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BAYMAG - High purity MgO from natural magnesite

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BAYMAG - High purity MgO from natural magnesite

Refratechnik, a leading German refractory company, acquired a majority shareholding in Baymag in 1979. This acquisition included the mining rights for a magnesite deposit of exceptionally high purity in the Canadian Rocky Mountains.

The deposit, situated in the Kootenay region, is of Cambrian age and has proven ore reserves of 50 million m.t. of magnesite. The Baymag magnesite deposit is one of the purest in the world. The deposit was opened up and mining commenced in early 1982. The production of various caustic calcined magnesia products in a rotary kiln operation in Exshaw, Alberta was started in mid 1982. The product application ranges from pulp and paper production over chemical industry to animal feed supplements. Since the end of 1983, Baymag has produced high quality refractory grade fused magnesium oxide for specialty applications in the steel industry.

Introduction

Despite the fact that magnesium is the eighth most plentiful element in the earth and forms about 2.06% of the earth's crust, common knowledge about magnesium and especially magnesium oxide as an industrial mineral is not very distinct. The main reason might be that with the exception of magnesium metal as the element, a negligible amount of MgO qualitites are sold as final products to end users, but rather are needed for the production of final products such as steel, cement, paper etc. Therefore some general words should be said about the different sources of MgO, the different products, world production and consumption, before Baymag specifics are addressed. Magnesium metal will not be discussed in this paper.

Sources of Magnesia

While the element Mg is found in 60 or even more different minerals, only magnesium carbonate or Magnesite ($MgCO_3$) and to a far lesser degree, Brucite, the natural form of magnesium hydroxide ($Mg(OH)_2$), are commercially used to produce MgO. Aside from the extraction of MgO from these natural sources, the synthetic production of magnesia from seawater and brines plays an especially important role for higher grade products.

Magnesite, is mined in about 30 - 35 countries from more than 65 deposits. It occurs mainly in two different forms: as coarse crystalline and crypto-crystalline magnesite. Knowing that theoretically 2.4 g of MgO can be extracted out of each liter of seawater and that all oceans together contain 51×10^{15} m.t. of water, the reserves seem infinite. It is difficult to compare production of MgO from natural ores with a seawater magnesia operation, because the comparison is between a mining operation and a chemical plant. The process of obtaining MgO from seawater is definitely more complex than the rather simple calcination of $MgCO_3$ to MgO. As shown in Table 1 below, it is necessary to first produce a material you do not want, calcined limestone or dolomite, to obtain magnesium hydroxide sludge - after an ion exchange reaction - which is finally calcined to MgO.

TABLE 1: **MAGNESIA PRODUCTION PROCESSES**

NATURAL MAGNESITE PROCESS

$$MgCO_3 \xrightarrow{T} MgO + CO_2\uparrow$$

SEAWATER PROCESS

a1. $CaCO_3 \xrightarrow{T} CaO + CO_2\uparrow$

a2. $CaO + H_2O \longrightarrow Ca(OH)_2$

b. $Ca(OH)_2 + MgCl_2 \longrightarrow CaCl_2 + Mg(OH)_2$

c. $Mg(OH)_2 \xrightarrow{T} MgO + H_2O\uparrow$

The purity of the final product depends very much on the complexity of the chemical system and mainly on the purity of the limestone or dolomite. A very important contaminant, boron oxide, should be mentioned. Boron oxide which is characteristic of seawater magnesia, is damaging to the refractoriness of a dead burnt MgO product.

WORLD MARKET

Some general figures about the magnesia world market should be given, before switching specifically to Baymag. As Table 2 illustrates, the production capacity of caustic calcined and dead burnt magnesia adds up to about 7 million mtpy, excluding figures for the USSR which vary between about 2 and 4 million mtpy, pointing out as well that dead burnt MgO is by far the leading product between the two.

TABLE 2: **WORLD PRODUCTION CAPACITY**

WORLD PRODUCTION CAPACITY

MAGNESIA

NATURAL MAGNESITE*	
CAUSTIC CALCINED MAGNESIA	$= 1.0 \times 10^6$ MT
DEAD BURNT MAGNESIA	$= 3.5 \times 10^6$ MT
SEAWATER/BRINE MAGNESIA	
CAUSTIC CALCINED AND DEAD BURNT MAGNESIA	$= 2.5 \times 10^6$ MT

*USSR NOT AVAILABLE

While dead burnt MgO only serves as a raw material for the production of basic refractories -the consumption for steel making refractories is by far the leading application- caustic calcined magnesia's applications are of a far higher variety. Table 3 gives a rough idea of only the more important applications. This diversified structure is the main reason for a higher stability of this tonnage-wise smaller portion of the magnesia market.

TABLE 3: **APPLICATIONS**

APPLICATIONS

CAUSTIC CALCINED MAGNESIA

1. ACID NEUTRALIZATION
2. ANIMAL FEED SUPPLEMENT
3. CELLULOSE ACETATE
4. EPSOM SALT
5. FERTILZER
6. FLUE GAS DESULPHURIZATION
7. MgO BASED CEMENTS
8. PHARMACEUTICAL INDUSTRY
9. PULP & PAPER INDUSTRY
10. RUBBER/RAYON INDUSTRY
11. SUGAR REFINEMENT
12. URANIUM REFINEMENT
13. WATER TREATMENT

BAYMAG - The Company

Baymag, a 100% German owned company has been commercially producing caustic calcined magnesia since June 1982. Baymag Mines Co. Limited was founded in 1971 in Calgary as a amalgamation of Baykal Minerals Ltd. and Brussilof Resources Ltd. Exploratory work and claim staking in the Mt. Brussilof area near Radium Hot Springs, B.C., goes back to the mid 1960's after the magnesite deposit was originally discovered by G.B. Leech of the Geological Survey of Canada in 1966. The first extensive feasibility study about exploitation of the deposit for production of up to 200,000 mtpy of dead burnt MgO was carried out by Acres in 1970/71 and was based on a large diamond drilling program. The results of the study were very encouraging.

In 1973/74 additional core drilling by Canex Placer Ltd. as well as preliminary technical Research and Development for the production of MgO products were carried out at Veitscher Magnesitwerke, Austria.

The contacts between Refratechnik, Baymag's parent company and Baymag go back to the year 1975. Refratechnik, a major German producer of refractory products, showed interest in the Baymag deposit, due to the lack of deposits in Germany, and the possibility of securing a raw material source. Between these initial contacts and 1979, several research programs were carried out to develop modern technology for calcining and dead burning Baymag magnesite.

In 1979 Baymag was finally acquired by its German owners and a large feasibility study was carried out by Techman/Kilborn which was finished in 1981. The positive outcome of the study finally led to large scale industrial testing of calcining Baymag magnesite in a rotary kiln at Canada Cement LaFarge, Exshaw, Alberta in the spring of 1981. The exciting results of these tests, as well as an agreement between Canada Cement LaFarge and Baymag about the leasing of part of the Exshaw facilities (including 2 rotary kilns), formed the basis for Baymag's successful beginning in the caustic calcined magnesia market. In mid 1982 reconstruction of the existing facilities turned them from a cement to a magnesia production plant.

The Deposit

As mentioned before, the Baymag/Mount Brussilof Magnesite Deposit was originally discovered in 1966 by G.B. Leech of the Geological Survey of Canada (GSC) during summer field mapping in the vicinity of the Rocky Mountain Trench at the British Columbia/Alberta border. Leech indicated that magnesite occurs within the Cathedral Formation of Middle Cambrian Age along the west flank of Mount Brussilof near the confluence of the Cross and Mitchell Rivers. The deposit lies on a west-dipping limb of a broad anticline. The beds strike north 30° west and dip southwest at 20-40°. No major faulting has been found. The exact geographical position is 115° 39' west and 50° 49' north. Magnesite was also noted to occur at the south end of the ridge between the Mitchell River and Assiniboine Creek, within the same formation. Grab samples were collected and analyzed by the GSC and found to contain up to 97% $MgCO_3$.

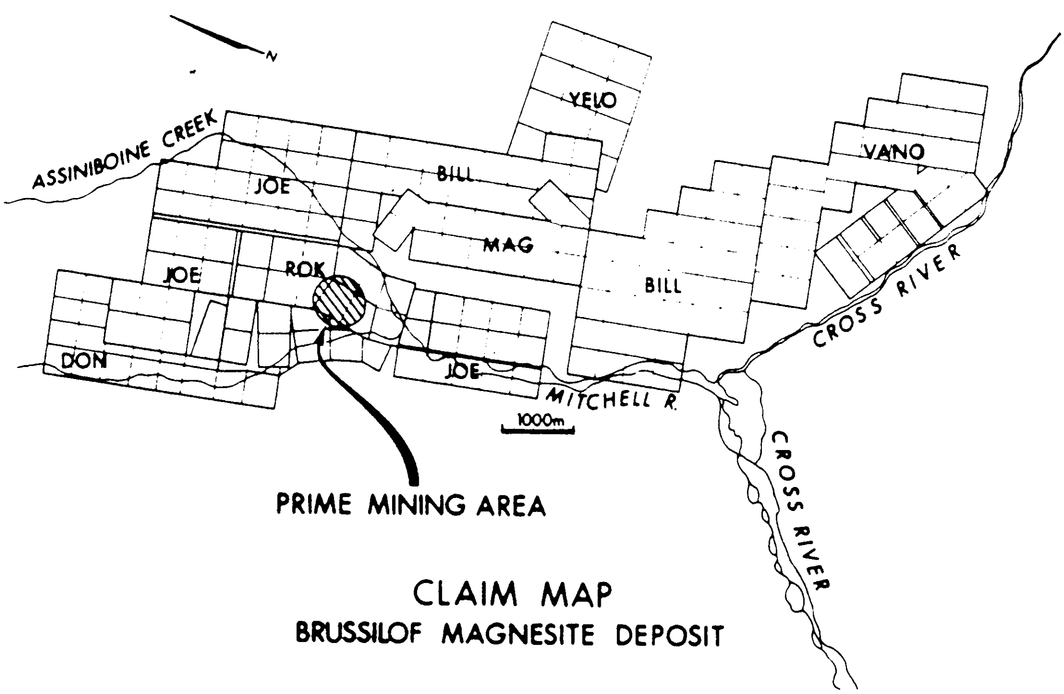

FIGURE 1: **CLAIM MAP**

Shortly after, a claim staking rush started by several different companies, leading finally to the configuration shown in Figure 1 with 233 claims in total. This block extends from approximately 8 miles north of the prime mining area to approximately 10 miles south of the Cross River/Mitchell River confluence. Exploration carried out within the claims indicated that the magnesite ore is present throughout the block.

Exploratory core drilling to date consists of 59 holes varying in length from 32.3 m to 143.3 and totalling to 5,255 metres (17,239 feet), see Figure 2. The drill hole spacing over the deposit is variable with most of the reserves indicated being extrapolated beyond the drilled area. A total of 1,160 samples of core were assayed for MgO, CaO, Fe_2O_3, Al_2O_3, and SiO_2 in predominantly 10 foot (64% of samples) and 20 foot (23% samples) lengths.

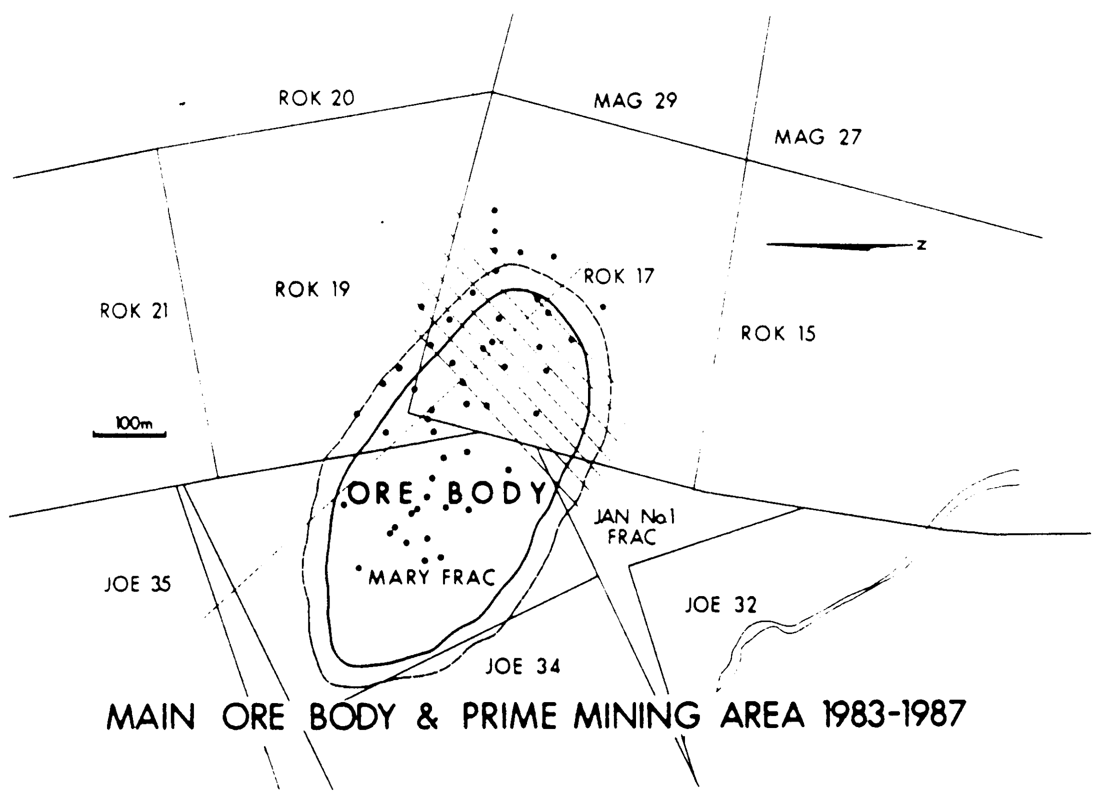

FIGURE 2: **MAIN ORE BODY & PRIME MINING AREA 1983 - 1987**

The proven and probable geological reserves in the vicinity of the prime mining area were calculated by Techman Engineering Ltd. to total approximately 9.5 million tonnes of High Grade ore of +95% $MgCO_3$ and 13.6 million tonnes of ore containing 93-95% $MgCO_3$. An additional 17.6 million tonnes of ore, with an average grade of 92.44%, have been identified as possible reserves with the deposit.

The precise geometry of the Mount Eon magnesite deposit cannot be defined due to inadequate exposure and incomplete penetration by diamond drilling. The deposit, as has been drilled thus far, is approximately 790 m in length (along a NW-SE axis), and about 500 m wide (along a NE-SW axis). The maximum thickness of the ore body is at least 120 metres.

The main lithologies present on the Baymag property include magnesite, dolomite with minor limestone, quartzite, shale and argillite. Magnesite which occurs mainly as white, very coarsely grained, massive, crystalline rock is quite resistant and weathers to light buff-coloured projections with overhanging cliffs. Dolomite and dolomitic limestone lenses occur within the magnesite. As well, thin irregular stringers of finely crystalline pyrite occur in fracture fillings.

Some controversy exists as to whether the origin of the magnesite is sedimentary or replacement. Although the deposit is rather massive and bedding is rarely seen, there are some sharp contacts with the surrounding dolomite. These contacts could be evidence that the deposit had a sedimentary origin. Conversely, the presence of many veins and veinlets, indicative of hydrothermal emplacement, and the presence of some gradational contacts with the dolomite, suggest the magnesite might have resulted from replacement phenomena. While magnesite is the most predominant mineral, with dolomite, pyrite and calcite present to a lesser extent, other minerals including leuchtenbergite, sericite and illite are present in minor quantities and constitute most of the alumina and silica content in the deposit, as shown in Table 4.

TABLE 4: **TRACE MINERALS IN THE BAYMAG DEPOSIT**

Anberite $Ca(Mg,Fe)\ [CO_3]_2$
Pentlandite $(Fe,Ni)_9S_8$
Boulangerite $Pb_5Sb_4S_{11}$
Muscovite $KAl_2\ [(OH,F)_2/AlSi_3O_{10}]$
Leuchtenbergite $(Mg,Fe^{2+},Al)_6\ [(OH)_8/Al_{>0.5}Si_{<3.5}O_{10}]$
Phlogopite $KMg_3\ [(OH,F)_2/AlSi_3O_{10}]$
Talc $Mg_3[(OH)_2/Si_4O_{10}]$
Palygorskite $(Mg,Al)_2\ [(OH)/Si_4O_{10}]\ .\ 2H_2O + 2H_2O$

Ore quality and quantity as shown in Figure 3 were evaluated using a geostatistical computer program (Kriging method) and were based on the results from exploratory drilling. These results showed that the Baymag deposit is the largest and most pure coarse crystalline magnesite deposit of the western world and that it is possible to consistently ensure an ore quality, for the production of magnesia qualities with +97% MgO contents, by using strictly controlled selective mining with no special ore treatment or any beneficiation.

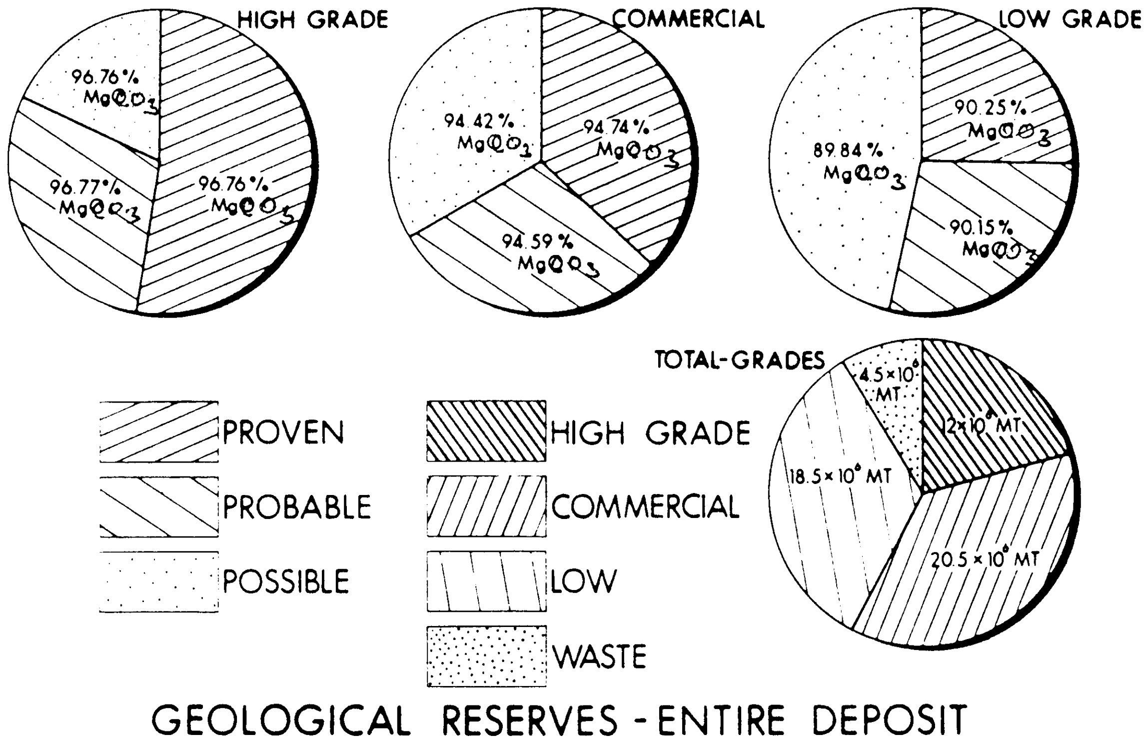

FIGURE 3: **GEOLOGICAL RESERVES - ENTIRE DEPOSIT**

The Mine and Ore Transportation

The Baymag mine is an open pit operation which is run year round and produces at the time being between 100 - 130,000 mtpy of high quality magnesite ore. In 1981 Baymag entered into a contractual agreement with John Wolfe Construction Co. Ltd. to operate the mine and also be responsible for the necessary ore supply to the production plant at Exshaw.

In the preproduction period in 1981/1982, the following work had to be carried out to be ready for starting up:

- 5.4 km access road construction including construction of three bridges,
- 42 km road upgrading - existing Forestry Road system - Cross River bridge to junction of Settlers Road and Highway 93,

- 65 ha logging and clearing - mine site, mine road, material handling area and dumps,
- 1,000 m mine road construction,
- 176,000 m^3 pit waste stripping and initial bench development, and
- installation of a primary crusher and screening system, stockpile, load out facilities and truck scale.

The commercial scale mining started in the second quarter of 1982 and increased dramatically since then from about 35,000 m.t. in 1982 to more than 85,000 m.t. in 1984 with an expected tonnage of 110,000 m.t. in 1985. The mining operation consists of the following functions:

- stripping and stockpiling of top soil and overburden,
- drilling and blasting the ore and waste,
- hauling, crushing and screening the ore,
- loading and hauling the ore for processing.

Figures 4 and 5 show the development of the mining operation up to 1987. It is obvious that the waste to ore ratio becomes more favourable at the higher production rate, mainly as a function of still being in mine development as can be seen in Figure 4. This figure shows that even for the next years, the "to be mined" area will be opened up further, meaning that year by year, there will still be an excessive amount of overburden and cap rock to be removed. But even now, the waste to ore ratio has rarely exceeded 1:1. Comparing this to other magnesite mines, figures of about 10:1 are considered to be normal, going as high as over 100:1 at some grecian deposits of crypto-crystalline magnesite.

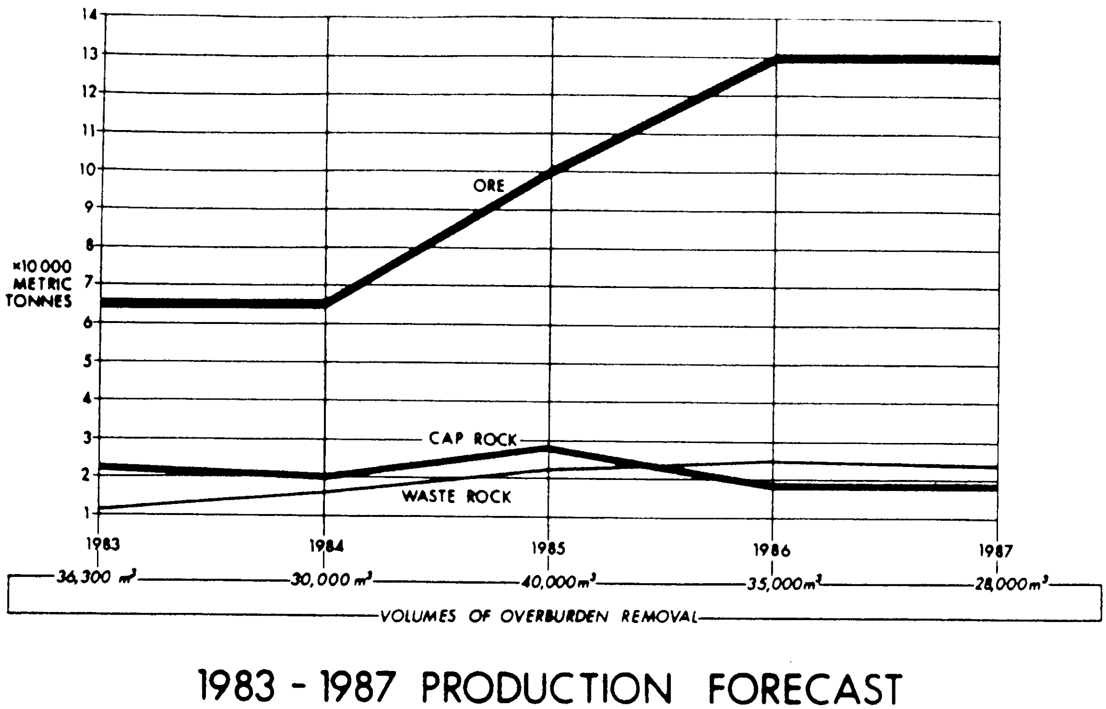

FIGURE 4: 1983 - 1987 PRODUCTION FORECAST

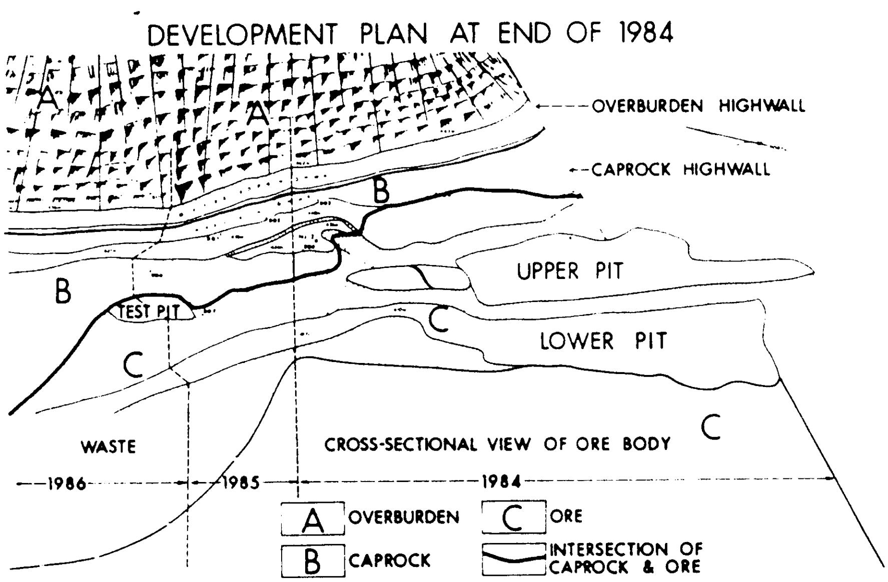

FIGURE 5: **DEVELOPMENT PLAN AT END OF 1984**

Figure 6 shows the very simple layout of the mine site facilities. Before rock blasting, a selection of drill cuttings from blastholes is analyzed in Baymag's quality control lab in Exshaw to build the base for a selective mining. After blasting the high grade ore is loaded into 20 m.t. end dump mine trucks using a backhoe, hauled down to the primary crusher area and either dumped directly into the jaw crusher, which reduces the size to -6", or onto the raw ore stockpile. After primary crushing the ore goes to a triple deck screener where the so called fines (-1/2" fraction) are removed. This is an additional quality assurance measure, because it was found that most contamination from clay filled cracks, dirt, and roadways ends up in this fraction. The -6" +1/2" primary crushed ore is again stockpiled to be loaded onto 38 m.t. payload trucktrailer units, and hauled to the production facilities at Exshaw.

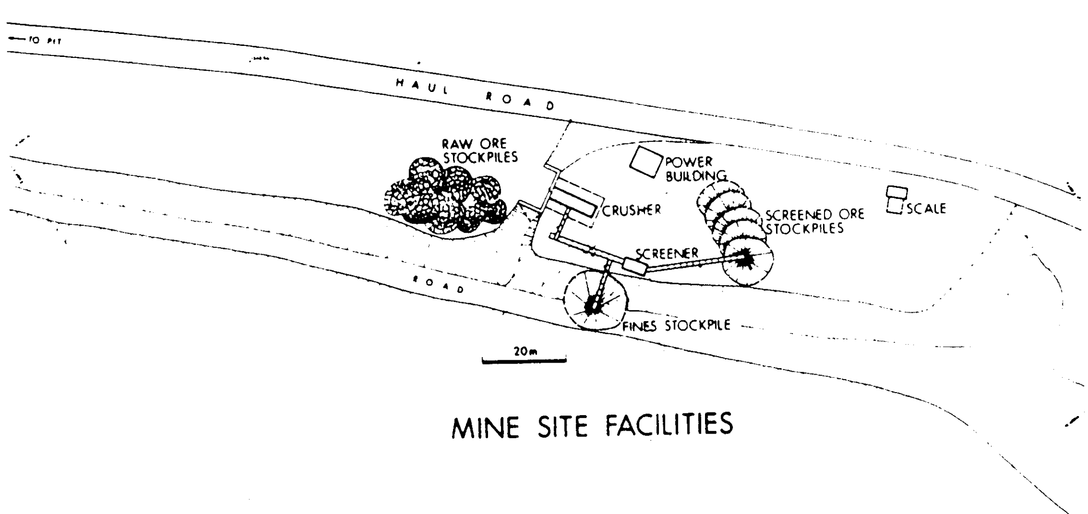

FIGURE 6: **MINE SITE FACILITIES**

The route is highlighted in Figure 7. It is about 200 km in length and leads over about 40 km of forestry road from the mine to Highway 93 junction and from there another 160 km over Highway 93 and TransCanada Highway No. 1. While the mine site obviously lies outside of the National Park boundaries, a fair bit of the 200 km long haul crosses the Kootenay and Banff National Parks and Baymag needed special permission to haul over the Settler's Road portion crossing part of the Kootenay National Park.

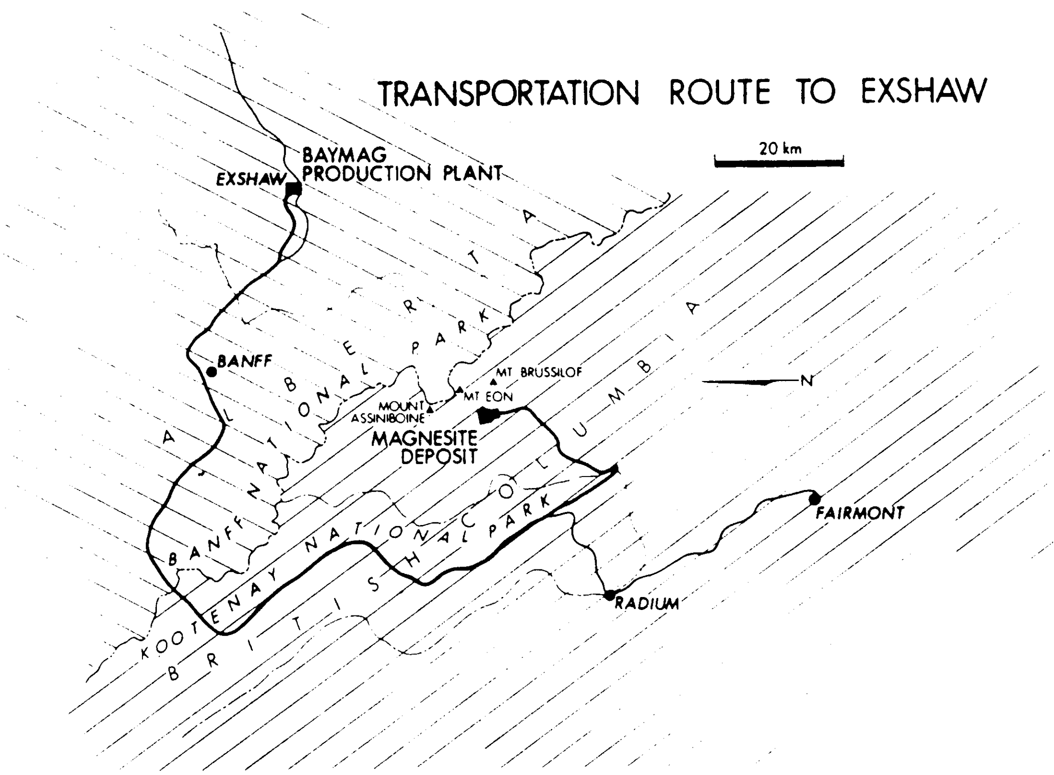

FIGURE 7: **TRANSPORTATION ROUTE TO EXSHAW**

Hauling as well as mining is done year round with two exceptions:

- hauling stops from 2 - 6 weeks during spring breakup season,
- hauling is restricted during the peak tourist season in July/August.

The Plant

The Baymag ore processing plant is situated in Exshaw, Alberta, on the grounds of the Canada Cement LaFarge Plant. As stated earlier, Baymag is leasing a part of CCL's facilities, mainly consisting of two rotary kilns as well as the kiln building and necessary auxiliary equipment.

Before commencing production, Baymag had to add certain equipment to transform its part of the cement plant into an independently functioning MgO calcining facility: the ore storage pads, secondary ore crushing/storage, kiln feeding, product screens, air separator, controlled grinding circuit, general bulk handling equipment, storage and load-out facilities as well as offices and a quality control laboratory.

Nevertheless, the kiln remains the most important piece of equipment in this production flow sheet. It is the facility which adds sufficient heat to the magnesite ore to set the CO_2 free and leave the MgO behind. This reaction theoretically starts at about 650° C and requires about 770 Kcal/kg for completion. Depending on the type of caustic calcined MgO which shall be produced, the calcining temperature in the kiln burning zone needs to be between 850 and about 1,350° C and the heat consumption is about double to three times the theoretical due to kiln shell and mainly off-gas heat losses.

Second in importance after the kiln, are the sizing facilities. Chemical reactivity, one characteristic specification of the product, is not only influenced by the kiln burn but equally influenced by the final fine grinding of the product.

One interesting phenomenon about Baymag magnesite should not be forgotten: the decrepitation at calcination. The grain destruction at elevated temperatures is not easily explained but severely effects the burning technology. The destruction works to Baymag's advantage because the most common contaminants - calcite and dolomite - do not show this behaviour and therefore beneficiation by selective screening can be used. This phenomenon is not unique for Baymag magnesite, but it is restricted to coarse crystalline magnesite and has not yet been determined at crypto-crystalline magnesite.

To put it in the simplest terms, a description for caustic calcined magnesia could be: MgO with clearly defined chemical reactivity, chemistry and sizing. Contrary to dead burnt magnesia, caustic calcined is "alive" and may change with age, depending mainly upon general storage conditions. This sensitivity makes it necessary to carry out a very detailed on-line quality control. Baymag's production is permanently quality controlled on up to eleven (11) subsequent positions before the product ends up in storage. Once it is finally shipped, a separate quality certificate is issued for each single shipment and a retain sample is thereafter kept for minimum one half year.

The production capacity runs at the moment at about 60,000 mtpy, but ongoing technical improvements will have increased it to 75,000 mtpy in early 1986.

The Products/Markets

Returning to the market for caustic calcined magnesias as it is shown in Table 3, Baymag's two mainstays are MgO for the pulp and paper industry and animal feed market. In addition to these two, Baymag is active in most of the mentioned market areas, offering a line of products in sizes from 95% minus 200 mesh, to special fractions for feed grade applications; MgO contents range from minimum 94% up to over 97% and specially designed reactivities for various chemical applications are available.

The Future

While the future of Baymag, in all studies completed so far, has always been connected to the production of mainly dead burnt MgO with caustic calcined magnesia as a byproduct, in 1982 it made most sense to begin a pure calcination operation. There were two very good reasons for this decision: an overly saturated world market for dead burnt MgO and the availability of existing facilities for calcining versus the need for a very high investment for dead burning.

After nearly three years in production and being one of the three leading caustic calcined magnesia producers in North America, the obvious question arises: Where does Baymag go from here? While Baymag will always be committed to the existing market for its calcined products and hopes to double sales in this area within the next five years, it cannot deny its parent company's "refractory heritage".

One year ago Baymag jumped into cold water again, left well known territory and started to develop and market a brand new product: fused magnesia, specially developed and designed for refractory applications.

A pilot plant at Exshaw was started up at the end of 1983 for trial production and soon it became necessary to upgrade it to produce commercial quantities because of the very strong market response. Fused magnesia becomes a unique refractory raw material due to its special treatment during production. It crystallizes out of molten magnesia at temperatures above 2,800°C once brought to these temperatures by an electric arc. This treatment makes the resulting product superior to chemically comparable dead burnt magnesias and with advanced steel making technology there is a need for top quality MgO refractory raw materials. Baymag is in the process of carefully studying the possible expansion of its fusing capacity in 1986.

Summary

Baymag, founded in 1971, controls the purest coarse crystalline magnesite deposit in the western world. After intensive exploratory work in the deposit which was discovered in 1966, and the final takeover in 1979 by the German owners, Baymag has started producing caustic calcined magnesia in 1982. Since then, the company has become one of the three leading suppliers of high quality caustic MgO in North America. Plans for building up a second production line for fused MgO are in progress.

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