 tonnes per month for a total of 80,000 tonnes.

Since this project does not incorporate any new technology or complicated metallurgical recovery processes but is a basic quarry-type operation, it is not expected that the project learning curve will extend beyond the first operational season.

The working capital of $ 542,358 is 52% of the typical annual mining cost, which will suffice for the first three months to pay salaries and consumables necessary to run the mine. It is assumed that the payments for gypsum will be made immediately upon delivery to customer's port facility.

12.7 OPERATING COST SUMMARY

British Columbia Coastal Gypsum Deposit

Operating Cost

Case Study: Gypsum rock is crushed at the mine site and transported to a designated dock facility, a distance of some 120 km by land.

1. Manpower

	1986 $ CDN.
Mine Manpower (11 people - Operating and Maintenance) Straight Time	138,160
Regular Overtime 3 hours/day	77,715
Regular Overtime Saturdays and Sundays	103,620
As Required Overtime (extra overtime)	10,020
Camp Manpower (1 Cook), Straight Time at $ 3,500/month	17,500
Camp Manpower (1 Cook's helper) Straight Time at $ 2,500/month	12,500
Mine Surveying, Mapping and Quality Control (Contract at $ 4,000/month)	20,000
Sub-Total	379,515

2. Benefits (Mine and Camp Manpower)

Holiday Pay at 4.0%	14,381
C.P.P. at 1.7%	6,112
W.C.B. at 6.0%	21,571
U.I.C. and W.I. at 1.5%	5,393
Sub-Total	47,457

3. Camp Operations

Permanent Workforce at $ 35.00/man/day for 13 people for 150 days	68,250
Visitors at $ 35.00/man/day for 150 days	5,250
Fuel, Oil and Lube	18,533
Parts and Maintenance (5% of camp capital)	3,000
Sub-Total	95,000

4. Mine Operations (Consumables)

Fuel, Oil and Lube	173,405
Parts and Maintenance (10% of equipment capital)	128,400
Explosives, Caps, Primers and Primacords	101,000
Consumable Materials and Supplies	15,000
Gasoline	5,000
Quality Control (Sampling and Laboratory Analysis)	5,000
Sub-Total	427,805

5. Land Transportation to Dock Facility

Trucking at \$ 9.30/tonne x 206,000 tonnes	1,915,800
Road Maintenance Operations (Fuel, Oil and Lube)	8,156
Road Equipment Parts and Maintenance (10% of capital)	14,000
Sub-Total	1,937,956

6. Storage and Loading at Dock Facility

Loading at \$ 1.40/tonne	280,000
Stockpiling Dock Charges at \$ 0.70/tonne for 42,000 tonnes	29,400
Dock Facility Lease Rental for 3,200 square metres at \$ 2.27/square metre/month for 5 months	36,320
Dock Facility Equipment Parts and Maintenance (5% of capital)	10,000
Fuel, Oil and Lube: Loader and Dozer	23,385

Shipping Supervisor	50,000
Marine Surveyor	15,000
Dock Facility Manpower	78,062
Stockpile Stacker and Load-Out Stacker:	
Fuel, Oil and Lube	10,000
Communications	1,000
Consumable Material and Supplies	4,800
Real Estate Rental and Utilities	7,500
Sub-Total	545,467

7. Marine Transportation to Customer's Port

Barging and Insurance at $ 8.75/tonne	1,750,000
Sub-Total	1,750,000

8. Annual Mobilization and Demobilization

Camp and Equipment Storage and Mothballing	1,750
Camp and Equipment Start-up	1,750
Equipment Transportation to Central Shop	25,000
Equipment Transportation to Mine Site	25,000
Demobilization Manpower 4 Men for 7 Days	6,212
Mobilization Manpower 4 Men for 7 Days	6,212
Dock Facility Storage and Mothballing	1,521
Dock Facility Start-up	1,521
Sub-Total	68,966

9. Marketing

Marketing Cost at $ 0.50/tonne	100,000
Sub-Total	100,000

10. Head Office Overhead

Accounting	10,000
Communications (telephone, mobile radio)	2,000
Insurance	5,000
Property Tax	5,000
Leases, Licenses and Claims	13,000
Legal Fees	1,000
Management	19,000
Sub-Total	55,000

11. Mining Tax and Royalties

Mining Tax and Royalties Not Included in Operating Cost

TOTAL (1-10)	5,407,199

Total annual operating cost for 200,000 tonnes of gypsum is $ 5,407,199, or $ 27,04/tonne.

Operating Cost Breakdown

No.	Cost Centre	1986 $ CDN/YEAR	1986 No. $ CDN/TONNE
1.	Manpower	379,515	1.90
2.	Benefits	47,457	0.24
3.	Camp Operations	95,033	0.47
4.	Mine Operations	427,805	2.14
5.	Land Transportation to Dock	1,937,956	9.70
6.	Storage and Loading at Dock	545,467	2.70
7.	Marine Transportation	1,750,000	8.75
8.	Annual Mobilization and Demobilization	68,966	0.34

9	Marketing	100,000	0.50
10.	Head Office Overhead	55,000	0.27
11.	Mining Tax	-	-
	TOTAL	5,407,199	27.04

Operating Cost Centre Grouping

Cost Centre	1986 $ CDN/YEAR	1986 $ CDN/TONNE
Mining (1 + 2 + 3 + 4 + 5/Road Maintenance Operation + 8)	1,040,932	5.21
Land Transportation to Dock (5/Trucking)	1,915,800	9.58
Storage and Loading at Dock (6)	545,467	2.73
Marine Transportation (7)	1,750,000	8.75
Marketing (9)	100,000	0.50
Head Office Overhead (10)	55,000	0.27
TOTAL	5,407,199	27.04

12.8 OPERATING COST ESTIMATE DISCUSSION

1. Manpower ($ 379,515)

Mine Manpower (11 People - Operating and Maintenance at $ 338,230)

It is estimated that 11 people will be employed at the mine as shown on the manpower list below:

	No. of Operators
Loader Operator (Ore and Waste Mining)	1
Truck Operators (Ore and Waste Hauling)	2
Bulldozer Operator	0.5
Backhoe Operator	0.5
Drill Operator	0.5
Blaster	0.5
Gravel Truck Operator	0.5
Grader Operator	0.5
Loader Operator (Crushed Gypsum Loading)	2
Crushing Plant Operator	1
Service Truck Operator	0.5
Mechanic/Electrician	0.5
Supervisor	1
TOTAL	11

The operation is one 12-hour shift per day. One loader operator is required for loading ore and waste.

Two truck operators are needed to operate two haulage trucks which are scheduled for ore and waste hauling.

One operator is required for the bulldozer and the backhoe. These machines will be used as required and the operator will operate the machine scheduled for a particular work. During a shift duration, the operator will switch from one machine to another as necessary.

One operator is required for blasthole drilling, and the same operator will be required to hold a blaster's certificate in order to handle the explosives and load the holes when drilling is completed on the blast site. During the loading of explosives, he will be assigned a helper, or will be assisted by a supervisor.

One operator is required for the grader and gravel truck. The same operator will spread the aggregate alongside the sections of the road and, when done, will switch to operating the grader.

Two operators are required for loading of crushed gypsum onto the highway trucks. Since this operation is continuous throughout the 24-hour period, one operator for each 12 hour shift is necessary. In order to avoid shift change, this work will be scheduled from 12 noon to 12 midnight and 12 midnight to 12 noon, so that each operator will have the same hours and conditions of work. This arrangement will eliminate otherwise necessary break periods and the need for extra personnel to fill in during shift changes.

One crushing plant operator is required to operate the crushing plant, conveyors, and portable stacker.

One mechanic/electrician is required for maintenance work on equipment. He will also operate the service truck and will be assisted by the equipment operator whose equipment is being repaired.

One supervisor is required to co-ordinate and administer the entire operation. He will be the holder of a mine foreman's certificate and first-aid certificate. The supervisor will be responsible for production and safety on the site.

Operators wages are computed as follows:

Equipment Operator	- straight time	=	$ 14.00/hr.
	- overtime (1-1/2)	=	$ 21.00/hr.
Mechanic/Electrician	- straight time	=	$ 16.00/hr.
	- overtime (1-1/2)	=	$ 24.00/hr.
Supervisor	- straight time	=	$ 15.00/hr.
	- overtime (1-1/2)	=	$ 22.50/hr.

Calculation Procedure

Equipment Operators:

Straight time	= 8 hrs. x $14.00/hr. x 110 days x 9 operators	110,880
Overtime	= 3 hrs. x $21.00/hr. x 110 days x 9 operators	62,370
Sat.'s & Sun.'s	= 11 hrs. x $21.00/hr. x 40 days x 9 operators	83,160
Extra Overtime	= 2 hrs. x $21.00/hr. x 40 days x 4 operators	6,720
Sub-Total		$ 263,130

Mechanic/Electrician

Straight time	= 8 hrs. x $16.00/hr. x 110 days x 1 tradesman	14,080
Overtime	= 3 hrs. x $24.00/hr. x 110 days x 1 tradesman	7,920
Sat. s & Sun.'s	= 11 hrs. x $24.00/hr. x 40 days x 1 tradesman	10,560
Extra overtime	= 2 hrs. x $24.00/hr. x 50 days x 1 tradesman	2,400
Sub-Total		$ 34,960

Supervisor:

Straight time	= 8 hrs. x $15.00/hr. x 110 days x 1 supervisor	$ 13,200
Overtime	= 3 hrs x $22.50/hr. x 110 days x 1 supervisor	7,425
Sat.'s & Sun.'s	= 11 hrs. x $22.50/hr. x 40 days x 1 supervisor	9,900
Extra overtime	= 1 hr. x $22.50/hr. x 40 days x 1 supervisor	900
Sub-Total		$ 31,425

During one 12-hour shift, an operator gets paid for 11 hours. One hour is dedicated for lunch and is not paid. During these 11 hours, 8 hours are paid as straight time, while 3 hours are paid as overtime (one and a half times). It is estimated that during the 5 month period (150 days), 40 days will be Saturdays and Sundays for which all 11 hours are paid at the rate of one and a half times of the straight time wage scale. It is also estimated that some extra time will be accumulated for work on an as required basis and as the need arises. This is projected as 2 hours for 5 operators for 40 days. For the mechanic/electrician tradesman, these extra hours on an as needed bases are projected as 2 hours for 50 days. The supervisor will also have one hour extra overtime for 40 days to be able to work on administration, planning, shift reports, and quality control.

The work force will be hired as permanent employees for seasonal work of 5 months duration each year.

Camp Manpower ($ 30,000):

One cook will be hired for the camp at a rate of $ 3,500/ month. No allowance for overtime is given for this position. The cook will be in charge of the food supplies and kitchen facilities and will co-ordinate his planning and budget with the supervisor. Also, one cook's helper will be hired at a rate of $ 2,500/month. No overtime is allowed for this position either. The cook's helper will help in the kitchen and in other work around the camp, as required. He will also drive a vehicle to the nearest supply centre and back when fetching supplies and materials.

Mining, Surveying, Mapping and Quality Control ($ 20,000):

It is estimated that mine surveyors will be contracted once per month for detailed pit survey and mapping which will keep the planning and quality control up to date. At a rate of $ 4,000 per month, five surveys per operating season will be carried out.

2. Benefits ($ 47,457)

Benefits are calculated as the percentages of the total mine and camp manpower cost ($ 359,515) excluding contract survey and quality control.

These percentages are computed as follows:

Holiday Pay	at	4.0%	=	14,381
C.P.P.	at	1.7%	=	6,112
W.C.B.	at	6.0%	=	21,571
U.I.C. & W.I.	at	1.5%	=	5,393
Total			=	47,457

3. Camp Operations ($ 95,033)

Permanent Work Force ($ 68,250):

This cost is calculated at a rate of $ 35.00/man/day for 13 people. $ 35.00/man/day x 150 days x 13 people = $ 68,250.

Visitors ($ 5,250):

It is estimated that visitors and some contractors will be staying in the camp periodically for short durations. Therefore, one extra space for one man per day for 150 days is allocated for this cost subcentre. $ 35.00/man/day x 150 days x 1 man = $ 5,250.

Fuel, Oil and Lube ($ 18,533):

It is estimated that the camp fuel consumption utilizing one 30 kw generator is 13 litres/hour.

13 l/hr. x 24 hrs. x 150 days	$ 46,800
46,800 l x $ 0.36	$ 16,848

Assuming 10% of the fuel cost is for oil and lube, then: $ 16,848 x 0.10 = $ 1,685 + $ 16,848 = $ 18,533.

Parts and Maintenance ($ 3,000):

It is estimated that 5% of the camp capital cost will be needed to maintain the camp.

$ 60,000 x 0.05 = $ 3,000

This money is allocated for parts and replacement of parts needed to operate the camp and other consumables directly associated with the camp operations.

4. <u>Mine Operations ($ 427,805)</u>

<u>Fuel, Oil and Lube ($ 173,045)</u>:

Fuel consumption is based on Caterpillars projections for Caterpillar equipment. The working conditions were estimated as medium hard with the following fuel consumption rates:

(1) 1 Rubber-Tired Loader (988B) or equivalent	=	44.0 l/hr.
(2) 2 Rock Trucks (769C) or equivalent	=	23.0 l/hr. ea.
(3) 1 Bulldozer (D8L) or equivalent	=	40.0 l/hr.
(4) 1 Backhoe (235) or equivalent	=	23.0 l/hr.
(5) 1 Rubber-Tired Loader (980C) or equivalent	=	30.0 l/hr.
(6) 1 Drill and Compressor	=	30.0 l/hr.
(7) 1 Grader (14G) or equivalent	=	21.0 l/hr.
(8) 1 Crusher	=	40.0 l/hr.

Equipment Utilization and Work Hours are estimated as follows:

Equipment	Total Hours	Availability & Utilization	Work Hours
(1) 1 Rubber-Tired Loader (Ore and Waste Loading)	1,800	80%	1,440
(2) 2 Rock Trucks (Ore and Waste Loading)	3,600	80%	2,880
(3) 1 Bulldozer	1,800	80/60%	1,080
(4) 1 Backhoe	1,800	80/40%	720
(5) 1 Rubber-Tired Loader (Crushed Gypsum Loading)	3,600	80%	2,880
(6) 1 Drill and Compressor	1,800	80/70%	1,260
(7) 1 Grader	1,800	80%	1,440
(8) 1 Crusher	1,800	80%	1,440

Total hours are hours available during one shift operation for 150 days.

12 hours x 150 days = 1,800 hours.

Availability is estimated to equal utilization, i.e., when equipment is available, it will be utilized all the time. In the case of the bulldozer/backhoe operation, the utilization is estimated 60:40 ratio respectively, due to one operator being assigned to both machines.

In the case of the drill-compressor availability, this is estimated at 80% availability and 70% utilization because the same operator will spend time loading the holes with explosives when not drilling.

Fuel cost is estimated at $ 0.36/litre delivered to the mine site.

The cost of fuel is computed as follows:

(1) 44 l/hr. x 1,140 hrs. = 63,360 l x $ 0.36 =	22,810
(2) 23 l/hr. x 2,880 hrs. = 66,240 l x $ 0.36 =	23,846
(3) 40 l/hr. x 1,080 hrs. = 43,200 l x $ 0.36 =	15,552
(4) 23 l/hr. x 720 hrs. = 16,560 l x $ 0.36 =	5,962
(5) 30 l/hr. x 2,880 hrs. = 86,400 l x $ 0.36 =	31,104
(6) 30 l/hr. x 1,260 hrs. = 37,800 l x $ 0.36 =	13,608
(7) 21 l/hr. x 1,440 hrs. = 30,240 l x $ 0.36 =	10,886
(8) 40 l/hr. x 1,440 hrs. = 57,600 l x $ 0.36 =	20,736
TOTAL	$ 144,504

Oil and Lube is estimated at 20% of the total fuel cost for the total of $ 28,900.

Therefore, fuel, oil and lube is: $ 144,504 + 28,901 = $ 173,405.

Parts and Maintenance ($ 128,400):

This cost is estimated at 10% of the mine equipment capital cost. $ 1,284,000 x 0.10 = $ 128,400. This estimate covers equipment at the mine only.

Explosives, Caps, Primers and Primacord ($ 101,000):

It is estimated that a powder factor of 0.15 kg/tonne of gypsum rock and waste rock on a drill pattern of 3 metres x 3 metres and 4 metres x 4 metres respectively, is sufficient to break the material by blasting.

The Amount of Explosives for Entire Production.

210,000 tonnes (gypsum) + 126,000 (waste) 336,000 tonnes x 0.15 kg/tonne = 50,400 kg of explosives.

The prepacked amonium nitrate base explosive "Economix" will be used for blasting. The bags of economix will be loaded into 4" diameter drill holes, approximately 6.5 metres deep. This explosive comes in 25 kg bags at a cost of $ 34.00 per bag.

Therefore, the explosives cost is:

$ 34.00:25 kg = $ 1.36/kg
50,400 kg x $ 1.36 = $ 68,544, say $ 69,600

The cost of explosives, caps, boosters, primers, primacord and delays is estimated at $ 32,400.

Thus, the total cost of explosives is $ 101,000.

The gypsum rock will be drilled and blasted on 6.0 metre high benches. Drilling will incorporate a subgrade of 0.5 metres in order to break the rock smoothly and evenly along each bench elevation. The subgrade helps to control the grade on the bench floors.

The blasts will be of 9,639 tonnes magnitude securing enough broken ore for a six day ore supply. Each blast will be drilled minimum 8 rows deep and 16 holes long on a 3 metre x 3 metre drill pattern in order to control proper fragmentation in the muck pile and backbreak on the bench. The blasts will be drilled either by vertical holes or angled holes, depending on the nature of the rock.

The blast design will be:

8 rows deep and 16 rows long, or 21 metres x 45 metres in dimension.

Volume of blasted material in each blast:

21 metres x 45 metres x 6 metres (bench height) 5,670 cubic metres.

Tonnage of blasted material:

5,670 cubic metres x 1.7 tonnes/cubic metre = 9,636 tonnes. Number of holes in one blast, 3 metre x 3 metre pattern, 8 rows deep and 16 rows long = 8 x 16 = 128 holes.

Metres drilled in each blast including subgrade:

128 holes x 6.5 metres = 832 metres.

Total metres drilled in ore:

210,000 tonnes: 9,636 tonnes (one blast) = 22 blasts
22 blasts x 832 metres = 18,304 metres

Waste Rock Drilling and Blasting Calculations:

Drill pattern	= 4 metres x 4 metres
Drilling depth	= 6.5 metres
Blast design	= 5 rows deep and 9 rows long
Blast dimension	= (4x4) x (8x4) = 16 metres x 32 metres
Blasted volume	= 16 metres x 32 metres x 16 metres
	= 3,072 cubic metres
Blasted tonnage	= 3,072 cubic metres x 1.7 tonnes/cubic metre = 5,222 tonnes
Number of holes in one blast	= 5 x 9 = 45 holes
Metres drilled in each blast	= 45 holes x 6.5 metres = 292.5 metres
Total metres drilled in waste	= 126,000 tonnes:5,222 tonnes = 24 blast; 24 blasts x 292.5 metres = 7,020 metres.

Total metres drilled in ore and waste:

18,304 metres + 7,020 metres = 25,324 metres.

Consumable Materials and Supplies ($ 15,000):

This money is allocated for materials and supplies such as safety and protective equipment and other consumables used during mining operations.

<u>Gasoline ($ 5,000):</u>

It is estimated that some 13,889 litres of gasoline will be consumed by vehicles and other equipment powered by gasoline. It is estimated that the pick-up (4x4) truck will be travelling to the nearest supply centre and back at least once a week to bring in groceries and supplies, and will commute to a dock facility on an as needed basis. One vehicle will be driven by the cook's helper who will bring in the groceries and supplies from a supply centre on a regular basis.

The gasoline cost for the pick-up trucks is estimated as follows:

Consumption per 100 km = 25 litres or 0.25 litres/km
Travel Mine-Supply Centre-Mine once a week = 1,000 km
Total gasoline consumption = 1,000 km x 0.25 l/km x 22 trips = 5,500 litres
Gasoline cost = 5,500 l x $ 0.40/l = $ 2,200.
Travel Mine-Dock Facility-Mine once a month - 250 km
Total gasoline consumption 250 km x 0.25 l/km x 5 trips = 312.5 litres.
Gasoline cost = 312.5 l x $ 0.40/l = $ 125.00.

Travel on site for two pick-ups and one service vehicle:

It is estimated that these vehicles will cover approximately 120 km per day travelling on and around the mine site. 120 km x 150 days x 0.25 l/km x $ 0.40/l = $ 1,800.

Total gasoline consumption for vehicles:

$ 2,200 + $ 125.00 + $ 1,800 = $ 4,125.00

The rest of the money ($ 875.00) is allocated to other small equipment and machines that use gasoline.

Total gasoline cost = $ 5,000.00.

Quality Control ($ 5,000):

It is estimated that gypsum samples will be collected and periodically sent to a Vancouver laboratory for analyses. Assuming a cost of $ 50.00 for shipping and analysis of one sample, a total of 100 samples will be analyzed during one operational season on an as required basis.

5. Land Transportation to a Dock Facility ($ 1,937,956)

Trucking ($ 1,915,800):

The cost of trucking is estimated at $ 9.30/tonne. This was chosen as a conservative estimate from several ranges of budget costs quoted by various transport companies. It is estimated that after crushing, a total tonnage of 206,000 tonnes of gypsum will be transported to a dock facility. Mined tonnage is 210,000, crushed tonnage is 206,000 tonnes, and shipped tonnage to customer is 200,000 tonnes. Approximately 5% or 10,000 tonnes account for losses at the mine during crushing, and other losses during transportation and rehandling at the dock facility during stockpiling and loading of gypsum into barges.

Road Maintenance Operations ($ 8,156):

Included in this estimate are gravel screening plant and a gravel truck. The grader is included in the mine operating cost centre.

Gravel Screening Plant:

500 operating hours x 25 l/hr. = 12,500 l x $ 0.36 = $ 4,500
Oil and lube at 10% of $ 4,500 = $ 450.00
Total cost = $ 4,500 + 450 = $ 4,950

It is estimated that 500 operating hours will produce enough aggregate for the access and mine roads upkeep during one operating season.

Gravel Truck:

540 operating hours x 15 l/hr. x $ 0.36 = $ 2,916
Oil and lube at 10% of $ 2,916 = $ 290
Total cost = $ 2,916 + 290 = $ 3,206
Overall total = $ 4,950 + 3,206 = $ 8,156

It is estimated that 540 operating hours are needed for the gravel truck to spread the aggregate for grading on the access and mine roads during one operating season.

Road Equipment Parts and Maintenance ($ 14,000):

This cost is estimated at 10% of the equipment capital cost including the screening plant, gravel truck and grader.

$ 45,000 + 35,000 + 60,000 = $ 140,000
$ 140,000 x 0.10 = $ 14,000

6. Storage and Loading at a Dock Facility ($ 545,467)

Loading ($ 280,000):

This estimate is based on discussions and quotes from port authorities whereby a charge of $ 1.40/tonne is used for barge loading at the dock facility with a load-on-roll-off barge loading method. Therefore, 200,000 tonnes x $ 1.40/ tonne = $ 280,000.

Stockpiling Dock Charges ($ 29,400):

This estimate is also based on quotes from port authorities whereby $ 0.70/tonne would be charged for storage of stock-piled gypsum. It is envisaged that only 42,000 tonnes of gypsum will be stockpiled in inventory at the dock. Therefore, 42,000 tonnes x $ 0.70 = $ 29,400.

No other wharfage, handling, dockage, or pier storage fees regarding storage and loading of gypsum are considered in this estimate except the loading and stockpiling charges as described above.

The cost estimate is done on the premise that the Dock Authority will not charge other taxes and fees above and beyond those already quoted for loading and stockpiling inventory.

Dock Facility Lease Rental ($ 36,320):

It is estimated that a lease rental of $ 2.27/square metre/ month will be charged for dock facility for some 3,200 square metres. 3,200 square metres x $ 2.27/square metre = $ 7,264 x 5 months = $ 36,320.

Dock Facility Equipment Parts and Maintenance ($ 10,000):

It is estimated that this cost will amount to 5% of the equipment capital including loader, dozer, and two stackers. Therefore, ($ 60,000 + 60,000 + 80,000) x 0.05 = $ 10,000.

Fuel, Oil and Lube ($ 23,385):

The consumption of fuel, oil and lube for the dock facility equipment, loader, dozer, and stackers, is compiled on the basis of operating hours.

Fuel consumption rate:

(1) 1 Loader (996D) or equivalent	=	17.0 l/hr.
(2) 1 Dozer (814B) or equivalent	=	21.0 l/hr.
(3) 1 Stockpile Stacker	=	13.0 l/hr.
(4) 1 Loadout Stacker	=	15.0 l/hr.

The fuel consumption rates are based on light-duty conditions.

Equipment Utilization and Work Hours:

	Total Hours	Availability/ Utilization	Work Hours
(1) 1 Loader	1,800	80/60%	1,080
(2) 1 Dozer	1,800	80/50%	900
(3) 1 Stockpile Stacker	3,600	80/80%	1,440
(4) 1 Loadout Stacker	480	90%	432

Cost Computation:

(1) 17 l/hr. x 1,080 hrs. x $ 0.36 =	$ 6,610
(2) 21 l/hr. x 900 hrs. x $ 0.36 =	6,804
(3) 13 l/hr. x 1,440 hrs. x $ 0.36 =	6,739
(4) 15 l/hr. x 432 hrs. x $ 0.36 =	2,333
TOTAL	$22,486

Oil and lube is calculated at 4% of the total which is considered to be sufficient due to low equipment utilization, giving a total of $ 23,385 for equipment fuel, oil and lube.

Shipping Supervisor ($ 50,000):

It is estimated that a permanent employee on an annual salary will be working on dock site at $ 50,000/year. The shipping supervisor will control and co-ordinate all loading and storage at the dock facility and will administer and supervise the work of the contractor's and others.

Marine Surveyor ($ 15,000):

It is anticipated that a marine surveyor from the Port Authority will survey and verify every shipment according to tonnage loaded onto the barge before it is shipped to customers.

Dock Facility Manpower ($ 78,062).

It is estimated that one equipment operator and one tradesman (mechanic/electrician) will be employed during the day shift hours on a 12 hour shift.

Operators Wages: Equipment Operator and Tradesman

Straight time	= $ 16.00/hour
Overtime (1-1/2)	= $ 24.00/hour

Straight time	= 8 hrs. x $ 16.00/hr. x 110 days x 2 operators =	$ 28,160
Overtime	= 3 hrs. x $ 24.00/hr. x 110 days x 2 operators =	15,840

Sat.'s & Sun.'s	= 11 hrs. x $ 24.00/hr. x 40 days x 2 operators =	21,120
Extra overtime	= 2 hrs. x $ 24.00/hr. x 40 days x 2 operators =	3,840
TOTAL		$ 68,960

During the day shift hours, two operators will operate the loader/dozer and stockpile stacker. The highway trucks delivering crushed gypsum during the day shift hours will dump the gypsum directly onto the stacker hopper at the bottom of the stacker. During the night shift hours, the highway trucks will dump gypsum onto a pile next to the stacker, since no equipment is planned to operate during the night shift.

On the day shift, the pile of gypsum will be dumped onto a stockpile hopper by a loader.

In an emergency, when the stacker is broken, a loader will carry and dump the gypsum on the stockpile from the highway trucks discharge pile.

Benefits ($ 8,850):

The benefits are calculated as a corresponding percentage of the total manpower cost ($ 67,040) for each particular benefit group.

These percentages are computed as follows:

Holiday pay	at 4.0%	=	$ 2,758
C.P.C.	at 1.7%	=	1,172

W.C.B.	at 6.0%	=	4,138
U.I.C. & W.I.	at 1.5%	=	1,034
TOTAL		=	$ 9,102

The total cost of manpower at the dock facility for equipment operators is $ 68,960 + 9,102 = $ 78,062.

Communications ($ 1,000):

This sum of money is allocated for communications, assuming telephone and radio communication with head office and the mine office respectively.

It is estimated that approximately $ 300.00/month will be spent on the telephone system.

Real Estate Rental and Utilities ($ 7,500):

Some rental charges will apply to the dock facility during the five month operation. Therefore, it is estimated that $ 2.27/square metre per month will be charged for rental of a space 30 metres x 22 metres = 660 square metres. The office trailer and warehouse shed can be accommodated in this space for a total of $ 1,500/month or $ 7,500 for five months. Electricity and water are included in this cost.

7. Marine Transportation ($ 1,750,000)

Barging and Insurance ($ 1,750,000):

This cost is derived from the in-house data on barge transportation which was compiled specifically for the purpose of obtaining a budget cost estimate for transportation of gypsum to markets on the North American Pacific Coast. A cost of $ 8.75/tonne of gypsum was delineated without any backhaul.

It is assumed that 40,000 tonnes/month of gypsum are shipped from the designated dock facility to customer's port. The shipment is planned to be carried out by two 5,000 tonne barges with one tug boat. A tug will pull two barges in tandem. One barge train would be travelling, while the other would be loaded at the dock facility, thus, making it feasible to ship 40,000 tonnes of gypsum per month. It would take five months to ship all 200,000 tonnes to customers.

8. Annual Mobilization and Demobilization ($ 68,966)

It is estimated that $ 3,500 is going to be spend for camp storage, mothballing and start-up of the mining operations.

Equipment mobilization and demobilization (transportation) for the mining operations is estimated at $ 50,000.

Mobilization and demobilization manpower at the mine site.

8 people x 8 hrs. x $ 14.00/hr. x 7 days =	$ 6,272	straight time
8 people x 4 hrs. x $ 21.00/hr. x 7 days =	4,704	overtime
Sub-Total	$ 10,976	
Benefits	1,448	
TOTAL	$12,424	

Mobilization and demobilization manpower at the dock site.

4 people x 8 hrs. x $ 16.00/hr. x 3 days =	$ 1,536	straight time
4 people x 4 hrs. x $ 24.00/hr. x 3 days =	1,152	overtime
Sub-Total	$ 2,688	

Benefits	=	354
TOTAL	$	3,042

9. Marketing ($ 100,000)

It is estimated that a reasonable profit of $ 0.50/tonne could be used for negotiation with a marketing firm if the marketing effort to sell 200,000 tonnes of gypsum is combined with an outside marketing specialist and in-house staff, or to hire a marketing specialist permanently allocating this money to an in-house marketing department.

10. Head Office Overhead ($ 55,000)

It is estimated that the additional accounting load during the mining operation can be handled partially with the in-house established system and with extra help hired on a temporary basis, not exceeding $ 10,000 for the five month operating season.

Communications using telephone and mobile radio is estimated at $ 2,000, or $ 400 per month for the five month operating season.

Insurance is estimated at $ 5,000, which would cover the property insurance as required by law.

Property tax for the camp and mine site area is estimated at $ 5,000.

Leases, licenses and claims cost is estimated at $ 13,000 which will suffice to pay rental on all claims in the area covered by the gypsum deposit.

Legal fees are estimated at $ 1,000 based on in-house experience.

A management cost of $ 19,000 will cover travel and visits to the mine and other administrative incidentals related to the mining operation.

11. Mining Tax and Royalties

Mining tax and royalties are not included in this operating cost.

TOTAL (1-10)	**$ 5,407,199**

The total annual operating cost for 200,000 tonnes of gypsum is $ 5,407,199, or $ 27.04/tonne.

APPENDIX 1: LIST OF MINING COMPANIES IDENTIFIED FOR SURVEY

Province or State, and Company	Mine Name
British Columbia:	
o Canada Cement Lafarge	Falkland
o Domtar Inc.	Luccier River
o Westroc Industries Ltd.	Windermere
Washington:	
o Agro Minerals Inc.	Poison Lake
California.	
o Glen C. Archer Gypsum	Archer
o CalMat Co.	Shoreler Annex
o CV Organic Fertilizers Co.	Amboy
o Fannin-Superior Gypsum Co.	Lost Hills
o H.M. Holloway Inc.	Lost Hills
o Monolith Portland Cement Co.	Quatal Canyon
o Superior Gypsum Co.	Midland
o Tembler Gypsum Co.	Farming Camp
o U.S. Gypsum Corp.	Plaster City
Nevada:	
o Genstar Gypsum Products Co.	Las Vegas
o Pacific Coast Building Products Inc.	Las Vegas
o U.S. Gypsum Corp.	Empire
o Art Wilson Co.	Adams Claim

APPENDIX 2: LIST OF WALLBOARD MANUFACTURERS IDENTIFIED FOR SURVEY

Province or State, and Company	Plant Location(s)
British Columbia:	
o Westroc Industries Ltd.	New Westminster
o Domtar Inc.	Surrey
Alberta:	
o Domtar Inc.	Calgary (closed)
	Edmonton
o Westroc Industries Ltd.	Calgary
Washington:	
o Domtar Gypsum America Inc.	Tacoma
o Norwest Gypsum Inc.	Seattle
California:	
o Domtar Gypsum America Inc.	Antioch
	Long Beach
o National Gypsum Co.	Richmond
	Long Beach
	Newark
o U.S. Gypsum Corp.	Plaster City
	Fremont
Nevada:	
o Genstar Gypsum Products Co.	Las Vegas
o Pacific Coast Building Products Inc.	Apex
o U.S. Gypsum Corp.	Empire

APPENDIX 3: LIST OF CEMENT PRODUCERS INDENTIFIED FOR SURVEY

Province or State, and Company	Plant Location(s)
Alaska:	
o Alaska Basic Industries	Anchorage
British Columbia:	
o Canada Cement Lafarge Ltd	Kamloops
	Richmond
o Genstar Cement Ltd.	Delta
Alberta:	
o Canada Cement Lafarge Ltd.	Exshaw
	Edmonton
o Genstar Cement Ltd	Edmonton
Washington:	
o Ideal Basic Industries	Seattle
o Lehigh Portland Cement Co.	Metaline Falls
o SME	Bellingham
Oregon:	
o Ash Grove Cement West	Durkee
California:	
o CalMat Co.	Colton
	Mojave
o General Portland Inc.	Lebec
o Genstar Cement Co.	San Andreas
	Redding
o Riverside	Riverside
	Oro Grande
o Kaiser Cement Corp.	Permanente
	Lucerne Valley
o Lone Star Industries Inc.	Davenport
o Monolith Portland Cement Co.	Monolith
o Southwestern Portland Cement Co.	Victorville
Nevada:	
o Nevada Cement	Fernley

APPENDIX 4: LIST OF PAPER PRODUCERS IDENTIFIED FOR SURVEY

Province or State, and Company	Plant Location(s)
British Columbia:	
o Belkin Paper	Burnaby
o Crown Forest Industries Ltd	Elk Falls
	Richmond
o B.C. Forest Products Ltd	Crofton
o Eurocan Pulp and Paper	Kitimat
o Island Paper Mills Ltd.	New Westminster
o Scott Paper	New Westminster
o MacMillan Bloedel Ltd	Port Alberni
	Powell River
Washington:	
o Georgia Pacific	Bellingham
o Crown Zellerbach (James River Corp.)	Camas
	Port Angeles
o Scott Paper	Everett
o Grays Harbor Paper Co.	Hoquiam
o Longview Fibre Co.	Longview
o R.W. Paper Co.	Longview
o North Pacific Paper Corp.	
o ITT Rayonier Inc.	Shelton
o Boise Cascade	Steilacoom
	Vancouver
o Simpson Timber Co.	Tacoma
o Weyerhaeuser Co.	Tacoma
Oregon:	
o Willamette Industries	Albany
o Crown Zellerbach (James River Corp.)	Clatskanie
	West Lynn
o James River Corp.	
o Publishers Paper	Newburg

APPENDIX 4: LIST OF PAPER PRODUCERS IDENTIFIED FOR SURVEY (continued)

Oregon: (continued)

o Publishers Paper	Oregon City
o Weyerhaeuser Co.	North Bend
	Spring Field
o Georgia Pacific	Toledo
o Boise Cascade	St. Helens

California.

o Simpson Paper Co.	Shasta Mill
o Crown Zellerbach (James River Corp.)	Antioch
o Fibreboard Corp.	Antioch
o National Gypsum Co.	Stockton

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