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INDUSTRIAL MINERALS
AND THEIR UTILIZATION IN ALBERTA

by

W. N. Hamilton

Geology Division
Research Council of Alberta

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INDUSTRIAL MINERALS AND THEIR UTILIZATION IN ALBERTA

Introduction

Industrial minerals are literally the minerals or raw materials of industry. They comprise generally the nonmetallic minerals and rocks used in indigenous industries and construction of all kinds, but exclude those used as fuels and from which metals are extracted. Most are of low value per unit weight or volume and cannot be economically transported long distances; therefore, they do not generally enter into export trade as do many of the metallic minerals and coal. The utilization of industrial mineral resources accordingly affords a direct measure of the industrial diversity within the regional economy.

The value of production of industrial minerals in Alberta amounted to $65 millions in 1971, which is just below 4 per cent of the total mineral production. This is a decline from the previous few years (caused by a decline in sulfur prices from record highs in 1966-69), although it represents a steady rise in tonnage production. The importance of these materials in Alberta is enhanced by their close association with the petroleum and petrochemical industries, both as input and processing requirements and as byproducts or coproducts at the extractive stage. Much of the existing knowledge of industrial mineral resources in fact has been acquired as an offshoot of petroleum exploration. It is clear, however, that industrial minerals (along with coal) eventually must inherit the role of petroleum as the major source of mineral wealth to the province, with greatly expanded use of these resources, new discoveries, and newer ways of utilization with more efficient resource conservation.

Alberta's known deposits of industrial minerals are described below in groups according to their principal industrial use, beginning with the construction industries, followed by the chemical and metallurgical industries, and concluded with a group of miscellaneous industrial uses. These groupings may be logical for the current state of industrial development in the province, although undoubtedly for certain minerals the emphasis will shift from one industry to another in the future.

Cement Raw Materials

Cement (or Portland cement) is the product of a process which involves mixing lime-bearing and clayey materials, burning the mixture to a clinker at a temperature of incipient fusion, and grinding the clinker to a fine powder. The raw materials used in this process are limestone and shale (or clay), both of great abundance in Alberta. Another very important material in cement making -- not in the actual process but as an additive in the final product -- is gypsum, also found in Alberta but in remotely located (and as yet undeveloped) deposits.

Alberta's cement industry currently comprises two major producing plants, one at Edmonton, and one at Exshaw 60 miles west of Calgary, with an additional plant at Edmonton which is used only for grinding clinker. The productive capacity of the plants is rated at slightly more than 1.1 million tons of cement per year. A smaller plant presently under construction and scheduled to come on production later this year will add 70,000 tons to the annual capacity. In 1971, the production of cement in the province amounted to just over one million tons valued at $22 millions.

Cement plant locations in Alberta are shown in figure 1. Cement, like many industrial mineral commodities, is a heavy, bulky, and low value material with a limited market area. Most of Alberta's production is consumed in the indigenous construction industry. The volume of production varies directly with the value of construction and thus reflects the level of construction activity in the province.

Portland cement is unquestionably the most versatile and widely used of all construction materials. Its main use is with aggregates in forming concrete, but it also finds wide use in soil-cement mixtures for road building, and in masonry cements (Portland cement mixed with finely ground limestone and a plasticizer). New concrete design techniques and building products are continually being developed, so that the use of cement is likely to progress at an increasing rate in the future, gradually replacing many other building materials.

Limestone, the primary raw material of cement, is composed largely of calcium carbonate ($CaCO_3$), one of the more common minerals in the earth's crust. Basically, limestone is classified into two types; high-calcium and high-magnesium, the latter containing from 10 to 40 per cent magnesium carbonate. High-calcium limestone is the type most sought after for industrial purposes, and the essential type for cement-making.

In normal Portland cement, the approximate raw material proportions are 63 per cent lime, 21 per cent silica, 6 per cent alumina, and 3 per cent ferric oxide (with a tolerance of 3 per cent magnesia). These proportions normally require that 80 per cent of the batch consist of limestone (the source of the lime), with about 1 1/4 tons of limestone required to make one ton of cement.

Limestone exists in vast quantities in Alberta. High calcium limestones are found in formations of Cambrian, Devonian, and Mississippian ages exposed almost continuously along the Rocky Mountains in western Alberta, and in Upper Devonian strata exposed along the Athabasca and Clearwater Rivers in northeastern Alberta (Fig. 1). Limestone also exists in the subsurface throughout the province, but its shallowest depth near a major industrial area is below 3,000 feet -- too deep for consideration as a raw material source.

The best known limestone deposits are those indicated on figure 1, along the front ranges of the Rocky Mountains in west-central and southwestern Alberta. Most are adjacent to railway lines that extend into and across the mountain ranges, these being the most suitably located deposits for exploitation. Quarries are operated in several of the deposits, and at two of the quarries limestone is produced for cement-making. At Cadomin, the limestone is hauled by unit train to a cement plant in Edmonton, a rail distance of 180 miles. The limestone deposit is in the Palliser Formation of Late Devonian age and extends over a thickness of 500 feet, with proven reserves calculated in excess of 22 million tons. About 600,000 tons are now quarried annually. At Exshaw, 160 miles to the southeast, a cement plant uses limestone of the same formation, quarried on the plantsite, in roughly the same quantities as at Cadomin. Other quarries in the mountains produce limestone mainly for lime manufacture (Fig. 2). Numerous quarriable deposits of similar quality undoubtedly could be located in the hinterlands between railway lines in areas accessible by road.

Alberta limestones generally are medium to dark grey in color. High grade white limestone of the type used for specialized products, including white Portland cement, is not found in the province. The grey limestones, however, can be very pure, and in most of the deposits indicated in figure 1 they range from 94 to 98 per cent $CaCO_3$ with 1.5 to 4 per cent $MgCO_3$.

Limestone has many industrial uses other than in cement and lime manufacture. In other parts of Canada its major use is in crushed stone for road metal, concrete aggregate, and railroad ballast. It also finds considerable use as a flux in metallurgical industries, for agricultural purposes, and as building and ornamental stone. However, these other uses are rarely applicable in Alberta, and more than 90 per cent of the limestone requirements are for cement and lime production.

Other calcareous rock types that could substitute for limestone as a cement raw material include marl, coquina, and tufa. These materials merit consideration only in areas many miles distant from sources of limestone.

Marl is a lime-mud material generally formed in shallow lakes as accumulations of clay mixed with calcareous material secreted by algae. The $CaCO_3$ content can range from 30 to 80 per cent in these deposits, which are widespread in Alberta, but tend to be thin and lensy, have a high water content, and generally are too limited in extent for commercial development. One marl deposit is being developed near Clyde, 40 miles north of Edmonton, for use in a small-scale cement plant now under construction.

Coquina is a rock formed mainly of compacted fossil shells. The best known deposit in Alberta is in the southwestern corner of the province, near Hillspring, where a bed of oyster shells up to 15 feet thick is exposed along the Belly River. Whether the deposit would have sufficient recoverable tonnage to support a local cement industry is uncertain.

Tufa is a deposit of calcium carbonate from lime-rich spring water. None of the few known deposits in Alberta are large enough for consideration as a raw material source.

Shale is the indurated rock equivalent of clay, an earthy, easily disintegrated material composed of particulate hydrous alumino-silicates called the clay minerals. Shale, or clay is the raw material that furnishes the bulk of the alumina and silica requirements for cement making.

Clays and shales are widespread in Alberta in the bedrock formations and surficial deposits throughout the Plains, and in the Rocky Mountains as well. The clays commonly are the low grade, low alumina variety; however, for cement-making no special grade of clay is needed. Cement manufacturers normally will use whatever clay is handiest to the plant, achieving the desired $SiO_2:Al_2O_3$ proportions by correct batching of raw materials (using, for example, sand to adjust the silica).

The distribution and quality of clay and shale deposits in Alberta are discussed more fully in the section on Ceramic Raw Materials.

Gypsum is hydrated calcium sulfate ($CaSO_4 \cdot 2H_2O$). Its chief use is as raw material for the manufacture of plasterboard, but it also finds major use as a component of Portland cement, this use accounting for 30 per cent of the consumption of gypsum in Alberta. The gypsum is added in the final processing stage, interground with the cement clinker in amounts of four to five per cent, to retard the setting rate. Crude uncalcined gypsum is used, essentially to supply calcium sulfate which effects the retarding action. Anhydrite, the anhydrous calcium sulfate mineral, is even more effective for this purpose but less easy to obtain than gypsum.

Deposits of gypsum in Alberta are discussed in detail under Building Products Minerals. Several deposits are known (Fig. 1), but at the present time no gypsum is produced in the province, and local requirements must be brought in from Manitoba and British Columbia. Alberta's cement industry in 1971 consumed 46,000 tons of gypsum valued at $0.4 millions, all of which was obtained from deposits in British Columbia.

Ceramic Raw Materials

Ceramics, as the term is commonly understood, are products first shaped from natural materials (mainly clay) and then permanently hardened by heat. In a broader sense, ceramics also include glass and certain other products for which applied heat is essential to the forming process, although the heat has a somewhat different function than in clay ceramics. The principal raw materials are clay and silica sand, materials ~~which are~~ common in Alberta but are of low quality. Most of the province's requirements for high-grade clay and silica sand must be imported.

The ceramics industry in Alberta is regarded generally as two distinct industries; clay products, and glass. The clays products industry is centered largely in the southeastern part of the province (Fig. 1), the bulk of production coming from plants in Medicine Hat, Redcliff and Lethbridge. Six plants currently are in operation in this area, two for structural clay products, three for pottery, and one for porcelain ware. Plants are in operation also at Edmonton (for structural ware) and Calgary (pottery), and recently a plant manufacturing brick from fly ash came on production at Wabamun Lake, 40 miles west of Edmonton.

The glass industry is distributed somewhat similarly, with a plant in Redcliff for the production of glass containers, and two plants in the Edmonton area for glass fibre products. In addition, several small plants produce handmade ornamental glassware.

Locations of ceramic plants and of mineral deposits that are utilized as raw materials are shown in figure 1. Alberta's production of clay products in 1971 was valued at $3.3 millions; the value of glassware produced is unknown. Ceramic products are marketed widely throughout western Canada, although most glass fibre and structural clay products are consumed locally in the construction industry.

Clay in the ceramic sense is an earthy material which becomes plastic when wet, can be molded to any shape which is retained when dry, and on firing is converted to a permanent rock-like mass. Clays, and their indurated rock equivalent, shales, are composed essentially of particulate hydrous alumino-silicates called the clay minerals, of which there are several basic kinds, each with unique physical properties. Clays are classified into several ceramic types according to their properties, which determine the kinds of products that can be made from them.

Clays and shales undoubtedly are Alberta's most voluminous mineral resource. Clay or shale is found in varying proportions in practically all the Cretaceous and Tertiary formations that outcrop on the Plains, is present extensively in the surficial deposits as well, and is the dominant rock type of the Mesozoic strata in the Rocky Mountains and Foothills. The clays are mostly of the low grade type, "common brick" clay, suitable only for low value structural ware. Some intermediate grades such as stoneware clay and fireclay are known in a few scattered deposits, but high grade clays of the type required for whiteware, for example, china clay and ball clay, are not found in the province.

Clay deposits in Alberta are indicated in figure 1 for the two main types of clay found. "Common brick" clay is a low fusion material commonly containing two or more kinds of clay minerals with a high proportion of fluxing impurities and quartz: it burns hard and strong at low temperatures, usually to a red color, and is used mainly in the manufacture of common and facing brick, structural tile, drain tile, etc. Stoneware and refractory clays have kaolinite as the dominant clay mineral and will withstand much greater heat without deformation: these clays are used for the more densely fired ware such as sewer pipe, flue liners, facing brick, pottery, stoneware crocks, and in low heat-duty refractories. The deposits indicated in figure 1 are those which either have been quarried in the past for ceramic use, or have been tested as favorable for use.

In general, of the bedrock clays in Alberta only those of non-marine formations are suitable for ceramic use. The marine shales almost invariably are unsuitable owing to poor plasticity, poor drying and fired characteristics, or a tendency to bloat. Surficial clays of lacustrine and floodplain deposits have had considerable use in the past for brick making, mainly because they were handiest; in fact, they made rather poor quality brick.

The better grades of clay in the province are found mostly in the Cypress Hills area, where stoneware clays from the Whitemud Formation are quarried. The Whitemud Formation, a thin but complex sedimentary unit, is undoubtedly the most important source of clays in western Canada. Its eastward development in Saskatchewan has provided fireclay and ball clay in addition to stoneware clay, -- the dominant clay type of the formation in Alberta. Other stoneware clays are known in a few widely scattered deposits, the most promising exposed along the Athabasca River in northeastern Alberta, directly under the Athabasca Oil Sands. Good quality fireclay has been found in coal measures being mined at Wabamun Lake, 40 miles west of Edmonton, forming extensive partings up to 2 feet thick between minable coal seams. The clay appears favorably disposed for large tonnage recovery as a byproduct in the coal stripping operation; it is white-burning, consists mainly of kaolinite, and shows promise for ceramic use.

Structural clay products plants in Medicine Hat and Redcliff use clays from the Cypress Hills, mainly from the Whitemud Formation, along with local red-burning clays from the Oldman Formation. The plant at Edmonton uses ~~local~~ Pleistocene lake/ clay (from ~~the~~ glacial Lake Edmonton ~~Formation~~ sediments) blended with Pleistocene clay from near the town of Athabasca. Pottery plants use a variety of clays, local and imported.

Clays and shales have other uses in products not normally regarded as ceramic ware. The most important of these is in cement making. Clays which bloat on rapid firing are used for lightweight aggregate manufacture, discussed in the section on Aggregates. Siliceous shales from the Mississippiar Banff Formation at one time were used in Alberta to manufacture mineral rock wool -- a product similar to fibreglass. Bentonite, an important variety of clay with many industrial uses, is described separately under Miscellaneous Industrial Minerals.

Silica sand implies sand composed essentially of quartz (SiO_2) with few impurities, sufficiently pure to be used as a commercial source of silica. As a ceramic raw material, silica is the prime ingredient in glass, silica brick, and enamels, and as an additive ("potter's flint") in many kinds of clay ware.

Most of Alberta's requirements for high quality silica sand are imported at present, the major use being for glass manufacture, which has the most stringent specifications. A few deposits of fairly good grade material are known in the province (Fig. 1), but are poorly situated with respect to transportation and markets. The best known deposit, in the friable upper part of a Cretaceous marine sandstone exposed along the Peace River in northwestern Alberta, has a 40- to 60-foot thickness of clean quartz sand which can be upgraded readily to glass sand specifications. Similar quartzose sandstones are known in other parts of northern Alberta. The tailings remaining after extraction of the oil from the Athabasca Oil Sands are another possible source, with beneficiation; residual oil film plus the relatively high content of accessory mica need to be removed to qualify the tailings for glass sand use. Sands of better quality and larger grain size than these tailings probably could be found along the Athabasca and Clearwater Rivers. Other possibilities include some quartzite formations exposed in the Rocky Mountains, and alluvial quartzite pebbles found in the major river valleys of Alberta: these materials would have to be crushed to the specified grain sizes for silica sand.

For uses of silica sand in which the specifications are not so exacting, the dune sand deposits common in many parts of Alberta are worth consideration. Although of relatively low grade, these sands respond well to beneficiation and probably could be upgraded sufficiently for use in colored container glass. Sand from dune deposits near Edmonton has been used with beneficiation for some time in the production of fibreglass. Dune sands are discussed further in the section on Building Products Minerals. The distribution of dune fields in Alberta is shown in figure 1.

In 1971, approximately 75,000 tons of silica sand were imported into Alberta, of which about 85 per cent was used in glass products manufacture, the remainder going mostly to foundries for molding purposes and oil well servicing companies for hydraulic fracturing. The sand came from many sources; Manitoba, Washington, Illinois, and Texas. In the past, Alberta deposits have received little attention because of high beneficiation costs and because top-quality, low cost sand has been readily available for import; however, with rising freight costs consumers are looking more closely at local deposits.

Building Products Minerals

This category includes industrial minerals that are used in the production of various kinds of unit building materials other than ceramic and cement - aggregate products, the minerals of which are discussed elsewhere in the chapter. Building products minerals may undergo a manufacturing process involving chemical changes (e.g., gypsum for plasterboard manufacture) or may be used with only slight modification, such as dressing (building stone) or screening (sand), but in general they are relatively unchanged in product form from their raw condition.

The building products industry is so diversified that generalized discussion is difficult. Individual products are mostly unrelated, having in common only their function as important materials of the construction industry. Following are specific discussions of minerals and their products that are of significance in Alberta. In general, the products are low cost materials with a limited market area, mainly within the province, although the raw materials may be hauled long distances owing to local deficiencies of suitable mineral deposits.

Gypsum, hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$), is an important component of Portland cement as discussed in the Cement Raw Materials section; its chief use, however, is for the production of calcined gypsum or plaster of paris, the main constituent of plasterboard.

Pure gypsum contains 20.9 per cent combined water. and most commercial deposits grade between 90 and 95 per cent purity. When gypsum is calcined under controlled conditions three-quarters of its water is expelled, yielding the product commonly known as plaster of paris. Mixed with water this material forms a plaster which may be molded to any desired shape, and which on setting will revert to gypsum. Plaster of paris is valued as a construction material for its light weight, strength, chemical inertness, and fire retardent properties. In its principal use for plasterboard manufacture, plaster of paris mixed with water, foam and other ingredients is introduced in a thin layer between two sheets of cardboard and allowed to set, forming a rigid panel of the type now used almost exclusively in the building trade for interior wall construction.

Several known deposits of gypsum in Alberta are undeveloped at the present time, due in part to low grade but primarily to their remote or difficulty accessible locations, which are given in figure 1. Two of the deposits lie within National Parks and are interdicted from commercial exploitation. Of those outside the Parks, three are considered to have potential for future development: these are the so-called Kananaskis, Fort McMurray, and Fetherstonehaugh deposits.

The Kananaskis deposit lies in the vicinity of Kananaskis Lakes, in the Rocky Mountain front ranges 80 miles southwest of Calgary. The deposit outcrops on a mountainside near the 7,000-foot level. An 80-foot thickness of gypsiferous strata is exposed, from which grab samples assayed 90 to 92 per cent purity. The gypsum beds dip steeply into the mountain and would require underground mining methods for recovery. Extent and grade of the deposit are undetermined. The Kananaskis Lakes region is one of great scenic attraction and recreational importance, so that any mineral development likely would be subject to very strict regulations.

In the Fort McMurray region, a gypsum deposit 30 to 50 feet thick has been proven to underlie the Clearwater River valley at depths ranging from near-surface to 300 feet over a distance of 18 miles. The average grade of gypsum rock (in continuous core from two test holes) is 84 per cent. A similar deposit, but of higher purity, is postulated to exist beneath the Athabasca River valley about 60 miles north of Fort McMurray. The higher purity is inferred from borehole data in which core analyses indicate an increase in grade of the gypsum northward, and from the lateral presence of high grade deposits farther north, at Peace Point in Wood Buffalo National Park (Fig. 1). The Fort McMurray deposits are 300 miles by rail plus another 30 to 60 miles by road or barge from Edmonton.

The Fetherstonehaugh deposit straddles the Alberta-British Columbia border in the Smoky River headwaters, approximately 270 miles west of Edmonton. Its remote location is offset somewhat by proximity to the Alberta Resources Railway, which passes 40 miles to the east. The deposit forms a small hill at an elevation between 6,500 and 7,000 feet, and appears to contain several million tons of ore; however, estimates of reserves are hampered by structural complexities plus a high content of dolomite in the deposit, which reduces the percentage of recoverable gypsum. The grade also is uncertain, due to a discrepancy in assays reported for outcrop channel samples (95 per cent), and test hole samples (75 to 80 per cent).

Gypsum is easy and inexpensive to mine and process: the procedure involves quarrying, or in some cases, shallow underground mining, followed by crushing, grinding, and calcining at temperatures between 150 and 190 degrees centigrade. The calcined product has a wide variety of uses; in the building trade for various types of plasters, for dental and surgical plasters, in the dehydration of oil, and in filtering. Raw gypsum also has many uses besides in the manufacture of Portland cement; as a filler, as a base for paints, in the purification of water, and as a soil conditioner in agriculture. By far the largest use, however, is of the calcined gypsum for the manufacture of plasterboard, which in Alberta accounts for about 70 per cent of the gypsum consumed.

In Alberta, three plasterboard plants currently are in operation, two located in Calgary and one in Edmonton. Their combined consumption of gypsum in 1971 was about 125,000 tons valued at just over $1 millions. Most of this was brought by rail from Windermere, British Columbia, with a small amount coming from deposits in Manitoba.

Dimension Stone is the term applied to stone marketed in blocks or slabs of specified shapes or sizes for building or ornamental purposes, whether as "rough" or "dressed" stone. It includes stone of all types, the most common being granite, sandstone, limestone, and marble.

At the present time, the only dimension stone quarried in Alberta is known as "Rundle Stone" -- a dolomitic siltstone, hard, flaggy, medium grey, from the Spray River Formation of Triassic age. This stone is quarried in the Rocky Mountains near Canmore, some 60 miles west of Calgary, for use as rough building stone. Rundle Stone is seen in many of the fine, picturesque buildings of Banff National Park.

Field stone, the term for glacial erratic boulders found in the surficial glacial deposits that cover much of Alberta, is used extensively as facing and decorative stone for houses and buildings. Boulders of two basic types are found; Paleozoic sedimentary rocks, e.g., limestone, from outcrop areas of these rocks, and Precambrian crystalline rocks, e.g., quartzites (Athabasca Sandstone), granites, gneisses, from the extensive Precambrian Shield area to the north and east. Oversize material from gravel operations and stone piles in farmers' fields are the main source of supply.

Granite found in plutonic masses in the Precambrian Shield terrain of northeastern Alberta shows promise as a local source of excellent quality ornamental and building stone. Locally, the rock is massive in outcrop, uniform in grain size and color, with an aesthetic deep red tone and texture that takes a high polish. Seemingly it fits all the requirements of a commercial dimension stone except perhaps for location. Preliminary studies on the economic feasibility of producing granite from this remote area of the province have given encouraging results. At present, granite is used in Alberta chiefly for monumental stone and exterior cladding of commercial buildings, much of it obtained from Quebec.

Sandstones of the Paskapoo and Porcupine Hills Formations of Cretaceous and Tertiary ages in central and southern Alberta were quarried until 1914 for building stone. Many of the older, more substantial buildings of Alberta, including the Legislative Building in Edmonton, are built with this stone. Initially the sandstone came into use because of its friability and ease of working; partly for the same reason it has passed out of use, despite its utilitarian service over the years.

Some dimension stone possibilities exist in the Rocky Mountains, although generally the rocks are rather unattractive as well as extensively jointed and fractured. Rock slide boulders of pink quartzite from the St. Piran Formation of Lower Cambrian age have been used for building stone at Jasper. Precambrian quartzite cobbles from the mountain streams also have been used as building stone material. Igneous rocks in the Precambrian Kinsella Formation in the North Kootenay Pass area and certain volcanic porphyries and breccias of the Cretaceous Crowsnest Formation near Coleman could make attractive ornamental stone.

Stone quarry production in Alberta in 1971 was 200,000 tons valued at $700,000.

Industrial sand could be any sand having consistent, predictable properties that are desired for some industrial purpose. The term is interchangeable to some extent with silica sand, except that the latter carries a compositional limitation -- primarily quartz (SiO_2) with few impurities. Most industrial sands are in fact high in silica, but are utilized more for their physical properties than their chemical composition.

Various building products require industrial sand in their manufacture. In Alberta, the main ones are asphalt roofing tile and, until recently, sand-lime brick. Included with these could be glass and glass fibre building products, except that they require sand of fairly rigorous specifications as to chemical quality; they are treated instead as products of silica sand under Ceramic Raw Materials.

The best potential sources of industrial sand in Alberta are the surface dune deposits found in many parts of the province (Fig. 1). These sands were derived by wind action from glacial lacustrine and outwash sands, are well sorted, generally fine grained, and more siliceous than the parent material as a consequence of reworking by wind. The sands respond to simple beneficiation techniques and can be upgraded to an acceptable material for many industrial sand applications just by washing and screening. Dune sand in the Edmonton area has been used for some years in asphalt roofing tile, among other things. Dune sand east of Calgary was used for sand-lime brick.

Other sand sources in the province show less potential. The glacial outwash and lacustrine sands, and their beach and alluvial derivatives, tend to vary widely in composition and texture. Known deposits of high grade silica sand are too remotely situated for development at present.

Industrial sand has uses other than in building products in Alberta; as an abrasive in sandblasting, as a "propping agent" in hydraulic fracturing, as a filtering medium in water treatment, and as engine (traction) sand. Consumers in some cases specify high quality silica sand only to ensure consistency in the material supplied; in fact, they accept a lesser grade industrial sand which is dependably uniform. With beneficiation, local sands probably could replace much of the sand now imported.

Aggregates

Aggregates include sand, gravel, and crushed rock, plus a variety of natural and artificial mineral materials of comparatively light weight, which, in the strict definition of the term, serve as the framework component for concrete and for asphalt road surfacing material. Aggregate materials have other and more important uses than in concrete and asphalt mix, however. As basic materials of construction, they constitute by far the largest volume of all the industrial minerals produced in Alberta;

although the lowest priced per unit weight, they are exceeded in total value of production only by cement and sulfur.

Aggregates, being heavy, bulky, low-priced materials, cannot be marketed beyond distances of but a few miles; consequently, numerous aggregate producing sites are scattered across the province, each one serving local construction requirements. Sand and gravel are the major minerals used in Alberta. Lightweight aggregate is used mainly in large urban construction projects. Crushed rock for aggregate use is not significant in Alberta at present.

Sand and gravel are unconsolidated materials derived from the natural disintegration and abrasion of rocks. Sand of this category refers to the crude product used as fine aggregate for general construction purposes (as opposed to the "silica" or "industrial" sands of more specialized use): gravel is the coarser phase -- particles larger than 2 millimeters in diameter. Both commonly are found together, mainly as surficial deposits, in a wide variety of sizes and types. The major uses are as sub-base material in road building, in earth-dam construction, as aggregate in concrete and asphalt mixes, and as railroad ballast. Some of the many minor uses include aggregate in the finer grades for plaster, mortar, and stucco, screened "pea gravel" for roofs, and crushed chips for traction on runways. In Alberta, road building accounts for two-thirds or more of the gravel used.

Economic deposits of sand and gravel in Alberta are common in parts of the Plains, and most plentiful in the Rocky Mountains and Foothills. The Plains deposits are of three main geologic types; preglacial, glacial, and recent.

Preglacial deposits are composed mainly of rounded quartzite pebbles derived from the Rocky Mountains. They include semi-consolidated gravels of late Tertiary age that cap bedrock highs such as the Cypress, Hand, Swan, and Clear Hills; and the gravels that occupy preglacial bedrock channels, normally buried under glacial drift. Although these sands and gravels are of good quality, economic deposits are few in number because of the depth of overburden. Edmonton is supplied largely from deposits of the preglacial channel type.

Glacial deposits of sands and gravels originated from the meltwaters of wasting glaciers, loaded with debris picked up from the bedrock terrain during their advance. This debris consisted mostly of Cretaceous clays and sands, with only small amounts of gravelly materials carried from the Precambrian Shield several hundred miles to the north. Thus, gravel deposits were left only in a limited number of large glacial drainage ways, where very large amounts of meltwater could wash out the fine material and concentrate the gravel. This gravel is heterogeneous in composition, with a high content of Shield-derived granite and gneiss pebbles, and, toward the mountains, an increasing proportion of quartzite, carbonate, and chert pebbles. Glacial gravels are the most important commerical type of deposit in the province. Gravel pits supplying the Calgary area and much of central and southern Alberta are in glacial gravels.

Recent sands and gravels are found along most of Alberta's river valleys, either in the river bed itself, or as older terrace deposits above the present river levels. The gravels vary considerably in composition along the lengths of the rivers: in the mountains, the pebbles consist mostly of carbonate and quartzite from the local bedrock; downstream toward the east, pebbles of granite and gneiss from the glacial deposits are added in increasing amounts, along with quartzite from preglacial deposits. Gravel from these deposits, although generally of poor quality, is used in the absence of better materials.

In 1971, the production of sand and gravel in Alberta was 16.4 million tons valued at $13.3 millions.

Lightweight aggregates are materials which weigh less than the usual concrete aggregates of sand, gravel, and crushed rock, and can substitute in concrete to reduce the dead load by one-third without any loss in strength. The major use of lightweight aggregate is in concrete blocks, the reduced weight of which results in lower handling and transporting costs. Lightweight concrete also is gaining greater acceptance as a structural material (i.e., poured in place), particularly in multi-storied structures, where reduced dead load reduces the need for structural steel and permits greater design flexibility.

Lightweight aggregates may be natural or manufactured. Natural materials include pumice, tuffs, breccia, and diatomite, none of which are found in Alberta. Pumicite, a powder form of pumice, is known to be present in the province in a few small deposits, but has no use as lightweight aggregate because of its fineness. All the lightweight aggregate production in Alberta is manufactured, mainly from expandable clay and shale resources of the province, but also from imported vermiculite and perlite.

Expandable clays and shales are widespread in Alberta. These are the clays and shales which on heating rapidly to a temperature of incipient fusion will expand or bloat. The bloating is caused by entrapped gases generated within clay or shale particles as they partially melt, forming many small gas pockets that enlarge the volume of each particle. Shales and clays containing either illites, montmorillonites, or chlorite-vermiculite mixtures are the most promising sources of lightweight aggregate.

The best bloating materials in Alberta are in the Upper Cretaceous Belly River and Bearpaw Formations ~~(Fig. 2)~~; however, most of their outcrops are too far from present markets for large-scale quarrying. Other good sources are the surficial lake clays common throughout the province: the clays with a fairly high content of organic matter and a low content of silt are best, generally those in the upper 2 or 3 feet of the surface deposits. A plant in Edmonton produces expanded clay aggregate from a Pleistocene lake clay that underlies the plant site. Another plant in Calgary uses shale from uppermost beds of the Paskapoo Formation, quarried a few miles south of the city. Formerly, this plant used shale from the Belly River Formation in the Foothills west of Calgary.

Other plants in Edmonton and Calgary use imported vermiculite and perlite for making lightweight aggregate. Although most of the expanded, or exfoliated vermiculite is used as loose insulation, some is used as aggregate in lightweight plasters and insulating concretes. Perlite, because of its spherical particle shape, is preferred to vermiculite as a plaster aggregate and is used mainly for this purpose.

Pulp Processing Minerals

A surprising number of minerals are used by the pulp and paper industry from the initial stages of pulp processing on through to the final stages of paper-making. Generally, only those employed in pulp processing are found in Alberta in commercial quantities, namely salt (sodium chloride), saltcake (sodium sulfate), sulfur, and limestone (calcium carbonate). These minerals have many other industrial uses, some of them major, but for the first three minerals the pulp industry constitutes the principal market outlet for Alberta deposits.

An expanding pulp industry in Western Canada provides expanding markets for Alberta's output of salt, saltcake, and sulfur. In Alberta only one mill presently is operating (at Hinton), but another (at Grande Prairie) is scheduled to begin production in mid-1973 (Fig. 2). The backbone of the pulp and paper industry is in British Columbia, where as many as 34 mills are either operating, under construction, or planned.

The locations of known deposits of these minerals are shown in figure 2 in relation to pulp mills.

Salt, or sodium chloride (NaCl), is a basic industrial raw material that is not used directly to any great extent in a pulp mill, but is the starting point for three very important chemicals of the kraft pulping process widely used throughout the industry. These are chlorine, sodium hydroxide (NaOH), and sodium chlorate ($NaClO_3$), used principally in the bleaching stage of the kraft process.

Deposits of common salt extend over a vast portion of the Alberta subsurface, underlying almost the entire area east of the diagonal joining the southeast and northwest corners of the province (Fig. 2). The salt beds dip southwesterly from a depth of 700 feet at Fort McMurray to about 6,000 feet at Edmonton and reach an aggregate thickness of nearly 1,400 feet at one point in east-central Alberta about 110 miles east-northeast of Edmonton. From here the beds become thinner in all directions, but the salt nevertheless retains brinable thicknesses sufficient to support a major brining operation practically anywhere within the salt-bearing area. Moreover, salt of such purity is available to meet any quality specifications now existing.

Salt plants presently exist at two localities in Alberta. At Fort Saskatchewan, a few miles northeast of Edmonton, salt is brined from beds as deep as 6,100 feet for the manufacture of chloralkali chemicals (for use largely in the kraft pulp industry). At Lindbergh, about 120 miles east of Edmonton, salt for domestic and industrial use is brined from beds 3,600 feet below the surface. Salt beds also are used in an indirect way at three other localities in the province for underground storage of petroleum products (in artificially created caverns).

Salt has a wide range of industrial uses other than the manufacture of chloralkali chemicals. One of the more important of these in Alberta is for ice control on roads. Other uses include salting and curing of meat and fish, for cattle and stock feed, water softening, textile-dyeing, in refrigeration, and a small part (approximately 3 per cent) for domestic use. Total Alberta salt production in 1971 was 250,000 tons valued at $2.5 millions. Of this, about 170,000 tons was for chemical use -- primarily in the pulp and paper industry.

Saltcake is the white mineral incrustation observed at the margins of the many "alkali" lakes scattered about the southern prairies of Alberta and

Saskatchewan and is a crude form of anhydrous sodium sulfate (Na_2SO_4), containing at least 97 per cent sodium sulfate. Saltcake is an essential make-up chemical in the kraft pulping process, in reconstituting the spent cooking liquor. Sodium sulfate generally crystallizes as "Glauber's salt" ($Na_2SO_4 \cdot 10H_2O$), in which form it is marketed to a small extent. However, most of the production is dehydrated to remove the water content, yielding saltcake. Some saltcake is refined to reduce the impurities (mainly calcium and magnesium) to less than 0.3 per cent for marketing as anhydrous sodium sulfate.

Natural deposits of sodium sulfate are formed by evaporation in closed drainage basins under fairly arid climatic condtions, circumstances which exist at many localities in eastern Alberta and Saskatchewan, where the bulk of Canadian saltcake production originates. Only one deposit is worked in Alberta, at Metisko Lake, containing an estimated 1.8 million tons of sodium sulfate. Several other deposits are known (Fig. 3), although none appear sufficiently large for economic development at present.

In addition to its chief use in pulp ~~and paper~~ processing, sodium sulfate is a raw material in the manufacture of glass, sodium chemicals, synthetic detergents, pharmaceuticals and fertilizers, and in dyeing, tanning and uranium processing. However, these uses are insignificant compared to the kraft pulping process, which consumes 95 per cent of the production from Alberta and Saskatchewan (500,000 tons in 1971, supplying British Columbia, the Prairie Provinces, and the Pacific Northwest). Current production is slightly more than half the combined capacity of existing sodium sulfate plants. Alberta's lone plant has an annual productive capacity of 100,000 tons.

Sulfur is a bright yellow nonmetallic element which is widely distributed in its elemental state, although most of the commercial sulfur production is recovered from metallic sulfide minerals or from hydrogen sulfide (H_2S) in natural gas. The uses of sulfur are many and varied, it being one of mankind's most important industrial chemicals, but by far the major users in Canada and elsewhere are the pulp and paper and fertilizer industries, which together consume three-quarters of Alberta's sulfur production.

Alberta is the world's largest producer of sulfur from hydrocarbon sources, with practically all the production coming as a byproduct or coproduct of sour natural gas production. A small percentage also is recovered from synthetic crude oil extracted from the Athabasca Oil Sands. Sulfur recovery plants operate at a number of localities in southwest and west-central Alberta (Fig. 3) where sour gas is found. Hydrogen sulfide concentrations in these gas fields range as high as 53 per cent, although in most they are between 3 and 20 per cent. As a rule, the H_2S percentages increase to the southwest, that is, with increasing depths and temperatures of formation reservoirs. Recoverable reserves of sulfur from Alberta's sour gas fields currently are estimated at about 140 million long tons.

In 1971 the combined production of Alberta's sulfur plants was just under 3 million tons valued at $20 millions, which amounted to 79 per cent of the Canadian production and about 10 per cent of the world production for that year. About one-third of the sulfur produced in Alberta is consumed by Canadian industries, with most of the remainder going to export markets throughout the world. Sulfur is one of the few nonmetallic minerals valued highly enough for long distance marketing and export trade.

Alberta sulfur has equally strong markets in both the pulp and paper and fertilizer industries; the former utilizes sulfur in the kraft pulping process for the manufacture of bleaching liquor and also in the sulfide process for cooking and bleaching liquors. Among the many other lesser uses are the manufacture of chemicals, rubber products, plastics and synthetic resins, and explosives, and in petroleum refining and uranium ore processing. Nearly all sulfur is consumed in the form of sulfuric acid.

Limestone, calcium carbonate rock, outcrops extensively in the Rocky Mountains where it is quarried at several localities, principally for cement and lime manufacture (Fig. 3). Limestone is an essential process mineral of the kraft pulping process, for which it is calcined (generally at the mill) into lime ($Ca[OH]_2$) for use in the chemical recovery stage. Alberta's pulp industry requires from 5,000 to 7,000 tons of limestone annually, an insignificant quantity compared to the nearly 2 million tons consumed by the cement and lime industries. Nevertheless, the availability of limestone is important to the future development of the pulp industry.

A more detailed account of the distribution and production of limestone in Alberta is presented in the section that follows and in the Cement Raw Materials section.

Lime: Limestone and Dolomite

Lime is the product of calcination of the carbonate rocks, limestone or dolomite, at a moderately high temperature to expel the carbon dioxide as a gas. The term applies to the residue of oxide (calcium or calcium-magnesium) commonly known as quicklime, and also to the secondary product of quicklime -- namely hydrated lime or slaked lime (calcium hydroxide).

All the lime presently being manufactured in Alberta is the high-calcium type, requiring limestone as the starting raw material. The abundance of this rock type in Alberta forms the basis for a substantial industry, which includes four lime plants presently in operation. Two of the plants, at Taber and Picture Butte, are small ones associated with sugar factories and producing lime for sugar refining. The other two, at Kananaskis and Coleman, which together comprise the bulk of the productive capacity, produce lime for the open market. The locations of lime plants and raw material sources are indicated on figure 2. In 1971, the production of lime in Alberta was more than 99,000 tons valued at just over $2 millions.

Lime produced in Alberta serves many markets, both in the province and outside, the major users being the chemical and metallurgical industries. Chemical uses are as an acid-neutralizing agent, a bonding agent, a solvent, and for hydrolization and absorption; metallurgical uses include the control of acidity and alkalinity, neutralization of waste sludges and liquors, and in the fluxing of steel. Lime at one time was a principal material of construction, as an ingredient in plaster, mortar, brick and stucco; although still important, this use has declined in recent years to a point where it now accounts for only 10 per cent of the production. Other important markets are in sugar refining, in highway construction for stabilizing sub-bases, in tanning, treating water, making insecticides and fungicides, and in glass manufacture. Lime required for pulp processing is produced directly at the pulp mills, although some lime is shipped to the mills whenever mill production falls behind consumption.

Limestone, calcium carbonate rock, is discussed in detail under Cement Raw Materials. For lime manufacture, both high-calcium and high-magnesium limestones are used, the latter referring to limestone containing more than 10 per cent magnesium carbonate up to about 40 per cent, above which the rock is called a dolomite. Ideally, about 2 tons of limestone are required to make 1 ton of lime.

Limestone for use in lime making is quarried in two main areas in Alberta (Fig. 2). In the Crowsnest Pass, limestone from the Mississippian Rundle Group is produced in several quarries near the site of a lime plant west of Crowsnest Lake. These quarries also supply to the lime kilns of the sugar factories at Taber and Picture Butte. In the Bow Valley, limestone also from the Rundle Group is produced for use in a lime plant near Kananaskis, from quarries 9 miles west of the plant site. Formerly, the original plant used limestone from the Cambrian Eldon Formation quarried on the site.

Production from these two quarrying areas runs in the order of 250,000 to 300,000 tons annually. Not all the limestone is used for lime manufacture. Raw limestone is marketed as crushed or pulverized rock for use as flux in the smelting of ores, in glass making, in the manufacture of calcium chloride, as a soil conditioner in agriculture, as chicken grit, and in certain building materials.

Dolomite is carbonate rock composed essentially of the mineral dolomite ($CaMg[CO_3]_2$). In the purest state, its composition is 45.6 per cent $MgCO_3$ and 54.4 per cent $CaCO_3$. The rock is similar and closely related to limestone (most dolomites in fact are replaced limestones), and for many industrial uses of limestone (with the notable exception of cement making) dolomite is interchangeable. Dolomite has some use in lime manufacture, of magnesian limes, although its principal use is as fluxing stone and as a refractory material (dead-burned dolomite) in metallurgical industries.

Dolomite is extensive in the Rocky Mountains of Alberta, commonly found associated with limestone, with a distribution that closely parallels that of limestone (Fig. 2). Although large quantities of high-purity material are available, little exploitation has taken place owing to lack of markets. Dolomite is quarried to a small extent in the Crowsnest Pass area, from Upper Devonian Fairholme Group strata at the east end of Crowsnest Lake, and also from a limited number of beds present in the limestone quarries in Mississippian Rundle group strata. The dolomite is crushed for use as flux stone in smelters in British Columbia.

Other uses of dolomite with possible future application in Alberta include the production of metallic magnesium and magnesium compounds, extraction of magnesia from brines, desulfurization of crude oils, as a source of agricultural magnesium, and as crushed aggregate for various construction purposes.

Fertilizer Raw Materials

The principal minerals that serve as raw materials for the fertilizer industry are sulfur, phosphate rock, and potash. Of these, only sulfur is produced in Alberta. Consequently, the fertilizer industry in Alberta must depend on imports for its requirements for phosphate rock and potash.

Agriculture continues to rank as one of the basic industries of Western Canada, and helps to sustain a substantial and thriving fertilizer industry which is based largely within Alberta owing to the availability of low cost sulfur and natural gas. Out of ten plants in Western Canada, five located in Alberta (Fig. 2) contain 53 per cent of the total productive capacity of 2,800,000 tons annually. The industry uses Alberta-produced sulfur with phosphate rock from the United States for the manufacture of ammonium phosphates and sulfates. Small amounts of these materials are blended with Saskatchewan potash for limited production of complete fertilizers, although generally in Western Canada the soils do not require potash. Thus, most of Saskatchewan's potash production is shipped to eastern Canadian and export markets.

Western Canada consumed slightly more than half its own fertilizer production in 1971, which totalled nearly 2 million tons valued at nearly \$100 millions. Consumption has increased more than 20 per cent per year on an average basis since 1960, although since 1967 the rate has levelled off to approximately 10 per cent. The remainder of the production is marketed mostly in western regions of the United States.

Sulfur is discussed in some detail under the heading of Pulp Processing Minerals. ~~Nearly 3~~ Out of 4.5 million tons of sulfur ~~were~~ produced in Alberta in 1971, nearly 3 million tons was sold, one third of which was utilized by the fertilizer and pulp processing industries of Western Canada (in about equal proportions).

The most important use of sulfur in the fertilizer industry is in the leaching (by sulfuric acid) of phosphate rock for the manufacture of phosphates. Sulfur, however, is an essential plant nutrient in its own right, and is made available for fertilizers as ammonium sulfate, produced by reacting ammonia (NH_3) and sulfuric acid (H_2SO_4). In some areas of the world elemental sulfur is applied directly to sulfur-deficient soils, but this practise is not common.

The fertilizer industry of Western Canada consumed 600,000 tons of sulfur in 1971, valued at \$10 millions. Two thirds of this was produced in Alberta from sour natural gas, with most of the remainder derived from sulfur dioxide in smelter gases from metallurgical plants in British Columbia.

Phosphate rock is the term used for natural phosphate ore, commonly a bony material containing one or more minerals of which the main component is tricalcium phosphate ($Ca_3[PO_4]_2$) or "bone phosphate of lime" (also the main inorganic constituent of bones). When leached with sulfuric acid, it reacts to yield phosphoric acid, which can be granulated directly to make a "superphosphate" fertilizer or, as is more commonly the case, reacted with ammonia for various grades of ammonium phosphate, $(NH_4)_3PO_4$.

Phosphate rock is not known to be present in commercially significant deposits in Western Canada. Widespread showings are reported from the Rocky Mountains of Alberta and British Columbia, but detailed investigations have shown the phosphate-bearing zones to be thin, discontinuous, and generally of low grade. The likelihood of finding economic deposits now seems rather remote in view of the extensive searches that have been carried out.

All of Western Canada's requirements for phosphate rock are imported from the United States, where enormous reserves exist sufficient to last hundreds of years. Alberta imported more than 600,000 tons of phosphate rock in 1971, most of it coming from Florida in a unique two-way haul arrangement with Saskatchewan potash that enables the two materials to be shipped economically such a great distance.

Potash is the term applied to any soluble salt containing potassium as a major constituent. In its principal use as fertilizer (for supplying the potassium essential to plant growth), Canadian potash is marketed in the form of potassium chloride (KCl), a refined form of the mineral sylvite, which is the commercial ore mineral.

Enormous deposits of potash exist in the deep subsurface of Western Canada, closely related to a vast salt deposit that extends in a continuous, broad belt across Alberta (Fig. 2) and Saskatchewan. The potash, however, is restricted largely to Saskatchewan. Only in one small area of eastern Alberta, near the town of Provost, is potash mineralization inferred to extend across the border, but the deposit here is subeconomic in terms of grade, thickness, and depth.

The potash requirements of Western Canada are quite small, amounting to little more than 1 per cent of the 3.9 million tons produced in Saskatchewan in 1971, the bulk of which is for export markets. Saskatchewan's reserves of potash are in the order of billions of tons.

Miscellaneous Industrial Minerals

The minerals of this group are those found in Alberta which are not identified with any specific industry in regard to use, but may serve in a number of unrelated industries, mainly in auxiliary or secondary capacities. In most cases, the minerals are involved in some form of industrial processing or treatment, and do not emerge as an end product.

Abrasives are the mineral materials used to cut, grind, polish, abrade, scour, clean or otherwise remove solid material by rubbing action or by impact. Hardness and toughness are the principal properties required of these minerals.

In Alberta, sandblasting sand is the most common abrasive in use. Much of the local lake, outwash and dune sands are suitable, after washing and sizing, for use for the finer grades of blasting sand. However, material coarser than 20- to 30-mesh is very scarce in the province, and must be imported or obtained as screenings from gravel crushing operations. Industrial sand, which includes blasting sand, is discussed in further detail in the section on Building Products Minerals.

Other Alberta materials which might be potential abrasives are garnet, pumicite, and pebbles. Garnet is widely disseminated in the glacial deposits of Alberta, and is found in places concentrated in alluvial gravels, particularly in some parts of the South Saskatchewan and Milk Rivers, but the concentrations and abrasive quality of this garnet are undetermined. Garnet sands also can be used for sandblasting: garnet (iron-magnesium-aluminum silicate) is almost as hard as quartz, and its density is greater by as much as 50 per cent, therefore delivering a harder blow grain for grain than quartz.

Pumicite, or volcanic ash, which is used as an abrasive mostly in cleaning and scouring compounds, is found in deposits at several localities in the province ~~(Fig. 4)~~. The deposits for the most part are too thin (rarely more than 1 foot thick), too limited in extent, and too far from markets or transportation facilities to be developed. One deposit 5 to 10 feet thick, in the vicinity of Irvine in southeastern Alberta, intergrades irregularl with bentonite. Pumicite normally contains a high proportion of volcanic glass -- an active ingredient in natural pozzolans, but none of the Alberta pumicites have been tested for pozzolanic properties.

Pebbles of quartzite, washed into stream beds on the northern flank of the Cypress Hills from a conglomerate rock formation capping the Hills, were used at one time in ball mills in British Columbia. Tests indicated the pebbles to be comparable in quality to commercially used Danish flint pebbles. Quartzite pebbles derived from the same ultimate source -- quartzite formations in the Rocky Mountains -- are found also along many of the present-day rivers of the province, in places comprising more than 80 per cent of the coarse fraction in the gravels. These pebbles generally are not as well rounded and graded as from the Cypress Hills, but may have potential use as a source of crushed quartz.

Bentonite is a clay composed largely of montmorillonite, a chemically active mineral with well-developed adsorptive, absorptive, and ion-exchange capacities. It has a wide variety of industrial uses, the most important of which are as an iron ore pelletizing agent, as an additive in drilling muds, and as a foundry clay.

Bentonite deposits have been reported from a number of localities in Alberta (Fig. 1). Most are associated with sandstone and shale formations of Late Cretaceous age, which crop out extensively in the Plains region of southeastern and central Alberta, and in the Peace River district of northern Alberta. The quality and extent of the deposits varies widely from one locality to another, depending on such factors as silt content, exchangeable cations, and the degree of oxidation of the deposit. In fact, bentonite samples from adjacent sections of the same deposit or bed can exhibit noticeable differences in swelling properties which directly affect the "yield" and other characteristics of the deposit.

Two Alberta bentonite deposits have been mined in recent years; near Rosalind along the Battle River about 70 miles southeast of Edmonton, and at Onoway about 30 miles northwest of Edmonton. At least six types of bentonite are produced from the Battle River deposit, some of which are beneficiated to meet specific consumer requirements. Total production is approximately 12,000 tons a year, and most is sold as foundry clay. The Onoway deposit has not been mined since 1968; however, about 2,000 tons a year currently are processed from stockpiles, mainly for use in drilling muds.

The petroleum industry is probably the largest consumer of bentonite in Western Canada, although most of the bentonite now used in oilwell drilling is imported from the United States. This is due to differences in quality between the Alberta and imported products: generally, Alberta bentonites have lower swelling capacities than Wyoming bentonites and do not react as well to chemical additives which are used to improve the "yield" of bentonites currently used in deep drilling operations.

The major problem facing Alberta bentonites is distance from markets, especially the iron ore industries of Ontario and Quebec which consume about 70 per cent of the bentonite used in Canada (about 150,000 tons in 1968, all of which was imported). Attempts have been made, some involving full-scale plant tests, to promote the use of Alberta bentonites in the iron ore pelletizing industry of eastern Canada, but have met with little success to date.

Formation waters in Alberta have potential economic value for their content of dissolved components. In 1971, over 90 million barrels (3,150 million gallons) of formation water were coproduced with crude oil, condensate, and natural gas. With a mean concentration of 46,400 milligrams per litre, these formation waters contain more than 650,000 long tons of dissolved salts of different compounds such as the chlorides, carbonates, sulfates, bromides and iodides of sodium, calcium, potassium, magnesium and strontium. Essentially all of these formation waters are returned to the ground either in 'waste' disposal wells or are used in repressuring and water flooding schemes, with no attempt made to extract specific components.

Proration of crude oil production in Alberta means that the amount of coproduced formation water is dependent on the production of crude oil. The contingencies of optimum reservoir production economics, together with the proration plan in operation in Alberta, decrease the likelihood of the use of coproduced formation waters as a source of industrial minerals. This is quite apart from the fact that many of the coproduced formation waters are chemically unsuitable.

However, study of the regional distribution and composition of formation waters in Alberta indicates that enormous volumes of potentially valuable formation waters are present outside the limits of known oil and gas fields. These latent brine fields have been delineated with respect to calcium and magnesium, and are presently being evaluated for bromide, iodide and boron.

Brines with more than 60,000 mg/l calcium and more than 9,000 mg/l magnesium are similar in composition to commercial brines in the United States which presently are being exploited for calcium chloride. These same brines also may be a potential source of magnesium. In Alberta, potentially commercial brine fields are present only in the Upper Devonian Beaverhill Lake Formation of southern Alberta, and in the Middle Devonian Upper Elk Point Subgroup, Keg River Formation, and Lower Elk Point Subgroup of north-central Alberta (Fig. 1). A typical analysis from each of these units is shown in the accompanying table.

Formation waters with potentially commercial concentrations of bromide and iodide may be present in stratigraphic units other than those which contain potentially commercial calcium and magnesium brine fields. This suggests that the eventual development of a chemical industry in Alberta based on resources derived from formation waters should be viewed optimistically.

		Upper Devonian Beaverhill L. Fm.	Middle Devonian Keg River Fm.	Middle Devonian Lower Elk Point Subgroup
Location		10-5-25-12-W4	4-16-74-24-W4	1-27-60-26-W4
Depth	(ft)	5470-5545	5060-5108	6140-6195
Na (calculated)	(mg/l)	22,189	25,797	40,719
Ca	(mg/l)	88,800	101,472	75,485
Mg	(mg/l)	15,552	13,333	10,663
Cl	(mg/l)	236,253	258,070	227,300
SO_4	(mg/l)	64	48	179
HCO_3	(mg/l)	712	216	80
Total dissolved solids (calc.)	(mg/l)	363,599	398,948	354,436

Helium is an inert gas with a wide variety of specialized industrial and research applications. It is found in small amounts (generally less than 1 per cent) in natural gas from which it is produced as a byproduct. The only Canadian production at present is from a plant in Saskatchewan, which has an annual capacity of about 36 million cubic feet. Recovery is achieved from natural gases containing about 2 per cent helium.

Several small gas fields in Alberta contain helium in amounts ranging from 0.3 per cent (considered to be the lower limit for economic recovery) to 0.9 per cent, none of which is currently recovered. In addition to these relatively rich but small reserves, many of the larger gas fields in Alberta contain helium in amounts ranging from 0.01 to 0.1 per cent, values well below the limit for economic recovery. Currently, the Research Council of Alberta is carrying out an industry-supported program to determine a technique for the recovery of helium from natural gas deposits with large reserves but low helium contents. The process is based on selective permeation of helium through polymer films, and the results to date appear promising. However, further development and commercial application of the process will depend on the availability of export markets or on a government-supported conservation (storage) program similar to that now operating in the United States. Otherwise, the province's helium resources will continue to be dissipated as the natural gas reserves are utilized or exported.

Other byproduct minerals include fly ash from coal-fired power generation and gypsum from phosphoric acid manufacture. Fly ash is the residual mineral matter from combustion of pulverized coal, and consists primarily of silica, alumina and iron oxide. In Alberta, fly ash is produced in power generating stations at Drumheller, Forestburg and Wabamun ~~(Fig. 4)~~. At present, only the Wabamun fly ash is marketed, mainly for use as pozzolan -- a siliceous additive in cement, which can retard alkali-aggregate reaction, increase resistance to sulfate-carrying waters, reduce heat generation in massive structures, increase tensile strength, reduce permeability, and improve workability. Fly ash is used also for making brick in a brick plant at Wabamun. A great variety of minor uses for fly ash hold promise for future application in Alberta.

Gypsum originates as a byproduct of phosphoric acid production in fertilizer plants at Redwater, Fort Saskatchewan, and Calgary. The amount produced is undetermined, probably in the order of 1 million tons annually. The gypsum presently is wasted in disposal ponds at the plant sites. Chemical impurities, mainly residual phosphoric acid, have prohibited its use in cement or wallboard manufacture; methods of purifying the gypsum have thus far proven uneconomic.