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**NONMETALLIC MINERALS OTHER THAN COAL:**  
Industrial minerals, gemstones and aggregate in  
British Columbia, Canada

George Simandl, P.Geo., Ph.D.

British Columbia Geological Survey,  
Ministry of Energy, Mines and  
Petroleum Resources

# Nonmetallic minerals other than coal: Industrial minerals, gemstones and aggregate in British Columbia, Canada

By George J. Simandl, P.Geo., Ph.D.

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## Cover Photo

Mount Brussilof magnesite mine, southeast British Columbia, Canada.

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**Simandl, G.J., Ph.D., PGeo.**

**British Columbia Geological Survey, British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria, BC, Canada.**

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**KEYWORDS:** Industrial minerals, aggregate, gemstones, specialty metals, British Columbia, Canada.

### **EXECUTIVE SUMMARY**

Nonmetallic minerals other than coal (NMsOC) are key components of economies in developed countries. For the purpose of this paper, the term NMsOC includes traditional industrial minerals, natural aggregate and crushed stone, dual minerals that can be used both as industrial minerals and metal ore (e.g., magnesite for magnesia and magnesium metal; chromite for ferrochrome alloys; quartzite for silicon metal), specialty metals (e.g. Ta, Nb and REE that are commonly used in oxide form as industrial minerals), and gemstones.

The main NMsOC produced in British Columbia are magnesite, limestone, gypsum, sulphur (derived as byproduct from oil and gas processing), construction aggregate, crushed rock, silica, dimension stone and white calcium carbonate. NMsOC produced in lesser quantities include jade (nephrite), magnetite, dolomite, barite, volcanic cinder, pumice, flagstone, clay, tufa, bentonite, Fuller's earth and zeolites.

Metals, metal ore concentrates and coal produced in British Columbia are largely exported; however, a substantial portion of NMsOC are locally processed and incorporated or transformed into finished products such as cement, lime, wallboard, paper, paint, absorbants, soil conditioners, fertilizers, bricks, refractory materials, etc. NMsOC are therefore essential to the economy of British Columbia.

Similar to coal and metals markets, demand for the NMsOC is cyclical; however, the maxima and minima for number of these commodities are less affected by downturns in the global economy.

Value of NMsOC produced in British Columbia during 2008 was estimated at \$754 million; however, this estimate does not reflect value-added processing. In 2009, the value of NMsOC is expected to be lower than in 2008. Production of low-value, large tonnage NMsOC (with the exception of resources located along the coast) is constrained by the size of British Columbia's industrial base and the needs of local populations.

NMsOC markets are shifting due to technological breakthroughs in construction, chemical, automotive, metallurgical, cement, glass, refractory, telecommunications and other industries. For example, a new process permitting production of solar-grade silicon (sgs) metal by upgrading widely available metallurgical-grade silicon improves competitiveness of the sgs against technically inferior, lower-cost substitute materials.

Newly introduced environmental legislations, in both USA and Canada, particularly those that target greenhouse gas emission limits, change long established patterns in use of industrial minerals. An example is the increased use of pozzolanic materials by the cement industry.

Such rapid market shifts are of concern to established producers; however, they also represent exceptional opportunities for new players.

### **INTRODUCTION**

NMsOC are an increasingly significant component of international trade. British Columbia is strategically located on the west coast of North America (Figure 1) and has well-developed infrastructure in the southern, more populated third of the Province, including several deep-water ports, and a well-maintained highway system. Rail links British Columbia's industrial centres to terminal points across the continent. The Province

has attractive energy costs and untapped mineral resources.

The value of solid mineral production for the year 2008 is estimated at \$5.9 billion (Figure 2). Coal (51%) was by far the largest contributor; however, industrial minerals (8%) and aggregates (5%) are also significant (DeGrace et al., 2009) with a production value of \$454 million and \$300 million respectively ((DeGrace et al., 2009).



Figure 1: Strategic geographic location of British Columbia in western North America (with access to Pacific Rim countries).

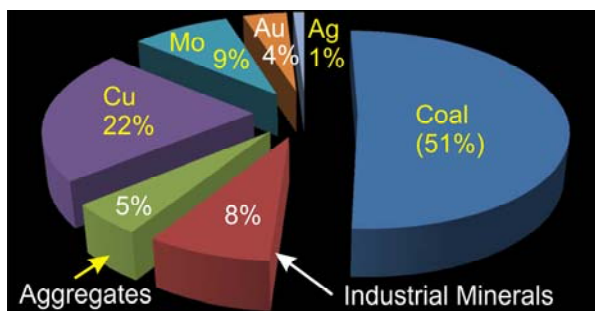


Figure 2: Estimated solid mineral production in British Columbia for the year 2008 (DeGrace et. al. 2009).

Coal and metals produced in British Columbia provide more direct jobs than NM\$OC; however, NM\$OC may generate more indirect jobs related to processing in the province. Most of the metals and coal produced in British Columbia are exported, while a larger proportion of the industrial minerals and aggregates are processed and used locally. Overall, industrial minerals and aggregate may have much larger economic importance for British Columbia than is suggested by Figure 2. For example, if we accept that the total cement-making capacity of the three cement plants located in British Columbia is 2.620 million tonnes/year, assuming that the three plants operated at 90% of their designed capacity during 2008, and that the price of cement was \$150/tonne, then the value of locally produced cement alone would be over \$350 million for the year 2008. This example illustrates that the importance of value-added NM\$OC activity is not adequately reflected in traditional statistics summarized in the Figure 2. Transformation of gypsum into wallboard would be another good example. NM\$OC are therefore much more important to the British Columbia economy than is generally believed.

## PRODUCTION AND EXPLORATION REVIEW

The most economically significant NM\$OC produced in British Columbia are magnesite, limestone, gypsum, sulphur, construction aggregate, crushed rock, silica, dimension stone, and white calcium carbonate. Commodities produced in lesser quantities include jade (nephrite), magnetite, dolomite, barite, volcanic cinder, pumice, flagstone, clay, tufa, bentonite, Fuller's earth, and zeolites. There are more than 40 mines or quarries (Figure 3) and at least 20 major sites where upgrading of NM\$OC into value-added products takes place.

Low value – high volume NM\$OC are used mainly locally, unless located near low cost transportation corridors. High value minerals and value-added products are “world-travelers”. Absence of infrastructure and/or large distance to the market is less critical to the development of gemstones, ornamental stones and specialty minerals.





Figure 3: Industrial Mineral Mines and Quarries in British Columbia.

Difficulty of finding the financing and the necessity to compete for part of the market with existing well established, in many cases vertically integrated producers, are universal constraints for all non-metallic projects.

## MATERIALS PRODUCED IN BRITISH COLUMBIA IN 2008

NMsOC that are currently produced in the Province are covered in this section.

### BARITE

Barite ( $\text{BaSO}_4$ ), is characterized by its high specific gravity ( $\sim 4.5 \text{ g/cm}^3$ ). Its main use is as a weighting agent in drilling oil and gas (> 85% of total market). Smaller quantities find use as a filler in paint, plastic and paper and in production of barium chemicals. In 2008, Fireside Minerals Ltd. was the only barite producer in British Columbia. Ore was processed from the stockpile produced in 2006 and the **Fireside** quarry east of Watson Lake remained dormant. Most of the production was used in drilling for oil and gas. The 2008 sales amounted to 8 000 tonnes (Wojdak and Feebo, 2009).

Fireside is a vein-type deposit (Butrenchuk and Hancock 1997; Hora, 1996, and Wojdak, 2008). Information regarding over 100 other barite occurrences and deposits in British Columbia was compiled by Butrenchuk and Hancock (1997).

High-grade barite, requiring only rudimentary processing was historically produced from the Parson Mine (9 km by road from the community of Parson) by Mountain Minerals. The highest grade was sold as functional filler, but most of the production was used in oil/gas well drilling. Since the closure of this mine, a number of junior companies have attempted to fill the void in the market.

Large, more remote barite resources are linked with undeveloped world-class SEDEX (Pb-Zn) deposits in the Gataga district (Figure 4) such as Cirque, (Paradis et al., 1998). A barite occurrence discovered recently by R. Thompson (Geological Survey of Canada, personal communication), south of Revelstoke, may belong to this category. Barite was extracted in the past from the Irish-type Pb-Zn deposits in Ireland and from variety of base metal vein type deposits in Europe.

Today, there are stringent trace metal limits on barite products and the majority of barite producers rely on nearly base metal-free stratiform or vein-type barite deposits (Paradis et al., 1998). There is an

ongoing effort by US and Chinese producers to lower the density specifications for barite used in drilling of oil and gas wells. If this change in specifications takes place, the number of undeveloped deposits entering the market may change current structure of the barite industry.



Figure 4: A thick zone of SEDEX-type mineralization (> 40% barite) located in the Gataga area in northern British Columbia. The mineralized area is vegetation free and loosely referred to as a “Kill zone”. Photo used with the permission of Suzanne Paradis (Geological Survey of Canada, Sidney, British Columbia).

### CARBONATES

Calcium and magnesium carbonates represent an important portion of British Columbia’s industrial mineral production for local use and for export. Magnesite, limestone, white calcium carbonate (including filler-grade high calcium carbonate) and dolomite are discussed below.



## MAGNESITE

Magnesite ( $\text{MgCO}_3$ ) is a raw material for production of caustic-calcined, dead-burned, fused magnesia and magnesium metal (Simandl, 2002a; Simandl and Schultes, 2007; Simandl et. al. 2007a,b,c). British Columbia hosts important magnesite resources (Grant, 1987; Simandl, 2002a). Caustic-calcined magnesia is used in water treatment, flue gas desulfurization, specialty wallboards and cements. It is essential in chemical, fertilizer, pharmaceutical, ceramic, glass, and paper industries. Dead-burned and fused magnesia are key ingredients used in the production of basic, high-performance refractories.

There is currently only one producing magnesite mine in Canada. *Baymag Inc* produces magnesite at the **Mount Brussilof** mine (Figure 5). The mine is located approximately 35 km northeast from Radium Hot Springs in the southeastern part of the Province. Over the past few years, the production rate has been about 110 000 tonnes of magnesite/year. The ore is blended at the mine site (Knuckey, 2001) and transported by truck to the company's processing plant located in Exshaw, Alberta. The magnesite is converted into caustic-calcined magnesia in a 50 000-tonne capacity, multiple hearth furnace, a vertical-kiln dedicated to producing specialty calcined  $\text{MgO}$ . The plant also houses an electrofusing installation, which has been dormant during the last few years. In 2008 it was reported that Baymag Inc was considering getting involved in production of dead-burned magnesia. Some of the crushed white magnesite is also sold for landscaping.



Figure 5: Mount Brussilof magnesite mine, southeastern British Columbia.

The only exploration or development activity on other sparry magnesite deposits located in British Columbia in 2008 was the drilling program by *Tusk Exploration Ltd.* at the **Driftwood Creek** deposit. This easily accessible deposit, located west of Brisco, was described by Simandl and Hancock (1992) and Kikauka et.al (2004).

## LIMESTONE

Limestone consists mainly of calcite ( $\text{CaCO}_3$ ). Most significant limestone deposits in British Columbia were described by Fishl (1992), but many other deposits may be delineated if the market permits. The largest limestone/crushed stone production centre in the Province is Texada Island, where three main quarries, **Gillies Bay** (*Texada Quarrying Ltd*), **Blubber Bay** (*Ashgrove Cement Corporation*) and **VanAnda** (*Imperial Limestone Company Ltd*). They traditionally ship 5 to 6 million tonnes annually to customers in the Lower Mainland of British Columbia, Washington, Oregon and California, for cement, chemical and more recently, agricultural and construction use.

In 2008, 6 million tonnes of material, including 4.5 million tonnes of limestone were shipped from Gillies Bay (Figure 6). Ashgrove Cement Corporation upgraded its Blubber Bay crushing plant in 2002.



Figure 6: Modern shiploader at Gillies Bay, photo used with the permission of Texada Quarrying Ltd.

Since 2005 this operation has shipped only crushed stone. During 2008 the company crushed approximately 600 000 tonnes of stone and shipped 480 485 tonnes.

In addition to pulp mills, which normally produce lime internally, three cement plants and two lime plants in British Columbia process limestone. *Graymont Western Canada Inc.*'s **Pavilion Lake** limestone quarry and lime plant near Cache Creek has an annual maximum production capacity of about 190 000 tonnes of lime. The Chemical Lime Company of Canada has its lime plant in the Vancouver area.

Limestone is an essential ingredient in Portland cement manufacturing (Simandl and Simandl, 2008). *Lafarge Canada Inc.*'s plant in Richmond (Figure 7), and *Lehigh Northwest Cement Limited*'s plants in

Delta, are state-of-the-art operations. The Richmond and Delta plants have a capacity to produce over one million tonnes of cement annually each (Simandl and Simandl, 2008). The Lafarge Canada Inc. cement plant in Kamloops is older and smaller. During the last few years it has operated close to its full production capacity.

The Chemical Lime Company of Canada owns a limestone quarry 5 km southeast of **Giscome** (near Prince George). In past years, small quantities of limestone from this quarry were shipped to pulp mills in the region, but there was no sign of activity during 2007 or 2008.



Figure 7: The heart of any Portland cement making facility is a kiln. The Lafarge Canada Inc. cement plant, Richmond.

## WHITE CALCIUM CARBONATE

White, ground calcium carbonate (GCC) is the most widely available filler and extender used in paper, paint, plastics, adhesives, and sealants.

In most situations, where GCC meets technical specifications, it has a price advantage over other more specialized fillers such as talc, mica, wollastonite, precipitated calcium carbonate (PCC) and kaolinite.

The white, sugary (recrystallized) portion of limestone, traditionally produced by *Texada Quarrying Ltd.* from its **Gillies Bay** quarry, *Imperial Limestone Company Ltd.* (**Van Anda quarry**) and *IMASCO Minerals Inc.* from its **Benson Lake** quarry (Figure 8) (if processed) meets filler grade specifications.

In 2008, the **Benson Lake** deposit produced 38 400 tonnes and 40 800 tonnes were barged from Port Alice to company's processing plant in Surrey (Northcote, 2009). If needed, IMASCO Minerals Inc. may also reactivate its **Lost Creek** deposit near Salmo.



Figure 8: Benson Lake high purity, white, calcium carbonate deposit; northern Vancouver Island.

Over the past 10 years, the production of white-filler grade limestone from Gillies Bay appears to have declined. The *Imperial Limestone Company Ltd.* is reported to have produced 280 000 tonnes from its **Van Anda** quarry in 2008 (Northcote, 2009) and shipped it to the parent company *J.A. Jack & Sons Inc.* of Seattle. It is not known what proportions of this tonnage were sold for chemical use, glass-making, plaster or as terrazzo chips. In the past, a portion of production (fine-grain, high-brightness, white calcium carbonate) was used in high-end applications including paper, paint and plastic filler and extender.

Coarser material is used in stucco manufacturing and for other construction applications.

## DOLOMITE

Dolostone consists mainly of the mineral dolomite ( $\text{Ca,Mg}(\text{CO}_3)_2$ ). It is used in glass making and refractory applications; for soil conditioning (as dolime); effluent treatment; as plastic and paint filler; to produce white ornamental aggregate, and roofing granules; as fine aggregate; and, in synthetic marble products (Simandl et al., 2006a). On the world-scale, dolomite remains the main ore for production of magnesium metal (Simandl et al., 2007c); however, there is no magnesium production in the Province.

Dolostone is widespread in the Canadian Rocky Mountains. It is less abundant along the coast of British Columbia (Fishl, 1992), where operations would also be able to target export markets (Simandl et al, 2006a). In 2008, 40 000 tonnes of dolostone were quarried by *Imasco Minerals Ltd* at its underground **Crawford Bay** mine (Figure 9) on Kootenay Lake (Grieve, 2009). *Mighty White Dolomite Ltd.* has its plant and quarry near **Rock Creek** (Simandl et al., 2006a).



In 2003 *Ashgrove Cement* started mining limy dolostone from an area adjacent to their limestone quarry on Texada Island. It produces approximately 24 000 tonnes/year (Simandl et al., 2006a) for US market.



Figure 9: Crawford Bay dolomite mine on the Kootenay Lake, southeastern British Columbia. Photo used with the permission of David Grieve, British Columbia Geological Survey.

## CLAY, SHALE AND RELATED RAW MATERIALS

Individual members of the clay group of minerals are distinct in their chemical and physical properties (Grim, 1968) and these properties determine their potential use. Harvey (2004) categorized industrial clay resources with emphasis on the Pacific Northwest (including British Columbia). Kaolinite and montmorillonite are the two most commercially important clay minerals.

Kaolinite is the key component of white-firing porcelain mixes and an important filler and extender in a variety of products including paper. Harvey (2001) produced the most recent public overview of kaolin resources, specific to the Pacific Northwest and Central Canada.

Montmorillonite is the main component of commercial bentonite products. Sepiolite, attapulgite and hectorite are highly priced but have much smaller and more specialized markets; however, no occurrences of economic interest have been reported in the Province up to now (Hevilin and Murray, 1994). Illite is an important constituent of common clays and shales used in bricks.

Refractory (fire) clay is a commercial term describing alumina-rich, firing off-white clays consisting largely of kaolinite. Gibbsite ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ),

diaspore ( $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ) or boehmite ( $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ ) are present in various proportions within the best of the high-quality refractory clay resources.

## CEMENT MATERIALS

The three cement plants in British Columbia have a combined production capacity of 2.62 million tonnes. Cement production in British Columbia is covered in more detail by Simandl and Simandl (2008) and Simandl and Brûlé (2008). According to the *Portland Cement Association*, Canadian Portland cement consumption for 2008 declined 2.3%, to 9.4 million tonnes. Cement consumption in British Columbia was down 7.4% from 2007. The use of supplementary cementitious materials (SCMs) for Canada was up 14.1% in line with the published predictions and projections for British Columbia (Simandl, 2007; Simandl and Simandl, 2008). Canadian demand for cement for 2009 is expected to decline by 19.7% (Cement Americas; May 21, 2009).

*Sumas Shale Ltd.* produces around 500 000 tonnes of raw materials (including clay/shale, refractory clay, conglomerate and sandstone) from its Sumas Mountain quarries (Figure 10). Most of the production is used by lower mainland cement plants.



Figure 10: *Sumas Shale Ltd.* is producing around 500 000 tonnes of clay-shale, conglomerate and sandstone from its Sumas Mountain quarries.

The difficulties encountered by the cement industry to access raw materials from Sumas Mountain during early 2000 resulted in a renewed exploration for alumina-rich materials in the Lower Mainland and elsewhere. The **Lang Bay** deposit, originally evaluated as potential source of kaolin for paper-making (Farris and Harvey, 1991), is one of the potential sources. The clinker (naturally calcined shale, that was host to

burning coal seams) from the **Décor pit**, located in the Hat Creek area (Figure 11), owned by *Pacific Bentonite Ltd.* (Simandl and Simandl, 2008) is already being used. Coal-related clays at **Quinsam** (Simandl and Brûlé, 2008) also received attention from the industry as potential cement raw materials.



Figure 11: Pacific Bentonite Ltd. ships natural clinker from its Décor deposit (Hat Creek area) to the Lafarge cement plant in Kamloops.

## BRICKS AND REFRACTORY PRODUCTS

*Clayburn Industries Ltd.*, located in Abbotsford, uses the material from a specific fireclay seam (high-alumina bed) mined by *Sumas Shale Ltd.* at **Sumas Mountain** to create a variety of refractory and insulation bricks and castable products. When demand for refractory materials softens the company switches to production of a variety of residential bricks (Figure 12) for the North American market.

The *Sumas Clay Products Ltd.* plant (Figure 13) manufactures small quantities of ornamental and facing bricks on an artisanal scale from its plant near Abbotsford.

## BENTONITE AND FULLER'S EARTH CLAYS

Bentonite is a commercial term for clay materials consisting largely of smectite group minerals (Na-montmorillonite, Ca-montmorillonite and beidellite). The proportions of  $\text{Na}^+$ ,  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  cations influence ion-exchange capacity and the thermal stability of these montmorillonite-based products. Na-montmorillonite (also commonly called “swelling bentonite”) is the preferred variety for most of the applications, including oil/gas well drilling, civil engineering, iron-ore pelletizing, foundry sands, absorbent applications, geosynthetic liners etc. Bentonite consisting mostly of Ca-montmorillonite is a lower value product, which may be used in some of the

above applications. It may also be chemically modified to incorporate more  $\text{Na}^+$  because  $\text{Na}^+$ ,  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  cations in montmorillonite are exchangeable.



Figure 12: Construction brick product display near the gate of the *Clayburn Industries Ltd.*, plant in Abbotsford, Lower Mainland.



Figure 13: Clay bricks - an unique art at the historical Sumas Clay Products Ltd., near Abbotsford.

*Absorbent Products Ltd.*, previously known as *Western Industrial Clay Products Ltd.*, produces domestic and industrial absorbents at its processing plant in Kamloops (Figure 14).

Raw materials used in the process are sourced principally from its Red Lake Fuller's earth deposit



north of Kamloops and from its **Bud** bentonite property located near Princeton. Several other bentonite deposits located in British Columbia look technically promising. Additional investigations are justified for the **Hat Creek** deposit, located near Hat Creek (owned by *Pacific Bentonite Ltd.*) and the **HK** deposit (Figure 15) located near Clinton (owned by *Tillava Mining Corporation.*)



Figure 14: The *Absorbent Products Ltd.*, processing plant, Kamloops.



Figure 15: Good quality, naturally-expanding bentonite outcrops have typical “popcorn” texture (photo used with the permission of Laura Simandl; St. Michaels University School).

The Province has over 100 clay deposits and occurrences, including those described as bentonite, fireclay or kaolinite. Some deposits were historically used in brick-making (Cummings and McCammon, 1952). Most of these deposits probably meet modern industry specifications; however, clay-based construction materials compete with wood, aluminum, steel, asphalt and fiberglass roofing products and

sidings. Flagstone, ashlar and other dimension stone products, concrete, glass, steel, aluminum, vinyl and stucco are also popular materials for the outer shell of buildings. One of the marketing advantages of clay-based roofing tiles and bricks over wood is their high fire-resistance.

## MEDICAL CLAY

Clays have been used in medical and cosmetic applications for centuries particularly in dealing with serious burn injuries and other skin care. Some British Columbia products marketed as medical clays, are very low crystallinity clays of glacial origin. The *Ironwood Clay Company Inc.* is the largest and oldest producer of cosmetic/medical clay in British Columbia. It mines seasonally from the **De Cosmos Lagoon** on Hunter Island, west of Bella Coola. *Precision Laboratories Ltd.* is also active in this business.

Similar material is produced by *Precision Laboratories Ltd* and *Glacial Marine Clays Inc.* (previously known as Carrie Cove). The latter company, in the Comox Valley, had closed down by early 2009.

Ten years ago, natural cosmetic/medical clays from British Columbia represented a niche market; however, as more players try to enter the market, this is changing. It is difficult to assess what proportions of these products are exported in bulk or sold over the Internet (where they are commonly advertised for more than \$50.00/100grams).

## CRUSHED STONE AND AGGREGATE

Natural aggregate and crushed stone are essential construction materials in concrete-making. In highly populated areas, such as the Lower Mainland, San Francisco, Los Angeles and Seattle, rapid urban expansion interferes with the development of local aggregate resources. Over the last few years, bids for contracts to supply US coastal cities with aggregate from British Columbia became competitive. Shipments of crushed stone from **Texada Island** and other coastal sources have made significant inroads into the Vancouver, Seattle, San Diego, San Francisco and Los Angeles markets.

Texada Island producers are well established. Originally crushed rock was only an unwanted byproduct of their limestone operations and they were happy to sell it at costs equal to costs of waste disposal. In recent years crushed rock production has gained in importance and has become the main product of some of limestone operations (see section on limestone).

*Construction Aggregates Ltd*, a subsidiary of Lehigh Cement Company, processed 5.7 and sold 5.1



million tonnes in 2007 from its **Sechelt Pit**. In 2008 the operation was expected to increase its production to compensate for closing of its **Producer's Pit** in Metchosin, however, for variety of technical and market reasons this did not happen. The 2008 production is estimated at 5 million tonnes of which 4.5 million tonnes was shipped. Sechelt's principal market remains the Lower Mainland, with an estimated 20-25% of its production going to California and lesser quantities to Victoria and the Gulf Islands (Northcote, 2009).

The Orca Sand and Gravel Ltd. operation near **Port McNeill** (Figure 16) sold 2,107,290 tonnes of aggregate (Polaris, annual report for 2008, Northcote, 2009). This is up from 1.04 million tonnes in 2007; however, the tonnage and value of the 2009 production will be lower.



Figure 16: Orca Sand and Gravel Ltd. plant (photo used with the permission of Mr. Jim Balmer).

The **Swamp Point** quarry of *Ascot Resources Ltd* is now under care and maintenance. In 2008, Ascot carried out most of the site work necessary to install a ship-loader conveyor system designed to accommodate 'Panamax' size (70 000 dwt) vessels; however, a sharp downturn in the US market price for aggregate prompted Ascot to suspend the construction (Wojdak and Febbo, 2009). The **Cox Station** quarry of *Mainland Sand and Gravel Ltd.* produces crushed aggregate from quartz diorite on the north side of Sumas Mountain. The 2008 production is estimated at 2.7 million tonnes. *Lafarge North America* operates a large sand and gravel quarry at the mouth of Skookumchuk Narrows at **Earle Creek**, capable of producing 2.5 million tonnes per year. Recently it has run at 60% of its capacity. All material is barged to the Greater Vancouver area.

On the **Pitt River** in Pitt Meadows, *Lafarge's* crushed aggregate plant produces 1.3 to 1.5 million tonnes of material per year. Three large sand and gravel operations located on **Pipeline Road** in Coquitlam, belonging to *Jack Cewe Ltd*, *Allard Contractors Ltd* and *Coquitlam Sand & Gravel*, are

expected to achieve a combined production exceeding 2 million tonnes in 2008. *Valley Gravel Sales Ltd* in Aldergrove also has a capacity in excess of 1 million tonnes per year (Northcote, 2009).

*Canadian Pacific Railway* mined, crushed and shipped railroad ballast from its **Swansea Ridge** gabbro quarry south of Cranbrook. Total production for 2008 is estimated at 400 000 tonnes and shipments for 2008 are expected to be 250 000 to 300 000 tonnes. Other quarries supplying railroad ballast, such as **Ahbau** basalt quarry (northeast of Quesnel), **Giscome** basalt quarry (northeast of Prince George) were not covered by this survey. They operate largely on an "as needed" basis.

The **Teko** pit (near Taylor) supplies road construction material to the oil and gas sector in northeastern British Columbia.

There are over a thousand smaller sand and gravel operations dispersed across British Columbia supplying predominantly local needs. Many of these quarries and pits operate on an "as needed" basis.

## ***DIMENSION STONE AND ARMOUR STONE***

British Columbia has a long history of dimension stone quarrying (Parks (1917), White (1987a), Hora and Hancock (1993), Hora and Miller (1994) and Simandl and Gunning (2001)). Principles of dimension stone evaluation are provided by Harben and Purdy (1991) and Purdy et al. (2004). Esthetic appeal (color, texture, homogeneity, resistance to staining and the way the stone takes polish) are important factors. Standard tests of the American Society for Testing Materials were designed to insure adequate resistance to weathering and minimum strength.

## ***"GRANITE" AND "MARBLE"***

*Westcoast Granite Manufacturing Inc.* in Delta, *Margranite Industries* in Surrey, *Bedrock Granite* in Port Coquitlam and *Matrix Marble Corporation* in Duncan operate some of the larger stone-processing plants in British Columbia. *Margranite Industries* processes a wide variety of imported stone and nine local granite varieties from **East Anderson River**, **Beaverdell** and **Skagit Valley** quarries. The *Huckleberry Stone Supply Ltd.* of Burnaby and *Mountain High Properties Ltd.* of Pemberton produced basalt from small quarries in the **Whistler** area. In 2008, Matrix Marble Ltd. concentrated on processing imported and domestic materials at its plant near Duncan, but it also extracted marble from its **Black Carmanah** and **Berto Bertoya** (white) quarries on Vancouver Island (Figure 17).



Figure 17: White marble extraction on Vancouver Island.

*Hardy Island Granite Quarries Ltd.* extracted about 4 800 tonnes of stone this year from their granite quarry on **Hardy Island** (Figure 18) and the product was sold through *Bedrock Granite Sales Ltd.* in Coquitlam, British Columbia. Small tonnage of Haddington andesite was also mined in 2008 by them.

## FLAGSTONE, SLATE AND BASALT

*Revelstoke Flagstone Quarries*, *Kootenay Stone Centre*, *Biostone Natural Resources Inc.*, *Gerex Developments Ltd* and *Golden Rock Product Inc.* (in the southeastern part of the province), *K2 Stone Inc.* (Vancouver Island) and number of other relatively small producers and family-type operations across the province (Figure 19) provided variety of flagstone products for local markets and for export.



Figure 18: Loading a barge at the Hardy Island quarry, which has long history of granite production (photo used with permission of Mr. Helgi Sigurgeirson).



Figure 19: Recent flagstone discovery by Don Sandberg of Kelowna.

Near Kelowna, the *Kettle Valley Stone Company* produced flagstone, ashlar, thin veneer and landscape rock products from several quarries. The most popular stone was dacite ash (Mountain Ash) from its **Nipple Mountain** quarry. Near **Valemount**, *Hunterstone Quarries* ships small quantities (350 tonnes in 2008) of blocky quartzite talus to customers in Canada and the United States.

## ARMOUR STONE

*Armour stone* is used along the USA and Canada coast to protect structures and marine or industrial installations from effects of waves. Size (weight), shape of the blocks, strength and durability of the stone are the main requirements (color and esthetic appeal are not important). Armouring at the Ogden Point Breakwater located in Victoria is a prime example, produced from quarries located on Hardy Island. The demand for armour stone is intermittent but individual contracts are large. Development of an armour stone quarry on the southwest coast of the Province may be worth considering.

## GEMSTONES AND ORNAMENTAL STONES

Jade is the main gem and high-profile ornamental material currently produced in British Columbia (Makepeace and Simandl, 2004; Simandl et al., 2000) but other gem/ornamental stones and related opportunities should also be considered.



## JADE (NEPHRITE)

British Columbia is a world-class producer of nephrite (Figure 20), a variety of jade (Makepeace and Simandl, 2004; Simandl et al., 2000; 2001a).



Figure 20: Section through a high grade jade block. Large blocks of high-quality nephrite, like this one, are rare even by British Columbia standards. Kirk Makepeace for scale.

*Jade West Resources Ltd.* and its affiliated company *Polar Gemstones Ltd.*, *Cassiar Jade Contracting Inc.*, and the *Cassiar Mountain Jade Store Ltd.* and related companies are the main nephrite producers in the Province.

Four main active properties in the northwestern region in 2008 were the **Cassiar** mine, **Polar Jade** and **Provencher Lake** (Wojdak and Febbo, 2009) and **Mount Ogden**. The jade market in 2007 and 2008 was exceptionally good and the Mount Ogden jade stockpiles that were considered as industrial grade a few years ago were re-examined and cut into smaller blocks. The Polar Jade deposit, owned by Polar Gemstones Ltd. and operated under contract by *Jedway Enterprises*, produced 35 tonnes (also mostly from stockpiles). Cassiar Jade Contracting Inc. continues to recover nephrite from mine dumps at the former Cassiar chrysotile mine. This company also mined nephrite under contract at the Provencher Lake site (owned by *Glenpark Enterprises Ltd.* of Portland Oregon). According to Wojdak and Febbo, (2009), an exceptional high-quality boulder of nephrite weighing 16.5 tonnes was found at **Provencher Lake** deposit in 2008.

*Cassiar Mountain Jade Store Ltd.*, historically extracted nephrite from the **Princess Jade Mine** area, near Jade City (Northwest BC). During 2008 it did

surface exploration for alluvial and hardrock deposits in the **Dorothy Creek** area.

There are no known commercial jadeite deposits (variety of jade consisting predominantly of jadeite or Na-pyroxene) in British Columbia. However, high-pressure (eclogite / blueschist) facies rocks known to host (or be associated with) with jadeite occur in British Columbia (Erdmer et al., 1998; Simandl, 2004a).

## OTHER GEMSTONES AND ORNAMENTAL STONES

British Columbia hosts a variety of gemstone occurrences (Willson, 1997; 2007) including, *precious opal* (Simandl et al., 1997, 1999d); *rhodonite* (Simandl et al., 2001a; Hancock, 1992; Hora et al., 2007), *beryl-group* gemstones (Legun, 2004; Simandl et al., 1998) and *corundum-group* (“star sapphire”) minerals (Gauthier and Dixon, 1997), *amethyst*, *garnet*, *iolite* (*gem quality cordierite*) (Simandl et al., 2000; Marshall and Simandl, 2006), and *amber* (Legun, 1997). Spectacular amber pieces were reported to have been recovered during coal mining in the Princeton area in the early 2000’s. An example of moderately fractured amber with good colour was found in the waste pile of one of the mines.

Small tear-size amber grains were observed in 2008 within the leonardite bed at the Red Lake Fuller’s earth mine north of Kamloops.

Transparent gem-quality olivine (*peridot*) is a common constituent of mantle xenoliths (or xenocrysts) brought to the surface by alkali basalts in British Columbia. Xenoliths are granular and most of the individual gemmy fragments are less than 6 mm in their longest dimension.

Diamond exploration in neighbouring Alberta resulted in the discovery of anomalous concentrations of diamond indicator minerals, barren and diamondiferous kimberlites. British Columbia is known to host at least two kimberlite pipes (Smith et al. 1988; Pell and Ijewliw, 2003); however these are not located within the “stable craton” setting, which is considered as an ideal hunting ground for kimberlite-hosted diamond deposits (Mitchell, 1991). This model currently attracts 95% of diamond exploration.

Nevertheless, it is theoretically possible for diamonds to form in subduction zone settings similar to those that have existed at various times in the geological past in British Columbia (Baron et al., 1994, 2005; Simandl, 2004).

A diamond was recently reported from surface material in NE British Columbia (Simandl et.al. 2005).

Negative results of the follow-up sampling suggest that this diamond was most likely introduced as contamination during laboratory processing.

Descriptive deposit profiles for a number of sapphire, ruby and precious opal deposit types were provided by Simandl and Paradis (1999a,b,c), Paradis and Simandl (1999b,c), Paradis et al. (1999b) and Simandl et al. (1999,a,b). Gemstone showings are staked in the Province every year. These showings may be profitably exploited by individuals or family-type operations, however, most of them are too small to support publicly-listed companies. A production success is the **Klinker** precious opal property (Simandl et al., 2004b), located west of Vernon. The mining and processing of the opal from this deposit is done by *Opal Resources Canada Inc.* (a small, family-run company), which also markets the jewelry made from the precious opal that it mines (Figure 21).



Figure 21: Pendant produced from precious opal extracted from the Klinker deposit (stone is approximately 6 mm in length), Vernon area; photo used with permission of Opal Resources Canada Inc.

Precious opal has also been discovered elsewhere in the Okanagan area, near Burns Lake and in the Whitesail Range (Simandl et al., 1999d).

Agate alone, or in association with common and precious opal, is probably the most abundant and widely distributed semiprecious stone in the province. It occurs mostly as amygdules and fracture fillings within the Tertiary or younger volcanic rocks. It is appreciated mainly by the rockhounds and other hobbyists.

## Gypsum

Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) and anhydrite (its anhydrous equivalent) are typically found together. For most industrial uses gypsum is the preferred starting material. Most gypsum production is converted to

“plaster of Paris” ( $\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$ ) which hardens if mixed with water (with use in wallboard, plasters and industrial applications). Uncalcined gypsum is used largely as the time-setting moderator in cement formulations, and as a mineral filler/extender and as soil conditioner.

The *Certain Teed Gypsum Canada*’s operation, based in Windermere, has benefited recently from strong Canadian construction markets. Its production for 2007 was 525 000 tonnes, all of it was derived from the **Elkhorn Mine complex** (Figure 22).



Figure 22: Elkhorn gypsum mine, owned and operated by Certain Teed Gypsum Canada southeastern British Columbia.

The production for 2008 is expected to be similar to that of 2007, but the softening construction market suggests that the 2009 production will be lower.

*Georgia-Pacific Canada Inc.* produced an estimated 175 000 tonnes of gypsum from its **Four J** quarry near Canal Flats, and about 100 000 tonnes were shipped to its wallboard plant near Edmonton, Alberta in 2008.

Both *Certain Teed Gypsum Canada* and *Georgia-Pacific Canada Inc.* operate wallboard plants in the Vancouver area. Lafarge Canada Inc. typically mines a small quantity of gypsum from its **Falkland** pit (approx. 6000 tonnes/year) for its Kamloops cement plant. This production is traditionally supplemented by material supplied by *Certain Teed Gypsum Inc.*

On the world-scale, the gypsum market has evolved substantially over the last 20 years. Synthetic gypsum, derived from the flue gas desulphurization process in coal-fired power plants (Simandl, 2003), has become the main raw material for wallboard-making. Because coal is not used to generate electricity within British Columbia, local cement and wallboard plants rely on locally derived and imported natural gypsum. Information regarding the geology of the gypsum



deposits in the province was compiled by Butrenchuk (1991).

## MAGNETITE

British Columbia has never had its own steel industry, but in the past a number of large magnetite skarn deposits located near the coast produced iron ore for export. The Texada Island group of deposits, Argonaut, Kennedy Lake (Brynnor) and Merry Widow, are good examples (Simandl et al., 2006b). In recent years, *M-Seven Industries Inc.* has produced between 60 000 and 70 000 tonnes of magnetite annually for industrial applications, by processing the **Craigmont** mine tailings. The company is supplying most coal mines in western Canada with heavy media material for their wash plants (Figure 23).



Figure 23: Use of magnetite in coal upgrading process at the Quinsam Coal plant on Vancouver Island (from Simandl and Brûlé (2008).

During 2007-08, a number of known magnetite prospects across the province, including **Beaver Lake** (magnetite paleoplacer); **Bacon Lake** (magnetite  $\pm$  cobalt; Figure 24); **Iron King** (magnetite  $\pm$  gold); and **Mag** (originally explored for gold), were examined as potential sources of iron oxides for coal-washing or as a source of iron for cement plants located in Alberta or Lower Mainland. Other companies, including *Pacific Iron Ore Corporation* which owns an iron ore prospect located near **Port Renfrew** and *Logan Resources Ltd.*, which own the **Brynnor** project were actively engaged in mineral exploration. These companies appeared to consider the possibility of direct shipping iron ore to Asia but also looked at the above described markets.

Current trends in clean coal processing may lead to the development of additional magnetite resources within the province; however, successful development of British Columbia skarn deposits as sources of iron

ore will remain difficult unless new large and high-grade deposits are discovered (Simandl et al., 2006b). Magnetite occurrences in British Columbia were reviewed by Hancock (1988) and modern markets for magnetite ores that characterize skarn deposits in British Columbia are discussed by Simandl et al. (2006b).



Figure 24: Stripped magnetite-rich rock; Bacon Lake prospect. Mr. Joe Paquette in the background.

## MINERAL WOOL

A variety of products are used to provide thermal and sound insulation. Mineral (or rock) wool, fiberglass, foamed glass, expanded perlite- or vermiculite-based product and other materials (see light weight aggregates) compete for part of this market.

*Roxul (West) Inc.* is continuously modernizing its insulation/mineral wool manufacturing plant in Grand Forks, southeast British Columbia (Figure 25). Between 1999 and 2002 alone, Roxul invested \$29 million in this plant. Currently, this plant is the largest employer in Grand Forks area.

In 2008, the plant's main source of raw material was the **Winner** diorite quarry in the Greenwood mining camp, 4 kilometres south of the former Phoenix mine. Material from the Winner quarry is



supplemented by material from the **Burrell Creek** quarry, which is located approximately 45 km north of Grand Forks. Slag, another raw material used at the Roxul's insulation plant, was provided by *Pacific Abrasives & Supply Inc.*



Figure 25: Mineral wool (insulation) producing plant in Grand Forks; Roxul (West) Inc.

### ***PUMICE, SCORIA, TEPHRA AND EXPANDING SHALE/SLATE***

Pumice, scoria, tephra (lava rock), expanded shale and clays and expanded slag are commonly referred to as “lightweight aggregates”. Lightweight aggregates are valued mainly for their low density, but also have superior sound and thermal insulation properties, seismic performance, fire resistance and other geotechnical properties. Lightweight aggregates are preferred materials in concretes used to construct upper levels of high-rises, minimizing the weight of the concrete column on foundations and lower levels.

*Lightweight Advanced Volcanic Aggregates Inc.* and its predecessor companies traditionally produced about 20 000 m<sup>3</sup> / year (up to 50 000 m<sup>3</sup> / year) of tephra from its **Nazko** quarry, approximately 100 km west of Quesnel. The material is used for landscaping, sporting facilities, growing and filtration media, lightweight aggregate applications and more recently as traction material used on Canadian roads during the winter conditions. Red and black varieties are available from this deposit (Figure 26).

The **Mount Meager** operation (**Pum** deposit), owned by *Great Pacific Pumice Ltd.*, located north of Pemberton, was placed on care and maintenance following an accident in 2007 (Figure 27).

Historically, the production ranged from 7000 to 12 000 m<sup>3</sup> annually. The site was investigated by ground-penetrating radar in 1999 in order to estimate the approximate size of the deposit required for future

expansion (Carefoot, 2004). The material from this deposit was tested by a major cement-producing company located in the Lower Mainland as a pozzolanic additive. The potential of this property should not be underestimated in this regard (Simandl and Simandl, 2008). Several years ago, *Garibaldi Aggregates Ltd.* also initiated production of pumice from the Mount Meager area, but until now the extraction remains on bulk sample scale. According to Northcote (2009), the company is working towards obtaining a mining lease.



Figure 26: Production of red tephra at Nazko quarry located near Quesnell; central British Columbia.



Figure 27: Pumice processing facility near Mount Meager; Great Pacific Pumice Ltd.

Expanding shale has its niche where natural lightweight aggregates, such as pumice or tephra, are not readily available or do not meet users specifications. Five occurrences of expanding shale are known in the province (on Vancouver, Salt Spring and Saturna islands). Two of these are past producers. When thermally processed under controlled conditions, these shales release gas and expand causing bloating (Figure 28).

The main disadvantage of expanded shale over pumice or tephra is the cost of energy required for its thermal processing. The main advantage of the

expanded shale, relative to other lightweight aggregates, resides in tightly controlled specifications.



Figure 28: Expanded shale; sample of light weight aggregate produced on experimental scale from expanding shale deposit located on Vancouver Island.

### ROOFING GRANULES

World-wide, a variety of sedimentary, igneous and metamorphic rock is used for production of roofing granules. Large roofing shingle producers are vertically integrated companies that exploit deposits with consistent raw material and large reserves, able to supply granules suitable for color coating. Particle size distribution, shape, color, adhesion, opacity and resistance to blistering of the particles are the key elements of quality control.

In October 2001, *IG Machine and Fibers Ltd.*, a subsidiary of *IKO Industries Ltd.*, opened its **Ashcroft basalt** quarry and roofing-granule plant (Figure 29). The plant produces granules of six distinct colors and is gradually increasing its production from 250 000 tonnes (in 2002) to its designed capacity of 500 000 tonnes per year. Basalt, the main raw material, is quarried and crushed near the plant. Basalt granules are sized and coloured prior to shipping to IKO Industries shingle plants in Sumas (Washington State), Calgary and High River (Alberta) and elsewhere.

### SILICA

Quartz veins, pegmatites, sand, sandstone, quartzite, siliceous sinter, graphic granites, cherts and laska are some of the common silica raw materials. Silica raw materials are used in construction, cement and glass (flat, container, optical, etc). Finely ground and sized silica is used as filler in rubber, paint, plastics and adhesives. Silica materials having sands-size particles are used in filtration, as proppants in oil/gas drilling and as sand blasting media. Lump silica is commonly

used in production of ferrosilicon and silicon metal. Silicon carbide, fused silica, synthetic quartz crystals are other energy-intensive value-added products (Foye, 1987; Simandl et al. 1995a).



Figure 29: Roofing granules plant; IG Machine and Fibers Ltd., Ashcroft area.

In 2008, *HCA Mountain Minerals (Moberly) Ltd* extracted approximately 85 000 tonnes of silica from its **Moberly mine** and processed a portion of it in its nearby plant north of Golden (Figure 30). Most of the processed material was shipped to Lavington, British Columbia to the *Owens-Illinois Inc* glass plant. This plant was closed on October 31, 2008 and *HCA Mountain Minerals* is actively looking for alternative markets.

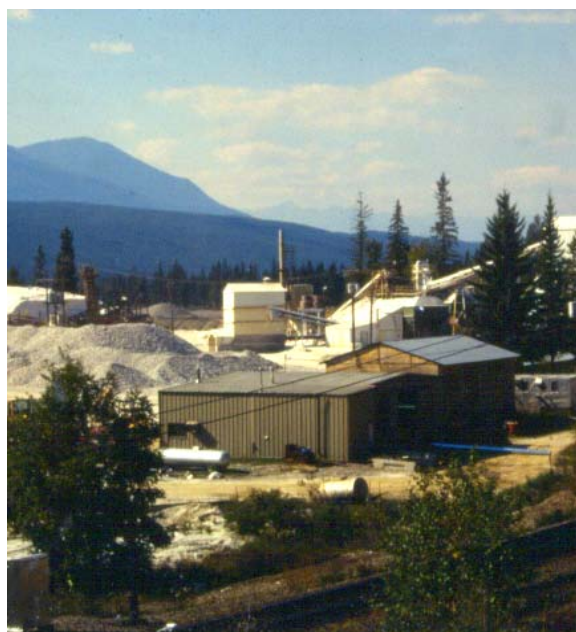


Figure 30: Moberly silica-processing plant, owned and operated by *Heemskirk Canada Limited*



In the past the mine also shipped lump silica to Springfield (Oregon) for ferrosilicon and silicon production. The silicon and ferrosilicon production in the USA collapsed in 1990's due to more competitively priced imports from overseas, and silica shipments from British Columbia ceased.

During 2007 and early 2008 silicon metal exports from China were declining and in response to this declining supply change prices of metallurgical and chemical grade silicon metal were climbing. Since October 2008, the prices of ferrosilicon and metallurgical-grade silicon in the USA have come under pressure once more. It is therefore unlikely that some of the traditional (now closed) metallurgical silicon plants in the USA will be reactivated. On the other hand, the demand for solar cell-grade silicon is expanding rapidly. In the past, metallurgical-grade silicon (Figure 31) produced in an arc furnace was considered as unsuitable for use in solar cells or semiconductors without significant purification (Simandl et al., 1995). Over the last two years, several companies have developed or acquired new technology to produce solar-grade silicon from upgraded metallurgical grade (UMG) silicon.



Figure 31: Metallurgical grade silicon produced from British Columbia quartzites. New technology allows such product to be economically upgraded to “solar-grade” silicon.

This technological development is good news for manufacturers of solar panels. The UMG silicon replaces relatively expensive low-grade polysilicon (not satisfying specifications for production of single silicon crystals) as the main feedstock in manufacturing of solar energy panels. It remains to be established if this technological change will provide a market for silica deposits located in southeastern British Columbia.

*Lehigh Northwest Cement Limited* owns the **Monteith Bay** deposit on western Vancouver Island.

This deposit traditionally supplies clay-containing siliceous sinter (“geyserite”) to its cement plant in Delta; however, during the 2008 the deposit remained dormant and the company relied on the material supplied by *Electra Gold Ltd.* from its **Apple Bay/Pem 100** property (Figure 32).



Figure 32: Pem 100 silica/clay sinter mine, on Vancouver Island.

Over the last five years, *Electra Gold Ltd.* became a major supplier of raw materials for the cement industry. The company reports that over the last 5 years it has produced over 500 000 tonnes of geyserite from their Apple Bay / Pem 100 deposits on Vancouver Island. Geology of the deposits is described by Shearer (2004).

Most of the mined material is shipped to the Ashgrove Cement plant (in Washington State) and to the Lehigh Cement and Lafarge plants (in Lower Mainland). Ashgrove had a slow third quarter of 2008 due to the reduction of sales to its main customer (Electra Gold, 2008). Company representatives hope that they will be able to increase its production during 2009.

During 2008 and 2009, several junior companies, including the *Stikine Gold Corporation*, became aware of high frac sand prices prevailing in the northeastern British Columbia. Transportation cost of imported material is a major factor keeping the costs high. These companies acquired several silica zones east of Prince George. Past Canadian attempts to produce frac sand from consolidated sandstone or quartzite were not commercially successful. It remains to be established if proppants meeting expectations of the Oil and Gas industry can be produced from local quartzite, at prices competitive with imported frac sands.

There are over 30 significant silica occurrences in British Columbia, most of them are described by Foye (1987), but only few are currently in production.

## SLAG

*Pacific Abrasives & Supply Inc.* is producing and processing slag from the historical **Granby smelter** near Grand Forks, mainly for sandblasting at major shipyards and roofing granules (Figure 33).



Figure 33: Slag left behind after the Granby Smelter, near Grand Forks, closed became an attractive commodity with uses as cement additive, abrasive, in making of anti-skid surfaces and in insulation (rockwool) making.

Slag was also shipped from **Anyox** by *Tru-Grit* for use as cement raw material, roofing granules, and for abrasive applications. *Teck* is the major slag producer at its **Trail smelter**, where it produces approximately 250 000 tonnes/year. It markets slag mainly for cement production and abrasive applications. During recent years, at least 500 000 tonnes of slag from its smelter were used by cement producers from the Vancouver area. The properties of the Trail smelter slag could be investigated to determine if the slag is acceptable for use as a pozzolan in cement-making (Simandl and Simandl, 2008). In the past, slag has also been erratically produced from the slag piles that resulted from the operation of historic **Greenwood** smelter.

## SULPHUR

Sulphur was historically mined as native sulphur, recovered by the Frasch well process, or produced by roasting of iron sulfides and/or base metal ores. Sulphur recovery as a byproduct of oil and gas processing debuted in the 1950's and it currently satisfies more than 70% of world sulphur market. Sulphur is a byproduct of natural gas processing at a number of plants in northeast BC (Figure 34).

During July 2008, sulphur prices reached unprecedented levels in excess of \$ 600/tonne at the plant gate (apg.) in the Western Canada basin. The

average price of sulphur for 2008 was probably above \$300/tonne apg (possibly above \$330/tonne apg.). A rough estimate of sulphur production for 2008 for British Columbia is 895 000 tonnes. Most of the Province's sulphur production in 2008 was pre-sold in contracts, so little was available for sale on the spot market.

Assuming that our estimates are correct, then the value of the 2008 sulphur production (apg.) of British Columbia would be probably in the \$265 million to \$300 million (apg.).

The situation has changed dramatically since the 2008 peak prices. March 2009 sulphur spot prices (FOB Vancouver) were down in the \$30-35/tonne range.



Figure 34: One of the sulphur-pelletizing plants located in northeastern British Columbia near Fort Nelson.

## TUFA

Tufa, currently exploited in British Columbia, is a precipitate of calcium carbonate formed near the surface discharges of mineral-rich springs. If the discharge is located in wooded or vegetation-covered areas, the calcium carbonate coats organic material, such as stems of growing plants, trunks of trees, rotting fallen tree trunks and branches and leaves. The organic components decay, leaving their casts behind (Figure 35). *Rocky Mountain Tufa*, located near Brisco in southeastern British Columbia produces pale gray or beige tufa rock for specialty gardening and landscaping applications. This small, family-run operation sells its products across Canada and the western USA. *Golden Rock Products Inc* located in the Kimberley area also advertises tufa on their website. A number of other tufa and travertine deposits are known in British Columbia. Travertine is a less porous tufa equivalent, commonly layered, with potential use as dimension/ornamental stone.



Figure 35: Tufa extracted near Brisco, is popular with gardeners and landscapers across Canada.

### ZEOLITE GROUP MINERALS

Approximately 40 natural minerals belong to the zeolite group. These minerals are characterized by a distinct crystal structure, which determines their ion exchange capacity, degree of hydration, stability, ability to adsorb gases, absorbancy and molecular-sieving characteristics.

Less than a tenth of these minerals are traditionally considered of economic interest. Depending on their properties, zeolites can be used for ammonium ion removal or immobilization (in pet litter, aquaculture, or farm- and sewage-related waste stream treatment). Natural zeolites are also used in nuclear accident cleanups, heavy metal removal from industrial and mine waste waters, as soil conditioners and as animal feed supplements and many other applications (Holmes, 1994).

In British Columbia, most of the zeolite deposits consist of clinoptilolite. These deposits were described by Reed (1987, 1996 and 2000). Junior companies and individuals who attempted to commercialize them met with a limited success. Currently, *Heemskirk Canada Limited* sells small quantities of zeolite derived from the **Ranchlands Z-1** quarry near Cache Creek and from the **Zeo (Bromley Vale)** zeolite project (Figure 36), which is located near Princeton.

The intended markets for the zeolite-bearing rock from the Bromley Vale deposit are lightweight and specialty cements for the oil and gas well cementing systems, and some industrial applications. The material from **Ranchlands Z-1** deposit was marketed largely for agricultural uses.

There was no activity at the **Sunday Creek** zeolite deposit near Princeton, formerly owned by *Canmark International Resources Inc.*

The processing plant in Cache Creek and related mine northeast of Cache Creek, that belonged to *C<sub>2</sub>C Industrial Minerals Processors* now belongs to *Mitch Industrial Group Inc.* The plant is dismantled and the mine site is inactive.



Figure 36: Zeo (Bromley Vale) zeolite quarry and stockpiles belonging to Heemskirk Canada Limited.

### MINERALS AVAILABLE, BUT NOT MINED, IN BRITISH COLUMBIA

This section covers some of the industrial mineral commodities that are not produced but are known to occur in British Columbia. The reasons for the lack of development may be technical (i.e. poor grade, tonnage, specifications, complexity in upgrading), linked to accessibility, lack of infrastructure or location in environmentally sensitive areas. Market limitations and difficult financing are two of the universal challenges for any new industrial mineral projects.

Commodities where deposits are under consideration for development, or those that may have been overlooked during previous assessments are discussed below in alphabetical order. They are brucite, chromite, diatomite-diatomaceous earth, fluorite, graphite, high-technology minerals and metals, kyanite family minerals, nepheline syenite, feldspar, peat, perlite, vermiculite phosphates, talc and wollastonite.

#### **BRUCITE, HYDROMAGNESITE AND HUNTITE**

Brucite ( $\text{Mg}(\text{OH})_2$ ), a relatively unknown Mg-rich mineral, has number of industrial and environmental applications. Brucite was used in the past (and remains a potential high-grade ore) for production of magnesium metal (Simandl and Schultes, 2007; and Simandl et al., 2007a,b). The geological setting of a



selection of brucite deposits and occurrences is provided in Simandl et. al., (2007b) and selected occurrences in British Columbia are also covered by Simandl et al. 2007c).

The brucite market is small, but expanding. Combined markets for synthetic and natural brucite probably account for 50 000 tonnes/year (Simandl et al., 2007b). Some of the brucite-bearing marbles, similar to the sample shown in Figure 37, are ground to acceptable finess and sold without any upgrading.

Hydromagnesite ( $\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$ ) and commonly associated huntite ( $\text{CaMg}_3(\text{CO}_3)_4$ ) are two other magnesium-bearing minerals of interest. Occurrences of these minerals in British Columbia and potential markets are discussed by Simandl et.al. (2004a).



Figure 37: Brucite (white patches) in calcitic marble, Kennedy Lake area, Vancouver Island; sample collected near the waste dump of a former magnetite mine.

## CHROMITE

Chromite is a spinel-group mineral characterized by high chrome content. Chromite concentrates are commonly subdivided into metallurgical, chemical and foundry, and refractory grades. In recent years, the metallurgical use accounted for more than 90% of the chromite market. 2008 was an exceptional year for ferroalloys and the steel industry in general. The demand for metallurgical and indirectly non-metallurgical grade surged to record highs. For example, the price of the South African refractory grade chromite (46%  $\text{Cr}_2\text{O}_3$ ; wet, bulk, FOB) reached \$880/tonne during November 2008. Since that time the price appears to be leveling off around \$500/tonne (Roberts, 2009). The prices are likely to stay near current levels in the foreseeable future. Compilation of data regarding chromite occurrences indicates that

there are at least 30 occurrences that were considered in the past by the industry (Hancock, 1990). Brief field visits during 2008 indicate that at least a few British Columbia occurrences have not been seriously assessed since the early 1900's (Figure 38).



Figure 38: Layered chromite mineralization (gray). Individual layers are displaced along minor faults. Host rock is serpentinized, silica and carbonates main fracture-filling minerals; WK prospect located near Clinton, Central British Columbia.

## DIATOMITE

Diatomite is a sedimentary accumulation of siliceous diatom skeletons. Such accumulations are unconsolidated or slightly consolidated (metamorphism destroys delicate structure of diatom skeletons). Depending on its physical/chemical properties, diatomite is used as abrasive, absorbent, functional filler, filter media in manufacturing of insulating bricks or pozzolanic material. Impure diatomite material is commonly referred to as diatomaceous earth. There are at least 45 known diatomite or diatomaceous earth occurrences in the province. Most are formed in lacustrine environments. Some are too small to be of economic interest but others are advanced prospects or past producers (Eardley-Wilmot, 1928; Reed, 1987, 1996 and 2000; McCammon, 1960; Hora and Hancock, 1995). The Crownite deposit and Clayburn excavation are examples of past producers (Figure 39).



Figure 39: Microsill plant (1982 photo). The diatomite rock from the Crownite deposit was calcined and transformed into a variety of absorbent products. Photo used with permission of Mr. Garry Miller, one of the contractors involved in the design and construction of this plant.

### **FLUORITE (FLUORSPAR)**

Fluorspar refers to a concentrate consisting mainly of mineral fluorite ( $\text{CaF}_2$ ). Depending on grade, fluorspar is used in production of hydrofluoric acid (HF) and its derivatives such as fluorocarbons, aluminum fluoride and synthetic cryolite and elemental fluorine (F). It is also used as flux in steel-making, smelting, and ceramics, cement and foundries (Simandl, 2009). Selected deposits are discussed within the global context by Simandl (2008, 2009). The **Rock Candy** mine, located north of Grand Forks, is the only past fluorite producer in the province. It supplied hand-sorted ore to the Trail smelter and is reported to contain small historical (pre-NI43-401) reserves (Figure 40). Currently the site is operated by *Geology Adventures* as mineral collecting site. There are at least 37 known fluorite occurrences in the province (Pell, 1992).

### **GARNET**

At least eleven members of the garnet group are widely recognized. Garnet-group minerals are used as abrasives, cutting materials, in sandblasting, and to a lesser extent as filter agents. They are used in polishing, shaping and cutting of wood, hard rubber, plastics, steel and other metals, dimension stone and glass. The almandine and members of almandine-pyrope solid solution are generally considered as the best for use as abrasives, but other members of the garnet group may be used as well (Austin, 1994). In specific applications garnets compete with other

natural or synthetic abrasives such as corundum, silicon carbide, emery, silica sand, slag and olivine. Small quantities of gem-quality garnets are used in jewelry but they are not covered by this discussion.



Figure 40: Fluorite (gray, pale green and purple) from matrix cementing host-rock (brown) fragments; Rock Candy Mine.

Garnet is recovered as a product or co-product (with gold, ilmenite and rutile) of large heavy mineral and placer operations (Levson, 1995) or as a byproduct of wollastonite or kyanite production (Simandl et al. 1999c, e). In exceptional situations, extraction of garnet from hard rock as a primary product may also be economically viable (e.g. Gore Mountain, USA).

There is currently no garnet production in British Columbia. The Stitt Creek placer deposit located near Revelstoke and the Crystal Peak deposit located near Pentticon (Grond et. al, 1991) have received exploration attention in the past. Selected garnet occurrences in the province are described by Pell (1988). The garnet market in North America is extremely competitive. Depending on grade, Idaho almandine is selling for US\$ 200-260/tonne, FOB mine site.

### **GRAPHITE**

Graphite is used in electrodes, brake linings, carbon brushes, crucibles, foundry facings, lubricants, refractory products, expanded graphite (further processed into high performance gaskets and graphite foil) and refractories (magnesia-graphite and alumina-graphite bricks). Several regions of British Columbia, underlain by amphibolite to granulite grade metasediments, have excellent geological potential to host crystalline flake graphite (Figure 41) deposits (Simandl and Keenan, 1998a; Marchildon et al., 1993) and to lesser extent vein-type (lump graphite) deposits



(Simandl and Keenan, 1998b). Coal beds subject to low- to medium- grade metamorphism could be converted to amorphous graphite (Simandl and Keenan, 1998c).

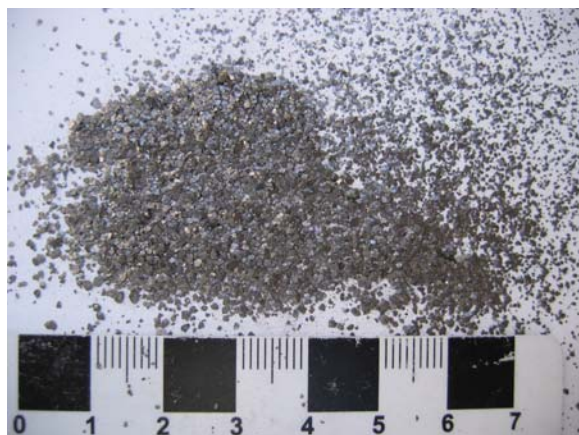


Figure 41: High purity crystalline flake graphite concentrate chemically treated to enhance volume expansion. This imported graphite product; sample provided by The Asbury Graphite Mills, Inc. Scale: smallest division equals 1mm. (not from BC)

There have been several attempts to mine graphite in British Columbia; however, none has been successful.

Overall, 2008 was a year of increasing graphite prices. However in the 4<sup>th</sup> quarter, China's exports increased which caused downward pressure on graphite prices. The prices for top grade large flake concentrate (+80 mesh, 94-97% graphitic carbon) currently range from US\$1000 to 1350/tonne (cost, insurance and freight to European port included). As with other high-value industrial minerals, the deposits with above average grade and tonnage, meeting consumer's specifications and located near existing infrastructure have the best potential to be transformed into successful mining operations.

The key aspects of the evaluation of graphite deposits were highlighted by Simandl et al. (1995b) and remain valid; however, the market tonnage and unit prices are evolving.

## HIGH TECH METALS

During 2008 exploration for high technology metals in British Columbia concentrated mainly on tantalum, niobium (Figure 42) and Rare Earth Elements (REE).

Niobium concentrates are mainly used to produce ferroniobium for the steel industry, niobium super alloys, and metal for use by the aerospace industry.

The tantalum market has evolved substantially since prices peaked in 2000 (Simandl; 2002b). Tantalum capacitors used in automotive electronics, pagers, personal computers, and cellular phones, still account for more than half of tantalum use.

REE are important in glass polishing, advanced ceramics, catalytic converters for the automotive industry, REE phosphors for computer, radar and television monitors, lighting systems, x-ray-intensifying films and as catalysts in petroleum refining. Pharmaceuticals, permanent magnets, metallurgical applications and alloys and laser and scintillator crystals represent smaller REE markets.

*Commerce Resources Corporation* continues its exploration and development work at the Upper Fir carbonatite deposit near Blue River. This deposit was previously described by Dahrouge (2002) and its mineralogy was covered by Simandl et al. (2002). During 2008, a total of 131 drill holes totaling 26,281 metres, were completed in the **Blue River** area and a 2000 tonne bulk sample was extracted from three different sample pits from the **Upper Fir** carbonatite (Commerce Resources Corporation, 2009). Recent drilling will probably result in increased reserves and it may also show that the shape of the mineralized carbonatite is more complex than previously believed.

The 2008 exploration conducted during 2008 on the **Hodgie Zone**, approximately 2 km southeast and upslope of the Upper Fir Carbonatite suggests that rare-earth mineralization consists of several bodies extending at least 2,000 meters along strike. A total of 84 grab samples was collected from float and outcrops within the area. Seven samples returned total REEs + Y (yttrium) greater than 2.0% to a high of 11.1%. Results of several samples are still outstanding (Commerce Resources Corporation, 2009).

**The Wichida Lake** carbonatite, owned by *Spectrum Minerals Corporation*, was drilled in late 2008 and again in 2009 (Chris Graff, 2008, personal communication). At the time of writing, complete analytical results were available only for the first of the four holes drilled. Hole #1 assayed 2.16% (Ce + La + Nd, combined) over 66 meters and within that zone it assayed 3.28% (Ce + La + Nd, combined) over 33.37 metres starting at the surface.

Partial results for hole #2 give 1.98% (Ce + La combined) over 84.85 meters, starting at surface. Within that zone, a shorter interval assayed 2.96% (Ce + La, combined) over 30.64 metres starting at surface. *Canadian International Minerals Inc* holds ground in the same area. **Rock Canyon Creek** fluorspar – REE occurrence previously described by Samson et al. (2001) and Simandl (2009) was also subject of intense

exploration activity in 2009. The road was rehabilitated and drilling is in progress.

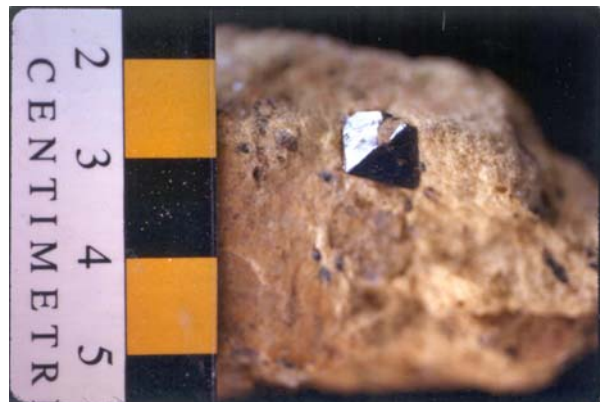


Figure 42: Euhedral pyrochlore (the main niobium-bearing mineral) from the Upper Fir deposit, Blue River area, British Columbia.

The Aley carbonatite was actively explored in 2007. Eleven boreholes (1 379 m) were completed by Taseko Mines Ltd.. The deposit is described by Thompson (1978), Mäder (1987) and Pell (1987). According to K. Pride, “the work by Cominco Ltd. defined extensive zones containing between 0.66 and 0.75% Nb<sub>2</sub>O<sub>5</sub>” at this locality (Pell and Hora, 1990). High technology minerals in British Columbia were last reviewed by Pell and Hora (1990).

### **KYANITE / ANDALUSITE**

There have been several attempts to produce kyanite in Canada, especially in Quebec, but none have moved forward (Simandl, 1989). Information regarding aluminosilicate minerals in British Columbia, mainly kyanite (Figure 43), andalusite (Figure 44) and sillimanite was covered by Pell (1988), Hancock and Simandl (1996) and Simandl et al. (1995a). Technical data and uses of these materials did not change since the publication of these documents and the specifications of the products evolved only slightly. Andalusite remains the most sought after of these products because of its low coefficient of expansion (Simandl et al., 1995d, 1999e). It does not have to be pre-calcined before use in refractory applications, representing substantial energy savings over kyanite.

There is currently very limited local market for these products, so if produced in British Columbia, aluminosilicates would be for export. Raw kyanite concentrates (54-60% alumina, ex-works USA) range in price from US\$ 220-330/tonne. The price of calcined material is substantially higher (US\$ 385-460/tonne).



Figure 43: Dark grey kyanite-rich horizon, Work Channel, north coast, British Columbia.



Figure 44: Andalusite (chiastolite) porphyroblasts showing characteristic cross in hornfels; Terrace area.

### **LEONARDITE**

“Leonardite” and “humate” are terms used to cover naturally occurring materials with a high humic acid content, such as weathered lignite and sub-bituminous coal, and a variety of carbonaceous mudstones, shales and claystones.

Leonardite of economic interest typically contains from 12% to more than 65% humic acid (Hoffman et al., 1993). Such materials are used as soil conditioners, drilling fluid additives, binder in iron pelletizing and in manufacturing of wood stains (Hoffman *et al.*, 1993).

Leonardite was documented at the Red Lake Fuller’s earth deposit north of Kamloops (Simandl et al. 2001b). Several years ago, *Absorbent Products Ltd.* secured a contract to sell humic acid to a major retail chain and the company experimented with the extraction of humic acid (Aylen et al., 2004). Oxidized coal seams elsewhere in the Province, especially in northeastern British Columbia and Hat Creek area may contain higher concentrations of humic acid. Such zones may be worth testing.

Currently there is no production of leonardite or humic acid in British Columbia.

## **LITHIUM**

Lithium market projections, based largely on anticipated increases in use of lithium for primary batteries in the automotive sector, are optimistic. Currently, the lithium market is estimated at 110 000 ( $\pm$  20 000) tonnes of lithium carbonate equivalent. In addition to batteries, lithium ore concentrates and chemical compounds are used in glass, ceramic and enamel production. Lithium metal is used as a desulfurization agent and oxygen scavenger in production of magnesium and aluminum alloys. Historically pegmatites and related residual deposits were the most important sources of lithium, with spodumene, lepidolite, petalite and anbygonite as main ore minerals. More recently, continental evaporate/brine deposits eclipsed pegmatites as the main source of lithium. In these deposits, lithium-bearing solutions of various origins are further concentrated by solar evaporation to 20- 5000 ppm lithium.

The recent discovery of a major jadarite ( $\text{LiNaSiB}_3\text{O}_7(\text{OH})$ ) deposit by Rio Tinto in Serbia represents a new deposit type (Rio Tinto 2009, Stanley et.al., 2007). The discovery of this deposit indicates, that our knowledge of lithium metallogeny is growing and new discoveries of similar or greater importance may alter the supply and demand balance. Hectorite deposits, previously discussed in the clay deposits section are also starting to receive some attention as a source of lithium (Bryan, 2009).

Only two lithium occurrences appear in the BC MINFILE; one of them is a hydrothermal brine, the other is described as pegmatite hosted by lepidolite schist. Composition of oil and gas field brines in the province should be examined in terms of lithium, boron, helium, magnesium and other elements.

## **NEPHELINE SYENITE AND FELDSPAR**

Feldspar and nepheline syenite are grouped together because their markets overlap. There are at least 10 feldspar and nepheline syenite occurrences in British Columbia (MacLean and White, 1991). Some of these deposits were investigated by metallurgical studies. Potential producers focused on the glass market will have to rely on exports. The main nepheline syenite user in British Columbia, the Owen – Illinois plant, near Vernon closed its doors in late 2008. Recently reported prices of Canadian nepheline

syenite, ceramic grade (sold in bags) ranges between Can \$90-110/tonne ex-works. Glass-grade (coarser) material from the same source, shipped in bulk sells at less than 50% of the above price range. Ceramic market in British Columbia is probably limited.

There is currently no industrial grade feldspar production in British Columbia. Feldspathic sand is reported to enjoy some popularity in golf course markets, based largely on its lower free silica content than quartz-rich sands.

## **OLIVINE**

Olivine is a competitively priced mineral, as there are several large tonnage, good quality deposits located near the coast in Norway and Greenland. Magnesium-rich olivine (forsterite) has a use in refractories and as foundry sand. It is also used as heavy aggregate or ballast, abrasive media, slag conditioner, and in the manufacture of heat storage devices, fireplaces and a number of industrial applications (see gemstones section).

British Columbia has a large number of ultramafic bodies, but with few exceptions, dunites in British Columbia are at least partly serpentinized (Voormeij and Simandl, 2005). A portion of the Tulameen ultramafic complex, commonly referred to as “Grasshopper Mountain”, is not serpentinized (Voormeij and Simandl, 2005). This prospect was investigated as potential source of foundry sand (White, 1987b; Scabo and Kular, 1987; Whiting et al. 1987; Hancock et al., 1988). Its suitability for  $\text{CO}_2$  sequestration was also tested (Voormeij and Simandl, 2005). A relatively fresh dunite deposit near Hope (commonly referred to as the Cogburn project) was considered as a potential source of magnesium metal by *Leader Mining International Inc.*

If these potential sources of olivine were located along the coast or near the market, they might already be developed.

## **PEAT**

Peatlands correspond largely to waterlogged terrains where the growth of plant material exceeds the rate of its decomposition. Such sites exist in number of Canadian provinces, including British Columbia (Maynard, 1988). Classification of peat deposits and the peatland distribution in Canada is summarized by Buteau (2001). The Canadian peat moss industry, described by Hood (2001), is considered as one of the world leaders. Canadian producers are environmentally-sensitive and adhere to strict policies which require returning bogs to functioning peatlands



(Hood, 2001). British Columbia is a past peat producer, but for many years it has satisfied all of its needs through peat imports.

### **PERLITE/VERMICULITE**

Perlite is a term used by the industry to describe naturally hydrated volcanic glass. Perlite commonly displays “onion-skin-like” fractures and may increase in volume up to 20 times (Rotella and Simandl, 2004). It has a variety of uses (White, 2001; Simandl et al., 1996), but rock that yields a high proportion of coarse particles after expansion, favored in horticultural applications, is the most desirable. In September 2003, *BBF Resources Inc.* extracted a 180-tonne bulk sample of perlite from the **Frenier** deposit, west of Clinton. The material was trucked to Abbotsford for processing and test marketing for horticultural use; results were not reported. There are other known promising perlite deposits, such as at Francois Lake. No advanced perlite projects have been generated in the southern part of the province, close to the market, over the last 10 years.

Vermiculite is a variety of mica that expands (Simandl et al. 1999a). Some vermiculite deposits, hosted by ultramafic-rocks and historically mined in USA, contained some associated asbestos. Carbonatite-hosted, vermiculite occurrences such as that of Blue River may be asbestos-free (Birkett and Simandl, 1999; Simandl et al., 2007d). Another vermiculite occurrence (Figure 45), identified during the 2009 fieldwork is probably related to the Rare Earth Zone previously drilled by Commerce Resources (Simandl et al., 2010, in press).

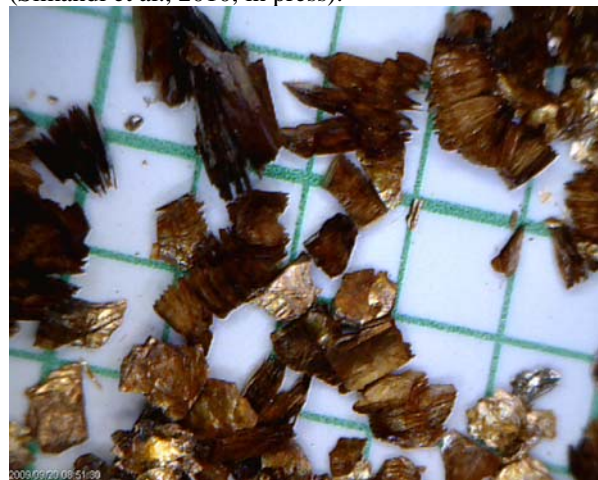


Figure 45: Bronze-coloured exfoliated vermiculite-rich material derived from 2-4 mm size fraction of sample 09-SP-305, Blue River area, east-central British Columbia. A 2 mm grid is used for scale.

### **PHOSPHATE**

Sedimentary phosphate deposits, typically consisting of apatite group minerals ( $\text{Ca}_5(\text{PO}_4)_3(\text{OH}, \text{F}, \text{Cl})$ ), mainly francolite. Such deposits supply most of the raw materials for the fertilizer industry. In recent years phosphates have also been considered as a potential fluorine resource (Simandl, 2009).

The price of diammonium phosphate (DAP) increased from US\$300/tonne in 2007 to US\$1200/tonne (FOB); however in January 2009 the price had decreased to US\$250-300/tonne (Feytis, 2009). Several new developments may affect the short term phosphate market. First, the Office Cherifien des Phosphates has struck a partnership with the Banque Centrale Populaire in Morocco to open four new mines by 2016 and upgrade processing facilities by 2020 (Feytis, 2009). Phosphate prices in Russia may be fixed by government (Hartley, 2009). The average prices of better quality “phosrock” (fine-grained apatite concentrate, about 70% bone phosphate of lime (BPL) is now probably well below US\$ 250/tonne FOB, Casablanca (1% BPL corresponds approximately to 0.458%  $\text{P}_2\text{O}_5$ ).

Over the medium to long term prices of phosphate are expected to recover.

In British Columbia, a number of phosphate occurrences were previously investigated as potential sources of phosphates or Rare Earth Elements (REE), but none of them are in production. During 2008, *Pacific Ridge Exploration Ltd.* acquired large phosphate holdings in BC. Work completed at the **Wapiti** and **Tunnel** zones yielded values up to 29.1%  $\text{P}_2\text{O}_5$  over 3 metres and 19.4%  $\text{P}_2\text{O}_5$  over 3 metres respectively. Five other targets where thicker and higher grade zones of phosphate are exposed and targets directed to tonnage and grade definition have been selected (Pacific Ridge Exploration Ltd., 2009). Phosphate occurrences are also known in the southern Rocky Mountains. They were explored since the 1930's up until as recently as 2007 (Paget Resources drilling). These and other phosphate occurrences in British Columbia are reviewed by Butrenchuk (1987, 1988).

### **TALC**

Talc is one of the best known industrial minerals because it was historically the main constituent of “baby powder”. Talc may be used in cosmetics, ceramics, paint, paper, and as filler in plastics and rubber. In USA, the price of talc ex-works varies from US\$92-210/short tonne, depending on grade. Most of the talc occurrences in British Columbia described by

MacLean (1988), are hosted by ultramafic rocks. They fit the model described by Simandl and Ogden (1999) but others are carbonate-hosted (Simandl, 2008). A new carbonate-hosted talc showing was recently identified in the **Bridesville** area (Figure 46), confirming that there is an excellent potential of discovering talc deposits in southern British Columbia (Simandl, 2008).



Figure 46: Carbonate-hosted talc mineralization near Bridesville, southern British Columbia.

## WOLLASTONITE

Acicular wollastonite concentrate is recognized as a high quality filler for use in plastic industry but it has many other applications (Simandl et al. 1999c). Non-acicular wollastonite (material with a low aspect ratio) is commonly used in ceramics. The deposits that are uneconomic as sources of functional fillers or ceramic materials may be used as flux in base metal smelting or as a source of CaO and SiO<sub>2</sub> in cement making. In these two applications, the substitution of wollastonite-bearing rock for limestone may result in substantial reduction of greenhouse gas emissions and potential CO<sub>2</sub> credits (Simandl et al. 2008b).

Morphology and textures characteristic of the wollastonite occurrences are described by Simandl et al. (1990).

Several wollastonite deposits located in British Columbia were investigated in the past (Fishl, 1991; Westphal et al.; 2001). *Tri-Sil Minerals Inc.* was the first local company contemplating use of wollastonite-bearing rock as source of CaO and SiO<sub>2</sub> for cement-making. In 2003, *RossWoll Industries Inc.*, a private company formed by *Grid Capital Corporation*, optioned a wollastonite deposit located near Rossland with intention to sell wollastonite to the Trail smelter as a flux. The material exposed in the test pit consists of wollastonite-rich layers (5-50 cm thick) interlayered with slightly thicker calcite-rich layers. The material

was deemed to be too variable in composition for use by the smelter. It remains to be tested if blending of ore prior to shipment, as practiced at the **Mount Brussilof** magnesite mine (Knuckey, 2001) would solve the homogeneity problem for smelter use.

## RELATED DEVELOPMENTS

There is no potash production in the Province; however, a large proportion of the potash originating in Saskatchewan is shipped through British Columbia. In June 2008 it was announced that *Canpotex Limited's* new potash terminal will be located on Ridley Island. Later, during the 2008, an expansion of the Vancouver Terminal was also announced. It is not known to what extent the current economic slowdown will affect these projects. In early 2009, BHP announced that it was considering development of a new potash mine in western Saskatchewan. If future BHP potash production will be marketed by *Canpotex Limited*, than these shipping terminal-related expansion projects may retain support.

## GREEN MINERAL – GREEN LIGHT

Industries have to comply with the government greenhouse gas emission standards (Simandl, 2003). The cement industry is one of the known greenhouse gas emitters (specifically CO<sub>2</sub>). Cement companies operating in British Columbia have gradually increased the use of imported fly ash as a pozzolan. Initially fly ash was used to reduce production (energy) cost. Today, the use of fly ash and other pozzolanic materials is also considered as one of essential elements in the effort to reduce cement-making related greenhouse gases (Simandl and Simandl, 2008). Fly ash accounts commonly for 8 to 25% percent of the cement and where specified by the builder, it may constitute 50%. As a result, the prices of fly ash increased significantly over the last 10 years reaching \$75-\$100 in the Vancouver area during 2008. High fly ash prices are creating an opening in the market for natural pozzolans (Simandl and Simandl; 2008). The use of natural pozzolans and lightweight aggregates in the cement industry is expected to increase over the next 10 years, but there are many hurdles to overcome (Simandl and Simandl, 2008; Simandl et al., 2008b). Green minerals are presenting medium to long-term opportunities. For example, the discussions surrounding the closure of the Cache Creek landfill, considerations of new sites, as highlighted by Sueck (2009) contribute to careful assessment of future landfill and extra safety incorporated into their design. The Cache Creek landfill is not unique, and demand for geotextiles and

minerals used in construction of impermeable linings and barriers, (such as bentonite) may grow more rapidly than in the past.

## SUMMARY

British Columbia has excellent geological potential to host additional NMOC deposits. The development of these resources is largely dependent on the size and accessibility of domestic and export markets.

The first three quarters of the 2008 corresponded to a “boom” in the field of non NMOC. Sulphur production alone may have contributed over \$265 million to the economy of British Columbia. The events of October 2008, followed by the current economic slowdown, are expected to result in a decrease in solid mineral production in British Columbia for 2009. As was the case during previous recessions, industrial minerals and aggregates may not be affected to same extent as many ferrous and nonferrous metals. Portland cement production is closely linked to the construction market and will probably strongly decline during 2009.

Environment-related programs (including carbon management) impose constraints on the existing mining industry and will lead to technological and market changes. Such programs are unlikely to be altered or discontinued due to the current economic slowdown. Consequently, such programs are creating commodity-specific project development opportunities. Natural pozzolans could strongly benefit from this situation.

Market changes related to technology breakthroughs, such as the use of upgraded metallurgical grade silicon as feedstock for production of solar panels are also important. However, they are much harder to predict.

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