

# **HITEC MINERALS PTY LTD**

## **PROSPECT RIDGE MAGNESITE PROJECT**

### **AN OVERVIEW OF THE INITIATION OF EXPLORATORY TESTWORK DEVELOPMENTS**

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PREPARED BY

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# 1 INTRODUCTION

Process Technologies Australia Pty Ltd (PTA) has been retained by HiTec Minerals Pty Ltd (HTM) to provide technical advice on appropriate steps that would, potentially, lead to the development of a magnesite resource located in North West Tasmania. In particular this involved a review of exiting historical data and the management of suitable testwork programs.

Prior to providing a brief summary of the objectives and preliminary outcomes of an exploratory series of laboratory-scale testwork procedures to yield a marketable caustic calcined magnesia (CCM) product from the Prospect Ridge Magnesite Resource (PRMR), it is considered appropriate for PTA to outline the content and recommendations of an earlier report prepared by PTA in relation to the general history of the PRMR.

PTA noted in its report dated 22 May 2017 a number of key issues with respect to recovery of marketable products from the PRMR. These and several other issues are noted below.

- PRMR has been subjected to various levels of development from limited drilling to incomplete feasibility evaluation at the PFS level of accuracy for the production of both caustic calcine magnesia (CCM) and dead burned magnesia (DBM). For a combination of both technical and commercial reasons the previous holders of the PRMR leases decided against undertaking any further development activities.
- Crushed/screened run-of-mine (ROM) magnesite and CCM of various grade typically are based at the lower end of the market value regime, and are mirrored by lower capital and operating costs when compared with those of DBM and more particularly with fused magnesia (FM). Not surprisingly, the metallurgical and engineering challenges increase substantially from CCM to DBM to FM.
- As a general comment, the chemical specifications of FM are more rigorous than those of DBM which in turn are more rigorous than those of CCM.
- A resource estimate for PRMR in accordance with the 2012 JORC code has been completed and reported by Jindalee Resources Limited (1). There is a significant opportunity to grow the scale of this Resource at Arthur River and at Lyons River (1). This upgraded resource estimate and report were completed subsequent to the PTA May 2017 review report noted above.
- While prior studies established that it is technically possible for produce various grades of CCM and DBM from the PRMR, virtually all of the historical data generated prior to 2010 is of no direct value to the generation of a bankable feasibility study (BFS). This is a direct reflection of the limited scale of development work undertaken, availability of test samples, etc. At no stage have suitable samples of final products been produced for market and end-use studies.
- The draft (but substantially incomplete) PFS and associated documents would provide a template for management to initiate the detailed geological, mining, metallurgical, environmental and engineering activities, as well as infrastructure and marketing considerations, required for management to make rational decisions on if, when and where to develop PRMR to a commercial operation.
- The magnesite/magnesia industry has undergone a number of changes over the past decade or so with many new producers, existing operations either mothballed or closed, and changes to product tonnage, specification and uses.

- CCM is and almost inevitably will be the logical end product if and when development of the PRMR becomes a commercial reality.
- Visual, chemical and mineralogical (XRD) analysis of selected drill core samples indicate that magnesite is the primary mineral component of the entire resource, with lesser amounts of the total magnesium content present in the form of dolomite. In some instances the dolomite is clearly intergrown with magnesite at the mm level while in other instances the dolomite can be clearly identified as a separate mineral phase. The intergrown dolomite is typically more difficult to physically separate from the host structures. Minor phases including free quartz, sheet silicates (talc) and “iron oxide” appear to be randomly located throughout the entire resource, with a higher proportion in what has been termed “weathered” magnesite. Calcination of a number of split core samples indicated that the magnesite component contained variable amounts of iron at the atomic level of substitution. Physical separation of this iron component of the magnesite is virtually impossible.
- Even though based on the very limited knowledge of the vertical and horizontal structure of the PRMR, it would appear that PRMR is more geologically and mineralogically complex than many of the magnesite mining/processing plants now in commercial operation. This limits the availability of suitable sources of comparative data as a guide to development of a sustainable commercial PRMR operation. Appropriate domaining of the existing resource from a geological and mineralogical perspective is recommended.
- Whatever the end use, run-of-mine magnesite will, almost without exception, be subjected to a range of physical beneficiation steps in order to meet final magnesia product chemical and physical specifications. Physical beneficiation of intermediate products may be required.
- Consideration of the available open technical literature clearly indicates that the principal physical beneficiation technique applicable at PRMR is froth flotation in combination with selective screening (size separation), both before and/or after calcination. Gravity, optical and magnetic separation steps have been proposed, largely in some of the academic studies, for selected samples from other resources.
- Although not routinely tested, largely because of the limited availability of bulk as-mined sample, it is possible that selective screening to remove liberated fines such as iron oxide and/or sheet silicates may be applicable.
- Calcined magnesia is considerably softer than, for example, dolomite and quartz. Selective screening of controlled crushed and ground calcined magnesite may be capable of removal of harder, coarser impurity fractions.
- The literature evaluation clearly demonstrates that there is no universally applied flowsheet before and/or after calcination.
- In contrast to conventional froth flotation of base and precious metal sulphide ores where the objective is to produce a “high” grade concentrate at a commercially sustainable recovery rate with the bulk of the feedstock discharged as tailings, physical beneficiation of a magnesite-rich feedstock involves removal of the bulk of the impurities in order to increase the magnesite component from say 85% to 95% and a correspondingly lower volume of tailings. The recovery rate can be significantly affected by the mineralogical complexity of the feedstock.
- The available technical literature would suggest that while magnesite itself can be recovered by froth flotation, a more logical approach would be to float the bulk of the

impurity mineral phases – the so-called reverse flotation approach. In the case of PRMR this would involve the “selective” flotation of quartz, sheet silicates and possibly iron oxides.

- Separation of dolomite from a magnesite-rich matrix via froth flotation is marginal at best, especially where the two mineral phases are intergrown at the micron level. As noted above, some separation of free dolomite from free magnesia from calcined feedstock may be possible by selective screening.

## 2 TESTWORK PROGRAMS

One of the objectives of the testwork programs initiated by HTM was to confirm that one or more grades of marketable CCM could be generated from the existing PRMR samples ahead of committing to the generation of the detailed and commercially critical PFS/BFS documentation.

In reality, the extent of the testwork undertaken by HTM to date has been limited as a direct consequence of the lack of suitable samples. At the present time, the available samples are limited to split diamond drill core samples recovered from previous ore resource definition studies. Thus testwork has been limited to laboratory scale batch procedures and excluded any attempt to develop new processing techniques, process reagents, etc. For obvious reasons it has not been possible to optimise any of the processing conditions.

In summary form, the testwork program consisted of the following techniques:

- Calcination to establish the temperature required to thermally decompose magnesite to crude reactive magnesia.
- Acid dissolution tests on selected crude magnesia products to establish their chemical reactivity.
- Physical beneficiation by screening and froth flotation of selected samples, both before and after calcination.
- Determination of the Bond Ball Work Index as an indication of the energy input required for comminution (grinding).

Three separate testwork programs using different split core samples were initiated:

- Small samples (typically 100-150 g) of selected drill core samples with variable magnesite contents crushed to 100% -2 mm and calcined at temperatures between 500°C and 1000°C for 1 h in a laboratory muffle furnace in a static atmosphere. Weight loss, size distribution, chemical assay and chemical reactivity data indicated an operating temperature of 800-850°C yielded a suitably reactive CCM. Depending on the initial sample, the MgO contents of the products were in the range 80-92%. The main contaminants were chemically analysed as CaO, Fe<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub>.

As a result of calcination, ferrous iron substituted in the magnesite crystal lattice was oxidised to the ferric state. Similarly, there was some evidence that the iron component of the talc was also oxidised. Because of the dispersed nature of this iron oxide (nominally hematite) it was not generally possible to remove this impurity phase by, for example, magnetic means. There was, however, some evidence that a small amount of iron oxide initially present as discrete goethite, was converted to hematite/magnetite.

The oxidation of ferrous iron during calcination was mirrored by a change in colour from off-white to a pronounced fawn.

Although there was a change in size distribution as a result of calcination, with a higher portion at the smaller particle size fractions, the small scale of the tests precluded any realistic assessment of the potential of upgrading purely on the basis of particle size degradation.

The chemical reactivity indices were determined by the rate and extent of dissolution of a given weight of sample in hydrochloric acid at pH 1 and confirmed the proposed 800-850°C calcination regime. It is noted that this needs to be confirmed at the continuous operating stage, along with the original feed size and the retention time. Several samples of commercially available CCM products were used for comparison purposes.

***All of the data generated indicated that a chemically reactive calcine could in principle be produced from the PRMR. However, a target MgO content of +95% was not routinely achieved, mainly because of the lack of any physical beneficiation steps and the mineralogical characteristics of the feedstock.***

- Two larger composite samples were prepared from selected samples of split drill core. One sample nominally termed “fresh composite” corresponded to a realistic average sample, the other “oxide composite” or “weathered composite” that clearly had a higher gangue (talc, iron oxide) content that represented a non-ideal (worst case) sample. The “fresh composite” had a higher dolomite content, as indicated by the higher CaO content.

XRF and XRD analyses confirmed the chemistry (%) and mineralogical contents of the two composites.

	CaO	Fe <sub>2</sub> O <sub>3</sub>	MgO	SiO <sub>2</sub>
“Fresh Composite”	2.14	1.11	44.0	4.15
“Oxide Composite”	0.83	2.94	42.6	6.36

In terms of the measured Bond Ball Work Index of 11.7 kWh/t and 7.0 kWh/t for the “fresh” and “oxide” composite samples respectively, they can be classified as “medium” and “soft” respectively. This data is required to specify the design criteria of the comminution circuit.

Based upon the available technical literature, flotation tests designed to remove the silica-rich (talc) gangue were carried out using several different combinations of HCl for pH adjustment, sodium phosphate for slimes dispersant, copper sulphate as activator, and MIBC as frother. The flotation reagent regime was not optimised, but as would be expected, a somewhat higher degree of silica rejection could be achieved using a rougher/cleaner flotation configuration rather than a conventional single stage circuit. The flotation tests were carried out with both “fresh” and “oxide” composites and their 850°C calcines.

In summary, the flotation tests showed that:

- (a) a significant portion of the silica-rich gangue can be removed by flotation although the MgO recovery is diminished;
- (b) removal of the silica-rich gangue from the calcine is less efficient with lower MgO recoveries;
- (c) flotation of the “oxide” composite is technically more challenging than the “fresh” composite; and
- (d) lowering the silica content has no overall significant effect on the iron content of the flotation products.

**Although flotation can enhance the quality of CCM derived from PRMR, the results clearly show that a higher silica/magnesite selectivity would be required to ensure that the overall MgO recovery at the end product target specifications would not be compromised.**

- Following the generation of the above data it was decided to assess the potential of adopting a more conservative approach to sample selection. That is, be more selective in sample selection from the split diamond drill core in order to minimise the overall gangue content. The rationale for this approach was partly driven by the fact that the detailed mineralogy of the entire resource was quite limited and that the samples available and subjected to testing may in fact be outliers.

A “high purity” sample of split drill core based on visual examination and chemical assay was assembled and subjected to calcination at 850°C. Analytical data (%) for the feed and calcine were as follows:

	CaO	Fe <sub>2</sub> O <sub>3</sub>	MgO	SiO <sub>2</sub>
Feed	0.98	0.74	45.6	0.60
Calcine	1.96	1.34	92.5	1.40

***This calcine should be marketable as a CCM product without any further beneficiation. However, it is not clear at this stage if there is sufficient run-of-mine ore of the required quality that would justify the extent of ore characterisation and mine planning that would be required to make the project economically sustainable based on selective mining and one product only. Domaining/characterisation of the current resource from a geological and mineralogical perspective would assist in defining the potential of “high grading” may represent.***

### 3 WHERE NEXT

From a processing point-of-view, the most significant challenge in developing a technically and commercially viable magnesite mining/magnesia production project based on the Prospect Ridge resource relates to its relatively complex mineralogical composition, and in particular, the lack of detailed knowledge of the vertical and horizontal distribution of the gangue minerals. At the outset, this requires execution of a robust drilling program and the recovery of bulk samples and end products suitable for market evaluation.

From a commercial point-of-view, it is essential that the developer fully understand the magnesite/magnesia industry and establishes appropriate links with end users. What and how much do the various end users require? The market is not static and new producers and new applications continue to evolve.

PTA is strongly of the opinion that development of the PRMR should be restricted to the production of various grades of CCM. This is based upon the mineralogical complexity of the resource itself, its location, competing projects, and market opportunities. In particular, PTA notes that there is an expanding market for CCM in the agricultural and metallurgical/environmental industries as an alternative to lime/limestone. For example, there are fewer problems with scale formation and avoids the co-generation of gypsum. Not only does this increase the volume of solids to be handled but can also have a deleterious effect on process water balance, key issues in many hydrometallurgical operations. Examples include treatment of acid mine drainage and for pH control in mixed hydroxide precipitation circuits. As a general comment, these applications of CCM do not necessarily require high purity products so that mine planning, physical beneficiation and

calcination can be simplified. The key property of the CCM is its chemical reactivity. The Prospect Ridge resource could well be developed for such applications.

***In summary form, PTA is of the opinion that the next steps required to develop the Prospect Ridge Magnesite Resource prospect, via preliminary and subsequently bankable feasibility studies, as a commercially viable operation include the following initial major steps:***

- ***Geological and mineralogical domaining of the existing resource with particular emphasis on identification of regions of high grade/low gangue ore.***
- ***Use the domaining outcomes to identify targets for in-fill drilling, characterisation of selected samples, and subsequently facilitate potential mine planning as well as provision of bulk samples for testing and end-product evaluation.***
- ***Complete integrated pilot scale crushing-grinding-flotation-calcination testwork programs to produce realistic masses (say 0.5 – 1 t) of CCM end products (3 - 5 different grades) for market evaluation.***
- ***Establish and maintain watching brief on magnesite/magnesia developments (producers and end users) in Australia and overseas,***

#### **4 REFERENCE**

- (1) ASX release by Jindalee Resources Limited dated 9 October 2017: ARTHUR RIVER MAGNESITE DEPOSIT – JORC (2012) RESOURCE ESTIMATE.