NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Photograph 13. Massive magnesite, Thuddungra mine, Young. The deposit formed in response to the release of Mg and Ca ions during weathering and erosion of ultramafic rocks in Cambrian sequences and their deposition as magnesite and dolomite sequences in lacustrine and channel-fill deposits in Tertiary palaeochannels. (Photographer D. Barnes)

Potential and Outlook

The best potential for magnesite in New South Wales is for sediment-hosted, ultrafine-grained, high-purity magnesite in Tertiary sediments similar to deposits mined at Thuddungra (Figure 15) (Photographs 13 and 14) in New South Wales (Figure 15) and Kunwarara (Queensland).

There are extensive areas of low relief in central-western New South Wales where magnesite may have accumulated in Tertiary sediments or in regolith developed on underlying Palaeozoic rocks. A basin averaging 12 m thick (the thickness of the Kunwarara deposit) over only a square kilometre would contain 12 million cubic metres (as much as 25 Mt to 40 Mt) of magnesite-bearing sediment. The Lachlan Orogen has considerable potential for deposits of that size, and lesser potential for larger deposits. There may also be potential for such deposits beneath the Clarence–Moreton Basin, adjacent to the Gordonbrook Serpentinite Belt.

Figure 15. Magnesite occurrences and prospective rocks in New South Wales

New South Wales also has considerable potential for regolith-hosted, ultrafine-grained, nodular to massive, high-purity magnesite developed on Alpine-type ultramafic rocks — such as the Great Serpentinite Belt and Coolac Serpentinite Belt — and on the Alaskan-type Tout Intrusive Complex and on other ultramafic or mafic bodies (Figures 6 and 15). The Gordonbrook Serpentinite Belt also has potential for this type of deposit. However, the potential of these deposits is probably smaller than for the sediment-hosted deposits.

Silica–carbonate alteration zones in the Great Serpentinite Belt represent a huge potential magnesite resource, but the magnesite is likely to be too high in silica and iron to attract commercial interest in the foreseeable future.

There is also potential for more deposits similar to the Piedmont deposit (Figure 15), in the Great Serpentinite Belt (i.e. ultramafic-hosted, ultrafine-grained, massive, high-purity, magnesite in hydrothermal veins). However, the Piedmont deposit (the only known example of this type) is small and the preservation potential for similar deposits is low in New South Wales, given their inferred development in the root zones of ancient springs, and the antiquity of the landscape.

Large, sediment-hosted sparry magnesite (Veitch-type) deposits occur in Kanmantoo Fold Belt rocks in the Arthur River area of northwestern Tasmania (Dickson 1990). Rocks of the Delamerian Orogen in northwestern New South Wales have potential for similar deposits.

Photograph 14. *Magnesite and fused magnesia. Magnesite from the Thuddungra mine is processed to caustic calcined magnesia for domestic and export markets for use in agriculture and industrial applications — mainly as a slag improver in steel making; waste water treatment; abrasives; paper manufacture; cement production; and pharmaceuticals. (Photographer D. Barnes)*

Nature and Occurrence

Magnesite refers to magnesium carbonate ($MgCO_3$, theoretically 47.8% MgO and 52.2% CO_2) (Table 17). There appears to be complete solid solution between magnesite and siderite ($FeCO_3$), with a progressive increase in colour from white to brown (Deer et al. 1992).

Table 17. Main properties of magnesite

Formula	$MgCO_3$
Colour	White
Specific Gravity	2.98
Hardness	3.5
Habit	Ultrafine-grained (crypto- to micro-crystalline or "bone") or coarsely crystalline ("sparry")

Source: Deer et al. 1992

Commercially, the term magnesite is sometimes used to refer to magnesia products made from natural magnesite or synthetic magnesia as follows (Duncan & McCracken 1994; Harben 1999).

- Refractory (or dead-burned) magnesia (or magnesite) is hard, dense, non-chemically reactive magnesium oxide produced by calcining magnesite or magnesium hydroxide at temperatures greater than 1450°C. It is primarily used in refractories due to its high melting point, stability and strength at high temperatures, and its resistance to slag attack.

- Caustic-calcined magnesia (magnesite) is produced by calcining magnesite or magnesium hydroxide at temperatures of 600°C to 1000°C. The product contains a small amount of CO_2 (<10% ignition loss remains) and has a relatively high specific surface area and reactivity (e.g. readily adsorbs water vapour or CO_2).

- Fused magnesia (magnesite) is produced by melting high-purity natural magnesite, caustic-calcined

magnesia or dead-burned magnesia in an electric arc furnace at temperatures of up to 3000°C. The product is dense (specific gravity of 3.5) and has superior strength, abrasion resistance and chemical stability compared with dead-burned magnesia.

World production of magnesite in 2004 was 11.6 Mt, excluding the USA (Table 18) (Kramer 2005).

Table 18. World magnesite production 2004	
Country	**Production (tonnes)**
China	3 800 000
Turkey	2 000 000
Russia	1 000 000
North Korea	1 000 000
Austria	700 000
Spain	520 000
Greece	490 000
Slovakia	490 000
Australia	490 000
India	380 000
Brazil	280 000
USA	Withheld
Other countries	450 000
Total (excl. USA)	**11 600 000**
Source: Kramer (2005)	

Many countries produce natural magnesite. Although available production data varies considerably, global production of magnesite is probably 10 Mt to 12 Mt yearly.

Synthetic magnesia is produced from seawater in the United Kingdom, USA, Japan, Mexico, Italy, Ireland, Norway, South Korea, The Netherlands and Israel.

Deposit Types

There are four classic European magnesite deposit types (Pohl 1989).

1. Kraubath-type, consisting of cryptocrystalline (or microcrystalline) high-purity, snow-white, magnesite forming veins and stockworks related to hot spring alteration of ultramafic rocks (e.g. Neogene alpine fault zones in southern Europe).

2. Bela Stena-type, consisting of fine-grained, high-purity, nodular, massive, banded, brecciated or vuggy magnesite forming lensoidal or irregular bodies grading into well-defined seams (less commonly sinter deposits) within mainly clastic lacustrine Tertiary-age sediments developed close to ultramafic outcrops.

3. Greiner-type, consisting of sparry, ferroan magnesite–talc or ferroan magnesite–chlorite assemblages (up to 70% granular magnesite) formed by carbonation of ultramafic rocks.

4. Veitch-type, consisting of sparry, high-purity magnesite associated with bedded siliciclastic and carbonate rocks, and commonly forming very large deposits (130 Gt in Liaoning deposits in China) and related either to marginal marine deposition (e.g. Coorong area in South Australia), sometimes with regional metamorphism or hydrothermal replacement of limestone (with dolomite as an intermediate stage).

These four magnesite deposit types are summarised in Table 19.

Table 19. European magnesite deposit types		
	Ultramafic-hosted	**Sediment-hosted**
Ultrafine-grained (cryptocrystalline to microcrystalline)	Kraubath	Bela Stena
Coarse-grained (sparry)	Greiner	Veitch
Source: Pohl (1989)		

Many Australian deposits (Table 20) share host and grainsize characteristics with the four classic European magnesite deposit types.

Table 20. Australian magnesite deposit types		
	Ultramafic-hosted	**Sediment-hosted**
Ultrafine-grained (cryptocrystalline to microcrystalline)	Attunga, NSW	Kunwarara, Qld
Coarse-grained (sparry)	Silica–carbonate rock, Great Serpentinite Belt, NSW	Coorong, SA
Source: Pohl (1989)		

However, these Australian deposits differ significantly from classic European types in certain details, arguably through development at lower temperatures (e.g. precipitation from groundwater instead of hot springs) — as summarised below.

- Weathering of ultramafic rocks (e.g. Attunga, Figure 15) produces ultramafic-hosted, ultrafine-grained, nodular magnesite that superficially resembles Kraubath-type deposits, but which are confined to the weathered zone, are less regular in form and simpler in mineralogy and depositional history.

- Lateral drainage and precipitation of magnesium-bearing groundwaters (e.g. Kunwarara in Queensland) produces sediment-hosted, ultrafine-grained, nodular to massive, banded magnesite broadly similar to Bela Stena-type deposits, but lacks evidence of hot springs activity (e.g. sintering, opaline silica deposits).

- Hydrothermal fluids produce a variety of alteration assemblages, including silica–carbonate rock ('Listwaenites' of Russian literature) which may be lower-temperature analogues of Greiner-type talc–magnesite deposits.

- Marginal marine alteration replaces calcium carbonate with magnesite (e.g. Coorong, South Australia) to produce fine-grained, sediment-hosted magnesite which would conceivably coarsen at higher metamorphic grades to form coarse-grained deposits resembling classic Veitch-type magnesite (which some attribute to magnesium-metasomatism by formation waters at elevated temperatures).

Main Australian Deposits

The Kunwarara magnesite deposit near Rockhampton is one of the world's largest deposits of cryptocrystalline magnesite, and is the only major source of magnesite in Australia. The deposit, which had been mined since 1991, produced 470 000 tonnes of magnesite in 2003 (Geoscience Australia 2004). The Kunwarara deposit has an inferred resource of 11 200 Mt of magnesite-bearing rock, which contains an inferred magnesite resource of 500 Mt. The magnesite occurs within Late Tertiary to Quaternary fluvial sediments associated with a serpentinised ultramafic complex, which is considered to be the source of the magnesium (Milburn & Wilcock 1998). The deposit has an average thickness of 12 m and extends over an area of about 63 km². The magnesite occurs as nodules, intergrown veins and sheets, and cemented aggregates (Milburn & Wilcock 1998). The magnesite is processed to caustic calcined, dead-burned and fused magnesia.

In South Australia there are widespread magnesite deposits (sedimentary, replacement and residual) within rocks of the Adelaide Fold Belt (McCallum 1990). The largest deposits occur in the Willouran Ranges, northwest of Leigh Creek, where a global resource of 579 Mt of magnesite has been identified (Geoscience Australia 2004). The deposits are of sedimentary origin and occur as interbeds within the Skillogalee Dolomite.

In the Arthur River–Lyons River area in northwestern Tasmania, fine-grained massive magnesite of possible sedimentary origin occurs within dolomites in a belt of deformed and metamorphosed Precambrian rocks (Dickson 1990). An indicated magnesite resource of 29 Mt has been identified at Arthur River (Geoscience Australia 2004).

New South Wales Occurrences

There are 68 occurrences of magnesite recorded in New South Wales, including three operating mines (Ray et al. 2003). The Thuddungra mine near Young produces between 20 000 tpa and 50 000 tpa. The magnesite is processed at Young to caustic-calcined magnesia, mainly for use in specialised chemical, metallurgical and agricultural applications. Two smaller mines near Lake Cargelligo produce much smaller quantities of magnesite for local agricultural use.

At Thuddungra (Figure 15), magnesite occurs in sedimentary deposits within Tertiary lacustrine and fluvial sediments (Photograph 13), and also in veins within the serpentinite source rocks (Diemar 1998; Downes et al. 2004). The current (and proposed) mining areas at Thuddungra have a magnesite resource of almost 2 Mt of hard (H = 5) cryptocrystalline magnesite containing 30% to 40% $MgCO_3$ (Brown pers. comm. 2005; Brown et al. 2005).

Two nearby relatively newly discovered magnesite deposits, the Noakes deposit and the Bailey's deposit, have total magnesite resources exceeding 10 Mt, with $MgCO_3$ grades comparable to the current and proposed mining areas. Numerous weathering-related deposits have developed in regolith on ultramafic and rarer mafic belts and masses, including the Alpine-type Great Serpentinite Belt (e.g. Attunga) and Coolac Serpentinite Belt (e.g. some deposits at Thuddungra and Gundagai) and hornblendite of the Alaskan-type Tout Intrusive Complex (e.g. Fifield deposits) (Figure 15).

At Lake Cargelligo, deposits are developed on nepheline-bearing olivine basalt (Burton & Downes 2005). All of these resemble the Kraubath-type magnesite deposits, but probably developed at lower temperatures (from groundwaters). Many may be

Tertiary, but some in the northern part of the Great Serpentinite Belt underlie Jurassic sedimentary rocks and are probably Triassic in age. The Fifield deposits are the largest deposits of this type in the Lachlan Orogen. The Attunga deposit (Figure 15), which produced over 100 000 tonnes of magnesite, is the largest recorded in the Great Serpentinite Belt.

Sediment-hosted magnesite deposits occur in regolith on metasedimentary rocks near many of the above ultramafic rocks. Important examples include the Thuddungra and Fifield areas, where the more economically important resources tend to be developed adjacent to source ultramafic rocks rather than overlying them (P. Downes pers. comm. 2002).

The Piedmont deposit (Figure 15) in the Great Serpentinite Belt is unusual among New South Wales deposits. It consists of veins of massive, ultrafine-grained magnesite and resembles Kraubath-type deposits in grainsize and host characteristics plus regularity of external form. It also displays features and stable isotopic characteristics indicative of hydrothermal origin, reinforcing the resemblance to classic Kraubath-type deposits rather than the low-temperature, regolith-hosted deposits that are so common in the Great Serpentinite Belt. Sparry magnesite is also present in this deposit as late-stage veins. This deposit is only small, and past mining produced only a few thousand tonnes.

Silica–carbonate rock is widespread in the Great Serpentinite Belt. These deposits may be lower-temperature analogues of Greiner-type deposits. None has been mined.

Applications

The main uses for magnesite and magnesia (Duncan & McCracken 1994; Harben 1999) are listed below.

- Crude magnesite is used for Epsom salts manufacture and Mg metal manufacture. It is also used to a limited extent in agriculture as a soil conditioner.

- Caustic-calcined magnesia is used in a diverse range of applications. These include the production of oxychloride and oxysulphate cements for lightweight flooring and other building materials; as a feedstock for the production of magnesium chemicals and pharmaceuticals; in animal feeds and fertilisers; water and sewage treatment; rayon manufacture; as a vulcanising agent in the rubber industry; and for removal of SO_2 from flue gases.

- Dead-burned magnesia is mainly for refractories in the steel, cement, glass and copper industries, owing to its ability to resist basic slags at high temperatures. It is used mainly as sintered grains in ramming mixes, gunning mixes and bricks. Other uses include the manufacture of chemicals and pharmaceuticals.

- Fused magnesia (Photograph 14) is used for the manufacture of magnesium–carbon and other premium-grade refractories for the steel industry. It is also used in electrical applications, including as an insulator in heating elements and welding machines.

Specifications for commercial magnesite and magnesia vary widely depending on the product and end use (Duncan & McCracken 1994; Harben 1999).

- Crude magnesite is used mainly to produce refractory or caustic-calcined magnesite, so purity and resistance to breakdown on heating are important.

- Dead-burned magnesia should contain at least 90% to 95% MgO but preferably >97% MgO for refractory use. Other requirements for refractory use include: low SiO_2 content (preferably <1.0%); "high" density >3.50 g/cm^3; coarse grainsize; CaO: SiO_2 ratio >2:1; and B_2O_3 <0.02%. Ease of sintering is important for monolithic refractories.

Product specifications for caustic-calcined magnesia vary widely depending on the likely application. Specifications include chemical composition, particle size, colour, LOI, bulk composition, SG and chemical activity. Caustic-calcined magnesite should generally contain 80% to 90% MgO but higher grade materials may exceed 98% MgO.

- Chemical-grade magnesia is produced to stringent standards, including rigorous physical and chemical specifications for pharmaceutical, medical, specialised filler, chemical and electrical uses.

- Fused magnesia (refractory grade) requires a high magnesia content (96% to 99%), low silica, density of >3.5 g/cm^3 and large periclase crystal size (>1000 μm). Electrical-grade fused magnesia must contain low levels of sulphur, boron and trace metals.

The principal alternative material to magnesia derived from natural magnesite is synthetic magnesia (MgO), which is produced from seawater. Production of synthetic magnesia currently amounts to 20% to 25% of total MgO production.

Economic Factors

The emergence of China as the dominant producer of magnesite and magnesium compounds has affected the profitability and market share of higher cost producers in the western world.

Demand for dead-burned magnesite (magnesia) in steelmaking refractories, the major market for magnesia, has declined, partly due to advances in refractory technology. In contrast, demand for fused magnesia, including refractory-grade material, should continue to increase.

Overall demand for caustic-calcined magnesia, which is used in a wide range of applications, is likely to remain relatively stable. Steady or declining demand is likely in some markets (e.g. pharmaceuticals, pulp, building products) while growth is likely in others, such as magnesium hydroxide for use in water neutralisation, flame retardants and de-icing.

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