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INDUSTRIAL MINERALS

AND MINOR METALS

and

THEIR POTENTIAL FOR DEVELOPMENT IN THE YUKON

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SCOPE OF THE STUDY

The primary objective of this study is to evaluate the potential of industrial minerals and minor metals in the Yukon through literature search and communications with industry and government agencies.

On a world-market scale particular attention has been given to those industrial minerals which fell into one or more of the following categories:

a) those of which Canada is a net importer,

b) those of which Western Canada is a net importer,

c) those for which there is an inadequate world-market supply, and which therefore command premium prices,

d) those for which there is a growing need due to a decline in existing supplies, and

e) those for which markets are growing due to changing modern technologies.

Narrowing the focus to the Yukon, the intention was to identify:

a) known industrial mineral deposits which could be developed given a likely change in market conditions,

b) industrial minerals and minor metals which are presently known to occur in the Yukon in uneconomic amounts, but for which there is a reasonable chance of discovering economically viable deposits,

c) industrial minerals which, though presently unknown in the Yukon, could be expected to occur, and which command a high-enough price to encourage exploration, and

c) industrial minerals and rocks for which base-line studies and inventories are needed to assess the potential for development or improve their present exploitation.

SUMMARY

The industrial minerals and minor metals are reviewed alphabetically. Where applicable, information has been included on mineral types, uses, deposit characteristics, mining methods, producers, market specification, prices, Canadian deposits, and Yukon occurrences.

Comments are also made on the likelihood of the discovery of Yukon deposits and the potential for their development.

Industrial minerals and minor metals which have been identified as deserving more attention in the Yukon are grouped as follows:

Group 1: Industrial mineral deposits known to occur in the Yukon which could be developed given a likely change in market conditions.

barite

Group 2: Industrial minerals and minor metals which are presently known to occur in the Yukon in uneconomic amounts, but for which there is a reasonable chance of discovering economically viable deposits.

cassiterite, fluorspar, gypsum, jade, nepheline syenite, olivine, phosphates, rare earths, talc.

Group 3: Industrial minerals which, though presently unknown in the Yukon, could be expected to occur, and which command a high-enough price to encourage exploration.

celestite, china clay (kaolin), cryolite, diamonds, lascas.

Group 4: Industrial minerals and rocks for which baseline studies and inventories are needed to assess the potential for development or improve their present exploitation.

dimension stone, lime, peat, sand and gravel.

INTRODUCTION

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REPORT FORMAT

The industrial minerals and minor metals are covered under alphabetically arranged headings. Information has been included, (where applicable), on mineral types, industrial uses, deposit characteristics, mining methods, market specifications, current prices, and documented Yukon occurrences.

An index of minerals and rock types has been included.

The locations of Yukon deposits and occurrences are shown on an attached 1:1,000,000 scale map, and the original sepia is available for reproduction.

FACTORS LIMITING INDUSTRIAL MINERAL DEVELOPMENT IN THE YUKON

All the major industrial minerals have been covered in this study, but even a brief glance at the table of contents will show that there are those that are either unlikely to occur in the Yukon, or, if they do occur, are unlikely to be developed successfully.

Some of the factors limiting deposit occurrences are the geological setting, past and present climate, and geomorphological environment. The major factor limiting deposit development is the distance to markets.

Geological Setting

The geological environments which favour the occurrence of commercially viable deposits of many of the industrial minerals are rare or absent in the Yukon.

Sillimanite, for example, occurs in the higher grades of thermally and regionally metamorphosed argillaceous rocks such as sillimanite-cordierite gneisses, biotite-sillimanite hornfels and micaceous sillimanite schists. In the Yukon this grade of metamorphism is rare, being limited to narrow zones on the contacts of the highest temperature intrusives.

Another example is graphite, economic deposits of which are usually confined to shield rocks, a geological environment which does not occur in the Yukon.

Climatological Environment

Climate, past and present, can have a bearing on the formation of mineral deposits. For example diatoms flourish in the warm waters of subtropical inland seas. Though they can, and do, survive in much cooler environments, the ratio of diatom remains to particles of sediment falls so that more northerly diatomite deposits tend to be low grade.

Other minerals that require warmer climates for their development include nitrates, manganese oxides, and borates.

Geomorphological Environment

Some deposits require a particular geomorphological environment, or land form, for their development. For example most of the world's supply of rutile, ilmenite, zircon and monazite is produced from beach sands and it is unlikely that such beaches will be found on the Yukon's Arctic coastline.

Transportation Considerations

Many industrial minerals are characterized by their low unit values and sensitivity to transportation costs. In such cases deposits have to be near their markets. Exceptions exist when deposits are directly on tidewater allowing the use of cheap water transportation.

The Yukon's small population and relative remoteness means that it is unlikely that the lower-priced bulk-usage commodities could be exploited profitably. The emphasis needs to be on quality deposits of those minerals that command a relatively high unit price.

BY-PRODUCT MINERALS

The original intent was to devote a separate section to placer and other by-product minerals, but as the project progressed it became evident that they should be included in the overall format.

Minerals that are referenced as placer by-products (or accessories) are anatase, cassiterite, garnet, ilmenite, kyanite, magnetite, monazite, rutile scheelite, staurolite, topaz, and zircon.

COMMODITY PRICES

Where possible product prices have been included, but it must be stressed that price structures for most industrial minerals are not as clear-cut as they are for precious and major metals. Quoted and list prices may bear little relationship to actual prices, which are usually negotiated between buyer and seller, taking into account such factors as transportation distances, product specifications, and local competition. Indeed the prices for some commodities are confidential, either because of intense competition for market shares, or conversely because a single company dominates production.

ABRASIVES: diamond, corundum, emery, garnet, staurolite

TYPES and GENERAL DESCRIPTION

Natural abrasives, in order of decreasing hardness, are diamond, corundum, emery and garnet. Some types of sandstones and grits are also used as grindstones, pulpstones, hones and scouring powders, and a variety of materials such as china clay and talc are used as 'soft abrasives' for polishing and buffing.

Synthetic abrasives include carborundum, made by fusing silica, coke and sawdust, and boron carbide, made by fusing borax and coke, and tungsten carbide. Corundum can also be produced artificially by fusing bauxite in an electrical furnace, and synthetic diamonds now compete with natural stones in the smaller size ranges.

In general synthetic abrasives are preferred to their natural counterparts because their size, shape and grain can be closely controlled during manufacture.

Among the low-cost abrasives are silica sand and pumice. Staurolite is a possible substitute for silica in sand blasting applications.

DIAMONDS

More than 80% of all natural diamonds are used industrially as cutting or abrasive agents. Those used as abrasives are the black diamonds (carbonado) and the badly coloured or flawed diamonds (bort).

Before 1870 all world production was from alluvial (placer) deposits, but in 1870 the diamond bearing kimberlites of the Cape Colony, (now South Africa) were discovered. The kimberlites form volcanic funnel-shaped necks or pipes and are composed of a rock derived from ultra-basic peridotite. Subsequently kimberlite pipes were found throughout southern and central Africa, in Australia, and in North America but only a few contain economic concentrations of diamonds.

Regional exploration for diamond deposits, both primary and alluvial, begins with the examination of stream sediments and soils for the presence of a specific group of high temperature minerals associated with kimberlite intrusives. Generally these are pyrope, chrome diopside, ilmenite, zircon and perovskite. Areas with concentrations of these minerals are then sampled taking very large volumes from which any diamonds are recovered by a portable treatment plant.

While gold sampling may focus on concentrations in the order of one part per million, diamond sampling may depend on sample concentrations of one part per billion.

Today the world's leading producers of natural industrial-grade diamonds are Zaire, Australia, USSR, South Africa, and Ghana.

The diamond market is very tightly controlled by the Central Selling Organisation of the De Beers group which markets more than 80% of the free world's production.

Though there is no commercial production to date in North America, exploration continues on the Colorado-Wyoming border where some one hundred pipes have been found, fourteen of them diamond bearing. Two bulk testing plants have been erected at Fort Collins, Colorado. Recently diamonds have also been found in Alaska.

Two diamonds have been found in glacial drift in Ontario, and nine kimberlites have been identified in Eastern Canada, two of which are diamond bearing. One is on the Ile Bizard, near Montreal, and the other is on Somerset Island in the North West Territories.

In Saskatchewan there has been considerable recent activity near Shellbrook where Monopros Ltd, an affiliate of De Beers Consolidated Mines, and Uranerz Exploration and Mining are said to have discovered kimberlite pipes. However Monopros has announced that its tests suggest that the kimberlite structure is not economically viable.

In British Columbia the Cordilleran alkaline belt occupies a broad zone parallel to and encompassing the Rocky Mountain Trench. In the Yukon this trend continues into the Tintina Trench. The alkaline rocks in this belt range in age from Devonian to Sub-recent, and include carbonatites, nepheline syenites and ultramafic lamprophyres. Though only one kimberlite, the Cross diatreme, has been found in this belt, there are several diatreme pipes, one of which contained two microdiamonds.

Synthetic diamonds can compete with natural stones in size ranges up to 16 mesh, and this has resulted in price decreases for the smaller stones. End uses for synthetic diamonds are machinery 27%, mineral services 18%, stone and ceramic products 17%, and abrasives 16%.

Diamond prices are weak due to an oversupply. Possible substitutes are cubic boron nitride, fused aluminum oxide, silicon carbide, garnet, emery and corundum.

CORUNDUM

Corundum has a composition Al_2O_3, and occurs as non-transparent grey to brown six-sided prisms which often taper at both ends to a barrel-shaped form.

The gem varieties of corundum are ruby (red), and sapphire (any colour but red).

Corundum crystallizes from a magma rich in alumina and poor in silica, and is also found in pegmatites that intrude basic igneous rocks. Prior to 1921 the world's primary production was from Ontario's nepheline syenites. Nowadays, however, almost all production is from pegmatites of the Eastern Transvaal of South Africa.

The United States consumes 400 tonnes of corundum per year, but it is predicted that future use will see a steady decline due to the substitution of plastics for glass in many optical components, especially eye-glasses.

EMERY

Emery is a natural mixture of granular corundum and magnetite with some hematite and spinel, and is so named from Cape Emeri on the island of Naxos, Greece. Deposits are formed usually by contact metasomatism of crystalline limestone, basic igneous rocks, and chlorite and hornblende schists. Producers are Greece, Turkey and the United States.

GARNETS

There are many different types of garnet but the most useful as abrasives are the iron-bearing almandine garnets with a composition $FeAl_2(SiO_4)_3$. Though these are common in many metamorphic rocks, the only commercial in situ deposits in North America are in the Adirondack Mountains of New York State and Maine where up to 80% of the rock may be formed of garnet. There is also some production from placers in Idaho. Reserves in the US are sufficient to the year 2000, so any new deposits would have to be of very high grade and exceptional quality to break into the market.

Many small deposits of garnet are known in Canada, and there was production in the past from Lennox and Addington Counties, Ontario, where almandine garnets occur in gneisses.

US production, 85% of which is consumed domestically, is some 31,000 tonnes per annum valued at more than US$ 6.8 million. End uses are abrasives 60%, water filtration 30%, electronic components 7%, ceramics and glass 3%.

STAUROLITE

With a composition $FeAl_4Si_2O_{10}(OH)_2$, Staurolite is a resistant heavy mineral recovered as a byproduct from Du Pont's heavy mineral mines in Florida. It is marketed under the brandname 'Starblast'. The supply is closely related to the demand for titanium dioxide, and at present there are large stocks of staurolite available. Continuing pressure from health agencies to limit the use of silica sand in sandblasting may result in increased demand.

PRICES

Emery $290 to $480 per tonne, Garnet $280 to $400 per 20 ton lot.

YUKON OCCURRENCES

To date there have been no diamond discoveries in the Yukon, and there are no commercially viable deposits of corundum, garnet, emery or staurolite. Though most placer heavy mineral concentrates contain garnet, the quantities are too small to warrant upgrading and marketing. Staurolite has been identified, usually with kyanite, in heavy mineral concentrates in the Klondike.

ASBESTOS

With a past asbestos producer in the Yukon at Clinton Creek, and a present producer in northern British Columbia at Cassiar, there has been intense exploration for asbestos in the Territory. The following section is intended only as a general summary.

Asbestos is a term applied to a group of minerals that can be separated easily into fibers that are resistant to heat. The properties that make asbestos valuable are incombustibility, infusibility, fibrous structure, strength and flexibility of fibers, low heat conductivity, high electrical resistance, chemical inertness, and resistance to decay.

The six varieties of asbestos fall into two mineral groups: 1) chrysotile, or serpentine asbestos, and 2) amphibole asbestos, including anthophyllite, amosite, crocidolite, tremolite, and actinolite.

Canadian chrysotile deposits in Quebec are the world's leading producers.

Cassiar Asbestos Corporation Limited produced mostly high quality fiber from a small ultramafic body located on Porcupine Hill on the south side of Clinton Creek, 80 km northwest of Dawson City.

Several other asbestos-bearing ultramafics in the Clinton Creek - Woodchopper Creek - Cassiar Creek areas have been explored, and several asbestos occurrences are reported in the Yukon's other main ultramafic areas in the Kluane and Campbell Ranges and near Teslin.

The market for asbestos products has been depressed for several years now due to increasing concerns over the health problems associated with asbestos fibers.

BARITE witherite

GENERAL DESCRIPTION

The two chief barium minerals are barite ($BaSO_4$) and witherite ($BaCO_3$), the former being by far the most commercially important.

Barite is found frequently as a gangue mineral in lead-zinc veins, and as veins and bedded replacement deposits, usually within limestones and dolomites. It can also form residual deposits from the weathering of barite-bearing rocks.

Witherite is a comparitively rare mineral found in association with barite or in narrow veins with galena and sphalerite.

CLAY MINERALS: ball clay, stoneware clay, china clay, kaolin, fire clay, bentonite, fullers earth, attapulgite, common clays

TYPES and GENERAL DESCRIPTIONS

Clay deposits are bodies of loose, earthy, very fine grained natural sediment or soft rock, composed largely of clay size (less than 4 microns diameter) or colloidal particles of hydrous aluminum silicates.

The clay minerals themselves are largely formed by the decomposition of feldspathic rocks, and hence clay deposits also contain fine grains of quartz, decomposed feldspar, carbonates, ferruginous matter and other impurities. The physical and chemical characteristics of each clay deposit are governed by the composition of the parent material and the manner and environment of deposition.

The most important commercial characteristics are plasticity, degree of swelling when wet, retention of shape after drying, shrinkage after drying, hardening by firing, and shrinkage after firing.

BALL CLAYS

Ball clays (pipe clays) are essential in the manufacture of pottery. They are highly plastic and therefore easily moulded before firing, and after firing they are white or cream coloured. They are widely used in general earthenware, electrical and other porcelain, wall tiles and sanitary ware.

STONEWARE CLAYS

Stoneware Clays or brick clays generally contain less than 20% Al_2O_3 and up to 50% silica, and are intermediate between low-grade common clays and purer kaolinitic clays. They are used in the manufacture of salt-glazed and other types of stoneware, sewer pipes, flue liners and facing brick. Deeply weathered shales may also be used as stoneware clays.

CHINA CLAY

China clay (kaolin, ceramic clay) is so called because it was originally obtained from China's Kiangsi Province in the eighteenth century. The term kaolin is a corruption of the chinese word 'Kauling', the 'high ridge' or Kuling range to the east of King-te-chen, the town which for centuries has been the focus of Chinese pottery manufacture.

China clay is used in paper and ceramics production, as a filler in rubber, wall plaster and paints, a stiffener in textiles, and a component of some types of cement.

China clay deposits are of two general types; in situ, and residual. They are formed as a result of the decomposition of feldspars in granite or granitic rocks. Decomposition leaches out the potash and leaves a residue of kaolin, quartz and mica. Residual deposits are from the transportation and redeposition of the kaolin.

Paper grade china clay commands a premium. Suitable deposits contain a minimum of 38% Al_2O_3, loss on ignition of about 14%, a maximum of 0.5% Fe_2O_3, a maximum of 0.2% TiO_2, and a combined maximum of 0.2% Na_2O and K_2O. The end product should be white with a brightness between 80 and 90, be free from grit, and fire white.

FIRE CLAY

Fire clay or refractory clay is a detrital clay composed mainly of kaolinite with a high alumina and silica content. It is used in the manufacture of firebricks and crucibles and as a component of foundry sand.

BENTONITE

Bentonite is the commercial name for material containing not less than 85% of the clay mineral montmorillonite, a hydrated silicate of aluminum with calcium and magnesium. Montmorillonite is a soft mineral with a white, grey-white or rose-red colour and a characteristic ability to absorb water.

There are two general types of bentonite deposit: sodium bentonite (or western bentonite) which absorbs a large percentage of water, swells considerably, and contains sodium as its predominant exchangeable ion, and calcium bentonite (or southern bentonite) which does not swell appreciably, and has calcium as its chief exchangeable ion. There are numerous intermediary types between these two. Most bentonite deposits are formed from the alteration of beds of volcanic ash, or by direct precipitation of montmorillonite in shallow marine basins.

In its natural form bentonite is used as a binder in stock feeds, iron ore pellets, and foundry sand, as a carrier for pesticides, a cleanser for animal fur, and as kitty-litter.

When treated with sulphuric acid bentonite becomes 'activated', and is used for purifying and decolouring petroleum and vegetable oils, animal fats, waxes, beverages and syrups. It is also used as a catalyst in the cracking of crude oil.

FULLER'S EARTH

Fuller's Earth (bleaching clay), very similar to calcium bentonite, is a fine-grained greenish brown or yellowish clay-like substance which differs from ordinary clay in its unusually low degree of plasticity. Its name is derived from its earliest use for 'fulling' or cleansing woolen fabrics and cloth by its ability to absorb grease and oily matter. It is still used to remove greasy matter from woolen goods, and to decolour oils, and as a filler in cosmetics.

ATTAPULGITE

Attapulgite is a lath-shaped clay mineral which forms a specific type of fuller's earth. North American production is primarily from Florida and Georgia.

COMMON CLAYS

Common clays and shales are used almost entirely for the manufacture of structural clay products, cement in particular.

CANADIAN CLAY DEPOSITS

Most Canadian deposits are the result of Pleistocene continental glaciation and subsequent stream transport. Deposits include marine and lake sediments, reworked glacial tills, interglacial clays and floodplain clays.

Clays and clay products are materials mainly characterized by high bulk, low unit value, and sensitivity to transportation costs.

Ball clay occurs as deposits of kaolinite, quartz and mica in the Whitemud and Ravenscrag Formations of southern Saskatchewan and southeastern Alberta.

Stoneware clay is also produced principally from the Whitemud Formation, with less important sources near Abbotsford, Quesnel and Williams Lake in British Columbia.

No Canadian China clay deposits have yet been developed because of their small size and attendent benefication problems. As a result almost all Canada's requirements are imported, 56% into Ontario, 35% into Quebec, 4% into Manitoba and 3% into British Columbia. Demand for China clay relies heavily on the paper industry which now accounts for 75% of its use.

Recently, however, Fargo Resource Limited has begun to evaluate its Lang Bay property in British Columbia. Fargo reports a primary kaolin deposit and a related secondary deposit in the Brown Bed formation. Beneficiation tests have been successful in producing a good filler-grade product from the primary deposit for use in the paper industry. The secondary deposit is of a grade suitable for ceramic and cement uses. A feasibility study is planned for 1989.

Ekaton Industries also reports that it is developing a kaolin deposit at Wood Mountain, Saskatchewan.

Kaolin prices vary greatly depending on the product grade, but recent quotes per tonne range from $150 to $240 for coating clays, $80 to $120 for filler clays, and $50 to $65 for pottery clays.

Fire clay deposits are found in the Whitemud Formation, and on Sumas Mountain in British Coulmbia, but nonetheless considerable amounts are imported from the US into Ontario and Quebec because of the cost of transportation from western Canada.

Canadian Bentonite occurrences are confined to the Cretaceous and Tertiary formations in Manitoba, Saskatchewan, Alberta and British Columbia.

Pembina Mountain Clays Incorporated produces non-swelling bentonite from the Upper Cretaceous Vermillion River Formation near Morden, Manitoba. Most of the production is processed at the company's Winnipeg plant where it is leached, washed, filtered, dried, pulverized and bagged. It's main uses are as a decolourizer and purifier of mineral and vegetable oils.

Avonlea Mineral Industries Ltd mines and processes bentonite near Wilcox, Saskatchewan, and supplies well-drilling muds, foundry sand binders, and animal feed binders from its plant which has a 60,000 tonnes per year capacity.

Dresser Industries Inc mines swelling bentonite from the Upper Cretaceous Edmonton Formation near Rosalind, Alberta. The mined material is dried, pulverized and bagged for use as foundry clay, a farm reservoir sealant, feed pelletizer, and drilling mud additive.

About 54% of Canada's bentonite is used as a binder in the pelletizing of iron ore concentrates, but with the recent decline in the iron ore industry this use is dimininshing.

Drilling muds contain about 10% swelling bentonite which is used to prevent the loss of drilling fluid in permeable formations, and as a suspension agent to carry drill cuttings to the surface. Currently drilling muds consume 22% of Canada's bentonite.

Drilling muds are expected to account for most of the future increase in demand for Canadian bentonite, while demand related to the iron ore industry is expected to remain flat.

YUKON OCCURRENCES

Of all the clays China clay commands the highest unit price, and a Yukon deposit could be well placed to serve the Pacific Rim markets. Unfortunately, however, there are no known deposits in the Territory, either because conditions were never right for their formation, or because deposits that did form were subsequently removed by glaciation. There is still the potential for a discovery in the Bonnet Plume Basin and in the Dawson coal basin.

Bentonite has been reported in the Tertiary coal basins near Watson Lake, and lower grade common clays are widespread.

With the exception of China clay it is unlikely that a clay deposit in the Yukon could be developed for external markets due to shipping costs. With regards to internal markets, although bricks were made in Dawson City in the days of the Klondike gold rush, no present-day demand of sufficient size has been identified.

CONSTRUCTION MATERIALS cement, sand and gravel, common clays and shale, perlite, pumice, vermiculite, dimension stone

CEMENT

The Romans discovered that quicklime added to the volcanic ash of Puzzuoli gave a cement that set under water, and Puzzuolan cement is still produced today. In 1756 John Smeaton in England made a cement that set under water by burning an argillaceous limestone. That led to a search for similar limestones and the production of 'natural' cements. However the composition of the limestones used was very variable, and the dependability of the product unpredictable. In 1824 Aspdin made the first Portland Cement, so named because it resembled the famous Portland stone of Ehgland.

Portland Cement is produced by burning in a kiln a finely ground mixture containing about 75% CaO_3, and clayey minerals consisting of 20% SiO_2, Al_2O_3, and Fe_2O_3, and 5% magnesia, alkalies etc. The kiln product is a fused complex of calcium silicates and aluminates in the form of rough spheres termed clinker. The clinker is ground to a fine powder and mixed with gypsum to prevent too rapid setting. When combined with water, sand, gravel, crushed stone or other aggregates, the cement binds the materials together to form concrete.

Limestone is the chief rock used to supply the calcium oxide, and the nearer it approaches the composition of the cement mixture the better. MgO should not exceed 10%, and pyrite and free silica should be absent. Calcium can also be supplied by marl, furnace slag and oyster shells. SiO_2 and Al_2O_3 are supplied by clay or shale. The combination of raw materials used are (1) limestone with clay or shale, (2) cement rock, alone or with high calcium limestone, (3) blast furnace slag and limestone, (4) marl and clay, (5) oyster shells and clay.

Shales are used in Newfoundland and New Brunswick to manufacture cement, and common clay from glacial drift is used in Ontario and Alberta. In British Columbia altered volcanic ash is used.

Cement production is energy intensive, using an average 4896 mega joules per tonne produced.

Cement consumption is directly related to the construction industry which has seen no appreciable growth in recent years.

Canada's total production capacity is 16.54 million tonnes per year. Cement plants are concentrated near growth areas and available markets and are typically diversified and vertically integrated as suppliers of ready-mix, stone, aggregates, and concrete products.

Total Canadian production statistics for the past five years are as follows:

	1983	1984	1985	1986	1987
t(000)	7871	9240	10192	10611	12205
$(000)	606101	717282	788357	824344	976025

Western Canadian plant locations and capacities are as follows. Canada Cement Lafarge Ltd's Edmonton plant has a grinding capacity of 220 thousand tonnes per year. Genstar Cement Limited's Edmonton plant has a grinding capacity of 2040 thousand tonnes per year and a clinker capacity of 1186 thousand tonnes per year. Canada Cement Lafarge Ltd's Kamloops plant has a grinding capacity of 190 thousand tonnes per year and a clinker capacity of 180 thousand tonnes per year. CCL's Richmond plant has a grinding capacity of 555 thousand tonnes per year and a clinker capacity of 522 thousand tonnes per year. Genstar's Tilbury Island plant has a grinding capacity of 1000 thousand tonnes per year and a clinker capacity of 855 thousand tonnes per year.

SAND AND GRAVEL

Sand and gravel are essential to modern construction, but because of their low unit cost they are generally only used locally. Sand is a broad term used to cover almost any comminuted rock or mineral, but technically it is restricted to quartz sand with minor impurities of feldspar, mica, and iron oxides.

Size classifications vary but it is generally considered that fine sand has grains between 0.06 and 0.2 mm in diameter, medium sand between 0.2 and 0.5 mm, coarse sand between 0.5 and 2 mm, and gravel between 2 and 8 mm.

Sand deposit types include fluvioglacial, stream channel, flood plain, beach, elevated beach, wind blown, desert dune and marine and fresh water beds.

Most sand and gravel is used for building and paving. Some more specialized uses include mouldings in foundries, abrasives, filters, and a component of glass and refractory products. The purer sands are discussed under the heading 'Silica'.

Canadian production statistics for the past five years are:

	1983	1984	1985	1986	1987
t(000)	233408	233759	256183	257971	260265
$(000)	619400	546328	609638	678612	729147

and for the Yukon:

	1983	1984	1985	1986	1987
t(000)	480	3074	1185	4902	2400
$(000)	1438	5104	2995	13355	6960

COMMON CLAYS and SHALE

Common clays and shales are used throughout Canada in the manufacture of lightweight aggregates and cement. Plants are usually adjacent to the deposits of raw material. Clays are dried and kilned, shales are crushed and screened before kilning.

DIMENSION STONE

Types include granite, limestone, travertine, marble, serpentine, sandstone, dolerite and soapstone. The term granite in this context can include syenite, monzonite, diorite, and granitic gneisses.

The important characteristics of a deposit are the ease of quarrying, the stone's strength, colour, hardness, workability, texture, porosity, and durability. Some lines of weakness, such as well spaced bedding or jointing planes, are necessary to assist in quarying, but deep and irregular weathering is undesirable.

Some rocks that combine several of the required attributes have gained world-wide reputations. Examples are Carrara marble, Mexican onyx marble, Italian travertine, Scottish granite, Virginia soapstone, Bedford limestone, Ohio sandstone and Vermont marble.

Although dimension stone is under increasing pressure from other products such as steel, concrete, glass and ceramics, demand for marble, limestone, sandstone and slate has grown in recent years. The greatest growth markets are in residential and interior decorative uses. In the US the end uses of dimension stone are building stone 42%, monuments 27%, rubble 13%, flagging 4% and curbing 4%. The US imports US$ 302 million annually, largely from Italy.

Western Canadian stones that have been quarried for building materials include Manitoba's Tyndall Stone which is a mottled dolomitic limestone mined at Garson; a red granite from Lac du Bonnet northeast of Winnipeg; a grey granodiorite from Nelson Island, British Columbia; an andesite from Haddington Island, British Columbia; a pink quartzite from Babette Lake, British Columbia; and a sandstone known as Rundal Stone from near Banff, Alberta.

A more complete description of British Columbia's dimension stone types can be found in 'British Columbia Dimension Stone' by G.V. White and Z.D. Hora, British Columbia Ministry of Energy, Mines and Petroleum Resources, Minerals Resource Division, Information Circular 1988-6.

Natural cryolite has only been mined in two places in the world, at Ivigtut in Greenland, and at Miask in the USSR.

The Ivigtut deposit, which was mined out in 1962, was a small pegmatite dike crossing a porphyritic granite. Accessory minerals were siderite, galena, chalcopyrite, sphalerite and fluorite.

There is a North American occurrence of this rare mineral at Pikes Peak, Colorado, and there is one reported Canadian occurrence.

DIATOMITE

Diatoms are microscopically small marine or fresh water algae, and diatomite consists of their siliceous remains, or tests. Diatoms extract silica from the water and secrete it to form an intricate microporous exoskeleton which is often symetrical in design. A single cubic inch of diatomite can contain up to 70 million diatom tests.

Diatomite resembles chalk or clay but is chiefly made up of opaline silica, with minor amounts of water, alumina, iron oxides and alkalies.

When dry, diatomite can absorb more than three times its weight of water. In addition it is extremely light, insoluble in acids, soluble in alkalies, and has low thermal conductivity.

It is used as a filter and filler, as a sound and heat insulator, an absorbent, an abrasive, and as a lightweight aggregate.

Diatomite deposits range in age from the Cretaceous to Recent, but the most important ones are Tertiary. They occur in marine and fresh water sedimentary beds where they must have accumulated while the deposition of other sediments was inhibited.

The world's largest deposits are near Lompoc, California where beds up to 430 m thick are mined on a large scale. Other thick deposits occur in the California Coast Ranges. The remaining US production is from Washington and Oregon. Overseas producers include Denmark, Germany, Japan, Algeria and France.

YUKON POSSIBILITIES

Cement consumption in the Yukon is probably of too low a volume to support a local plant, even though the required raw materials are to hand. In addition to a limited market, the Territory may not have the required inexpensive surplus power.

Though sand and gravel deposits are widespread in the Yukon, there is no inventory of their locations and characteristics. If such an inventory were made, particularly of those deposits nearer to roads, highway construction and maintenance could be planned more effectively. (If such a study were commissioned, the fine gold content of the gravels should not be overlooked.)

Common clays and shales are also widespread in the Yukon, but it would appear that the local market for products made from them is limited, and transportation to external markets would be too costly.

There are no recorded perlite, pumice or vermiculite deposits in the Yukon.

There are numerous intrusives in the Yukon that could be used for dimension stone. An inventory of those that occur near roads in the south-western part of the Territory and the collection of a suite of samples for cutting and polishing would be the first steps necessary to develop a source of Yukon dimension stone.

CRYOLITE

The name cryolite is derived from two Greek words meaning 'frost' and 'stone', in reference to the mineral's resemblance to ice. Cryolite is an aluminum and sodium fluoride (Na_3AlF_6) and at one time was the only source of aluminum. Nowadays it is entirely superseded by bauxite.

Nonetheless it is still of great importance in the aluminum industry for it serves as a solvent for alumina in the electrolytic process of extracting aluminum from bauxite ore. Small amounts are also used as a whitener and opacifier in enamel, a constituent in white glazes, an insulating material, an insecticide, and a flux. Cryolite is also a source of fluorine.

Due to its scarcity the natural mineral has now been replaced by artificial cryolite.

Conwest Exploration Company Limited has a barite-fluorite deposit on Cape Breton Island containing 2.7 million tonnes of 28% barite and 19% fluorite.

Eaglet Mines Limited of Vancouver has delineated 24 million tonnes of fluorspar with an average grade of 11.5% CaF_2 near Quesnel Lake. A feasibility study indicates that the deposit could be mined at a rate of 5,000 tonnes per day to produce acid grade (+97% CaF_2) and metallurgical grade (+83% CaF_2) products.

Consolidated Rexpar Minerals and Chemicals Limited has a uranium-bearing fluorspar deposit north of Kamploops, British Columbia reported to contain 1 million tonnes of 22% CaF_2, or 450 thousand tonnes of 29% CaF_2. There are other deposits in the Liard River area.

YUKON OCCURRENCES

Several Yukon properties have minor amounts of fluorite.

Fluorite is an occasional accessory in and near the Seagull Creek batholith (105-B), and is also reported in association with rare earth elements on the NOKLUIT propert, (105-F-8). There is a small fluorite showing with associated scheelite float in Big Creek, (115-I-5,6), and fluorite has been found associated with topaz and cassiterite on the GERMAINE property, (116-B-2).

GEM STONES

GENERAL DESCRIPTION

All natural precious stones are minerals, and all are inorganic except for pearl, coral, amber and jet. All inorganic gemstones are crystals except for agate, opal and turquoise which are amorphous. To be considered a gem, a mineral must possess some or all of the following characteristics: beauty, durability, rarity, fashionability, and portability. There is no sharp destinction between precious and semi-precious gems, but it is usual to consider only the diamond, ruby, saphire and emerald as precious stones because they are the most valuable and attactive of all gems.

The term gemstone is restricted to uncut stones, and the term gem applies only to cut stones. Gems are usually sold by the carat, a unit of weight equal to 200 mg.

The better-known gems are:

Stone	Constituents	Colour	Chief Sources
Diamond	C	x	Africa, USSR
Emerald	Be,Al,Si,O	gr	Columbia, Egypt
Ruby	Al,O	r	Burma, Sri Lanka
Sapphire	Al,O	bl	Sri Lanka, Burma
Opal	Si,O	var	Australia, Mexico
Amethyst	Si,O	purp	India, Iran, Brazil
Benitoite	Ba,Ti,Si	bl	
Chrysoberyl	Be,Al,O	gr,y	
Feldspar	K,Na,Ca,Al,Si	var	
Garnet	Al,Fe,Mg,Si	r,gr	Arizona, S Africa
Jade,nephrite	Ca,Mg,Fe,Si	gr	Burma,Canada
Jade,jadeite	Na,Al,Si	gr	Burma,China
Kunzite	Li,Al,Si	lilac	California
Lapis lazuli	Na,Al,S,Si	bl	India,Greece,USA, Chile
Peridot	Mg,Fe,Si	gr	Middle East
Quartz	Si,O	var	worldwide
Spinel	Mg,Al	r	Sri Lanka, Burma
Topaz	Al,Fe,Si	y	Brazil,Sri Lanka
Tourmaline	Bo,Si	gr	Urals, Madascar, USA
Turquois	Al,P,O,H	bl	New Mexico,Iran, Turkey
Zircon	Zr,Si	r,or	Sri Lanka, Thailand

(x,colourless;r,red;y,yellow;bl,blue;or,orange;var,various; gr,green;purp,purple)

Most gemstones are obtained from igneous rocks, pegmatites and alluvials. Metamorphism yields garnet, lapis lazuli, ruby, and nephrite. Hydrothermal solutions yield opal and agate, and supergene processes yield turquois.

Diamonds are mined from alluvial and placer deposits and from hard-rock kimberlite (mica peridotite) pipes. Regional exploration for diamond deposits begins with the examination of stream sediments and soils for the presence of a specific group of high temperature minerals associated with kimberlite intrusives. These minerals include pyrope, chrome diopside, ilmenite, zircon and perovskite.

Leading gem diamond producers are Botswana and the USSR. Only 10% to 12% of the world's gem production is from South Africa, but De Beers Consolidated Mines, a South African-based cartel, controls distribution of 80% to 85% of the world's rough diamond production.

Ruby (red) and sapphire (blue, green, yellow) are gem varieties of corundum, and are generally produced from placer deposits. Exploration methods use corundum as a tracer mineral. Mining is with heavy equipment and jigs.

Emerald is the clear green variety of beryl and occurs in pegmatites and their resultant alluvial deposits.

Jade ranges in colour from white through all shades of green, to red. Bright greens are the most valuable. It is believed by the Chinese to posess mystical properties such as the ability to ward off accident and ill fortune, and it is also a symbol of purity.

Jade is a generic term that includes two similar minerals, jadeite and nephrite.

Jadeite is a pyroxene ($NaAlSi_2O_6$), and is the rarest and most expensive jade mineral, sometimes referred to as 'Imperial Jade'. It is produced as stream boulders from Burma. The boulders have their source in an albite-jadeite dyke which intrudes a serpentinised ultrabasic. The dyke may be from magmatic segregation, or from metamorphism of an albite-nepheline rock.

Nephrite is a calcium magnesium amphibole in the actinolite-tremolite series $(Mg,Fe)_5(Si_4O_{11})_2(OH)_2$ and is the most common variety of jade. It is formed by metasomatic alteration of serpentine with addition of calcium, silica, and possibly iron by intrusion of gabbro and dioritic rocks, or by reaction of chemically dissimilar rocks in a shearing environment. Associated minerals are diopside, hydrogrossular, vesuvianite, talc, chlorite, prehnite, and actinolite-tremolite.

Nephrite jade deposits are often associated with small satellite bodies outside the main ultramafic mass.

DIAMONDS IN CANADA

Two diamonds have been found in glacial drift in Ontario, and nine kimberlites have been identified in Eastern Canada, two of which are diamond bearing. One is on the Ile Bizard, near Montreal, and the other is on Somerset Island in the North West Territories.

In Saskatchewan there has been considerable recent activity near Shellbrook where Monopros Ltd, an affiliate of De Beers Consolidated Mines, and Uranerz Exploration and Mining are said to have discovered kimberlite pipes. However Monopros has announced that its tests suggest that the kimberlite structure is not economically viable.

In British Columbia the Cordilleran alkaline belt occupies a broad zone parallel to and encompassing the Rocky Mountain Trench. In the Yukon this trend continues into the Tintina Trench. The alkaline rocks in this belt range in age from Devonian to Sub-recent, and include carbonatites, nepheline syenites and ultramafic lamprophyres. Though only one kimberlite, the Cross diatreme, has been found in this belt, there are several diatreme pipes, one of which contained two microdiamonds.

YUKON GEM OCCURRENCES

Alluvial nephrite jade boulders are recovered near Dease Lake and Cassiar in British Columbia, and nephrite jade has been found in situ in the Yukon's Campbell Range north of Watson Lake, (KING and ARCTIC claims, 105-H-3). Nephrite is also reported as float on the EKO - GREEN STUFF claims, (105-H-5), and 80 tonnes were shipped from Hasselberg Lake in 1982. Unfortunately much of this was of low quality with pyrrhotite inclusions. A few alluvial boulders have also been found in the Yukon River near Whitehorse.

Further exploration for nephrite, which weathers in such a way as to make it difficult to recognize in the field, will surely lead to more discoveries. In addition to the Campbell Range ultramafics, there are others near Teslin, Kluane, and Dawson City.

Canadian jade is exported to Germany, Japan, Taiwan, HongKong, China and the US. Prices vary greatly according to quality, and can reach up to $100 per kg for the highest grades.

GYPSUM anhydrite

GENERAL DESCRIPTION

Gypsum, with a composition $CaSO_4.2H_2O$, will lose more than half of its water when heated to 160°C. This 'hemihydrate', known as calcined gypsum, plaster of Paris, or gypsum hemihydrate, will absorb water and set into a comparatively hard mass. Plaster of Paris is a name derived from the gypsum deposits near Montmartre.

Gypsum was used by early civilizations for decorative carvings and plaster coatings. In the late eighteenth century it was discovered that it could be an excellent fertilizer and soil conditioner, and its agricultural uses came to dominate demand. In the late 1880's a way was found to retard its setting rate, and as a result it soon became important in the construction industry.

It is said that the first plasterboard was made in 1918, and this is now by far the most important modern use for gypsum, accounting for 75% of gypsum consumption in North America.

Most gypsum deposits are sedimentary beds of saline residues precipitated during the evaporation of seawater in enclosed marine basins. For this reason salt is a commonly associated mineral. Uninterrupted evaporation of seawater in a dry climate results in the successive deposition of calcium and magnesium carbonates (as limestones), calcium sulphates (as gypsum and anhydrite), rock salt, and potassium and magnesium salts which may form carnallite, kieserite, polyhalite etc.

A less common genesis of gypsum deposits is from the interaction of volcanically derived sulphuretted waters and limestones.

Most commercially exploited gypsum deposits have a gypsum content between 80% and 95%, with the remaining proportion occurring as anhydrite and other impurities such as shale, limestone, dolomite or clay.

MARKETS AND PLANTS

Gypsum deposits are generally mined as large volume highly mechanized open pit operations. Beneficiation of lower grade deposits may be necessary using log-washing, sink-float, and selective crushing and screening both wet and dry to produce a product of 80% or better purity.

In British Columbia gypsum is presently produced from three mines. Domtar Construction Materials produces an estimated 120,000 tonnes annually from its Lussier River deposit to supply its wallboard plant in Alberta. Westroc Industries mines between 300,000 and 500,000 tonnes at Windermere for its wallboard plant in New Westminster. Canada Cement Lafarge produces a smaller amount from its deposit at Falkland for use in its cement plant at Kamloops.

There are 18 other recorded gypsum deposits in British Columbia, most of which are in the southern and southeastern parts of the province.

Since industrial applications and renovations consume substantial amounts of wallboard, housing starts alone are no longer an accurate guide to gypsum demand.

Statistics for the last five years of Canadian gypsum production are:

	1983	1984	1985	1986	1987
t(000)	7507	7775	8447	8803	8811
$(000)	59297	61562	75076	83072	87908

The present structure of the Canadian industry is unlikely to change because wallboard and building material plants have sufficient capacities to meet short term regional demands and also to supply some of the demand in the US.

Any new western Canadian producer will have to be able to supply a high-quality product at very competitive prices in order to penetrate the existing integrated market.

YUKON OCCURRENCES

The only available record of a gypsum occurrence in the Yukon is on the BULLION claims (115-B-15), where stratabound discordant gypsum is associated with copper and lead mineralization. Additional exploration in this part of the Territory is likely to bring to light more gypsum deposits. These could be similar to the O'Connor River gypsum deposit located just to the south in British Columbia. This deposit, which has been evaluated in detail in the last few years, occurs in faulted early Permian to late Triassic carbonate rocks. The gypsum is in three zones, the most accessible of which is Zone 1 with a strike length of 400 m and irregular widths between 30 and 110 m. The deposit contains up to 8% anhydrite.

ANHYDRITE

Anhydrite has the composition $CaSO_4$ and is found associated with gypsum deposits.

Compared to Gypsum, anhydrite has few commercial uses and it is generally considered a nuisance mineral.

When treated with ammonia it forms the fertilizer ammonium sulphate. It can also be reduced to sulphur dioxide and used in the manufacture of sulphuric acid. It is an ingredient of Portland cement, and a fertilizer for peanut crops.

LIME

Lime is produced from limestones ($CaCO_3$), most of which are organic in origin, frequently containing parts of organisms such as shells of molluscs and coral skeletons.

Quicklime (CaO or CaO.MgO) is formed by the process of calcination in which limestones are heated to 903°C, the dissociation temperature of the carbonates, and held at that temperature long enough to release carbon dioxide. Slaked lime is a mixture of quicklime and water, and hydrated lime is slaked lime dried and reground. One hundred pounds of pure limestone yields 56 pounds of lime.

The largest consumption of lime is by the metallurgical industry which requires it as a flux, and the increased application of basic oxygen furnaces is resulting in a rising demand by this sector. The second largest user of lime is the pulp and paper industry which requires it in the preparation of digesting liquor and in pulp bleaching.

Other users include the uranium industry, sugar beet industry, and the manufacturers of cement, calcium carbide, calcium chloride, calcium cyanamide, fertilizers, insecticides, fungicides, pigments, glue, acetylene, precipitated calcium carbonate, calcium hydroxide, calcium sulphate, magnesia, and magnesia metal.

The construction industry, surprisingly, only accounts for 6% of lime consumption.

One probable growth area for the use of lime is in environmental applications which are predicted to increase as concern grows over acid rain and related issues. Environmental uses include desulphurizing stack gases of thermal power plants, smelters, refineries and chemical plants and the neutralizing of sewage and industrial effluent waters.

Lime is a high bulk low cost commodity not usually shipped any great distance. The preferred location for a lime plant is near a principal market, adjacent to a source of high quality raw material, and close to a supply of energy. The latter is important because lime production is energy intensive, consuming 6.7 million BTU per tonne of lime produced.

CANADIAN PRODUCERS

Most Canadian plants are in Ontario and Quebec, and those two provinces account for 80% of domestic production. In western Canada lime is quarried from Texada Island by Ash Grove West Inc (formerly Oregon Portland Cement Co). Being on tidewater, this deposit supplies the entire Pacific Northwest.

Other western lime quarries are near Pavillion Lake (between Lillooet and Clinton), near Rock Creek and Kootenay Lake, at Dahl Lake near Prince George, and at Ptarmigan Lake also near Prince George.

YUKON CONSUMPTION

The Yukon's hard rock producers, United Keno Hill, Curragh, and Erickson are reported to consume a total of 10 thousand tonnes of lime per year, all of which is imported into the Territory.

In addition there is a considerable consumption of calcium chloride for highway dust control.

There are large accessible limestone beds in a belt running through south west Yukon from Atlin to Carmacks, and it is possible that the present level of combined consumption would justify the development of a local lime plant.

Both United Keno and Curragh have claims over limestone deposits in the Carmacks area.

Olivine is a refractory mineral which can replace chromite in steel furnaces and be used above the slag line in nonferrous furnaces. Olivine is also mixed with magnesite to form refractory bricks, and used for moulds for casting brass, bronze, aluminum and magnesium.

World production is from dunite deposits in Norway, Sweden, Austria, Japan, New Zealand, Zimbabwe, and South Africa. Canadian production is from Ste. Anne des Monts Quebec.

In order to be economically viable a dunite deposit should contain at least 40% MgO, and accessory minerals such as serpentine, chlorite and vermiculite must be readily removable.

Recently listed prices are between US $50 and $75 per tonne for foundry sand grade olivine.

In the Yukon dunites have been mapped in the south west of the Territory in the Kluane Range, and on Dunite Mountain in the Quiet Lake area (105-F). Other dunites could be expected in areas of ultramafics, and possible associated minerals would be asbestos, chrome, and platinum.

PEAT

Peat is an accumulation of partly decomposed vegetable matter formed under anaerobic conditions. It represents the first stage in the formation of coal. Canadian deposits generally started to form 11,000 years ago and accumulate at a rate of 0.5 to 1.7 mm per year.

Horticultural peat is composed of poorly decomposed sphagnum moss, while fuel peat must be more thoroughly decomposed.

Peat materials are usually separated according to their botanical composition. Examples are sphagnum peat, sedge peat, brown moss sedge peat, woody sedge peat, woody peat, feather moss peat, sedimentary peat and amorphous peat.

In 1986 the US consumed about 1 million tonnes of peat valued at US$ 21 million. The principal producers are Florida, Michigan, Illinois, Indiana, and Colorado.

55% was marketed as packaged peat for potting soil and soil improvement. The remainder was sold in bulk for similar applications by nurseries and golf courses.

Recent trends have been to try and find new uses for peat. A diesel-like fuel has been synthesized from peat, but it is too expensive to produce. Some US states are experimenting with power generation from peat supplies.

The US imports 450 thousand tonnes of peat each year, most of this from eastern Canada.

In British Columbia it is estimated that 1% of the total land area is covered by peatland, though the resource has not been studied in any detail. Production is confined to accessible and populated regions, in particular from Burns Bog which in 1980 produced 26,000 tonnes with a value of $3.9 million.

Very little is known of the Yukon's peat deposits, and it would seem that an inventory of the territory's peatland resource is necessary. However remoteness, a cool climate, and permafrost will limit development. Climate has a strong impact on the feasibility of peat mining because the air temperature and the amount of sunshine and rainfall affect field drying of milled peat. Perennially frozen peatlands, permafrost, and a high ice content can be expected to cause additional technological and environmental problems.

PHOSPHATES rock phosphate, apatite, guano

GENERAL DESCRIPTION

Plants and animals cannot exist without phosphorus, and of all the substances necessary for plant growth, phosphorus compounds are the most likely to be deficient. This is not because phosphorus is scarce in nature, but because before it can be assimilated by a plant's roots it must be in a very fine form.

Rock phosphate can be finely ground and spread directly on the land, but this natural material is not readily soluble in water so that it decomposes slowly and is not immediately available to the plants.

Treating natural mineral phosphate with sulphuric acid produces 'superphosphate', a readily soluble form of fertilizer. 'Superphosphate' can be upgraded to 'double superphosphate' or 'concentrated superphosphate' containing up to 54% phosphoric acid.

CANADIAN PRODUCERS

Canada's salt producing provinces are Nova Scotia, Ontario, Manitoba, Alberta and Saskatchewan. The Atlantic Provinces' production comes from sedimentary deposits within the Mississippian Windsor Group which are exploited on a large scale. The salt deposits are associated with potash enrichments, and grade up to 97% sodium chloride. Reserves are in the billions of tonnes.

Ontario also has sedimentary salt beds which underlie much of the southwestern part of the province and are worked by underground mines and brine wells.

The Prairie Provinces are underlain by salt beds from the southwest corner of Manitoba across Saskatchewan and into north-central Alberta. The salt beds are contained in the Prairie Evaporite Formation which also hosts Saskatchewan's potash reserves.

British Columbia has no salt production and chloralkali plants in Prince George, North Vancouver, Squamish and Nanaimo depend on imports from Mexico and the US valued at more than $4 million per year.

No salt deposits have been found in the Yukon to date and the Territory's consumption is negligible.

Annual Canadian production statistics for the past five years are:

	1983	1984	1985	1986	1987
t(000)	8602	10235	10085	10332	10294
$(000)	172787	210191	215362	239466	235420

<u>SILICA SAND</u>, quartz crystal, lascas, silicon

GENERAL DESCRIPTION

Silica sand refers to high quality industrial sand containing 95% to 99% silica usually produced from relatively pure sandstones with some additional exploitation from pegmatites and quartz veins.

USES and MARKETS

The North American industry is dominated by a few large producers which are secretive about grades, capacities and prices. There is intense competition on a regional basis particularly since unit prices preclude distant transport.

Markets are concentrated in industrial areas, and deposits are generally within two hundred miles of them unless the product is specialized.

The largest consumption is in the manufacture of container glass, though this use is under severe attack due to the substitution of cans, plastics and paper cartons. The second largest user is the flat glass sector which includes automobile and architectural glass. In total, glass manufacture accounts for 40% of North America's silica sand consumption.

Other uses include abrasives, fluxes, roofing granules, fillers in asphalt rubber and paint, water filtration, coal washing, and the production of silicon, ferrosilicon and silicon carbide.

Fiberglass manufacture is a recent growth market, as is the use of frac sand required in the hydraulic fracturing of hydrocarbon formations to promote oil and gas production.

CANADIAN PRODUCERS

Canadian producers are Indusmin, with operations at Badgeley Island, Ontario, and St Canut and St Donat in Quebec; Steel Brothers with production from Black Island in Lake Winnipeg; and B. Miller, Chemtech Enterprises, and Mountain Minerals with operations in British Columbia.

The Black Island deposit is a poorly consolidated sandstone of the Winnipeg Formation. The pit run material is washed, screened, dewatered, scrubbed, laundered, separated, and dewatered again. The end product is pure white, sized to -20 +100 mesh, containing 99.58% SiO_2, 0.02% Fe_2O_3, 0.22% Al_2O_3, 0.005% TiO_2, 0.018% CaO, 0.037% MgO, and 0.106% LOI.

An example of a British Columbian quartzite used for silica production is the Mount Wilson formation quartzite which can be followed along the eastern ridge of the Rocky Mountain Trench for 50 km. At Brisco it is 70 m to 100 m thick, and analyses are better than 97.94% SiO_2, less than 1.25% Al_2O_3, less than 0.08% CaO, and less than 0.12% Fe_2O_3. The product is used in the manufacture of ferrosilicon and glass.

Total Canadian silica consumption is some 2.5 million tonnes per year, of which some 1 million tonnes are imported from the US.

Prices depend on local markets, sand grades, and transportation distances, and vary from $8 per tonne to $13 per tonne for glass sand, and up to $23 per tonne for frac and fiberglass sand.

There is the potential for the establishment of a flat glass producing facility in Western Canada since good quality silica sand is available together with relatively cheap natural gas and electricity.

However, with no local glass or fiberglass manufacturers it is unlikely that a silica sand deposit could be successfully developed in the Yukon.

Quartz crystal is essential for making piezoelectric filter devices that separate desired from undesired portions of the frequency spectrum, and oscillators that provide single frequency signal sources. Filters and oscillators are used for a wide variety of communications and instrumentation purposes.

Crystals of quartz suitable for electrical purposes are rare. They are found in cavities and on joint planes in quartzites that have been invaded by granitic rocks. World reserves are limited, but the increasing acceptance of cultured crystal is reducing the dependence on these reserves. Nonetheless natural crystals are still important because they are needed as seed material for growing cultured quartz.

The major producers are Brazil, Uganda, and Madagascar. There is no North American production of quartz crystal.

As far as is known none of the Yukon's quartz crystal occurrences have the characteristics required for development.

Lascas is a natural non-electronic grade of ultra-high purity quartz used as feedstock for growing cultured quartz crystal and for the production of fused quartz.

The US is a net exporter of lascas from deposits in Arkansas.

Japan is the leading producer of cultured quartz crystal, deriving most of its lascas from Madagascar.

Cultured quartz producers have their own strict grade requirements and sampling and analysis of a potential lascas source should be carried out in close co-operation with end users.

Some of the Yukon's quartz deposits may have the characteristics necessary to be exploited as a lascas source.

<u>SILLIMANITE</u> andalusite, kyanite, dumortierite

Sillimanite, andalusite, and kyanite all have the same composition, Al_2SiO_5; they differ only in crystal form. Dumortierite is an aluminum borosilicate with the composition $Al_8BSi_3O_{19}(OH)$. When fused at temperatures between 1100°C and 1650°C these minerals are converted wholly or partly into mullite, $Al_3Si_2O_{13}$.

Mullite remains stable to 1810°C, has a low coefficient of expansion, is resistant to check, and has low electrical conductivity. These properties make it an ideal material for the manufacture of spark plugs, laboratory ware, and refractory bricks.

The sillimanite group occurs as accessory minerals in metamorphic rocks such as gneisses and schists, and less importantly in granitic pegmatites.

Commercial deposits of kyanite are rare. They occur as disseminations and small masses in gneiss or schist, or as lenses in pegmatite dykes or clots in quartz veins.

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