Wollastonite

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Wollastonite is a brilliant white to gray or brown calcium metasilicate, $CaSiO_3$, with a composition when pure of 48.3% CaO and 51.7% SiO_2. The brightness of processed wollastonite is between 90 and 93, and the pH of a 10% slurry in water is 9.9; these properties are also utilized in its application.

Wollastonite is rarely found in the pure state since it is associated with manganese, magnesium, iron and strontium. It occurs predominantly as a contact metamorphic deposit forming between limestones and igneous rocks, often associated with garnet, diopside, epidote, calcite and quartz.

Wollastonite occurs in coarse-bladed masses usually as acicular or fibrous forms, even in the smallest particles. The fibre lengths are commonly in the ratio of 7 or 8 to 1; this is referred to as the "aspect ratio" and is the basis for many of its uses. The specific gravity is between 2.8 and 3.0 and the hardness on the Mohs' scale is between 4.5 and 5.0. Its melting point is about 1540°C.

Discovered just 200 years ago, wollastonite has been commercially mined since the 1930s. Its physical shape and chemical properties make it a versatile and valuable industrial mineral. The addition of even small amounts of wollastonite to products like plastics, ceramics, rubber and cement make them lighter and stronger. The medical world, as well, is beginning to embrace wollastonite since it is used in bone and dental cement and holds great promise as a key bioactive ingredient in the next generation of replacement joints.

While wollastonite is found in various parts of the world, significant differences in the products exist from source to source. These differences are partly related to the type and level of associated mineral contamination and, more importantly, to the level of metamorphism of the sediments and the volcanic and/or meteroric water migration through the orebody.

Local variations in temperature and pressure that occurred during metamorphism of the sediment are known to have markedly affected both crystal formulation and acicularity, and products ranging from powders to high-aspect-ratio crystalline materials are now found, depending on the specific location of the ore.

Canadian Occurrences

Canadian deposits of economic significance occur in Nova Scotia, Quebec, Ontario and British Columbia.

In eastern Canada, a wollastonite deposit occurs at Lime Hill, 20 km northeast of Port Hawkesbury on Cape Breton Island, Nova Scotia. In Quebec, an extensive deposit of banded wollastonite-diopside skarn occurs near Lac-Jean. The principal wollastonite deposit in Ontario occurs about 3 km from the town of Deloro, near Marmora in Hastings County, about 175 km northeast of Toronto. The wollastonite occurs in a skarn of silicified dolomite. A substantial deposit also occurs in Olden Township about 6 km south of Mount Grove, Ontario. Another deposit occurs at Seeley's Bay near Kingston, Ontario.

There are several potentially economic wollastonite skarn deposits in British Columbia (i.e., Sechelt and Little Billy mine deposits in the southwestern part of the province near Vancouver, and the Fintry Point, Silence Lake, and Horsethief Creek deposits in the southwestern portion of the province).

In the Yukon, not far from Whitehorse, a wollastonite deposit exists approximately 100 km from the port town of Haines, Alaska.

Production

World production (source: USGS's 2004 review on wollastonite) of wollastonite ore was estimated to be between 550 000 and 600 000 t in 2004. Sales of refined wollastonite product probably were between 500 000 and 525 000 t. China was the leading producer of wollastonite with an estimated production in 2003 of 300 000 t. The next leading producer was India with an estimated 2003 quantity of 176 000 t. The United States was the third largest producer with an estimated production of between 115 000 and 127 000 t, while Mexico ranked fourth with 51 900 t estimated in 2003 and Finland ranked fifth with 17 400 t estimated in 2002. Small amounts of wollastonite probably were produced in other countries.

Canada, at this time, has no wollastonite production and relies on imports for all of its consumption.

Quebec

Orleans Resources opened a mine located in St-Onge Township, 100 km northwest of Chicoutimi, near Lac St-Jean, and installed a mill and associated infrastructure in 1997 at a cost of over $37 million. It aimed to produced 50 000 t/y by 1998, but faced technical problems and increased operational costs, inadequate equipment purchases, and deficient commercialization of its products. It suffered important losses, which forced it to stop production for a year and a half. Orleans Resources discovered that the process of getting wollastonite certified for use by consumers in the polymer and paint markets was difficult, time consuming and expensive by under-estimating the processing complexity and difficulty of gaining market acceptance and penetration, especially in plastic components for the automobile sector. In the end, several financing rounds were unable to raise sufficient working capital to give the company time to overcome its problems. No buyer was found for the project and the plant was dismantled and the deposit was offered for sale in 2001.

Sequoia Minerals Inc. (Previously Mazarin Inc., now Cambior Inc.) acquired ownership of the wollastonite deposit from Orleans Resource Inc. Despite the deposit content of more than 20 Mt of ore reserves with an average wollastonite content of 36.6%, Cambior has no real interest in developing the property and is looking at alternatives.

Ontario

Wollasco Minerals Inc. (which evolved out of Ram Petroleum Ltd.) took on the development of the Olden, NR Mountain Grove deposit near Kingston, which indicated reserves of 2-9 Mt of high-aspect-ratio wollastonite. Testwork encountered problems with recovery rates and the separation of calcite from wollastonite. Wollasco was unable to secure development funding and the property was offered for sale in 2000. Company shares were suspended by the Ontario and British Columbia Securities Commissions, and Wollasco is now designated as “inactive” and must undergo reorganization.

Despite hurdles for new producers to enter into the wollastonite industry, Canadian Wollastonite is attempting to capture some market niche (e.g., construction, agricultural, etc.) with its St-Lawrence deposit. The company’s deposit contains over 9 Mt of high-grade wollastonite. It is located 1 km south of Seeley’s Bay and straddles the boundary between the city of Kingston and the municipality of Leeds.

The company has completed its bulk testing and process design, and is in the final stages of pre-production engineering/development. Operating plans and permitting are scheduled to be completed in early 2005 and plant construction should be completed by the end of 2005.

Canadian Wollastonite’s strategy is to initially install a dry process plant (even though the company has developed both a wet and dry process) and secure a small number of customers, primarily in the construction and agricultural products sector, that would support a 20 000-t/y operation. The company’s strategy is to be a reliable second source of supply after NYCO, specifically to potential customers who are currently purchasing over-engineered products.

Alberta

No wollastonite mining is being done in this province, but Calgary is where Fording Coal Ltd., owner of Fording’s industrial minerals headquarters operations, are located. Its NYCO operations comprise wollastonite mines and production facilities in Willsboro, New York, and Hermosillo, Mexico (Minera), and American Tripoli’s operations near Seneca, Missouri.

Fording is working on a number of new applications, including the development of wollastonite reinforced fertilizer coatings for use in the agricultural industry and the incorporation of wollastonite into cement products in order to increase strength while reducing weight. In addition, the company is working with automotive companies and their suppliers to further the use of wollastonite in the automotive industry (e.g., reinforced polymers in automotive body panels such as fenders, bumpers and side moldings, and in under-the-hood applications such as engine covers, air intake manifolds and battery trays).

British Columbia

Whitegold Natural Resources Corp.’s (formerly White Gold Resources Corp.) ISK wollastonite project in northwestern British Columbia, which had proven and probable reserves sufficient for a 20-year mine life at a mining rate of 50 000 t/y, completed a pre-feasibility study in 1997, but was unable to attract partners and/or raise financing for further development work. The project was offered for sale in 1998, but there were no takers. Therefore, the project was placed on hold in 2000 due to market conditions at the time.

Grid Capital Corp. of Vancouver (Source: Blendon's Information Services, July 2004) has started a second program of diamond drilling on the Rosswoll deposit located north of Rossland, British Columbia. The company has identified a wollastonite-marble zone that is 125 m long and varies from 38 to 60 m thick. The upper half of the zone is dominated by wollastonite, as much as 80% by volume; the lower part of the zone is coarsely crystalline white marble.

MINING

The typical timeframe from advanced exploration to production is 10-15 years. Years of study and assessments are required to determine the deposit characteristics, the extraction and processing plans, and to ensure operations are environmentally friendly.

Wollastonite can be mined by open-pit or underground methods. Surface-outcropping wollastonite or wollastonite covered by a thin overburden usually can be mined by open-pit methods where the ore grade may be as low as 25%. Underground mining is usually only justified if the ore grade is greater than 60% and there is a substantial amount of overburden to remove.

PROCESSING

Processing of natural wollastonite is carried out using either dry or wet methods. Processing of the NYCO deposit in Willsboro, New York (underground mining), is by the dry method, which involves primary jaw crusher, secondary gyratory crusher and tertiary roll crushing to less than 1.2 mm. The crushed ore is then screened into various size fractions, which are passed through high-intensity magnetic separators to remove garnet and diopside; garnet and diopside are separated from each other electrostatically. The wollastonite fractions are blended and further ground by pebble or attrition mills to produce aspect ratios between 15:1 and 20:1, which are sold under the "NYAD" tradename.

The wet method is used by Partek at Lappeenranta, Finland (quarrying at Lappeenranta is conducted on ore grading 20-24% wollastonite). Following primary crushing, the wollastonite is separated from limestone and dark-coloured waste rock by photometric sorting. The wollastonite "accept" fraction is further crushed and ground to about 200 microns and subsequently treated by reverse flotation. Calcite is floated from wollastonite and the wollastonite "tailing" is further beneficiated by wet high-intensity magnetic separation to remove iron oxides. Final processing involves filtering, drying and pebble milling to the required product size.

A potential producer will have to offer an extremely high-quality, cost-effective product or exploit a niche market if it is to compete with established producers. A possible alternative would be to supply a lower-grade product in a local or regional market that could be located some distance from its usual source of supply. Cost-effective processing techniques and proximity to consuming markets will, however, be the key factors contributing to the success or failure of any potential development.

Synthetic wollastonite is manufactured in countries that either do not possess the natural mineral or for whom the cost of importing natural wollastonite is uneconomic. The sintering process developed at Wülfrath in Germany is the most economic process. It requires quartz flour and finely ground limestone or dolomite, which are mixed and heated in a rotary kiln to a temperature below the melting point of wollastonite. The main use of synthetic wollastonite is in ceramic applications, such as earthenware. It is also used in fast-firing bodies for wall tiles, porcelain and sanitaryware, as a rheological additive for resins and paints, as a reinforcing agent for different polymer matrices, as a carrier for dry liquids, as a component in asbestos-free friction materials, as a carrier in chemical and biochemical catalytic reactions, and in flooring and roofing felt.

CONSUMPTION AND TRADE

Like the U.S. Geological Survey, data collection of wollastonite for end use is not done by Natural Resources Canada, and comprehensive trade data are not available for wollastonite. Information on market estimates is occasionally available in trade journals.

PRODUCTION AND MARKET CONSIDERATIONS

The global supply of wollastonite (source: *Industrial Minerals* magazine, article on wollastonite) is heavily concentrated, and has been for many years. Outside China there are only a handful of producers in North America, Europe and India. This is due to the high technical and commercial barriers that prospective producers have to overcome to penetrate wollastonite markets rather than to a lack of suitable reserves.

In 2004, wollastonite (source: USGS's 2004 review on wollastonite) was mined by two companies in the United States: NYCO Minerals Inc. (a subsidiary of Fording Canadian Coal Trust), which operates mines in Essex County, and R.T. Vanderbilt Co. Inc., which operates a mine in Lewis County, New York. NYCO used to be the world's leading wollastonite producer, but sales declined due to a decline in economic activity, particularly in the United States, and to competition from commodity grades of Chinese wollastonite (and to a lesser extent, Indian material); NYCO therefore had to invest heavily in process improvements, customer services and product development.

China dominates supply in terms of volume and has built a strong position in markets for 200- to 325-mesh grades through an aggressive pricing strategy. As a result, producers outside China have increased their efforts to add value to their products through the development of finely ground grades that retain a high aspect ratio, and by creating products with enhanced surface modification and coatings.

The problems/hurdles for new entrants can be summarized as follows:

- **Economics** - Chinese producers (and to a lesser extent, the Indian and Mexican operations) have very low costs compared to potential projects in Europe and North America. In addition, the leading established producers have considerable economies of scale compared to new projects that will inevitably have to start operating at a rate of a few thousand tonnes per year until they can gain market acceptance and market share.

- **Technology** - To earn good margins on wollastonite, companies need to be able to offer more than fine-ground powder grades. The grinding and classifying technology required to produce high-aspect-ratio products is not available "off the shelf." Major producers have many years of experience in customizing and optimizing equipment such as stirred media mills, jet mills, and air classifiers to produce acicular products in the particle size distributions their customers require. Coupled with this are extensive product development R&D and intimate knowledge of consumers' manufacturing processes and requirements.

- **Customer loyalty** - NYCO has been in the wollastonite business for almost five decades. The company has built long-term relationships with key accounts in the filler markets that are difficult to break into. Most major users have experienced supply or quality problems with Chinese products at one time or another, and they would not commit to significant purchase agreements with new entrants until they had proven their reliability, product consistency, and product quality.

- **Defensive strategies** - As in any industry, existing producers have the option of taking a range of measures to make life very difficult for any new entrant. In a business as concentrated as wollastonite, just the possibility of action should be sufficient to make potential new investors very hesitant.

PRICES

Quoted prices should be used only as guidelines because actual prices depend on the terms of the contract between the seller and the buyer. Prices for wollastonite (source: USGS 2004 review on wollastonite) ranged from US$50 to US$60/t for Chinese powder to US$1700/t for ultrafine surface-treated wollastonite. Prices for domestically produced acicular wollastonite, ex. works, were US$205/t for 200-mesh, US$248/t for 325-mesh, and US$275/t for 400-mesh. The price, ex. works, for acicular, high-aspect-ratio wollastonite was US$345/t. Prices for wollastonite from China, free on board (f.o.b.), in bulk, were US$80-$100/t for 200-mesh and US$90-$110/t for 325-mesh. Prices for filler grades of wollastonite from Asia and Africa ranged from US$89 to $510/t. Prices for ceramic grades from Asia ranged from US$58 to $137/t.

MAJOR USES AND SPECIFICATIONS

The largest volume of wollastonite used in the ceramics industry is consumed in wall-tile bodies and coating-glaze formulations, although smaller volumes are sometimes used in sanitary ware, earthenware, and various specialized ceramic-body applications. Wollastonite for refractory applications is used in load-bearing refractories, in metal-casting plasters, in investment castings, and in a variety of other casting processes. It may also be added to structural clay products, such as sewer pipe and building brick, to prevent chipping during handling.

The paint industry uses wollastonite in high-quality paints and bright-coloured paints, especially the pastel shades. It is used in exterior paints where it increases weathering resistance and in latex paints where it increases brightness and caulking reinforcement in the paint formulation. When employed in specialty paints, particularly industrial anti-corrosive coatings and textured paint, the acicular nature of wollastonite gives it a distinct advantage over cheaper minerals.

The resin-plastics industry uses wollastonite as a performance filler. It can also be used as an extender in vinyl plastisols and linoleum, and as a non-moisture absorbent filler in thermosetting, thermoplastic molding compounds, and casting resins. Surface-coated wollastonite, which increases compatibility between the filler and the resin-plastic media, also contributes to the physical, chemical and electrical properties of the finished product.

Wollastonite is also used for a variety of other applications: in specialized ultra-high-frequency electronic equipment such as high-temperature porcelains and high-tension circuit breakers; in ceramic artware; as a filler in grinding wheel-bonding formulations, ceramic-bonded abrasives, and abrasive wheels; in wollastonite-phosphate cement for such applications as decorative cement and insulating enamels; and in emulsion paints to add burnish resistance and acoustical properties to the surface of ceiling tiles. Wollastonite can replace limestone in the manufacture of glass since it not only acts as a source of lime, but also adds silica to the melt. It is often used as a metallurgical flux and as a coating on welding rods to ease flux applications. Minor applications include joint cements, laminates, marking compounds, matches, oil filters, plywood, urethane and wallboard.

OUTLOOK

The chief areas for wollastonite use will be in fine-particle-size, high-aspect-ratio, and chemically modified grades. Market sectors that are perceived as growth areas include plastics and chrysotile-replacement markets. High-aspect-ratio wollastonite is expected to be a major competitor to short-milled glass fibres on a cost basis, and fine-particle-size grades will have major applications in electronics, plateable plastics and powder coatings. Although wollastonite is expected to perform well in plastics, the market is not expanding, but applications towards automotive plastic should increase based on the strength of automobile sales. Intense and sustained technical support will be required to create such a market for wollastonite.

In penetrating the plastics market, wollastonite producers and processors are increasingly finding that their products need to be chemically modified in order to satisfy customer and end-product requirements and to enhance their market prospects in such applications as engineering thermoplastics.

Notes: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 64. (2) Information in this review was current as of June 30, 2005. (3) This and other reviews, including previous editions, are available on the Internet at www.nrcan.gc.ca/mms/cmy/com_e.html.

NOTE TO READERS

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TARIFFS

		Canada			United States	EU	Japan
Item No.	Description	MFN	GPT	USA	Canada	Conventional Rate (1)	WTO (2)
2530.90.90.93	Wollastonite (natural calcium silicate)	Free	Free	Free	Free	Free	Free

Sources: Canadian *Customs Tariff*, effective January 2005, Canada Border Services Agency; *Harmonized Tariff Schedule of the United States,* 2005; *Official Journal of the European Union* (October 30, 2004 Edition); *Customs Tariff Schedules of Japan, 2004*.
(1) The customs duties applicable to imported goods originating in countries that are Contracting Parties to the General Agreement on Tariffs and Trade or with which the European Community has concluded agreements containing the most-favoured-nation tariff clause shall be the conventional duties shown in column 3 of the Schedule of Duties. (2) WTO rate is shown; lower tariff rates may apply circumstantially.