The South Australian magnesium metal project

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Introduction

SAMAG Ltd (80% Pima Mining NL and 20% Resource Finance Corp. Ltd) plans to open a major new magnesite mine near Leigh Creek in SA's far north. A world-class magnesite resource of 516 Mt at 42.0% MgO has been defined over a strike length of >120 km, extending northwest from the town (Fig. 1). Magnesite ore will be used to supply a magnesium metal production facility which may be located in the Upper Spencer Gulf region, ~220 km to the south. The project will be a major boost to the State's mineral development profile.

The quality of the resource, the 'brown-fields' location, and acquisition of Dow magnesium metal production technology gives the SA project significant cost advantages over competing projects in the rapidly expanding magnesium metal market. A recently completed definitive feasibility study by Hatch Associates (Canada) and Thiess Contractors (Melbourne) confirmed the total cash operating costs to be below US$0.60/lb of magnesium metal or alloy, and a capital cost estimate of US$375 million.

Project outline

Two deposits — Mount Hutton and Witchelina — were considered for mining high-quality, low-impurity magnesite for the production of magnesium metal. The project as currently scoped envisages the mining of ~250 000 t/year of magnesite, initially from the Mount Hutton deposit located 25 km northwest of Leigh Creek. Ore will be crushed and screened on site, trucked to the railhead at Copley, and railed to the plant facility.

The proposed magnesium metal process facility is expected to initially produce 52 500 t/year of magnesium or magnesium alloys, primarily for use in the automotive industry, expanding to 100 000 t/year.

The magnesium market

Demand for magnesium in the automotive industry has increased radically due to global pressure to reduce the impact of fuel emissions. Car manufacturers are now competing for an increasing market for lighter, more fuel-efficient cars. Magnesium metal's light weight and advantages in die casting make it the ideal metal for the automotive sector.

All major automotive manufacturers in USA, Europe and Japan have made significant commitments to the future use of magnesium metal in new model automobiles.

With total world magnesium consumption currently >400 000 t/year and world manufacturing capacity only ~500 000 t, there are predictions that requirements for automotive applications alone will require an annual capacity of >1.5 Mt. There has already been a spectacular rise in the use of magnesium in die casting, which comprises 80% of the world's magnesium market. This market has sustained an annual growth rate of 15% for the past 10 years.

Coope (1999) observed that the average magnesium content of cars manufactured in North America in 1998 exceeded 3 kg/vehicle compared to 1 kg/vehicle in 1990. The industry is now set to use 40 kg/vehicle, at which rate Coope predicts that the demand will rise above 1.5 Mt/year.

Tenements

Three exploration licences (EL) are held in the area extending from Leigh Creek northwest to Screechowl Creek (Fig. 1). EL 2100 (BHP Minerals Pty Ltd) is subject to a farm-in agreement whereby Pima has the right to earn 100% interest in magnesite and 50% of any other mineral deposit discovered by spending $200 000 by 8 May 1999. This expenditure commitment has been met. EL 2100 contains the known magnesite deposits at Termination Hill, Pug Hill and Mount Playfair.

Magnesium Developments Ltd, a subsidiary of SAMAG, holds EL 2565, which covers the Mount Hutton north, Witchelina, West Mount Hut and Screechowl Creek magnesite deposits. EL 2570, held by Magnesium Developments at Mount Parry, covers possible western extensions of several of these deposits.

Three mineral claims have been pegged by Magnesium Developments at Mount Hutton (MC 3098, 3099 and 3100) and an application for a mining lease has been lodged with PIRSA.

Six mineral claims have been pegged at Witchelina (MC 3101–6) but application has not been lodged for a mining lease.

Geology

Magnesium is the eighth most abundant element in the Earth's crust and occurs primarily as the carbonate mineral magnesite ($MgCO_3$) and the mixed carbonate dolomite ($MgCa(CO_3)_2$). Magnesite has a theoretical maximum magnesia (MgO) content of 47.6%. Other magnesium minerals include chlorides, sulphates and silicates. Magnesium is a relatively reactive metal and is not found in the free state in nature.

Sedimentary magnesite interbeds occur within Neoproterozoic Skillogalee Dolomite extending throughout the Adelaide Geosyncline. These interbeds are developed extensively over a 120 km zone extending northwest from Leigh Creek to the northern Willouran Ranges. They

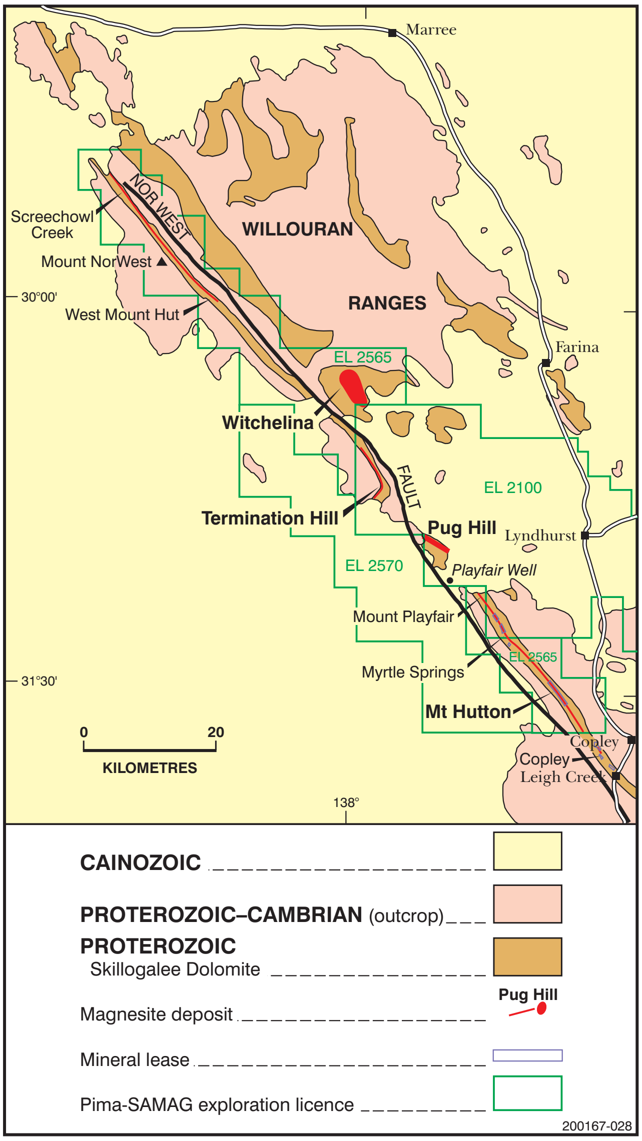

Fig. 1 *Magnesite tenements and regional geology in the Leigh Creek area.*

formed as an almost pure chemical magnesite precipitate in shallow, marginal marine lagoons and mud flats. Most mag-

Magnesite and dolomite outcrop in a creek bed, Mount Hutton deposit. (Photo 47257)

Magnesite and dolomite interbeds exposed in a quarry at Myrtle Springs. (Photo 47255)

nesite has been reworked by storm and tidal activity into widespread intraclast conglomerates of variable grainsize and sorting, with variable detrital silt and dolomite within the matrix.

The magnesite occurs as thin interbeds in dolomite, with individual magnesite beds ranging in thickness from <0.5 to 5 m and cropping out over distances of up to 10 km throughout EL 2100 and 2565.

Airborne spectrometer imaging

In November 1998, Pima commissioned Integrated Spectronics Pty Ltd to continue trial flights of the hyper-spectral visible–short wave infrared airborne imaging spectrometer (HyMap™; see article on previous survey in MESA Journal 11, pp.7–11). The HyMap survey was flown on 25 November 1998 and extended from Mount NorWest southeast through Termination Hill and Pug Hill to Playfair Well. Two lines were also flown over Witchelina with stunning results (Fig. 2). The extent of the Witchelina basin has been clearly defined and, more importantly, magnesite beds not previously mapped have been clearly identified.

Results of the HyMap work have significantly upgraded the inferred resource at West Mount Hut and pointed to new exploration targets at Screechowl Creek, West Mount Hut, Witchelina, Termination Hill and Pug Hill.

Drilling

Between October 1998 and February 1999, SAMAG completed 5199.1 m of fully cored diamond-drilling at Mount Hutton, Myrtle Springs, Pug Hill, Termination Hill and Witchelina. The programs were undertaken by John Nitschke Drilling Pty Ltd and Coughlan Drilling Pty Ltd. All core was logged, and magnesite intersections quartered and sampled at the Lyndhurst core shed.

A further program of resource definition drilling was undertaken at Mount Hutton between July and September 1999. Fifty fully cored holes (total 2895 m) were drilled on 20 sections located 250 m apart along the main package of magnesite beds (numbers 1–17). This provided engineering, mine planning and geological resource data.

pects drilled. The thicker magnesite beds are separated by wide dolomite interbeds, so that even though the magnesite beds are large, the ratio of magnesite to dolomite is essentially the same.

The magnesite beds at Witchelina are folded around a shallow, north–south elongate syncline (see Fig. 3). Magnesite bed 4 (average width 8 m) is buried by <10 m of dolomite overburden as the beds 'close-out' to the south of the syncline. The subparallel limbs of bed 4 crop out on either side of the north-northwest–south-southeast fold hinge (eastern limb dips 15°W, strikes 350°; western limb dips 30°E, strikes 330°).

This unique combination of flat-lying geometry and an exceptionally thick magnesite bed provides a 10-year resource (200 000 t/year) at stripping ratios of <1 to 1. SAMAG has identified a measured resource of 23.7 Mt as part of a total estimated 217 Mt magnesite resource at Witchelina.

Fig. 2 HyMap image of the Witchelina magnesite deposit delineating magnesite lithology (blue colour) and structure.

The Mount Hutton resource now comprises the following contained magnesite:

	Mt
• Measured resource	18.3
• Indicated resource	42
• Inferred resource	53
Total resource	**113.3**

Witchelina

Forty-six fully cored diamond-drillholes intersected ~25 magnesite beds ranging from 0.6 to 11.3 m in thickness, averaging 1.5–2.0 m, much thicker than at the other prospects drilled.

Termination Hill

Termination Hill deposit is folded about a major westerly plunging fold axis. Beds on the northern limb dip steeply to the southwest, averaging 75–85°. Beds on the southern limb dip ~35° to the northwest.

Magnesite crops out over a distance of 7 km, including both limbs of the syncline. HyMap data suggest that the package extends ~1200 m further to the north before significant burial occurs.

Central Termination Hill is relatively free of faulting and folding. Faults in the area express throws of 1–5 m. Magnesite beds in the area crop out well and are fresh at surface. Northern Termination Hill is subject to numerous small fault offsets.

Pug Hill

High-grade magnesite beds crop out over a 2.5 km length, ranging in thickness up to 2 m and dipping 55°SW. Initial inspection revealed a 5–10 m magnesite bed cropping out over a strike length of 2500 m. Magnesite outcrops are more continuous as beds fold and steepen to the west. Conspicuous, fine, convergent cleavage in competent magnesite is noticeable close to the hinge zone. Occasional larger bedding-parallel dolomite and quartz veining is often found along magnesite–dolomite interfaces.

Measured transects in creeks and areas of good outcrop exposure provided geological cross-section information on which to design the drilling program. Over 30 magnesite

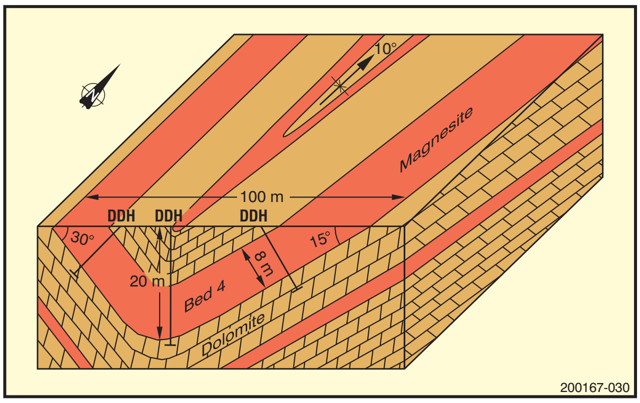

Fig. 3 Block-section of the Witchelina magnesite deposit.

beds were identified and numbered (1 = lowermost bed). A significant economic package of 16 magnesite beds was recognised, and mapping was concentrated on this 100 m thick (surface width) geological sequence.

At the northwestern end of the Pug Hill deposit, the beds fold into the hinge of the syncline, strike at 270°, and the dips increase to 70° to the southwest.

The major Norwest Fault truncates the westerly extension of the Pug Hill syncline. Combined with the influence of the Termination Hill Diapir, complex tectonics control structures further to the west.

Mount Hutton and Mount Playfair

Mapping has identified several major sinistral strike slip faults striking crudely southwest–northeast, with apparent offsets of 1–14 m. Patchy quartz outcrops mapped as dilational infill (parallel to bedding) have been interpreted as a result of the opening of bedding planes in response to the strike slip faulting.

Resource definition

The total measured, indicated and inferred resource in northern Flinders Ranges magnesite deposits held by Magnesium Developments Ltd now stands at 516 Mt with an estimated grade of 42.0% MgO (Table 1).

Table 1 *Magnesite resource (Mt) held by Magnesium Developments Ltd.*

	Measured	Indicated	Inferred
Mount Hutton	18.3	42.0	53.0
Mount Playfair	-	11.0	23.0
Pug Hill	-	10.0	10.0
Termination Hill	4.0	5.0	20.0
Witchelina	23.7	94.0	99.0
West Mount Hut	-	-	67.0
Screechowl Creek	-	-	36.0
Total	**46.0**	**162.0**	**308.0**

Mineralogy

Samples of core from Pug Hill, Termination Hill and Witchelina prospects have been described petrographically by Pontifex and Associates, with SEM and XRD analysis by CSIRO Division of Land and Water. The samples are dominated by pebble conglomerates with magnesite clasts ranging in size from 1 to 16 mm. Intricate intergrowths of clear microcrystalline dolomite and talc in variable concentrations comprise the matrix, along with minor amounts of albite, and rare quartz and tourmaline. No calcite has been observed in any of the samples so far examined.

Talc is the most abundant silicate mineral, occurring mainly between the magnesite clasts and mixed with microcrystalline dolomite; it is interpreted to be 'metamorphic', formed from inherent siliceous impurities. Albite, generally comprising <1% of individual samples, is considered to account for all Na, most Al and part of the Si reported by assay.

Small grains of tourmaline (~0.15 mm), comprising <1% of a given rock, have been identified in a number of samples. No other boron-bearing minerals were identified by petrography.

Ternary analytical diagrams (Fig. 4) demonstrate the geochemical consistency and low variability of the magnesite ore. Metamorphic talc is the major source of SiO_2,

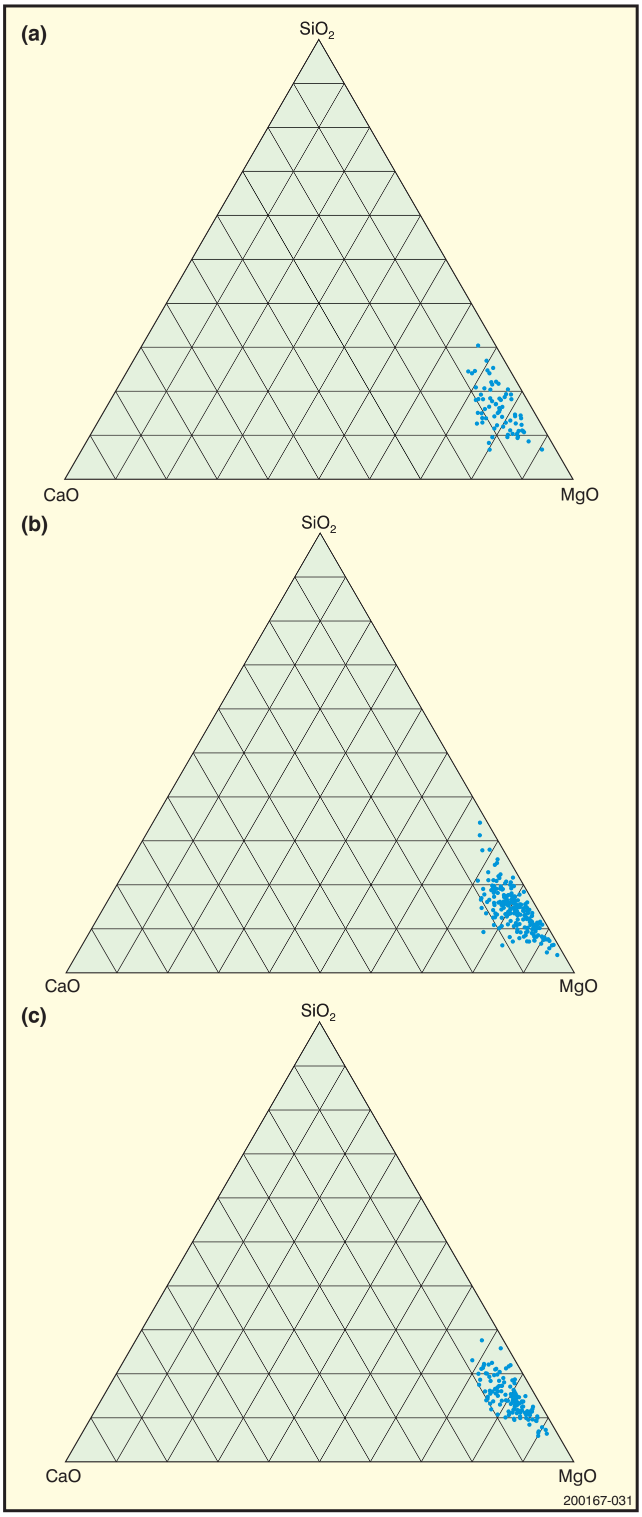

Fig. 4 *Ternary diagram showing MgO >40% for magnesite deposits near Leigh Creek.* ***(a)*** *Witchelina,* ***(b)*** *Termination Hill,* ***(c)*** *Pug Hill.*

and all CaO is derived from dolomite. The slight scatter for each deposit reflects differences between beds. Each individual magnesite bed has a highly consistent geochemical character and physical texture.

Beneficiation

Beneficiation of magnesite ore before leaching may save costs of contaminant removal in the magnesium plant. Flotation, gravity separation and scrubbing tests have been undertaken to remove dolomite which contributes calcium to the leach liquid, and talc which comprises most of the insoluble residue. Encouraging results were recorded from flotation testwork, and further tests are being undertaken by the Ian Wark Research Institute (University of South Australia).

Leach test work

A suite of six magnesite ore samples from Mount Hutton, Witchelina, Pug Hill and Termination Hill was submitted to Amdel for metallurgical testing. Batch leach tests were carried out following strict procedural guidelines provided by Hatch Associates, a Canadian consultant engineering group with experience in light metal processing plants. Results indicate that magnesium extraction for all samples was in the 80–95% total magnesium range when 90–100% stoichiometric acid addition was used. Soluble magnesium is even higher. The results also indicate that magnesium extraction was not enhanced when acid additions in excess of 100% stoichiometric were used. These tests indicated that the final magnesium dissolution and rate of dissolution are both dependent on the amount of acid present in the leach system.

At all temperatures, no significant activity (pH change) was noted when the initial pH of the $MgCl_2$ solution was higher than 6.5. At an initial pH lower than 6.0, neutralisation of the acid with magnesite was rapid. Raising the temperature of the system enhanced the kinetics of the neutralisation.

Dow technology

In August 1999, SAMAG entered into an agreement with Dow Chemical Company to purchase Dow's technology for the manufacture of magnesium. The company now has full access to Dow's magnesium technology database and patents for the building of a plant to manufacture magnesium. This was a major milestone in development of the South Australian Magnesium Metal Project. A basic manufacturing flow diagram is shown on Figure 5.

The Dow technology uses the electrolytic process for production of magnesium metal from magnesium chloride.

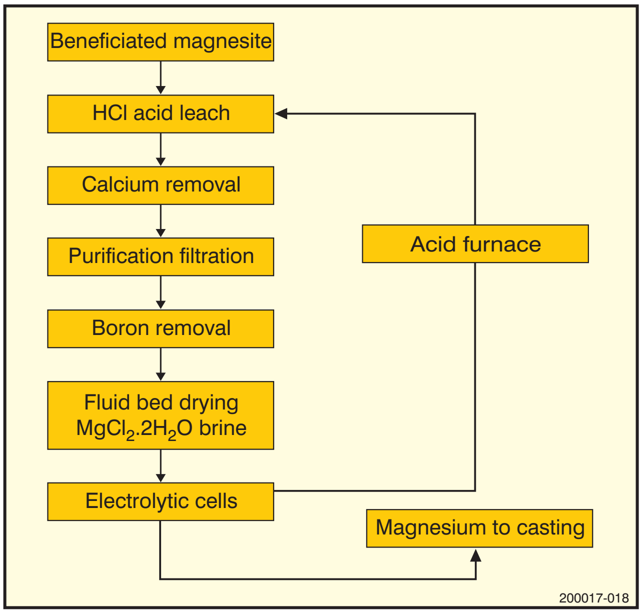

Fig. 5 *Block flow diagram of magnesium metal production.*

This comprehensively proven process provides SAMAG with:

- access to over 50 years of know-how in magnesium production
- reduction of construction and commissioning risks and elimination of the need for a pilot or demonstration plant
- accurate capital expenditure and operating expenditure costs on this well-established technology.

Mine design

The Mount Hutton magnesite deposit has been selected for mining by SAMAG as it offers high-grade, low-calcium ore and short ore hauls to Telford Siding. Open-cut mining will commence on MC 3098, north of Mount Hutton, and progress southwards to MC 3099 and 3100. The mine site is in a broad, unvegetated gully between two northwest –southeast-trending ridges.

Mount Hutton magnesite occurs as a 100 m wide package of steeply dipping sedimentary beds (Fig. 6) that extend over a considerable strike length. The open cut will therefore be long and narrow. In order to mine the ore, layers (beds) of ore and waste will be 'peeled' from the mining faces. The deposit will be mined from the east to enable the open cut to progress to the south. To facilitate this selective mining technique, each bench will require a number of stepped faces, 20 m in length, at the southern end of the pit (Fig. 7).

Government assistance

In addition to coordinating the prefeasibility study by Hatch Associates, PIRSA has been responsible for undertaking mapping and sampling of several of the deposits, including the trialing of the first HyMap survey over the Screechowl Creek deposit. The Department has also undertaken ore characterisation and mineralogical studies (Keeling *et al.*, 1998). PIRSA is commended for their recognition of the potential of these deposits and their potential for use in the manufacture of magnesium metal.

In granting EL 2565 to SAMAG Ltd in November 1998, the Deputy Premier and Minister for Primary Industries and Resources, Natural Resources and Regional Development referred to the project as a 'flagship project, which will stimulate regional development.' Premier John Olsen, on 26 February 1999, announced 'a dedicated team to oversee and facilitate' the project, and also undertook to promote to the

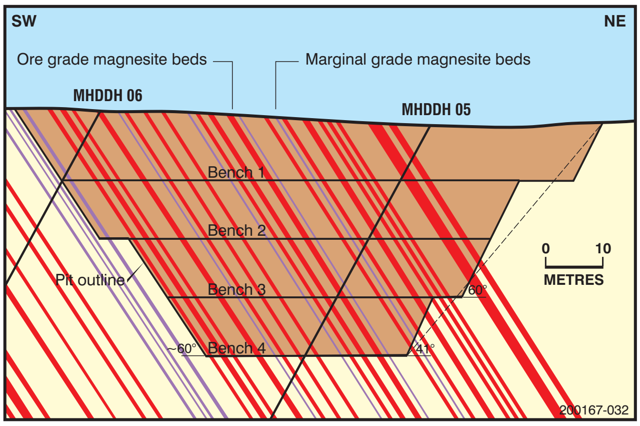

Fig. 6 *Cross-section through the Mount Hutton magnesite deposit.*

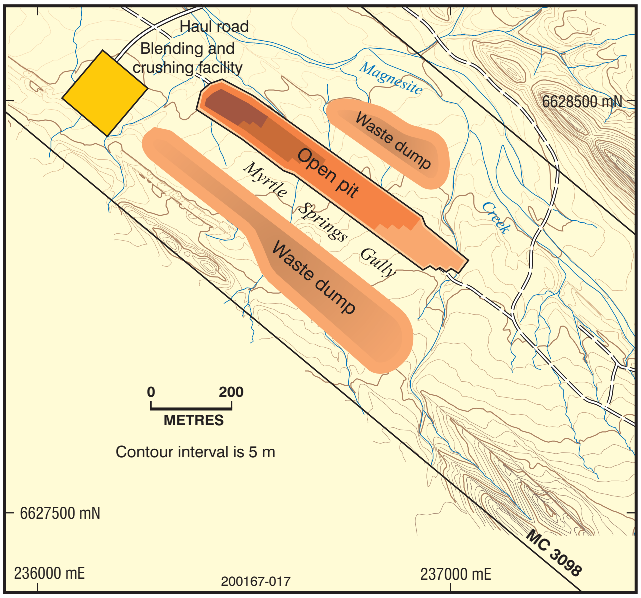

***Fig.** 7 Site design for the proposed Mount Hutton magnesite mine.*

Commonwealth the possibility of 'granting the project major project facilitation status.'

Competitive advantages

This project has some key advantages that will make it one of the lowest cost producers in the world and at the forefront of new entrants to the rapidly growing magnesium metal market. These advantages are:

- secure mineral tenure
- large, outcropping, magnesite deposits, allowing low-cost mining
- high-quality, low-impurity magnesite (+42% MgO) with fast acid leach times, permitting reduced capital and operating costs
- existing rail line from Leigh Creek to Port Augusta, providing low-cost transport of ore to the plant
- access to competitively priced power
- readily available coolant water from Spencer Gulf at Port Augusta
- a large, skilled work force is readily available
- established township and other infrastructure facilities
- low-risk proven process technology.

Environmental impact assessment

SAMAG is committed to the effective management of environmental issues and protection of Aboriginal and European heritage, which may be affected by mining activities and associated developments.

The proposed development falls into three areas — mining, ore transportation and magnesium metal production. Mining aspects are being dealt with under a mining operations approval required by the *Mining Act 1971*.

The SAMAG project is required to prepare an Environmental Impact Statement under the provisions of the *Commonwealth Environment Protect (Impact of Proposals) Act 1974*. An issues paper was released by the Major Developments Panel under Section 46 of the *Development Act 1993* to gain public input into what are considered to be the significant issues relating to the magnesium metal production facility.

SAMAG has evaluated the potential environmental issues that could be expected from the proposed development. This evaluation has included visits to similar production plants around the world, extensive literature research and the hiring of expert consultants to review and report on the alternative plant engineering and technical aspects of the world's commercially operating magnesium production plants. This research has covered all possible aspects of environmental and economic issues relating to magnesium production.

It is SAMAG's policy to address potential environmental issues from the design stage onwards to final site rehabilitation. The research undertaken to date has provided the basic environmental requirements for the engineering design and for the plant operating, monitoring and management plan.

The main objectives of the plant design and operation are therefore to:

- minimise fugitive gas releases
- store solid waste on site
- operate with a zero liquid effluent release
- minimise the storage and transportation of hazardous materials.

SAMAG has designed the magnesium plant to take into account all of the emission controls stipulated by the Environmental Protection Authority. The company will participate in the 'Greenhouse Challenge' and is investigating a number of initiatives to minimise the emission of carbon dioxide (CO_2).

Future program

The company is working towards a bankable project by March–April 2000 and commencing construction in the June–September 2000 quarter. Initial production is scheduled for early 2003.

SAMAG is negotiating with potential project partners and off-take users in the automotive and die-casting industry, and is progressing the preparation of an Environmental Impact Statement for release early in 2000. Native title negotiations have been initiated with respect to the proposed mine site. Additional detailed engineering design is in progress and metallurgical test work is continuing.

Low-cost, high-quality ore, economic energy, proven technology, an expanding market and a clear expansion path will help SAMAG achieve its goal of becoming a leading low-cost producer of magnesium metal.

For further information contact Ric Horn (ph. 08 8338 4242) or visit the website (www.pima.com.au).

References

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Keeling, J.L., McClure, S. and Raven, M., 1998. Mineralogy and chemistry of Proterozoic magnesite ores from South Australia. *CSIRO Land and Water, and Primary Industries and Resources South Australia. Technical Report,* 7/98 (unpublished). ■