

Primary Magnesium Industry at the Crossroads?

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Magnesium is the 8th most abundant element on Earth. There are over 80 minerals with more than 20% magnesium within their crystal structure; however, magnesium does not occur as a native metal. Magnesite, dolomite, brucite, bishofite, carnalite, and olivine have been used or are considered as raw materials for magnesium metal production along with brines, bitterns, fly ash, serpentine-rich ultramafic rocks, and asbestos tailings (Figure 1). Magnesite and brucite are also used in the production of caustic, dead-burned, and fused magnesia. Huntite and hydromagnesite have a high Mg content, but unless large deposits amenable to mechanized mining are found, their greatest potential will remain in flame-retardant applications.¹

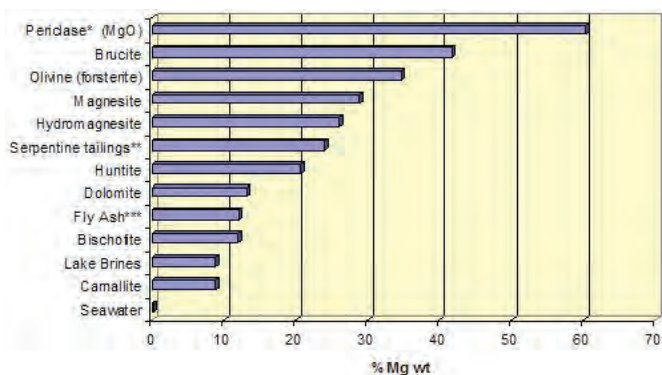


Figure 1. Magnesium-bearing materials used or considered for use in magnesium metal production. * Periclase does not occur in economically viable deposits (in nature it alters to brucite), but it has the same composition as man-made magnesia (MgO). ** Composition of tailing used for the Magnola project. *** Fly ash from the Hazlewood Magnesium project.

Dolomite [$\text{CaMg}(\text{CO}_3)_2$] and magnesite [$\text{Mg}(\text{CO}_3)$] are the most commonly used Mg metal ores. Dolomite, a widely available carbonate found on every continent, is the main magnesium ore for the Pidgeon process presently used in China. Magnesite has a higher Mg content than dolomite but large magnesite deposits are geographically restricted. World magnesite resources are estimated at over 12 billion tonnes and are primarily located in China, Russia, North Korea, Australia, Slovakia, Brazil, Turkey, India, and Canada. Over 90% of magnesite resources are sedimentary-hosted, either sparry type (also called Mount Brussilof type) as defined in Simandl and Hancock² or Kunvarra type as defined in Simandl and Schultes.³ The balance of the resource (<10%) occurs as veins⁴ or talc-magnesite bodies within ultramafic rocks.⁵ Magnesite production is estimated at 19 million tonnes per year and over 85% is the sparry variety.⁶

The production of Mg metal from magnesium silicates is technically feasible as was illustrated by the Magnola plant, Quebec, Canada, which operated from 2002 to 2003. However, the previously reported magnesium production costs for that plant are probably an underestimation. The real production costs may be too high in relation to 2006 Mg-metal prices for the plant to be economically viable. Brucite has a higher Mg content than the minerals mentioned but large tonnage, high-grade brucite deposits are uncommon.⁷ Periclase forms in nature; however, it is unstable and reverts to brucite in most geologic settings.⁷ Its composition is identical to man-made magnesia (MgO).

Magnesium Prices in Relation to Supply and Demand

Historic prices of magnesium metal were greatly affected by technology breakthroughs and the metal's use as a strategic metal during military conflicts. Governments have been involved in magnesium metal production, related research and directly or indirectly in market and price controls. The price of magnesium metal has varied since it was first isolated in 1808.⁸ For the first few years after its isolation, production took place only in the laboratory or bench scale. Prior to World War I, Germany was the only significant producer of magnesium, but during the war other countries recognized the strategic importance of this metal and built plants to meet the military demands. Figure 2 shows the key events causing variations in price since 1915.⁹ Overall, gradual variations in price are linked to global changes in supply and demand or inflation. The protracted periods of stable price are primarily caused by wartime government controls or other major political interventions. The use of Mg metal decreased after World War I. The onset of World War II resulted in increased military requirements and was reflected by higher prices.¹⁰ In the U.S., controls were implemented from 1943-1945, stabilizing the price.⁹

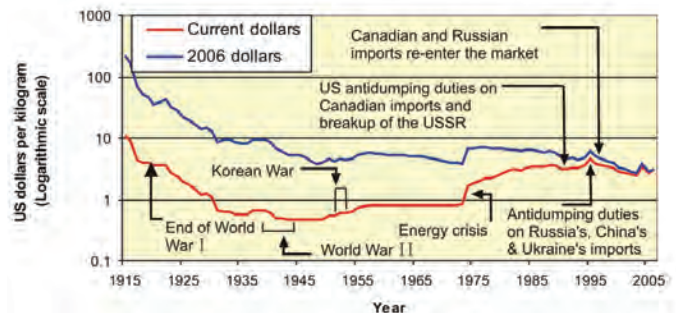


Figure 2. Historical prices of magnesium metal and significant events causing price variations. Data updated by year-end U.S. spot Western magnesium prices from Platts Metals Week. Vertical scale is logarithmic (1, 10, 100, 1,000) to enable the display of large, long-term variations.

The Korean War was another key event resulting in a significant increase in demand and prices following a positive trend until 1957.^{8, 10} Then, the price of magnesium remained uniform until 1974, when a rapid price escalation occurred (Figures 2 and 3).⁹ High energy costs abruptly increased the price of magnesium (one of the most energy intensive metals). Furthermore, there was a rise in inflation and in the use of aluminum cans (magnesium is part of the alloy) to replace glass containers in the beverage industry. The inflation effect persisted for some time as is suggested by the contrasting slopes of metal prices shown in current and in the "2006" dollars; but overall the magnesium price was stabilizing in the 1980s as inflation rates were declining (Figures 2 and 3).⁹ In 1987 and 1988 there was further growth in the use of aluminum, causing demand to surpass supply and a rise in the price of magnesium.⁹

In 1990, the opening of Norsk Hydro's plant in Canada diminished North American shortages and caused the price of the metal to drop (Figure 3).⁹ During 1991, antidumping duties were imposed by the U.S. on Canadian magnesium, significantly limiting the import of Canadian magnesium into the U.S. market. During the

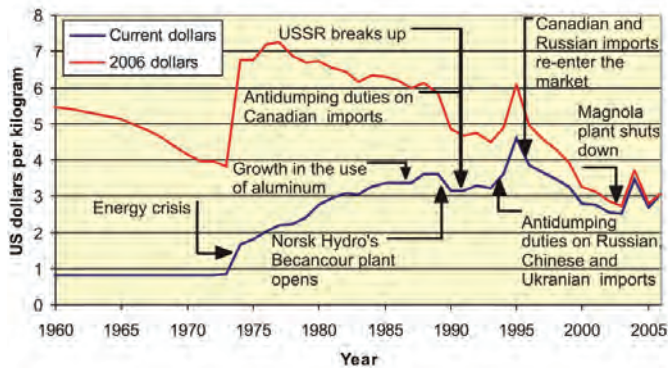


Figure 3. Prices of magnesium from 1960 to 2006. Data updated by year-end U.S. spot Western magnesium prices from Platts Metals Week.

same year, the Soviet Union (USSR) disintegrated and new supplies from Russia and the Ukraine reached the U.S. and replaced Canadian exports to the U.S. in 1992 and 1993.^{9, 10} In 1994, the U.S. investigated allegations of magnesium dumping by Russia, Ukraine, and China, and substantially limited imports from these countries to the U.S. As a direct consequence, magnesium prices in the U.S. increased. Two years later, Russia and Canada resumed exporting magnesium into the U.S. and once more supply surpassed demand, reducing the price of this metal.^{9, 10}

Since 1990, China has steadily increased its magnesium production capacity. By 1996, it became a major force and by 2002 its production accounted for half of the world's magnesium production (Figure 4).^{11, 12} Protracted periods of low magnesium prices put an end to a large number of potential magnesium projects and feasibility studies worldwide. Examples of projects that were terminated are Australian Magnesium Corp.'s Kunwarara (Queensland), Crest Magnesium (Tasmania), Golden Triangle Resource's Main Creek deposit (Tasmania), Hazlewood Magnesium project (Victoria State) that aimed at recovering magnesium from fly ash, Mount Grace Resources project at Batchelor (Northern Territory), and Pima Mining's SAMAG project (South Australia). Canadian examples include Cassiar Mines & Metals Inc.'s asbestos tailing project (British Columbia), Magnesium Co. of Canada's plant in Alberta which used magnesite ore from Mount Brussilof (British Columbia), Gossan Resources Ltd.'s Inwood Magnesium project, and Magnolia Metallurgy Inc.'s asbestos tailing project (Quebec). Many other projects were proposed during that period worldwide without being completed. On the positive side, low prices greatly favored an increase in the use of

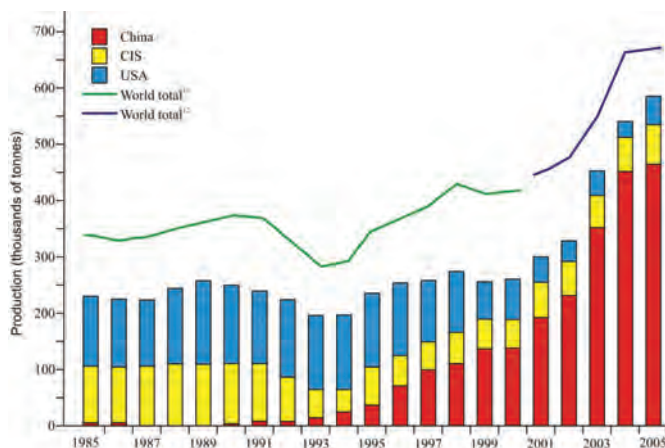


Figure 4. Production of primary magnesium from 1985 to 2005. Discontinuity in the curve is caused by different data sources.

magnesium metal relative to aluminum, zinc, and other competing materials. Traditionally, magnesium has had a higher price than aluminum, but it had an advantage over aluminum in that its lighter weight reduced operating costs of mobile machinery, particularly in the aeronautic and automotive industries. In the past, only when the magnesium/aluminum price ratio fell below 1.5:1 did magnesium start to replace aluminum in structural and appliance-housing applications. Between 1993 and 2003, this ratio declined from 2.7:1 to 1.64:1. Based on quoted aluminum and magnesium prices in mid-May 2006, the unthinkable happened. Aluminum metal became more expensive than magnesium, and for a period of time the magnesium/aluminum price ratio hovered near 1:1 (Figure 5).

Low prices of magnesium metal and the lack of a positive correlation between magnesium and aluminum prices resulted in favorable conditions for the substitution of magnesium for aluminum and other materials such as zinc and plastics (Figure 5).

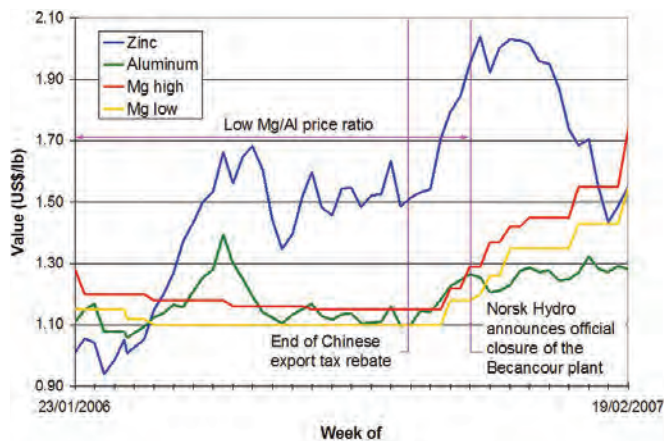


Figure 5. Comparison in price variations between magnesium, aluminum, and zinc (London Metal Exchange, 2007).

Geographic Shift in Primary Mg Production Capacity

As indicated in the previous section, magnesium prices rarely reflected the magnesium metal "supply and demand" equation. Magnesium production was historically greatly influenced by major military conflicts and government-related interventions (Figure 2).⁹ The situation is not much different today. The single most important development in the magnesium metal industry since 1990 is the gradual and systematic shift of magnesium metal production from North America and the Commonwealth of Independent States (CIS) to China (Figure 5). In 1993, North America, South America, Europe (including CIS), and Asia (including China) had primary magnesium capacities of 190,000; 10,600; 272,000 and 26,000 tonnes respectively.¹³ The 2005 supply of magnesium is estimated at 130,000 tonnes from Western producers and 530,000 tonnes from China and CIS producers combined, of which 320,000 tonnes are exported.¹² It also appears that in 2005, China had 27 smelters with individual production capacities in excess of 10,000 tonnes and their cumulative capacity reached 500,400 tonnes.¹⁴ China's production for 2006 was estimated at 490,000 tonnes; however, this needs to be confirmed because the same information release also indicates that there were only 10 companies with capacities of more than 10,000 tonnes.¹⁵ (A company may have more than one smelter each consisting of a large number of individual retorts. It is not clear if the rapid increase in the number of smelters with a capacity over 10,000 tonnes represents new smelters or simply

the addition of new sections to existing plants.) This geographic shift in production capacity of magnesium metal led to Chinese dominance of the magnesium market. It was caused by a combined effect of several factors, including Western countries' desire to normalize their relationships with China, China's need of foreign currency and foreign investment capital, the availability of its raw materials and abundant and inexpensive energy, relaxed environmental regulations for magnesium metal and ferrosilicon industries, low labor costs, and a favorable tax regime for Western investors.

Currently, Norsk Hydro and Timminco Limited in Canada, US Magnesium in the U.S., Dead Sea Magnesium in Israel, and Rima in Brazil are the main remaining Western magnesium producers. However, in 2006 Norsk Hydro decided to close their magnesium cashouse in Porsgrunn, Norway, which has had an annual production of 16,000 tonnes and on October 31, 2006, Norsk Hydro officially announced its plan to exit the magnesium business entirely through its closure of its Bécancour plant in Quebec.^{16, 17} Almost contemporaneously, magnesium prices started to rise (Figure 5).^{11,12}

The Past is the Key to the Future

China is the dominant magnesium producer (Figure 4)^{11, 12} and as a result, its internal and export policies have a worldwide impact and affect secondary magnesium producers and indirectly all the manufacturing industries using magnesium or competing materials. China's recent policies kept magnesium prices low and resulted in a worldwide increase in the use of magnesium metal (Figure 4).^{11, 12} On the negative side, the extremely competitive nature of the Chinese primary magnesium industry made it difficult for Western Mg producers to compete with low cost Chinese Mg exports while providing an acceptable return on investment for its shareholders. Periods of extremely low magnesium prices appear to be over. Several small Mg-producing plants in China shut down, as they were unable to satisfy the minimum environmental requirements recently enforced by the government.¹⁸ If environmental regulations (similar to those currently valid in North America and Europe) become the norm in China, this trend will likely continue. Furthermore, a number of countries, including the U.S., established and maintain antidumping duties on Chinese Mg imports.

As China's industrialization and modernization progresses at a rapid pace, the country is becoming susceptible to the same energy limitations as most of the developed countries and the availability of inexpensive energy resources allocated to the industry is shrinking. At the end of 2005, the Chinese magnesium export rebate was reduced from 13% to 5% and was removed entirely on September 15, 2006.¹⁸ New Chinese export taxes may be introduced. The apparent objective of these new taxes is to reduce China's internal industrial energy requirements by moderating exports of highly energy-intensive products such as magnesium. The announcement of the closure of Norsk Hydro's Canadian plant is related to the expiration of a 10-year contract with General Motors Corp.¹⁶, and other contributing factors are low prices of competing Chinese magnesium exports and increasing energy costs in Canada. This closure of Norsk Hydro's plant is important for the U.S. According to Kramer¹⁵, from early 2006 to August 2006, Canada supplied over 46% of U.S. magnesium imports and over 60% of U.S. magnesium alloy imports. It remains to be seen who will buy Norsk Hydro's Canadian plant or if the plant will have to be disposed of. Is there a possibility that the plant may be dismantled and reassembled elsewhere, possibly in China?

Should the currency exchange rate significantly change or the U.S. - China relationship deteriorate, then North American magnesium users, including the secondary Mg industry, automakers, and the aeronautic industry could be adversely affected. Magnesium metal is strategic for the North American automotive industry, which tries to reduce its average vehicle weight to increase efficiency and lower greenhouse gas emissions.

Thus, is it possible that North American secondary magnesium producers and other users such as the automotive industry are sacrificing long-term magnesium price stability and security of supply for a short-term material gain?

Magnesium Industry at the Crossroads

China is currently a giant as far as primary magnesium production is concerned. China's economy is rapidly expanding, the magnesium industry is modernizing, and small, inefficient, or obsolete primary magnesium plants in China are shutting down. Simultaneously, workers are expecting higher wages and more job-related benefits. With the modernization of all Chinese industries (including primary magnesium) and with emphasis on sustainable development, progressive environmental safeguards are being incorporated into all new projects. The cost of such safeguards is not negligible, as Western countries have already learned. Chinese people cannot absorb these costs forever; therefore, at least some of these costs will have to be passed on to the Western consumers. As the standard of living in China is improving, the use of electric appliances and motor vehicles is rising and consequently the availability of inexpensive energy for industrial applications is declining. If the Chinese economic revolution is completed, magnesium projects in China will be on the same footing as equivalent projects located in Australia or Canada. Western secondary magnesium producers and magnesium users (including the automotive industry) need to decide if they prefer to rely entirely on exports from China, preserve existing Western primary magnesium sources, or go even further and favor the development of new sources in countries such as Canada or Australia. Some may suggest that magnesium could be imported from CIS countries, but in those countries, a large proportion of magnesium production is considered an integral part of titanium production. "Keeping all one's eggs in the same basket" is rarely a wise business decision. Reactivation of previously shelved projects in Canada, Australia, or elsewhere may be possible if magnesium prices remain high for an extended period of time; however, only the best of these high-risk projects are worth considering. Only time will tell what the correct option is for Western users. A stable and geographically diversified base of primary magnesium producers would benefit not only the secondary magnesium industry, but it would ensure long-term stability of supply to all large North American, European, Australian, and Asian magnesium users. Stability of supply will ensure that magnesium research can continue and a robust market for magnesium usage can withstand the efforts of competing materials in the race for market share.

Editor's Note: For more information on magnesium raw materials in western Canada, especially British Columbia, contact George Simandl at: george.simandl@gov.bc.ca.

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