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ARTHUR RIVER MAGNESITE

PROJECT SUMMARY

SEPTEMBER 1991

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CRA SERVICES LIMITED

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INTRODUCTION

A summary description of exploration activities carried out at the Arthur River magnesite prospect in Tasmania is presented. This includes the results of diamond drilling to investigate the quality of the magnesite and resource potential. Preliminary testwork has also been performed to assess the suitability of the magnesite for the production of caustic calcined magnesia and refractory grade dead-burned magnesia. Results of this programme are briefly discussed.

Potential use of the magnesite as feedstock for magnesium metal production and sinter flux in steelworks is also reviewed.

LOCATION:

50 km south of Port Latta and 55 km southwest of Burnie, North West Tasmania.

ACCESS:

Good road access from Burnie to Arthur River prospect. Last 10 km gravel. 6 km access road and bridge across Lyons River required to connect with gravel road to Port Latta.

PORT FACILITIES:

Offshore bulk loading facility at Port Latta capable of handling 110,000 dwt ships. Deep water port at Burnie with capability of loading 50,000 dwt vessels.

TITLE:

Two Retention Licences each of 5 square kilometres area. (RL 8717 and 8718). Apart from reporting and nominal rental requirements, no minimum expenditure commitment applies.

OWNERSHIP:

Subject of a Joint Venture Agreement. CRA Limited 75%. Mineral Holdings Australia Limited, 25%. CRA is Project Manager. Joint Venture partners now contribute to project expenditure pro-rata to their interest.

GEOLOGY:

An extensive magnesite formation occurs within a thick steeply dipping sequence of Precambrian meta-sediments. The magnesite horizon is up to 300-400 metres thick (including minor dolomite beds) and can be traced along strike for more than 20 kilometres. Dips are generally 70-80°SE.

The magnesite is poorly exposed, especially towards the north where it is overlain by 5-20 metres of alluvium.

The magnesite may to have formed as a replacement of dolomite by percolating magnesium rich solutions during metamorphism.

MINERALOGY:

Typically the magnesite has an auto-breccia texture with 50-60% sub-angular to round fragments of fine grained to cryptocrystalline creamy magnesite, ranging from 0.2 - 50mm in size, enclosed within a grey matrix of coarser grained dolomite and quartz.

The grain size of the magnesite is around 1 micron, while the crystalline dolomite - quartz intermixture (veinlets and patches) has a grain size of 5 - 200 microns (average 100 microns). Quartz is sometimes coarser grained (up to 1 mm).

The silica content of the magnesite formation varies from 5-15% but 20-30 metre thick sections do occur with only 1-2% quartz.

Generally the silica content is higher (average about 10% SiO_2) in the upper 100-200 metres of the magnesite and decreases at depth (average about 5% SiO_2). High silica levels (10-20%) characterise the dark grey dolomite bands within the magnesite formation.

EXPLORATION DRILLING:

Diamond drilling was carried out to test the Arthur River magnesite horizon at two locations (Pinner and M1 Prospects), 5 kilometres apart along strike (Figure 1).

Pinner Prospect

At the Pinner prospect, the magnesite is 300-400 metres thick and dips 70-80°SE. It is outcropping, with pinnacles of magnesite exposed through an extensive veneer of clay. Parts of the magnesite is covered by Tertiary basalt.

A total of 9 holes aggregating 2502 metres was drilled from 1982 - 1984 to test the magnesite deposit along a strike length of 2.5 km at the Pinner prospect.

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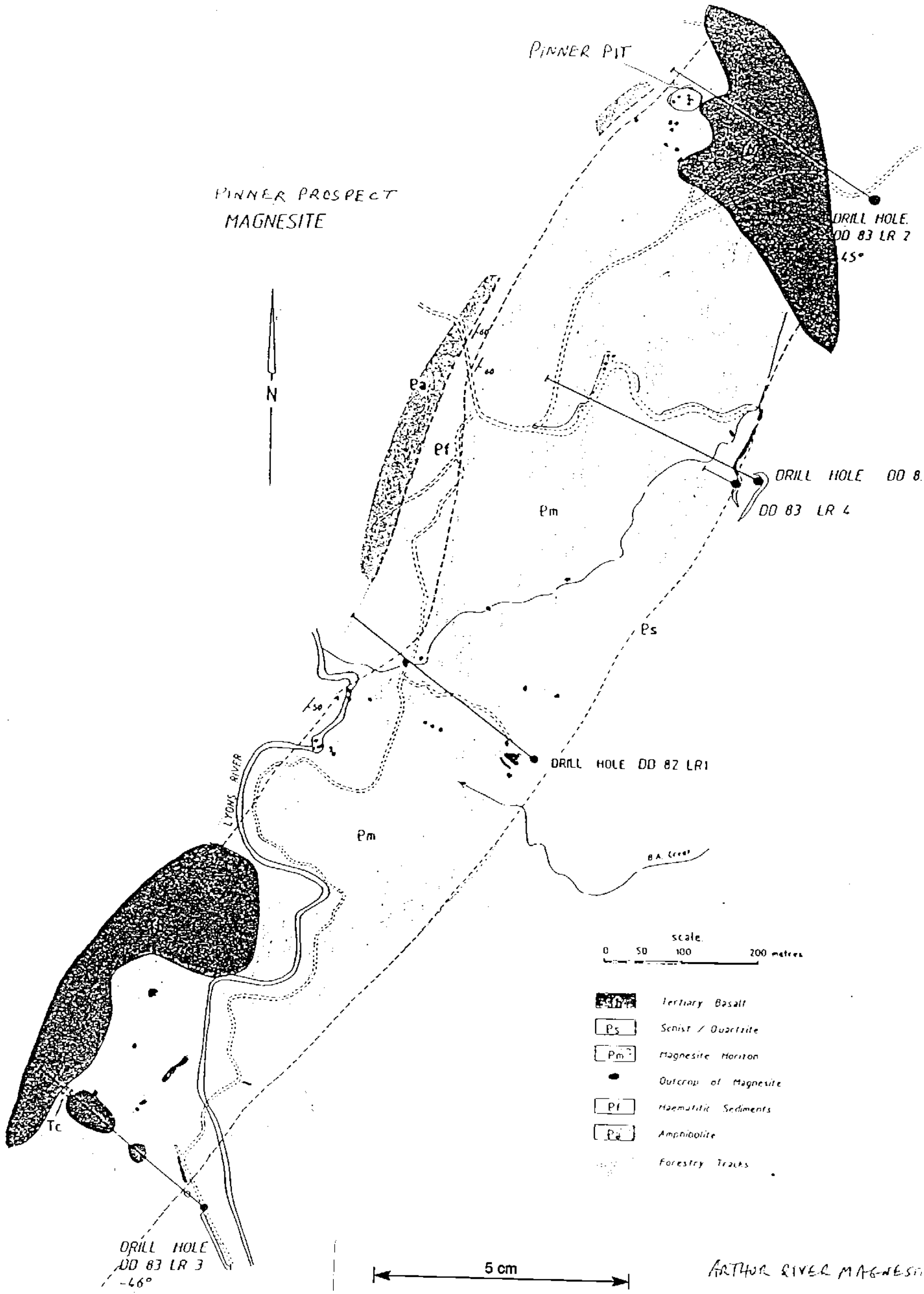

ARTHUR RIVER MAGNESITE

PINNER PROSPECT

DRILL HOLE LOCATI

FIGURE 2

Intersections obtained in these drill holes are as follows:

Hole No.	Depth (m)	Metres + 35% MgO	Metres + 40% MgO
LR 1	389	224	192
LR 2	419	284	191
LR 3	368	15	15
LR 5	425	218	72
LR 6	223	102	59
LR 7	176	125	76
LR 9	209	92	35
LR 10	138	31	7
LR 11	128	29	2

(Note: DDH 4 and DDH 8 were abandoned. Total depth 96 metres)

LR 1, LR 2 and LR 5 which tested a strike length of over 1,500 metres (Figure 2) intersected widths of 75-200 metres grading over 40% MgO. Detailed analyses of intersections in holes drilled at the Pinner Prospect area are presented in Tables 1 to 3. The MgO content varied from 39-43% over significant widths. The main impurities included 5-10% SiO_2, 2-4% CaO and 0.5-2% Fe_2O_3.

In 1989 16 shallow holes (to 45m depth) were drilled to test the open pit potential in the vicinity of LR 2 at the northern end of the Pinner prospect. These confirmed significant widths of magnesite with 35-43% MgO, 0.5-3.0% CaO, and generally 5-10% SiO_2 (up to 20% SiO_2).

In 1983 and 1986 bulk samples were excavated from this location (Pinner Pit). About equal amounts of magnesite and dolomite occur in the pit. The rock types are easily differentiated by colour.

Mean analyses (%) of magnesite samples from this pit are:

	MgO	SiO_2	Fe_2O_3	CaO	LOI
1983	43.8	5.6	0.55	1.15	48.5
1986	41.5	8.0	0.70	1.60	47.6

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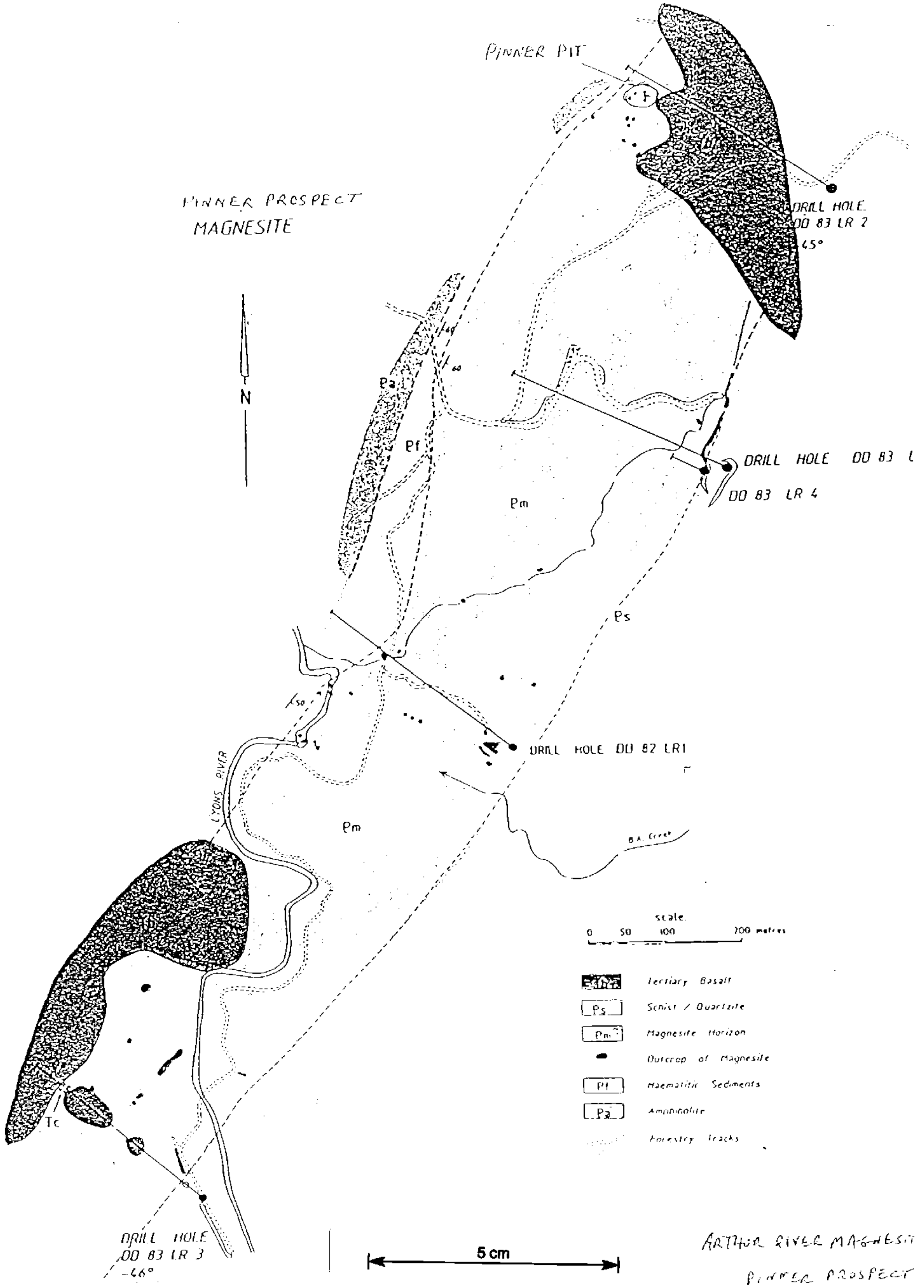


ARTHUR RIVER MAGNESIT

PINNER PROSPECT

DRILL HOLE LOCATI

FIGURE 2

TABLE 1: PINNER MAGNESITE PROSPECT

ANALYSIS OF DRILL HOLE INTERSECTIONS (+ 35% MGO)

Hole Number	Intersection (metres)	MgO %	CaO %	SiO_2 %	Fe_2O_3 %	LOI %
LR 1	224	42.8	2.8	4.1	1.7	48.5
LR 2	284	41.1	3.6	7.1	0.7	47.6
LR 3	15	43.0	4.1	2.5	0.7	49.4
LR 5	218	39.1	3.8	10.4	0.7	45.4
LR 6	102	40.1	2.9	9.9	1.5	45.4
LR 7	131	40.5	2.1	10.8	0.5	45.9
LR 9	92	39.3	2.9	10.7	1.5	45.4
LR 10	31	38.5	5.0	9.3	2.3	44.6
LR 11	9	39.3	2.9	10.7	1.5	45.4

TABLE 2: PINNER MAGNESITE PROSPECT

ANALYSES OF MAGNESITE INTERSECTIONS IN LR 1

MgO % Cut-off	From m	To m	Intersection m	MgO %	Fe_2O_3 %	CaO %	SiO_2 %	LOI %
40	97.7	109.7	12.0	42.36	1.00	3.64	4.45	48.59
	127.5	134.0	6.5	41.57	1.38	1.29	9.00	46.62
	139.0	170.2	31.2	42.19	1.21	2.26	6.46	47.75
	182.9	267.0	84.1	43.25	1.81	2.98	2.55	49.46
	296.9	317.1	20.5	44.97	1.81	1.91	1.10	50.09
	341.5	369.4	27.9	44.34	1.83	2.62	1.06	49.91
43	194.0	266.3	72.3	43.35	1.61	2.89	2.83	49.38
	296.0	317.1	20.5	44.97	1.81	1.91	1.10	50.09
	347.0	369.4	22.4	45.29	1.53	1.75	1.06	50.25
45	231.9	250.0	18.8	45.70	1.25	0.72	2.19	50.20
	296.6	304.6	8.0	45.84	2.04	0.98	0.70	50.55
	358.0	369.4	11.4	46.47	1.12	0.88	0.60	51.01

TABLE 3: PINNER MAGNESITE PROJECT

ANALYSES OF MAGNESITE INTERSECTIONS IN LR 2 AND LR 5

LR 2

MgO % Cut-off	From m	To m	Intersection m	MgO %	CaO %	SiO_2 %	Fe_2O_3 %	LOI %
35	68.5	157.5	89.0	39.9	2.2	12.4	0.4	45.1
	171.3	200.7	29.4	41.9	1.4	9.4	0.6	46.7
	240.0	403.0	163.0	41.6	4.7	3.7	0.8	49.1
40	74.0	85.0	11.0	40.8	1.9	10.7	0.5	46.1
	100.0	120.0	20.0	41.1	1.6	10.5	0.4	46.1
	175.0	200.7	25.7	42.5	1.5	7.9	0.6	47.4
	250.0	275.0	25.0	41.7	4.7	4.1	0.4	49.0
	325.0	370.0	25 0	43.5	3.7	1.7	0.8	50.3
	375.0	395.0	20.0	43.7	3.3	1.8	1.0	48.4

LR 5

40	181.0	195.0	14.0	42.3	1.4	9.0	0.3	46.0
	383.0	391.5	8.5	41.7	4.1	5.9	0.3	47.8

M 1 Prospect

Seven holes were also drilled at the M1 prospect in 1983 to test the magnesite formation about 5 km northeast along strike from the Pinner prospect. These holes (1610m) tested a 2.5km section of the carbonate horizon.

Results of the drilling are as follows:

Hole Number	Intersection (m)	Metres + 35% MgO	Metres + 40% MgO
AR 2	245	120	105
AR 3	408	180	87
AR 5	156	28	15
AR 6	382	237	93
AR 7	282	195	153

Holes AR 2, AR 3, AR 6 and AR 7 intersected 90-150 metre thicknesses of magnesite grading over 40% MgO along a continuous strike length of more than 1500 metres (Figure 3).

AR 4 was abandoned. AR 1 (138m) located at the north end of the zone tested, intersected low grade magnesite.

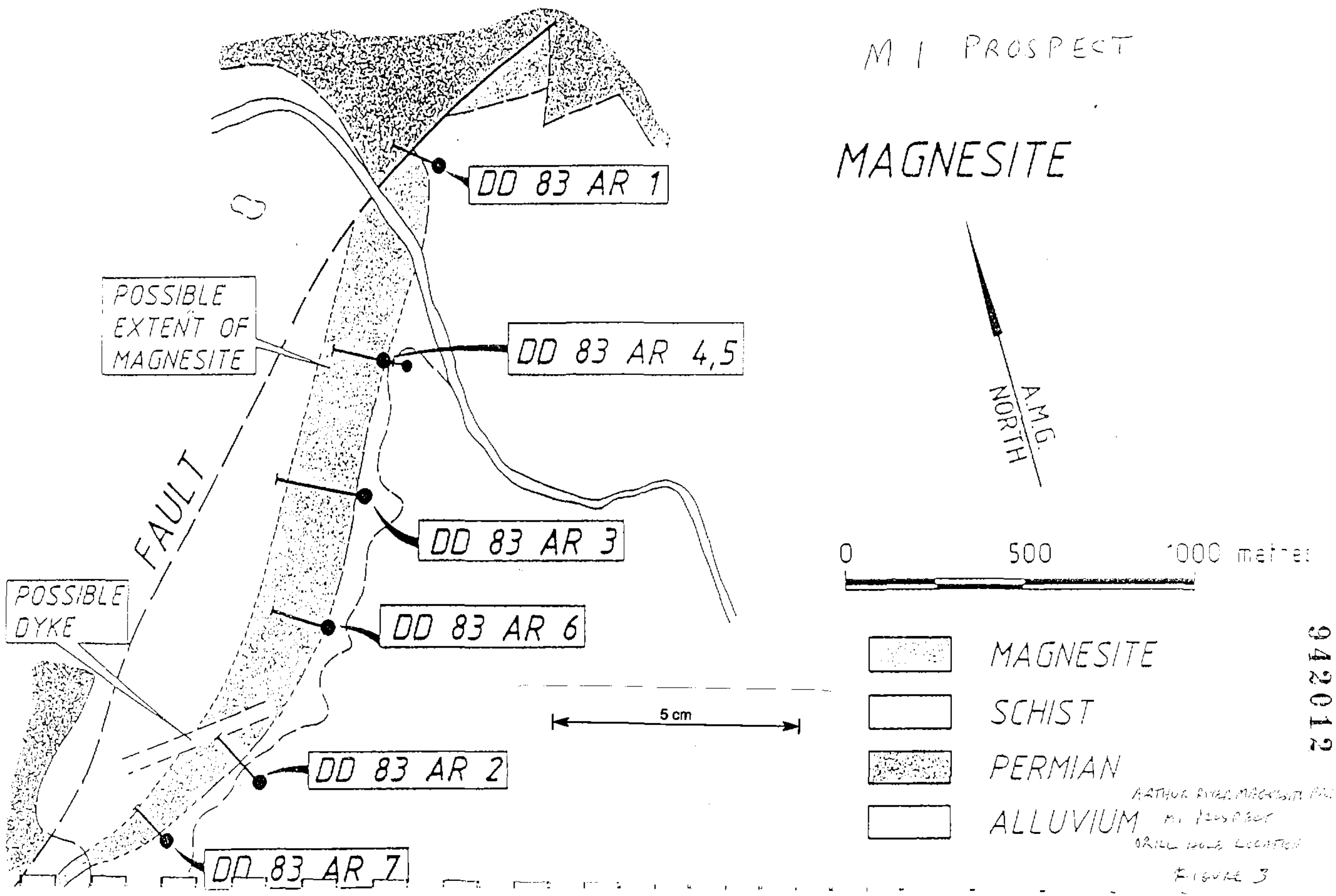
Detailed analyses of intersections in holes drilled at the M1 prospect are presented in Tables 4 to 6.

TABLE 4

M1 MAGNESITE PROSPECT

ANALYSIS OF DRILL HOLE INTERSECTIONS

Hole Number	Intersection (metres)	MgO %	CaO %	SiO_2 %	Fe_2O_3 %	LOI %
AR 2	120	41.7	3.0	8.6	0.7	45.8
AR 3	180	39.8	4.3	6.6	2.1	46.9
AR 5	28	39.6	5.0	6.5	1.6	47.1
AR 6	237	39.2	3.7	8.7	1.4	46.4
AR 7	195	43.0	4.1	2.5	0.7	49.4



ARTHUR RIVER MAGNESITE P/L
M1 PROSPECT
DRILL HOLE LOCATION
FIGURE 3

TABLE 5

M 1 MAGNESITE PROSPECT

ANALYSIS OF MAGNESITE INTERSECTIONS IN AR 2 AND AR 3

HOLE AR 2

MgO % Cut off	From m	To m	Intersection m	MgO %	CaO %	SiO_2 %	Fe_2O_3 %	LOI %
35	104	170	66	41.1	3.4	9.8	0.7	44.7
	174	189	15	42.4	1.7	8.1	0.5	47.3
	192	232	40	42.6	2.7	6.9	0.8	46.9
40	174	189	15	42.4	1.7	8.1	0.5	47.3
	192	232	40	42.6	2.7	6.9	0.8	46.9

HOLE AR 3

35	78	102	24	38.4	2.3	11.6	3.4	44.0
	179	243	64	42.0	3.3	3.9	2.0	48.6
	251	266	15	37.3	5.5	10.0	1.6	45.2
	295	315	20	38.2	6.4	7.5	1.2	46.6
40		90						
	178	176	12	41.7	0.4	8.5	3.6	45.6
	167		9	41.2	2.2	7.3	1.5	47.3

TABLE 6

M 1 MAGNESITE PROSPECT

ANALYSIS OF MAGNESITE INTERSECTIONS IN AR 6 AND AR 7

HOLE AR 6

MgO % Cut off	From m	To m	Intersection m	MgO %	CaO %	SiO_2 %	Fe_2O_3 %	LOI %
35	133	153	20	40.6	3.4	8.6	0.6	46.7
	179	219	40	39.8	3.8	8.9	2.0	46.2
	224	244	20	38.1	5.1	7.0	2.9	46.4
	259	336	77	40.1	3.3	9.0	1.2	46.3
	338	352	14	40.4	3.7	8.3	0.8	46.8
40	133	143	10	41.9	2.2	8.4	0.4	47.0
	179	189	10	40.8	3.0	8.8	0.6	46.7
	194	208	14	41.1	3.0	8.0	3.9	46.8
	303	313	10	42.9	3.0	5.1	0.3	48.7
	338	348	10	41.1	2.4	9.3	0.8	46.5

HOLE AR 7

35	13	40	27	42.0	2.0	6.8	1.6	47.5
	57	69	11	43.2	3.5	3.4	0.6	49.4
	121	242	121	42.6	1.7	6.7	1.8	47.2
40	13	40	27	42.0	2.0	6.8	1.6	47.5
	57	69	12	43.2	3.5	3.4	0.6	49.4
	121	145	24	43.6	0.8	6.0	1.5	48.2
	160	171	11	42.0	0.8	10.8	0.5	45.9
	177	238	61	43.2	1.8	5.0	2.4	47.6

A bulk sample taken from this area in 1986 assayed 43.7% MgO, 3.7% SiO_2, 0.8% Fe_2O_3, 2.8% CaO and 47.0% LOI.

Statistical analysis of drill intercepts from both prospect areas showed that:

- the average grade of all intersections (1823m) of +35% MgO at the Pinner Prospect is 40.7% MgO
- the average grade of all intersections (1104m) of +40% MgO at the M 1 Prospect is 42.4% MgO

RESOURCE:

Insufficient drilling has been carried to estimate a mineable reserve.

Pinner Prospect
Resource potential in the section of the Arthur River deposit tested by LR 1, LR 2 and LR 5 along a strike length of 1200 metres and to a depth of 200 metres, is estimated to be 150 million tonnes (760,000 tonnes per vertical metre) at a cut-off grade of 35% MgO or 100 million tonnes (480,000 tonnes per vertical metre) at a cut-off grade of 40% MgO.

This zone is open along strike although the thickness is reduced.

M 1 Prospect
The area tested by drilling 5km further north east along strike is estimated to contain 130 million tonnes (650,000 tonnes per vertical metre) at a 35% MgO cut-off or 80 million tonnes (390,000 tonnes per vertical metre) at a 40% MgO cut-off, both to a depth of 200 metres and along a strike length of 1,400 metres.

MINING:

The magnesite deposits at both locations may be mined either by open cut or underground from a decline access. The stripping ratio for open cut mining at the Pinner deposit is estimated to be 5 : 1 waste : ore. Environmental concerns could prohibit open cut development of the M 1 deposit which occurs partly within a sensitive rain forest area.

Both deposits are amenable to underground mining from a decline access. Costs for long hole open stoping are estimated to be about 20% higher than a similar sized open pit mine. Ground conditions for mining are expected to be good.

Selective mining to separate massive magnesite from dolomite bands can readily be done by visual examination, if required.

MINE PRODUCTS:

Pinner Prospect
Applying a 35% MgO cut-off, indicated run of mine magnesite composition is likely to be 40-41% MgO, 6-7% SiO_2,3-4% CaO, 0.7-1.2% Fe_2O_3 and 46-47% LOI.

On the basis of the 1989 shallow drilling programme the expected grade of magnesite mineable by open pit, assuming selectivity to reject dolomite and high silica magnesite

(10-20% SiO_2) which constitute 50% of the rock mined, will be 39-41% MgO, 7-9% SiO_2, 2-3% CaO and 0.5-1.2% Fe_2O_3.

The potential to produce higher grade by selective mining either from an open cut or underground mine is reflected by analyses of surface exposures and drill intersections from the Pinner area.

Bulk samples of magnesite boulders (50% of total rock) in the Pinner Pit had analyses ranging from 41 - 44% MgO, 6 - 8% SiO_2, 0.5 - 0.7% Fe_2O_3 , 1.1 - 1.6% CaO and 47.5 - 48.5% LOI.

High grade intersections from LR 1 (45% MgO cut-off) are as follows:

Hole Number	From (m)	To (m)	Interval (m)		MgO %	Fe_2O_3 %	CaO %	SiO_2 %	LOI %
LR 1	231.9	250.0	18.1		45.7	1.3	0.7	2.2	50.2
	296.6	304.6	8.0		45.8	2.0	1.0	0.7	50.6
	358.0	369.4	11.4		46.5	1.1	0.9	0.6	51.0

These intersections represent the highest grade obtained in the diamond drilling programme.

M1 Prospect

Run of mine grades of magnesite which could be recovered from the M1 pit area are likely to grade to 40-42% MgO, 3.5-5.5% SiO_2, 1.0-2.5% Fe_2O_3, 3-8% CaO and 44-47% LOI. These are similar to the average MgO grades for the M1 deposit which are likely to have higher SiO_2 (5-10%), and slightly lower Fe_2O_3 (0.5-1.5%) and CaO (2-4%).

UPGRADING OF MAGNESITE:

Flotation of crushed magnesite (100% - 80 micron) from the Pinner area was carried to yield an upgraded product. The original crude magnesite sample had the following composition:

43.8% MgO, 5.6% SiO_2, 0.5% Fe_2O_3, 1.2% CaO and 48.5% LOI.

The composition of the flotation concentrate and a selected sample of high grade lump magnesite from the Pinner area are as follows:

	Flotation Concentrate	High Grade Lump
MgO %	46.7	44.1
CaO %	0.6	1.2
SiO_2 %	0.3	5.5
Fe_2O_3	0.45	0.60
Al_2O_3 %	0.12	0.11
LOI %	51.4	48.4
B ppm	8	10
Ni ppm	10	30
Cu ppm	10	100
Pb ppm	10	30
Zn ppm	20	30
Cr ppm	12	20
P ppm	20	100
S ppm	70	200

Although flotation was successful in upgrading the magnesite, it is unlikely that there will be a market for this product, on account of the high production costs, compared with natural high grade magnesite deposits in Canada, North Korea, China and Australia (Kunwarara and Yaamba). Lump magnesite feed is generally used as feedstock for magnesium metal production and calcination kilns.

PROCESSING OF MAGNESITE:

1. DEAD BURNED MAGNESIA

Test Programme

Tests have been carried out at several laboratories to produce a dead burned magnesia suitable for refractory applications. The results have been unsatisfactory on account of:

- Low MgO content (82-85%). Higher than 95% MgO is desirable
- High Fe_2O_3 content (about 1% in sintered product) 0.2 - 0.4% Fe_2O_3 is preferred
- High CaO content and $CaO : SiO_2$ ratio is generally less than 1 : 1, and often 1 : 2. A $CaO : SiO_2$ ratio well over 2 : 1 is essential for refractory use. Very few sections meet this specification.

- Maximum density achieved on sintering was only 2.7g/ml. 3.3 - 3.4 g/ml bulk density is required (preferably > 3.44 g/ml)
- Poor crystallinity of MgO sinter. Crystal size should be 30-120 microns

Analysis of magnesite and dead burned magnesia from the Pinner and M1 Deposits are reported as follows:

	MgO %	CaO %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %
Pinner raw magnesite	43.8	1.2	5.6	0.5	0.1
Pinner dead-burned	85.0	2.3	10.9	1.0	0.2
M1 raw magnesite	43.7	2.8	3.7	0.8	0.1
M1 dead-burned	82.5	5.3	7.0	1.5	0.2

Dead burning of magnesite concentrate at 1850°C produced magnesia with a bulk density of only 2.7 g/ml. The density can be increased to 3.15 g/ml by fine grinding caustic calcined magnesia, pelletising and dead burning in a kiln, but this is still not good enough and is costly.

Usage:

The largest single end use of magnesite is as a raw material for basic refractory manufacture, especially steel convertor linings. Magnesia specifications are related to the severity of duty in still furnaces. Raw material specifications for magnesia refractories are typically:

	Superior Grade	Regular Grade	Fettling
MgO % Min	48.0	45.0	42.9
CaO % Max	1.0	1.0	1.3
SiO_2 % Max	0.15	0.15	1.1
Fe_2O_3 % Max	0.1	0.4	1.5
Al_2O_3 % Max	0.2	0.2	0.2

These suggest that impurities in magnesite should be less than 2% to produce regular or premium grade dead-burned magnesia. Arthur River magnesite impurities are much higher (often over 10%).

Flotation concentrate from Arthur River satisfies the lowest value specification (Fettling). SiO_2 and Fe_2O_3 levels in the magnesite are too high for regular grade magnesia refractories.

It is concluded that it is unlikely that a medium quality dead burned magnesia can be produced from the Arthur River magnesite. At best, a low grade refractory can be produced at very high cost.

2. CAUSTIC CALCINED MAGNESIA

A preliminary calcination test programme was carried out at Amdel Laboratories to determine the optimum kiln operating conditions to produce a reactive caustic calcined magnesia.

A differential thermal analysis showed that the magnesite decomposed in the range 570°C to 710°C. However, the magnesite component of the dolomite in the magnesite sample decomposed at 710°C to 780°C, while the $CaCO_3$ decomposed at 925°C - 960°C (Figure 4).

Laboratory test results for calcination at temperatures of 600°C - 900°C over 0.5 to 2 hours are presented in Figure 5.

The optimum calcinations conditions in a rotary kiln appear to be about 750°C with a residence time of 15 to 30 minutes in the hot zone. Results from rotary kiln tests using magnesite crushed to -12.7mm are presented in Table 7.

Surface areas of 70-95 m^2/g were obtained for magnesia containing 75-80% MgO, 2-7% CaO, 6-14% SiO_2 and 4-10% CO_2.

Analysis for two bulk magnesite samples calcined in the rotary kiln at 750°C for 15 minutes are presented in Table 8. Surface areas of 78 m^2/g and 96 m^2/g were obtained for magnesia assaying 68% and 76% MgO respectively. The low MgO reflects the high dolomite (uncalcined) and silica impurity levels in the magnesite/magnesia.

There was no evidence of decreptitation during calcination and the calcined product is a mixture of soft lumps of magnesia in fine powder.

Usage:

The emerging market for caustic calcined magnesia, with high volume potential, is in acid neutralisation, gas scrubbing and other environmental applications. Tests were conducted on the Arthur River calcined magnesia to assess its effectiveness in acid neutralisation and possible use for removal of heavy metals from mine water discharge.

The calcined magnesia reacts very quickly with acidic liquors and is highly effective in precipitating heavy metals (Cu and Zn) from solution (Figure 6). This suggests that the highly reactive magnesite could be used effectively for environmental applications including acid neutralisation and treatment of polluted mine waters. Although the samples have appreciable residual CO_2 content, there was no evidence of effervescence in acid neutralisation tests.

Tests are being done to upgrade the MgO product by screening to remove coarse particles of silica and dolomite. This should significantly improve the quality of the product and enhance its effectiveness in a range of applications.

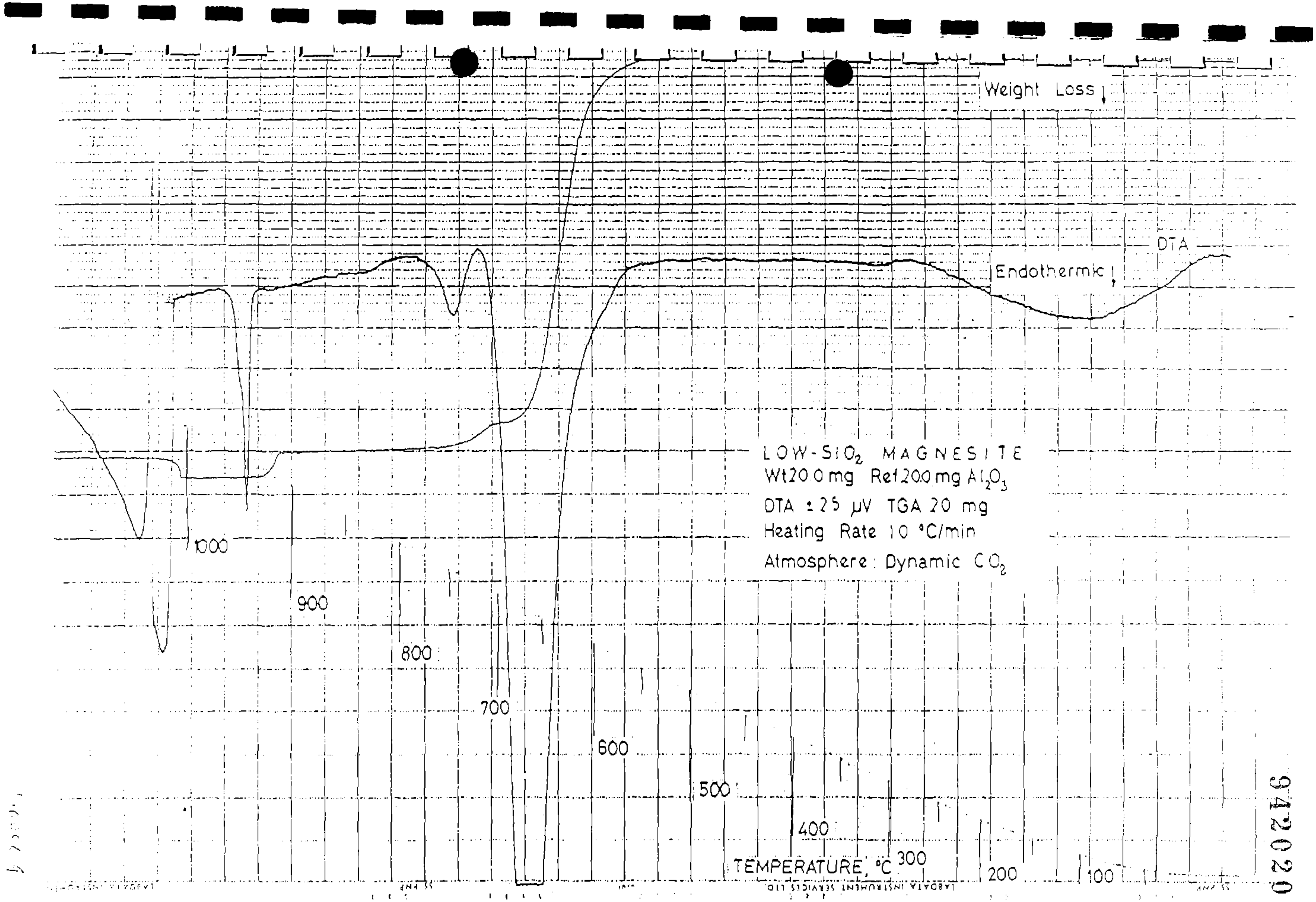


FIGURE B1: THERMAL ANALYSIS OF LOW SILICA MAGNESITE IN CO_2 ATMOSPHERE

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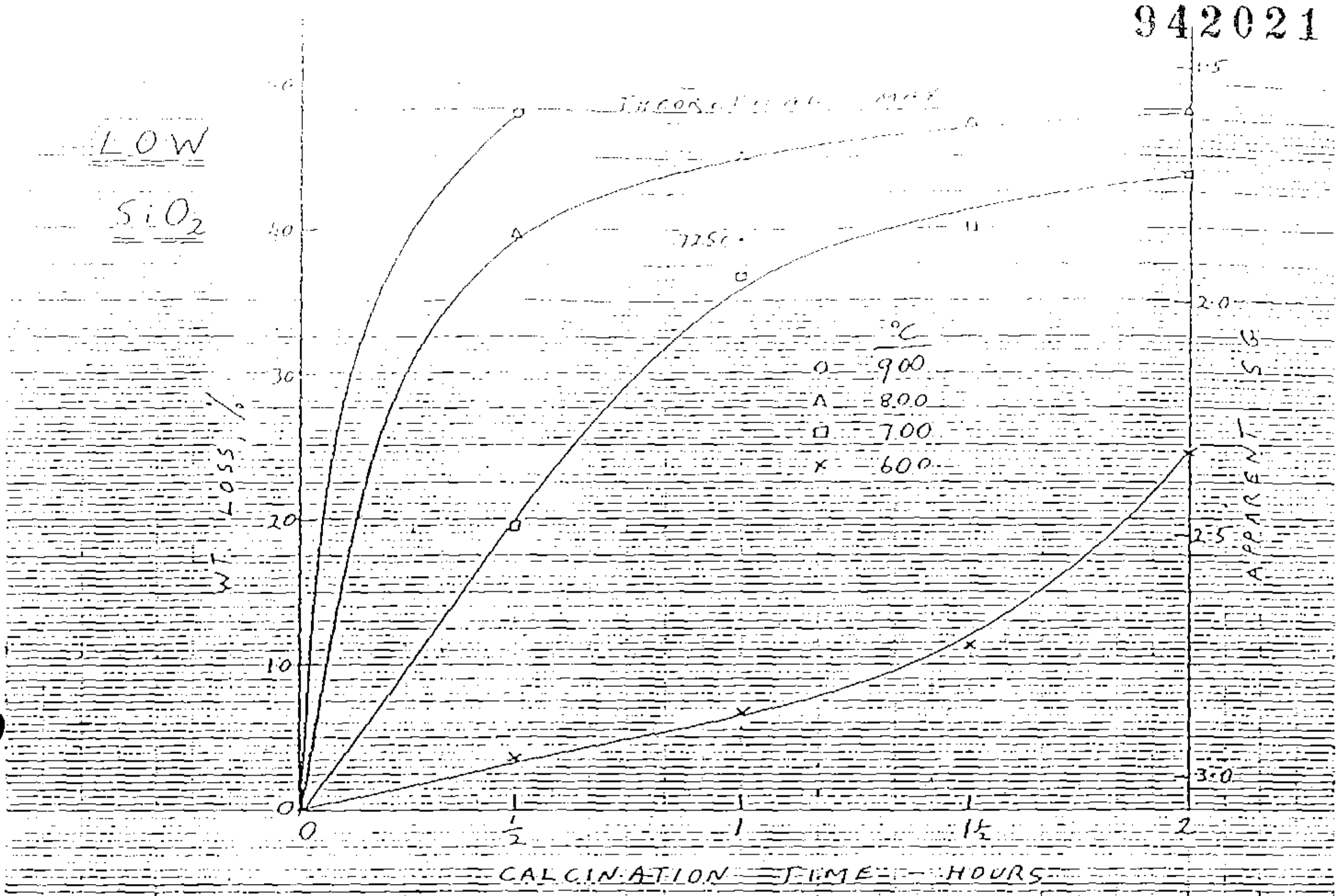

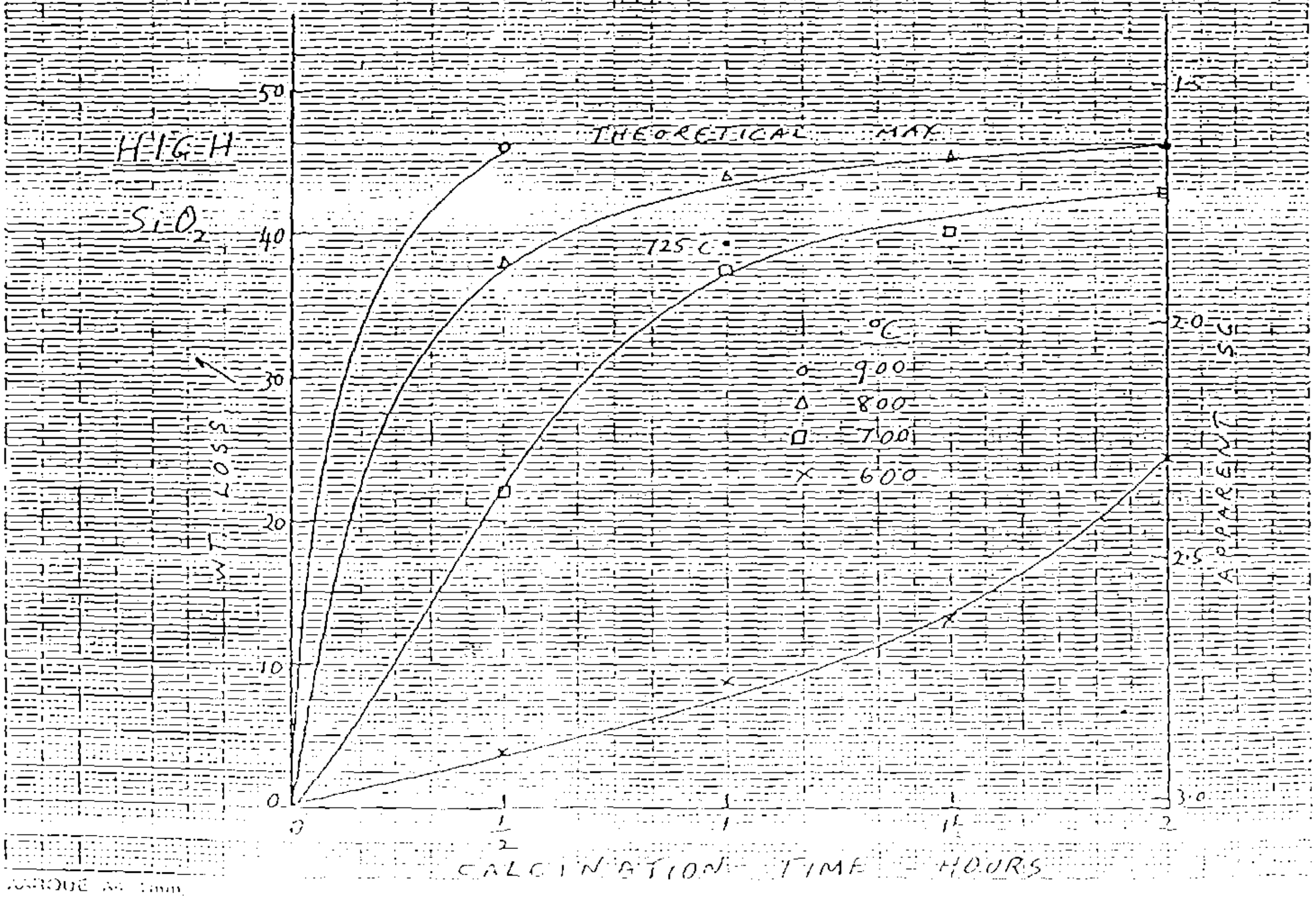

FIGURE 4: WEIGHT LOSS AS A FUNCTION OF TIME

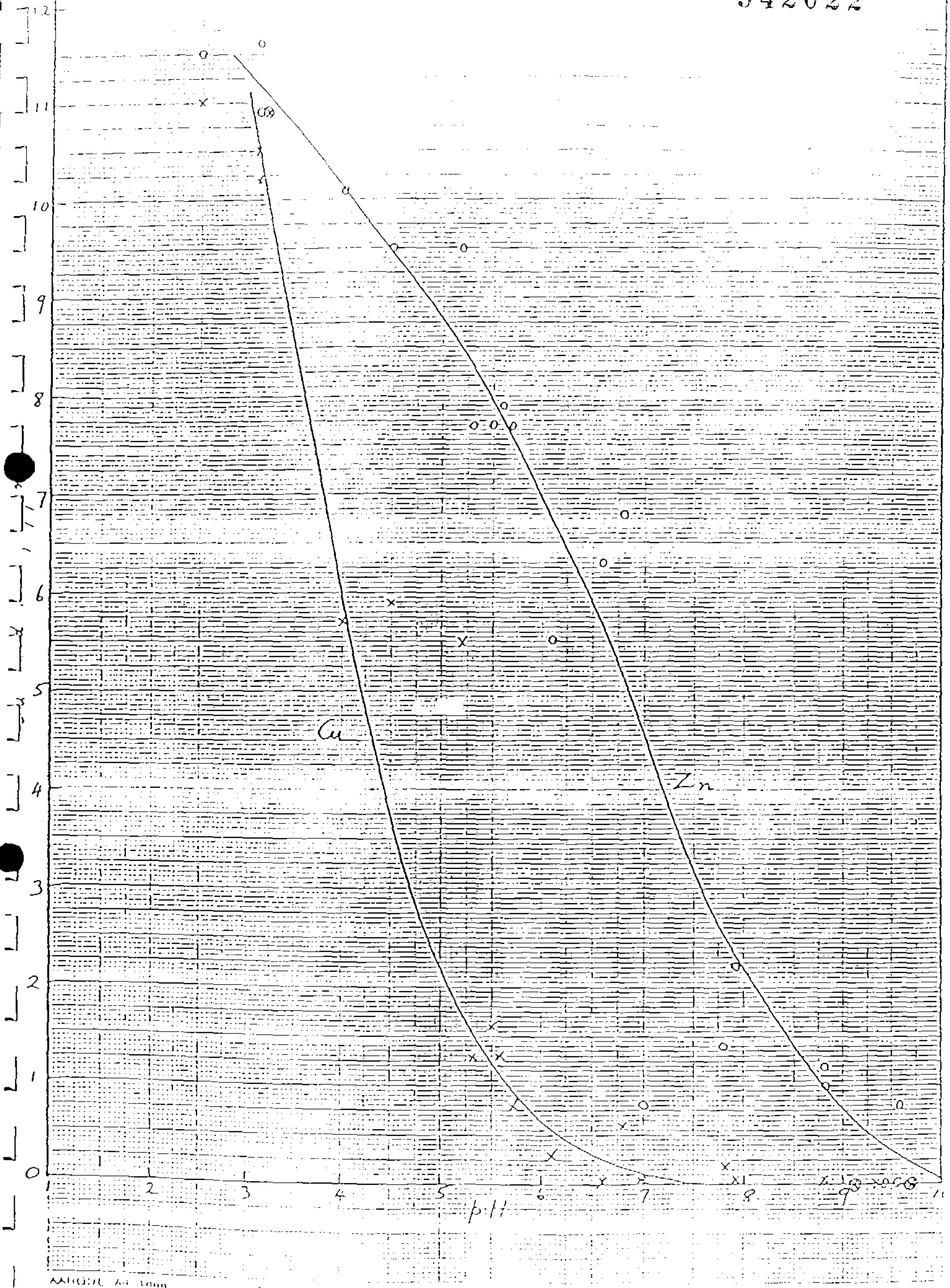

FIGURE 6. METAL PRECIPITATION AS A FUNCTION OF pH

TABLE 7: KILN CALCINATION RESULTS

Test No	1	2	3	4	5	6	7
	<----------1st Series---------->			<------------- 2nd Series ----------------->			
Feed		Sample A				Sample C	
Temperature, °C	800	775	775	700	750	750	775
Residence time, min	25	25	40	40	25	15	15
Reactivity, g solids	5.60	5.85	6.50	-	-	-	-
Surface area, m^2/g	57	70	56	83	92	96	72
Analyses, %							
MgO	77.7	74.8	77.5	67.2	77.2	76.8	79.8
CaO	7.55	7.25	7.90	2.38	2.24	2.15	2.36
Fe_2O_3	2.24	2.30	2.16	0.89	0.87	0.89	0.94
Al_2O_3	0.30	0.20	0.19	0.18	0.18	0.18	0.14
SiO_2	6.60	6.75	7.35	11.6	13.4	14.1	13.9
CO_2	8.30	10.7	8.00	18.7	7.50	7.00	3.65

TABLE 8: KILN PRODUCTION RUNS

Sample	Sample B (High Silica)	Sample C (Surface)
Temperature, °C	750	750
Residence time, min	15	15
Reactivity, g solids	6.40	5.95
Surface area, m^2/g	78	94
Analyses, %		
MgO	67.8	76.2
CaO	4.41	2.12
Fe_2O_3	1.41	0.84
Al_2O_3	0.05	0.06
SiO_2	16.3	13.0
CO_2	8.20	7.05

MARKET FOR RAW MAGNESITE

The market for crude magnesite is small compared with that for magnesia products. Magnesite is normally calcined close to the mine and MgO shipped to markets (50% less weight). Magnesite is expected to be the main raw material for future magnesium metal production using Norsk Hydro or possibly Magcan technology.

Magnesite specifications for two producers of magnesium are presented together with a weighted average composition of Arthur River magnesite (>43% MgO in DDH 1, 2 and 3) and analyses of high grade magnesite from the Pinner Pit.

		Norsk Hydro	Magcan	Arthur River Magnesite		
				Drill Core	Pinner Pit	
MgO	%	45 min	44 min	43.9	45.5	44.1
CaO	%	1.0 max.	2.4max.	1.2	1.12	1.2
SiO_2	%	1.5 max.*	1.3 max.	2.4	3.47	5.5
Fe_2O_3	%	} }1.0 max.	} }2.0 max.	3.1	0.35	0.6
Al_2O_3	%			0.07	0.04	0.1
LOI	%	-	-	49.3	48.9	48.4
Mn	ppm	250	300		332	800
Zn	ppm	200	100		42	30
Cu	ppm	20	50		32	100
Pb	ppm	20	30		29	30
Ni	ppm	2	3		9	30
B	ppm	15	-		2	10
S	ppm	40	-		-	200
Size		5mm-50mm	6mm-50mm			
CaO: MgO		<0.025	-			

Norsk Hydro and Magcan ppm are all maximum desirable content.

* Norsk Hydro acid soluble SiO_2 should be less than 50 ppm.

Other Magcan specifications provided by Mr. Ron Moore, Vice President-Sales, Baymag, in July 1991 are 92.5% $MgCO_3$ (absolute minimum), 4.3% $CaCO_3$ maximum if minimum of 95.7% $MgCO_3$ is present, 1.3% SiO_2 maximum if minimum of 98.7% is present, 2.0% Fe_2O_3 + Al_2O_3 maximum. The Magcan plant was closed in August 1991 due to technical problems in the commissioning of the 12,500 tpa first stage module.

It is apparent that the Arthur River magnesite does not satisfy specifications for magnesium metal feedstock except for 5-20 metre bands within the deposit (DDH 1 and 2). High silica and a low CaO : SiO_2 ratio are unacceptable, while nickel exceeds the critical 2 ppm maximum level. Calcium content has a significant impact on process economics.

Magnesite has also been tested for use as sinter flux in the steel industry. Specifications requested were 43-45% MgO, < 5% CaO and < 10% SiO_2. Sizing : 100% - 5 mm, 80% - 3 mm. Preliminary results using Arthur River magnesite suggest that it has potential to substitute for dolomite in this application.

SUMMARY

- The Arthur River magnesite deposit is large and low to moderate grade. There is little potential for significant tonnage grading more than 45% MgO (only occur in 10-20 metre thick zones).
- Resources at the Pinner and M1 Prospects (5 km apart) are estimated to be 100-150 million tonnes and 80-130 million tonnes respectively to a depth of 200 metres.
- Average grade is 40-42% MgO accompanied with 5-10% SiO_2, 2-4% CaO and 0.5-1.5% Fe_2O_3.
- The deposit is amenable to relatively low cost open pit mining or underground open stoping.
- Part of the deposit occurs in an environmentally sensitive area.
- Magnesite can be delivered by truck to a deep water port 50 km from the proposed mine.
- Tests have been carried out for several potential uses of the magnesite including:

  - refractories (dead-burned)
  - chemical and environmental (caustic calcined)
  - magnesium metal (lump magnesite)
  - sinter flux for steel

CONCLUSIONS

- The Arthur River magnesite is unsuitable for refractory manufacture on account of:
  1) the high impurity content
  2) inability to achieve high bulk density on sintering
  3) poor crystallinity of the MgO sinter
- The magnesite does not satisfy the Norsk Hydro or Magcan specifiaction except for narrow zones which would be expensive to mine.
- Further calcination tests are required to assess the potential to produce a caustic calcined MgO product suitable for emerging environmental markets such as acid neutralisation and SO_2 gas scrubbing.

- It is essential that future tests are carried out by an industrial company with technical and commercial expertise.
- The refractories and chemical grade magnesia markets are extremely competitive, due to the abundance of quality magnesite resources available and a number of experienced producers with established amortised plant.
- The low quality end of the caustic calcined and dead-burned magnesia market is oversupplied and intensely price competitive.
- The Arthur River magnesia would have to compete on world markets with low to medium grade Magnesia from China on the basis of price. This would not enable a profitable operation to be established in the foreseeable future.
- A new producer with inferior quality magnesite resource will experience considerable difficulty in entering the industry especially if the support of a company with technical and marketing knowledge is not available.

RECOMMENDATION

It is unlikely that the Arthur River Magnesite project can support a viable mining and processing operation of sufficient size to be of interest to CRA.

It is recommended that the joint venture agreement with Mineral Holdings Australia Limited be terminated.

N. Shepherd
Senior Project Manager

ADDENDUM

COMMENTS ABOUT THE MAGNESIA INDUSTRY

- There is no shortage of good quality magnesite deposits in the world. (North Korea, China, Australia [Kunwarara], etc.).
- The refractories market is extremely competitive due to oversupply.
- With declining markets and increasing demand for higher quality, some refractory producers are switching to caustic calcined magnesia for emerging environmental markets.
- Environmental markets for MgO are not growing as fast as expected and many companies are actively seeking market share.
- Substitution of MgO for other alkalis such as lime, caustic soda and soda ash is proving difficult.
- Cost benefits of MgO over currently used alkalis in environmental and other markets need to be demonstrated.
- It is essential that applications for MgO are properly engineered with close cooperation from the customer.
- For the caustic calcined magnesia to succeed there must be strong market pull not resource push.
- A CRA sized operation of 250,000 - 300,000 tpa MgO with sales at $150-200/tonne (sales $40-$60 million) is equivalent to about one third of the current world market for caustic calcined magnesia.
- China and North Korea are capable of swamping world markets with large amounts of high quality magnesite and magnesia at extremely competitive prices. There will be little profit margin if a company tries to compete with China or North Korea on price.
- Although China has a reputation for variable quality and unreliable supply, it will be a formidable competitor for most markets if it can access and apply improved technology.
- The Kunwarara magnesite resource is superior to Arthur River magnesite for the production of refractory grade magnesia.
- The QMC - Pancon - Radex Kunwarara project is based on mining 2 million tonnes per year to yield 1 million tpa magnesite nodules. 350,000 tpa of the best quality magnesite will be used to produce 150,000 tpa refractory grade magnesia and 25,000 tpa electro fused magnesia. Quality will rank with the best refractory grade MgO in the world. Around 30,000 tpa calcined magnesia of lower quality (not required for sintering to refractory product) will be available for sale on environmental markets, at potentially very low cost.

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ARTHUR RIVER MAGNESITE PROJECT

REVIEW OF COMMERCIAL POTENTIAL

FOR CRA LIMITED

G.G LOWDER

30 August, 1991

LEDESA PTY. LIMITED

INTRODUCTION

Following a visit to CRA's office in Melbourne on 27th August, 1991, the writer was asked to prepare a short report expressing his views on the commercial prospects for CRA's **Arthur River Magnesite Project**. These views are based on the writer's knowledge of the magnesite industry gained from his earlier work on the Kunwarara Magnesite Project in Queensland (specifically the Qmag Joint Venture), from his contact with consumers and other industry participants and from his reading of published and unpublished literature on the subject. Care has been taken to avoid conflict of interest or breach of fiduciary duty owed to the QMAG Joint Venturers.

GENERAL COMMENTS

Magnesite is a remarkably versatile mineral. Over 100 products can be made from magnesite as a raw material and the list of uses seems likely to expand in the future. For some of these products the world market is large and has a very significant value, sufficient to be of interest to a large mining company. In other cases the uses are very specialised and total market size is probably too small to be of interest to CRA. Still other products are at an early stage of their commercialisation and the market potential is not yet clear.

Broadly speaking, the end products of magnesite processing fall into five main groups, which are:

Refractories - making use of the high melting point and resistance to heat degradation of magnesium oxide.

Metal - using magnesite as feed stock for the production of magnesium metal.

Environmental - using the chemical reactivity of caustic calcined magnesia for pollution control and the conversion of industrial and other wastes for further use or disposal.

Magnesium cement - using various proprietary technologies for the production of a special cement which allegedly has strength and weight advantages over normal portland cement.

Agricultural - use of caustic calcined magnesia in animal feed stock and fertilizer manufacture.

The scope for CRA to participate in these markets by developing the **Arthur River Magnesite Project** is discussed briefly below.

REFRACTORIES

Magnesite can be converted by calcining at high temperature (more than 1800°C) to a stable, non-reactive form of magnesium oxide (dead-burned magnesia) which is suitable for use in the manufacture of refractory bricks, gunning mixes and other refractory products. Heating to even higher temperatures of around 2300°C causes melting of the feed stock and results in the production of electro-fused magnesia, which is used for the manufacture of superior quality refractories, as well as certain insulating applications.

Various qualities of dead-burned magnesia are available in the marketplace, at prices generally in the range of $300 to $600 per tonne. Electro-fused magnesia brings premium prices of the order of $1000 per tonne and upwards. The total world market for refractory magnesia has been shrinking for some years but, importantly, the market for the high quality end of the spectrum has been growing in both absolute and relative terms. This reflects the higher and higher demands on performance being placed on refractory products by end users, mainly the steel industry.

The consequence of this change in market requirements for producers of refractory magnesia, whether from sea water or from natural magnesite, is increasing competition in the high quality market and oversupply in the lower quality markets. For a new refractory magnesia project to be commercially viable it must be able to produce a consistent, reliable, high quality product that is at least as good as any other source of natural magnesia. Lower quality magnesia would be hard to sell because of general oversupply and particularly because of the ready availability of cheap Chinese material. Furthermore, unlike metal mining, firm sales contracts are not normally available to a new producer, as customers take a "wait and see" approach to his product. Developing a refractory magnesia project is therefore much more risky than an equivalent investment in metal mining.

In this context the Arthur River magnesite just does not make the grade. It contains too many impurities to allow production of the highest quality refractory magnesia. Even the best of the Arthur River material falls well short of competitive material in terms of crystal size and particularly bulk density, which should be over 80 microns and 3.4 respectively. Further metallurgical research may result in upgrading of the product, but there is so much ground to be made up that it seems highly unlikely ever to make the grade. The magnesite forming the raw material for the Qmag Joint Venture is much purer to begin with and is more amenable to beneficiation than the Arthur River material seems to be. It can also be mined at very low cost. Even without competition from Kunwarara the Arthur River project would be struggling to find a place in the world market. With Kunwarara soon to start producing high quality refractory magnesia there seems to be no scope at all for Arthur River to get off the ground as a refractory magnesia project.

MAGNESIUM METAL

The world market for magnesium metal has been fairly static for some time, although various commentators claim that there is major growth potential. This assumes that alloys incorporating magnesium will be used much more extensively in the future in industries such as automobile manufacture. While there is undoubtedly scope for consumption of magnesium metal to grow in response to such uses as the world economy recovers in the 1990's, existing metal producers are well placed to meet much if not most of that growth in demand. The very high capital cost of a new magnesium metal plant will restrict new entrants to the industry. Furthermore, the ready availability of suitable raw material and its relatively low component cost in the finished metal product, means that owning a deposit of magnesite offers little competitive advantage to any such new entrant to the business. Power costs are much more important than raw material costs and proximity to market also seems to be beneficial.

In view of this, it is hard to see how the Arthur River project could become the basis of new magnesium metal production in Tasmania, even if the quality of the raw material was adequate. In that regard, results of work done to date provide no encouragement that suitable magnesite in meaningful quantities is available at Arthur River. Thus even the prospect of selling raw magnesite to a magnesium metal producer elsewhere in the world seems remote. In contrast, the Kunwarara magnesite is quite suitable for the production of magnesium metal but even so, plans for a metal production facility based on that resource are being developed very cautiously by Queensland Metals Corporation and its partners.

ENVIRONMENTAL MAGNESIA

Calcining magnesite at around 750^{0}C produces a reactive or "caustic" magnesia which can be used in wide variety of environmental applications. For example, caustic magnesia has a much greater capacity for acid neutralisation than an equal tonnage of lime. It could therefore be used in place of lime to de-acidify mine waters or to remove heavy metal pollutants from other waste waters. Unlike lime, however, the use of magnesia does not produce gypsum as a useable by-product of de-acidification.

Caustic magnesia can also be used to treat the solid waste component of sewage, where its reactivity causes an exothermic reaction when mixed with the waste, sufficient to raise the temperature high enough to kill pathogens in the waste and make it suitable for conversion to fertilizer.

Numerous other environmental applications of caustic magnesia have been investigated by Queensland Metals Corporation, by the C.S.I.R.O. and by other producers of magnesite. The suitability if not superiority of caustic magnesia in many of these applications has been demonstrated by these workers. Few people would argue with the importance of environmental management for world industries now and in the future. Even so, actual consumption of magnesia for this purpose remains surprisingly low, although difficult to quantify. It seems that socio-political factors will be at least as important as economics for the future market potential of environmental caustic magnesia. Environmental standards will have to be set and enforced on a very widespread basis before demand for magnesia in this context really takes off.

Test work conducted so far on the Arthur River magnesite has confirmed that a highly reactive caustic magnesia can be produced from it. There is thus scope for an environmental magnesia project based on the Arthur River resource, provided predictions of large increases in demand are realised. Once again, the likely production of environmental magnesia from Kunwarara would represent serious and probably fatal competition for Arthur River until there is such strong demand that there is room for several new producers.

MAGNESIUM CEMENT

Several parties have been working on the development of an alternative to portland cement, using magnesite rather than limestone as the raw material. The incentive for this research is the reputed superiority of magnesium cement in applications where high strength but low weight concrete is an advantage. Most of the work being done is proprietary in nature but there seems still to be serious problems with the reliability of mag-cements. This application of magnesite is under study by Queensland Metals, with a view to developing a mag-cement industry on part of the Kunwarara resource.

At this stage there is too little published information on magnesium cement to be able to say whether the Arthur River resource would be suitable for this application. Furthermore, the total size of the potential market is very poorly known and it is likely that a great deal of market development would have to be done if a viable mag-cement project is to get off the ground.

AGRICULTURAL MAGNESIA

The use of caustic calcined magnesia as an additive in prepared stock feeds has been a common practice for a long time. Similarly, caustic magnesia has long been incorporated in various fertilizers. There is little doubt that the Arthur River magnesite could produce material suitable for this application, but it is a low value product with a restricted market and much competition, hardly the kind of industry that a company like CRA should become involved in.

CONCLUSIONS & RECOMMENDATIONS

The Arthur River magnesite deposit is a large resource of medium to high grade magnesite which is amenable to relatively low cost open pit or underground mining. The magnesite itself is mostly of cryptocrystalline type but is characterised by impurity levels which are too high for use of the material in refractory or magnesium metal applications. Preliminary calcining test results also indicate that Arthur River magnesite will not produce dead-burned magnesia of sufficient bulk density or crystal size to be competitive in world markets.

Highly reactive caustic calcined magnesia can be produced from the Arthur River magnesite and this material could prove suitable for environmental applications, such as sewage treatment, the de-acidifying of mine waters and the removal of heavy metals from other waste waters. Markets for these applications are more of a potential than real nature at this stage, but could become one of the growth areas of the 1990's, leaving scope for the Arthur River deposit to be developed if that happens.

The agricultural market for caustic magnesia is unlikely to have a size, value or structure of interest to CRA.

It is recommended that the **Arthur River Magnesite Project** be retained by CRA, provided it can be held at low cost, to allow time for the environmental market trends to become clearer. While that is happening some further low cost calcining and reactivity investigations should be carried out to determine more quantitatively the suitability of this magnesite for environmental use. At the same time, some research into its potential for use in magnesium cement should also be undertaken.

942037

REPORT ON OVERSEAS VISIT

MAGNESITE/MAGNESIA/MAGNESIUM

A ZADNIK AND N SHEPHERD

JUNE 24TH - JULY 8TH 1991

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AIL - please
have this
bound, then
accession all
four reports.
CF of course
Thanks G

CONTENTS

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1. OBJECTIVES

The prime objective of the overseas visit was to ascertain technical and commercial information on magnesite from industry sources.

Companies involved in the production and marketing of magnesium metal and caustic calcined and dead burned magnesia were contacted for information useful for an appraisal of the Arthur River magnesite project.

Key information sought from industry contacts included:

- Specifications of magnesite used in the preferred process for magnesium metal production (Becancour, Norsk Hydro and Magcan).
- Current sources of raw magnesite, quantities required and purchase price for magnesium plant feedstock.
- Assessment of Arthur River magnesite for refractory grade magnesia and comparison with competitors products including QMC Kunwarara magnesites.
- Assessment of Arthur River magnesite for caustic calcined magnesia production. Samples of Arthur River magnesia were available for tests by companies with technical expertise and knowledge of markets.
- Potential increased demand for magnesia in emerging environmental markets, and its ability to capture markets from lime, caustic soda and other alkalis.
- Physical and chemical characteristics of magnesia used in agricultural and environmental applications and indicative market price.
- Supply of magnesia and ability for new large scale producer such as CRA (Arthur River Project) to compete on world markets.

Opportunities for equity participation in the Arthur River magnesite project were discussed with parties that were deemed to have possible interest. The Mineral Holding's Australia Limited 25% interest was stated to be negotiable, while CRA would offer terms for another 25% interest to a party which could contribute technical and commercial expertise to the project.

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2. SUMMARY OF FINDINGS

2.1 Magnesite for Magnesium Metal Production

- The Becancour plant (Norsk Hydro) is supplied with 140,000 tpa crystalline magnesite from China. Purchase price for 20 - 40 mm lump magnesia is US $30/tonne FOB Yingkon China, but capable of supplying for under $US 20/tonne if competition existed.

- Norsk Hydro is keen to secure an alternative supply source provided specifications were satisfied and FOB price was US $25 - 30/tonne for a 5 year contract.

- MgO content must be >45% with <1% CaO and $\frac{CaO}{MgO}$ ratio < 0.025

  Reactive SiO_2 content (opaline silica) must be low.

- North Korea and China have huge resources of good quality magnesite.

- Arthur River magnesite has only narrow sections with suitable grade for magnesium metal feedstock, but these would be expensive to mine.

- Kunwarara magnesite may have too high reactive silica but otherwise satisfies specifications.

2.2 Refractory Grade Magnesia

- Demand for refractory grade magnesia is depressed due to the downturn in the steel industry. Lesser amounts and higher quality magnesia refractories is the trend.

- Require magnesite with +95% MgO, less than 0.2 - 0.4% Fe_2O_3 and $CaO:SiO_2$ *ratio greater than 2:1. Bulk density of sintered magnesia* should be 3.3 - 3.4. Capital size should be 80 - 100 microns.

- Dead burned magnesia sells for $300 - 500 per tonne depending on quality. Top grade magnesia (Israel periclase) sells for more, Chinese low grade product (fettling grade) sells for less.

- Arthur River magnesite does not satisfy specifications for refractory grade magnesia 80 - 90% MgO, 0.6 - 1.0 % Fe_2O_3, $CaO:SiO_2$ ratio < 2:1. Bulk density is 2.2 g/cc.

- Low grade refractory magnesia can be produced from Arthur River magnesite by sintering calcined magnesia produced from flotation concentrate, but this would be expensive and uneconomic.

- The low grade sector of the refractory magnesia market is oversupplied and dominated by low price Chinese product.

2.3 Caustic Calcined Magnesia

- New magnesia markets for acid neutralisation, gas (SO_2) scrubbing and other environmental markets will grow, but at a slower rate than forecast for the next 5 - 10 years.

- Environmental markets are not growing as fast as expected and many companies are actively seeking market share.

- There is no shortage of good quality magnesite deposits in the world (North Korea, China, Australia [Kunwarara] etc). China and North Korea are capable of swamping world markets for most grades of magnesite and magnesia products at low prices.

- Although China has a reputation for variable quality and unreliable supply, it will be a formidable competitor if it can access and apply improved technology. This activity has started.

- Substitution of MgO for other alkalis such as lime, caustic soda and soda ash, is proving difficult. If gypsum by-product of acid neutralisation or gas scrubbing using lime is saleable for plaster-board production, then alternatives will not be considered.

- For calcined magnesia there must be market pull (not resource push).

- The Kunwarara magnesite resource is superior to Arthur River for the production of refractory grade magnesia. At least 30,000 tpa reject calcined magnesia (ie marginal quality for sintering) will be produced and be available for sale on environmental and agricultural markets at potentially very low cost.

- Cost benefits of MgO over other alkalis currently used in environmental and other markets need to be demonstrated to prospective customers.

- Published world market estimates for caustic calcined magnesia are often overstated by producers. Current world markets are around 700 - 800,000 tonnes per year.

- For a CRA sized business unit, about 1/3 of the world market would need to be captured.

- *Minimal profits will be made if companies try to compete with* Chinese magnesia on price.

- The magnesia producer needs to engineer a specific solution for *MgO or* $Mg(OH)_2$ *usage on a customer by customer basis.* Accordingly detailed technical, engineering and market expertise is required by the producer or supplier of calcined MgO.

942042

- There is an increasing opinion that natural magnesia will prove to be more economic for new environmental markets than high purity high cost sea water/brine derived magnesia.

- Calcined magnesia prices range from $100/tonne to $300/tonne FOB. Chinese magnesia is sold in Europe for £75/tonne CIF, in USA for US$125/tonne CIF, and some is available for US$45/tonne FOB China.

- Caustic calcined Magnesia specifications:

Steetley's agricultural products

96% MgO 0.2% $Fe0_3$, 0.3% $Si0_2$
93% MgO 1.3% Fe_20_3 0.8% $Si0_2$

Otavi - Chinese MgO

45% Mg0, 1.5% Ca0, 0.3% Fe_20_3, 1.5% $Si0_2$
46% Mg0, 0.8% Ca0, 0.2% Fe_20_3, 1.2% $Si0_2$

Baymag (Surface area 35 m^2/g)

97% MgO, 1.8% Ca0, 0.6% Fe_20_3, 0.2% $Si0_2$, 2.2% L01

Lo1 for most caustic calcined magnesia is 1 - 2%. MgO with 3 - 8% Lo1 may be sold for fertiliser or environmental markets (generally lower price products).

Surface area (measure of reactivity) depends on application.
May range from 20 - 200 m^2/g

No companies showed any interest in equity participation in the Arthur River Project. Most suggested CRA adopt a "wait and see" approach. Otavi expressed interest in carrying out a market survey, conditional upon a review of the project technical data. Baymag and Steetleys undertook to evaluate samples of Arthur River magnesia and report on their assessment.

2.4 Suggestions by Industry re Arthur River Magnesite

- Otavi Mining indicated that they may be prepared to undertake a market study on magnesia provided they could secure an exclusive agency for Arthur River magnesia. This would be dependent upon analysis of product specifications.

- Baymag would not do further work until environmental market growth which may not be for 5 - 10 years.

- Martin Marietta experience has been that the environmental markets have been elusive and extremely competitive, offered little hope for a new producer with quality that had to compete with China on price. No point in entering industry without technical expertise for market development.

- Norsk Hydro seeking alternative supply of magnesite but must compete with China on specifications and price.

- National Refractories indicated that they may be interested in testing Arthur River Magnesite for environmental markets.

3. CONCLUSIONS

1. Arthur River magnesite is a large, medium quality resource which may be amenable to relatively low cost open pit or underground mining.

2. The quality of the magnesite is not suitable for the production of quality refractory grade products. It is inferior to synthetic and natural Chinese and Kunwarara magnesite for this market.

3. The Arthur River magnesite does not satisfy specifications for magnesium metal production feedstock using the Norsk Hydro or Magcan technology.

4. Further work needs to be done to determine the quality and uses of calcined product which can be produced from Arthur River magnesite.

5. CRA - Mineral Holdings will require support from a company with technical and commercial expertise to compete on the environmental markets for caustic calcined magnesia. This market is extremely competitive and growth is much slower than expected.

6. Refractory manufacturers are utilising surplus capacity to target alternative markets for magnesia. This renders it extremely difficult for a new producer to invest in a greenfields caustic calcined magnesia plant.

4. RECOMMENDATIONS

Either conduct further tests to investigate potential uses of caustic calcined magnesia in environmental applications with support from companies which can contribute technical and commercial expertise or relinquish the joint venture agreement with Mineral Holdings Australia Limited.

5. Company Contact Details

Companies Visited on Overseas Trip
June/July 1991 - Magnesite/Magnesia "Contacts"

Company Name Address and Contact Details	Company Representatives at Meetings
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942048

NOTES FROM OVERSEAS VISIT BY

A ZADNIK AND N SHEPHERD

TO MAGNESIA/MAGNESIUM PRODUCERS

RE: TECHNOLOGY AND MARKETING

JUNE 24TH - JULY 8TH 1991

Overseas Visit - Magnesium/Magnesia/Magnesite

Meeting with ICI, Chance and Hunt, Runcorn

Dr. David Taylor, Sales and Marketing Manager

This Division of ICI deals with agricultural magnesia products, i.e. animal feeds and fertilisers. This market is static. The U.K. fertilizer market is 40 - 50,000 tpa. Chance and Hunt sell Spanish MgO and account for 35% of the U.K. market. Bulk calcined MgO from China, Greece and Turkey are also sold on this market.

Animal feed MgO is 2 - 4 mm particle size and sold in bulk. Finer grained MgO is sold in bags. MgO dust is unpopular in market.

Price of caustic calcined magnesia for animal feed in U.K. is £70-80/tonne which is top of the market. Chinese MgO is poorer quality and cheaper. It is not well calcined (high LOI) and particle size control is poor. High CO_2 is undesirable in MgO animal feed. Availability is also unreliable (important).

Price of MgO for fertilizers is at low end of market.

<u>MgO Specifications.</u>

Important characteristics for animal feed.

MgO content	83 - 85% standard. Poor quality if below 80%.
Particle size and distribution	2 - 4 mm for animal feed
Profile of impurities	Fe, Si and Ca are not a problem

Important characteristics for fertiliser

MgO content	75 - 80%
Particle size	2 - 5 mm. Must be uniform particle size for blending with other components. Must be no dust as not acceptable in factories.

<u>Agricultural Market</u>

Need stock as supply a number of customers. In Europe, U.K. and France are the main MgO fertiliser market. France market may be larger than U.K., i.e.> 50,000 tpa. Total European market is however small. MgO fertiliser is very competitive with supply from Spain, Greece, Czechoslovakia and China.

The agricultural market is not of much interest to CRA (low volume and cheap) although the quality of Arthur River magnesia may be suitable for fertilizer applications.

Environmental Markets

Dr. Taylor did not know much about environmental markets and stated that another ICI office looked after this (Lime and Caustic Soda Branch). He volunteered however that environmental uses presented the best opportunity for development of large new markets. This market for caustic calcined magnesia was taking off in Europe.

He pointed out that reduced markets for chlorine were a source of concern to ICI caustic soda production. ICI is offsetting this imbalance in demand for chlor alkali plant co-products by producing caustic soda from soda ash (Na_2CO_3) although ICI does not have their own resources.

The substitution of MgO for lime in effluent treatment at sulphate TiO_2 pigment plants was considered only possible if there was not a plaster-board market for the gypsum residue. Most sulphate plants in Europe had already been retrofitted with lime based effluent controls and plaster-board factories established on site. If there was no construction market for gypsum, then the disposal of liquid $MgSO_4$ into the ocean constituted a possible advantage.

Dr. Taylor indicated there was a trend to building gas fired power stations in U.K. rather than coal fired on account of acid rain problems which are costly to reduce.

The ICI Chairman has announced company policy that all new plants must be built to the highest environmental standard, depending of course on cost.

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STEETLEY MAGNESIA SPECIALTY PRODUCTS, HARTLEPOOL, U.K.

MEETING WITH DAVID WILSON, TECHNICAL MANAGER - 24TH JUNE 1991

Production and Product

Steetley operates a synthetic magnesia plant which produces high quality magnesia from brine. Target only high price MgO markets with reactive calcined product having surface area ranging from 100 - 200 m^2/g (lowest 10 m^2/g). They tailor the product to meet customer requirements, have good control on quality and demand high price.

Steetley Product Specifications		2 Grades		
MgO	(1) Notionally	93%	(2) Notionally	96%
Fe_2O_3		1.3%		0.2%
SiO_2		0.8		0.3

Impurities are important, e.g. Mn limit for rubber.

Transport

Caustic calcined MgO is transported in 1 - 2 tonne bags, 20 bags per container. Also transported in bulk in ships to Europe. In U.K. MgO is transported in bulk tankers similar to cement tankers.

It is also sold in 25 Kg bags on pallets to small customers (3 - 4 tonnes per year).

Most MgO is sold in dry form, but increasing demand for slaked $Mg(OH)_2$ although transport cost is higher, limiting distribution to within 300 miles of plant.

For environmental acid neutralisation markets, $Mg(OH)_2$ is preferred so savings on drying costs for Steetleys.

Market

Steetleys only sell on the high quality MgO market. This apparently is a very profitable business, but can't tell CRA about it. Their production costs do not enable them to compete with Chinese MgO where quality is less important.

Israel makes best quality refractory grade (periclase) MgO in world from brine. Steetleys could be interested in bitterns from Dampier Salt (referred to Brian Horwood, who indicated that Steetleys had previously shown some interest but no further development).

Steetley Business Units

1. Bricks and Roofing Tiles) Main company focus is in construction
2. Concrete Products)
3. European Quarries - Sands and gravels, crushed limestone and dolomite. Biggest aggregate producer in France.
4. U.K. Quarries
5. North American Quarries
6. Industrial Products and Services - including magnesia. At Hartlepool have good dolomite resource for precipitating MgO from seawater. Hartlepool works £130 million annual turnover. Port can handle 10,000 dwt ships at Hartlepool. 100,000 dwt ships can be loaded / offloaded at Teesport (British Steel port terminal).

Steetleys are not really interested in investing in new calcining plant to treat imported raw magnesite. They have no spare calcining capacity at Hartlepool.

Magnesite Calcination

Suggested rotary kilns may not be the most efficient for production of competitive MgO. Better to use a flash calciner which is more energy efficient. Crushed product is dispersed in a high T gas stream. This type of furnace is low cost, energy efficient and easily controlled for calcination.

Chinese Magnesite and Magnesia Products

Steetleys cannot compete with Chinese magnesia on low end of market. Chinese ship to Europe lump magnesite and calcined magnesia products in bulk. Steetleys are concerned about the potential ability of the Chinese to upgrade the quality of their magnesia products. They are steadily improving product quality even at top end of the market.

Chinese caustic calcined MgO is sold for about £100/tonne CIF. Steetleys can't compete at this price:

∴ £80/tonne for calcined MgO landed is equivalent to
£40/tonne crude magnesite (2 : 1) less energy less shipping
Energy cost about £20/tonne MgO

Steetleys dabbled in trading Chinese magnesia but little profit margin.

Environmental Markets

It is a long, slow process to build up markets for MgO in acid neutralisation in Europe. The advantages and benefits of calcined magnesia over lime (which is cheap) as a pH control agent need to be demonstrated. MgO is more expensive but is a more efficient alkali. Benefits of reduced sludge disposal, etc., need to be promoted. Steetleys participate in trade exhibitions to promote MgO for acid effluent treatment and other uses. Also contact pollution control offices in areas where acid effluent is known to be discharged into controlled waters.

Gas scrubbing - a wet suspension of limestone is used for SO_2 gas scrubbing in coal fired power stations. Hitsuhi - Babcock process is based on cheap ground limestone and sell all the gypsum product (hundreds of thousands of tonnes gypsum/year).

Some power stations already use $Mg(OH)_2$ for SO_2 scrubbing. Produces $MgSO_4$ which is regenerated and recycled so only need to replace MgO losses.

Magnesia Price

Dow Chemical sell $Mg(OH)_2$ produced from brine for US$200/tonne ex works. This is equivalent to Steetley product and price (could not give Steetley prices!).

European Markets

Germany is a large European MgO market, but it is well serviced by Austria and Czechoslovakia.

U.S.A.

Producers are now achieving increased MgO sales after 5 - 7 years educating customers of benefits.

Australia

Steetley considers QMAG project is very optimistic about ability to service markets for deadburned and fused magnesia output. David Wilson was puzzled where they could sell total output as the market is very competitive. Radex will help in marketing, but prime interest may have been to sell furnaces to the project. (NS talked to Bill Duchatel, Director, Pancon [12/7/91] who seems confident sales will be achieved. Gary Lowder, ex GM - Corporate Development stated Possehl is also to market QMAG in Europe. Closure of Fimisco, Greece may help QMAG sales in Europe).

Advice to CRA

Be wary of the Chinese as competitors on the world MgO markets. They have huge resources and will be capable some day of producing cheaply a range of quality MgO products including top grade caustic calcined and deadburned.

The low quality end of the MgO market is over supplied and any producer must be prepared to compete with Chinese MgO on price.

Note for Mineral Holdings Australia Limited

Steetley could be interested in purchasing a quantity of high purity limestone. Contact Barry Brown, Managing Director, Steetley Quarry Products, Sheffield.

OTAVI MINING, FRANKFURT

Meeting with Hans Bohm, Mineralogist. Prime contact Hans-Jakob Henrich, Vice President, available only briefly due to conflict with Board Meeting - 25th June 1991

The Cookson Group, with £1 billion turnover, now controls Otavi. Since the takeover, the building products including insulation, and pure metals divisions have been sold.

Otavi now concentrates on raw material trade in the following industries :

- Refractories
- Glass, Porcelain
- Steel and Foundry
- Fillers and Chemicals

Magnesia

Otavi represents a China trading company in magnesia sales. They sell products world wide with value of DM 60-70 million per year. The main market is deadburned and fused magnesia for the refractories industry. They also sell minor refractory bauxite. Most sales are in Europe, especially Germany and U.K. where the largest refractory customers are located. Their relationship with Cookson has boosted refractory sales in U.K.

The market for refractory grade magnesia is expected to become tougher, with aggressive marketing by North Korea and China securing sales by dropping price.

Possible Interest in Joint Venture

Otavi does not market much caustic calcined magnesia. Mr. Bohm stated that Otavi would be interested in participating financially in a magnesia project and would supply technology and marketing in exchange for an exclusive agency for Europe. Otavi could prepare a marketing study including an indication of how much product they could sell. This study would provide quarterly, half yearly and yearly market forecast with quantities and sales distribution to give the producer an idea of Otavi shipping requirements. (Otavi has an exclusive marketing agency with Lithium Australia - Sons of Gwalia.)
It was suggested that Otavi could purchase 25% interest held by Mineral Holdings Australia Ltd. and obtain another 25% interest by providing technology and market development.

CRA stated they were keen to have a partner with a commitment to marketing and which could provide technological expertise. Otavi has recently adopted a new strategy to go further downstream to increase profit rather than sell commodities with a small margin.

It was pointed out that for a new magnesia project to be established market pull was essential, not resource push.

Mr. Bohm asked CRA to forward an update of the Arthur River project for their assessment. Information requested included:

Resource	Tonnage and Grade
Test programme and results	Calcination Tests
Product specifications	Physical and Chemical
Processing data	Calcination at mine source or at market

Customer requirements may be frequent small drops or larger, less frequent drops.

Mr. Bohm indicated that he would forward some information on magnesia marketing. Markets which could be investigated are Europe and regional markets in Australasia and Southeast Asia. The American market could also be considered.

Specifications for Chinese Magnesite (17/12/90)

Low Fe magnesite grade. Guaranteed specifications

L.M. 45 Composition	MgO	45% min.	CaO	1.5% max.
	SiO_2	1.5% max.	Fe_2O_3	0.2 - 0.3% max.
Size	0 - 6 mm (or similar)			
Price	US$35/tonne FOB (trimmed) Dalian or Ying Kon port.			
LM 46	MgO	46%	CaO	0.8% max.
	SiO_2	1.2% max.	Fe_2O_3	0.2 - 0.3% max.
Size	0 - 6mm (or similar)			
Price	US$45/tonne FOB (trimmed) Dalian or Ying Kon Port.			

THYSSEN SONNENBERG METALLURGIE, DUISBURG

MEETING WITH KURT RIFFEL, MANAGING DIRECTOR, AND KARL HEINZ VON DER HEIDEN, ASSISTANT MANAGING DIRECTOR - 25TH JUNE 1991

Thyssen is only interested in dead burned refractory grade magnesia. They purchase dead-burned MgO from Korea and China for their own use and also to distribute to the European market. Chinese MgO is dominant in the European refractory market. The product is good, but not as consistently good as MgO from Western sources. The Chinese need to improve their processing techniques and quality control. Greek and Turkish magnesia is no longer competitive. (Fimisco closing down as resources exhausted.)

Austrian magnesia has high Fe, so product is used for domestic use and not much is exported. The highest quality magnesia is not sold outside Austria. Radex and Veitcher have now merged to form a large refractories group.

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NORSK HYDRO, OSLO

MEETING WITH TORE VRALSTAD, CHIEF GEOLOGIST - 27/6/91

Norsk Hydro is the world's largest purchaser of raw magnesite. More than 100,000 tpa magnesite is purchased from China, mainly for the Becancour magnesium plant in Quebec.

If the magnesium business improves, Norsk Hydro may convert the plant in Norway from $MgCl_2$ brine feedstock to magnesite. Magnesium is produced from 6 different types of raw materials, and magnesite is clearly the best.

Chemical requirements eliminate a lot of potential sources of magnesite supply (purity is seen as a problem with Tasmanian magnesite). Also need to be a low cost producer near a deep water port, since price is important.

Magnesite Specifications

Norsk Hydro technology used at Becancour is accepted as the best for magnesium production. Plant specifications for magnesite are of two types:

1. Cost specification. Reactive silica is a problem as it forms a residue which introduces added cost in filtration capacity and sludge disposal volumes. Norsk Hydro can be flexible with this specification if there is a price offset.

2. Absolute specification which affects the quality of the metal. Nickel levels are critical as it affects corrosion resistance of magnesium. There is no way of removing nickel in the process. Norsk Hydro specifications are for less than 2ppm Ni in magnesite.
   Manganese content is also important and must be low.

Norsk Hydro purchases lump crude magnesite which is dissolved in an 8m deep HC*l* acid tank. Process kinetics require mostly lump magnesite, but can accept some fines. Impurities (especially Si) cause foaming which clogs the filters and does not allow the filtrate to sink.

At Becancour, the ideal lump size is 20-40mm (formerly 200mm) with none less than 4mm. Still on a learning curve to determine optimum lump size for magnesite feed.

Magnesite shipments for Becancour are 30-35,000 tonne lots from China. The China magnesite deposits are huge and include some high grade lenses which are mined selectively with hand sorting for highest purity.

The Norsk Hydro specifications for magnesite are very tight for quality control. They do not want to be 100% dependent on China and would be most interested in an alternative supply (eg. Tasmania) provided specifications for quality and price can be satisfied.

Magnesite Specifications

MgO	+ 45%
CaO	< 1%
CaO: MgO ratio	< 0.025 Critical
SiO_2	Must be minimum amount of reactive silica as it constitutes a cost factor. Non reactive silica content is less important, but prefer as low as possible.

Kunwarara magnesite has too high reactive silica in parts of the deposit.

Tasmania Magnesite

Tasmania magnesite has been tested by Norsk Hydro but impurity levels are generally too high, especially Fe. Although flotation concentrate meets the Norsk Hydro specifications, it is no good as lump magnesite is required for magnesium production.

Norsk Hydro has analysed Arthur River magnesite (only rely on own analysis).

ANALYSIS OF ARTHUR RIVER MAGNESITE

	<---- %					---->	<---- ppm				---->
	MgO	CaO	Si	Fe	Al	LOI	Mn	Ni	P	S	B
Sample 1 (lump)	45.3	2.0	0.4	0.03	0.002	49.9	50	1	40	-	2
Sample 2 (conc)	45.5	1.1	1.5	0.15	0.02	48.9	32	9	20	-	2
Sample 3 (conc)	46.6	1.0	0.4	0.36	0.02	51.4	460	8	-	70	8

Samples analysed were a small lump of magnesite and two flotation concentrates. An average analysis for the Arthur River lump magnesite was reported as 43.5% MgO, 2.5% CaO, 1.5% Si, 0.5% Fe, 0.01%Al and 49.8%LOI.

The 3 samples tested had variable Si (did not mention if reactive or not). CaO details were satisfactory. Ni was good, while sulphur, boron and phosphorus were acceptable (all crucial). Mn levels were considered high.

Caustic Calcined Magnesia

Norsk Hydro are not interested in the market for caustic calcined MgO. They are involved in a small way, but find it to be a troublesome and highly specialised market. Some caustic calcined MgO is produced as a by-product of Mg metal plant and this is sold (25,000 tpa). [NS advised by Garry Lowder, Pancon, that QMAG will also produce 25-30,000 tpa caustic calcined MgO which is reject refractory grade product]. Mr Vralstad offered his views on the magnesia market. Overall he is not optimistic for any prospective producer. There is adequate supply from a lot of eager producers.

Although the operating cost of producing quality synthetic MgO is high, the plants are nearly all amortised.

North Korea can produce natural caustic calcined magnesia to compete with quality synthetic MgO. China may also be capable of producing high quality magnesia if it can develop organic technology.

Presently, Israel produces the best quality calcined MgO from brine (periclase).

Tore Vralstad views on Australian Magnesite Projects

Kunwarara Project

He considers QMC may have an unrealistic view of magnesia markets. Need more than a good resource to be successful in any sector of the magnesium industry. Anticipates QMC may have problems in marketing dead burned magnesia. Radex is expanding rapidly in Europe through acquisitions and mergers (eg Veitcher merger). Vralstad has visited Kunwarara on several occasions to assess magnesite potential as feedstock for Mg plant. Samples of magnesite tested contain too high reactive silica, although parts of the deposit could be low enough for Mg production.

Yaamba Deposit

Norsk Hydro investigated the Yaamba deposit using legal advisers and consultants on account of political threats (backlash from Queensland Government re Kunwarara).

Howard Smith of QMC however found out about this investigation and objected to Norsk Hydro talking to Yaamba owners (Peabody).

Norsk believes parts of the Yaamba deposit may be better than Kunawarara as an alternative raw material for Mg metal production on account of its lower reactive silica content. The Yaamba deposit is dry while Kunwarara is under water. This may result in a key difference in the chemistry and geology - quartz is no problem in magnesite, but opaline silica may be the reactive form. Normal quartz is not soluble. Opaline silica goes into solution and damages filters. Norsk Hydro would like to obtain a 1kg sample of Yaamba magnesite for testing.

Norsk Hydro does not believe that Peabody is interested in developing the magnesite resource, as its core business interests are coal and energy. Billiton is apparently talking to Peabody. (NS has had an unsolicited call from County NatWest recently, asking if CRA could be interested in "Shell" magnesite resource).

Norsk Hydro considers that the Government would block any participation by them in the Yaamba project. They are only interested in purchasing magnesite for processing and not in mining. This could represent an opportunity for CRA or another Company.

Tasmanian Magnesite

Tasmanian magnesite may be attractive as it is close to a deep water port, and would have similar shipping cost as China to Becancour for 35-40,000 dwt loads. However price and specification criteria must be met for the opportunity to be realised.

Most important is the + 45% MgO and < 1% CaO specification. Other impurities may be filtered out (except Ni, S and B).

CaO cannot be removed without the loss of a similar amount of MgO. If the Ca O is low, then more can be paid for the magnesite (CaO steals MgO in processing).

If the Arthur River deposit has some sections with + 45% MgO and < 1.0% CaO, which could be mined economically, Norsk Hydro would be interested in obtaining samples for analyses and trial tests. Some drill intersections meet these specifications and this potential is to be assessed. Norsk Hydro would copy CRA with test results.

Devex

Produces very high quality caustic calcined and dead burned magnesia from Thuddungra and Fifield deposits in NSW. They target top end of the caustic calcined MgO market and high quality refractory grade.

Magnesite Price

Norsk Hydro currently buys 120-140,000 tpa magnesite from China. Price is less than US$30/tonne FOB China. Supply of high quality magnesite on a 5 year contract for US$25/tonne FOB Tasmania would be attractive, although Chinese are capable of supplying for US$15-17/tonne FOB. Chinese magnesite is now exported from Ying Kon port closer to the Lioanang magnesite deposit than Dalian.

The price of magnesite must be similar to bauxite for magnesium to compete with aluminium.

4 tonnes of bauxite	:	1 tonne aluminium
4 tonnes magnesite	:	1 tonne magnesium

On this basis magnesite cannot compete with bauxite which can be mined very cheaply, hence need lower cost of production for magnesium than aluminium to enable substitution.

If the price of magnesium drops then can expect a lower price for magnesite, although there could be increased tonnage. Australian port charges are high. Ship loading costs need to be lowered to compete with China.

Baymag - Magcan

The Magcan (MPLC) process is theoretically very good, but may need a few more years development. The Baymag magnesite deposit has high quality pods but has normally too high Ca content for magnesium production. Baymag keep best quality for own use. They cannot increase high quality magnesite production, as it would increase mine stripping ratio too much.

North Korean magnesite is much better quality.

Magnesium Technology

Norsk Hydro and Dow Chemical will not sell their magnesium process technology and consider it would take 10-15 years to develop. Norsk Hydro will not build another plant based on $MgCl_2$ brine technology. The Norway plant relies on $MgCl_2$ shipped from Germany at 25°C, but Norsk Hydro is considering switching to magnesite feed.

Magnesium Market

The magnesium market could be very large by year 2000 if it could get 0.5kg Mg into automobiles in USA, Europe and Japan. The automotive market potential is large but will be difficult to achieve, hence timing for market growth is uncertain.

Norsk Hydro Joint Venture Opportunity

Norsk Hydro will visit Australia late November or December 1991 to discuss specific project viability with an exploration company. Sound geological knowledge is required. CRA could provide this!

BRIAN COOPE, INDUSTRIAL MINERALS CONSULTANT, LONDON MEETING 28/6/91

Confident that MgO will make inroads into environmental markets. Legislation could accelerate usage of MgO.

Mr Coope is a metallurgist who now specialises in the marketing and technical aspects of magnesia and other industrial minerals. Has a commercial laboratory at Leeds University. He has done a lot of work in environmental applications in Europe and North America, including removal of heavy metals from water and leaching of heavy metals from slag dumps.

Currently working on use of MgO as filtration material in environmental uses. Highly reactive MgO is preferred. Si should be low as it reacts with MgO or CaO to form silicates which are unreactive. Can eliminate Si if produce $Mg(OH)_2$.

Flue Gas Desulphurisation

Ground limestone or lime is used in most stacks to capture SO_2. Gypsum by-product is used for plasterboard in construction.

Acid Neutralisation

Tioxide is using lime to treat effluent at a TiO_2 sulphate plant near Grimsby and has arranged for sale of gypsum to a German plasterboard company. However there is already abundant gypsum available in Europe.

If MgO is used for acid neutralisation, $MgSO_4$ can be released to sea or used for fertiliser provided it is low in heavy metals.

There is already a big effort by companies in USA and Australia to promote use of MgO in environmental applications. In USA, sales of seawater MgO for this market are already tens of thousands of tonnes (from zero few years ago). If there is a competition between MgO and CaO, lime will win if there is a nearby limestone deposit. However if MgO is more cost effective and benefits are demonstrated, then it will capture some markets from CaO.

The market for MgO (80-85%) in agriculture (low value) and low grade refractories is very competitive in Europe. Caustic calcined MgO from China sells for £75/tonne CIF in

Europe. MgO for animal feed is granular and sold in bulk. In the Industrial Minerals publication, recent quotes for magnesia is £80-90/tonne CIF Europe. Low grade refractory grade MgO sells for less than £100/tonne.

MARTIN MARIETTA MAGNESIA SPECIALTIES INC.

MEETING WITH PAUL SCHEERER, VICE-PRESIDENT OPERATIONS WASHINGTON 1/7/91

Paul Scheerer indicated he has communicated with Neil Thomas over a 15 year period but still has no understanding of resource potential.

Samples of Arthur River magnesite have been calcined by Martin Marietta. Indicated that the magnesite decrepitated and hence required double burning for refractory use. Better to use a high quality magnesite if double burning is required.

- Martin Marietta Magnesia Specialties Inc.

Martin Marietta Magnesia Specialties is part of the Materials Division including a highly profitable aggregate branch.

3 Commercial Sectors in Materials Division.

1. Aggregates. US$50-60m pre tax profit
2. Magnesia Specialties (Refractories)
3. International Light Metals (Aluminium). 48% owned by NKK (Japan)

Martin Marietta magnesia sales are US$120-130 million per year.

- Martin Marietta produces magnesia from natural brine mainly for refractory uses. Brine is quite concentrated - 120 g/l $MgCl_2$ and 225g/l $CaCl_2$. It is pumped from a 225 metre depth and reacted with calcined dolomite to precipitate $Mg(OH)_2$. The dolomite is high purity (0.15% SiO_2) from Ohio deposit.

The precipitate is washed to remove chlorine. It is then calcined (dead burned) to a periclase product with + 98% MgO, 0.2% SiO_2, 0.1% Al_2O_3, and 0.15% Fe_2O_3. By controlling the reactions (high pH using lime) boron can be kept below 70ppm (500ppm in brine).

Two thirds of MgO is used by Martin Marietta for gunning mixes and refractory linings.

45,000 tpa MgO is hard burned in a rotary kiln. It is sold for fusion and also in nodular form for chemical uses - filtration to remove heavy metals from solution. For heavy metal removal, need to provide cartridges with MgO product ie. a heavily service oriented market.

Some lower grade MgO is sold as animal feed and fertiliser. For some markets the nodular magnesia is milled to minus 200-325 microns.

A multiple hearth furnace is used to produce 50,000 tpa reactive MgO products. 5 grades are produced with surface area ranging from 15-70 m^2/g. These are used in chemical industries. Powders with average particle size of 5 microns.

Martin Marietta operates 2 multiple hearth furnaces and 3 shaft kilns to make high grade refractory and high purity MgO products. 1 rotary kiln is used to make low grade MgO for gunning mixes (other materials added to make product with 80% MgO).

In Ohio plant, 99% MgO is produced and sold to steel, rubber and plastic industries (fillers and extenders). Some very reactive MgO ($150 m^2/g$) is sold for acid neutralisation. Different proprietary processes are used to make small volume (5 tpd) products some of which sell for US$3,000/tonne.

Martin Marietta Ohio also produce 750,000 tpa dolomitic lime for steel fluxing.

A MgO fuel oil slurry is used to recover vanadium from Venezualan oil (contains 5-600 ppm V). MgO captures SO_2 to form $MgSO_4$ and prevents H_2SO_4 condensation in boiler tubes ie. stops corrosion. Minor MgO is also sold for dust control and spray surfactants.

Baymag has captured a significant share of the US MgO market for agricultural products. They have also picked up some chemical industry sales but little achieved in the environmental market.

A Clean Air Act has recently been passed in USA which will extend markets for MgO such as removal of SO_2 from stacks of coal fired boilers. The cost of scrubbing SO_2 stack gas will be very high and companies have 5 years to meet limits. It is cheaper to use CaO to scrub SO_2 but this requires approval for land fill disposal of the $CaSO_4$ sludge. There is only one operation using MgO (Philadelphia Electric) but this only requires 300 tonnes MgO which is recycled. This application is only economic if the $MgSO_4$ is burned to recover MgO and S by-product.

MgO Demand.

The market for MgO refractories does not look good. Prices have been stagnant for past 10 years and profits have been low (some producers making losses).

MgO chemical business has grown very slowly over past 20 years. There is however indication that environmental uses will grow.

MgO Refractory Market

Steel industry is demanding lower volume, but higher quality magnesia refractories. Refractory life in B.O.F. 7 years ago was 1400 - 1500 heats before relining. Now 3,000 heats can be achieved. 3.5 lbs./tonne steel ⟶ 2.7 lbs./tonne. Best Japanese 7,000 heats refractory life. Electric arc furnaces improved refractory usage 12 lbs./tonne ⟶ 8 lbs./tonne steel.

Process control in the steel industry is now much better.

Environmental Uses

There is a strong resistance from customers to meet environmental legislation standards. Companies delay as long as possible and plead that implementation costs will force closure or cutbacks.

It is very difficult to plan production if you do not know when product will be used to meet EPA standards. Utility boilers have facilities for SO_2 capture put in place but these are switched off after inspection!

Gas Scrubbing

The SO_2 gas scrubbing market for MgO will be small, as not much is used and CaO will continue to be main product as it is cheap - US$ 40 - 50/tonne. Dravo, Ohio produces a calcined dolomitic lime with 8-10% MgO which is excellent for SO_2 capture. Solid residue goes to landfill. This 8-10% MgO lime will be the major product used for SO_2 gas scrubbing in the future in U.S.A. If suitable dolomitic lime is not available then dolomite will be blended with lime to meet requirements. The relative cost of raw materials and land fill will determine what product is used for gas scrubbing.

At locations close to the coast $MgSO_4$ can be pumped to the ocean (but not into a lake).

Acid Neutralisation

MgO is used for neutralising H_2SO_4 acid as it does not yield a sludge residue. It will replace caustic soda which will become more expensive as the demand for chlorine is dropping in part due to chlorofluorocarbon (CFC) scare. Few new chlor alkali plants are being built and old plants are being closed down. Martin Marietta MgO is now competitive with NaOH for acid neutralisation.

MgO Supply - Refractory Producers switch to Environmental Products

Martin Marietta is switching emphasis from refractories to environmental MgO products. National Refractories is also doing this. Dow Chemicals is increasing calcined MgO from brine resources in Michigan for environmental markets.

Many refractory manufacturers are thus switching to environmental markets which are not growing as fast as expected. These companies have all the infrastructure already available, so no new investment is required. There is over supply in existing calcined MgO capacity in the world right now. Increased supply could come from Baymag, QMC (Kunwarara), and the Chinese are a big threat. The Chinese could contribute a lot to world market over supply.

It is difficult for synthetic MgO to compete with natural MgO except when purity and quality control are important. Synthetic MgO needs as much energy to produce as natural MgO or lime as the $Mg(OH)_2$ precipitate has to be dried and calcined.

Outlook

Martin Marietta are unsure how fast environmental markets for magnesia will grow and recommend that CRA should wait at least 2 years before planning any production. Growth will take place but timing and rate are difficult to predict.

Mr Scheerer suggested it may be worthwhile looking at niche markets, but these would be small.

The market for MgO chemicals and animal feed has been better than fertilisers. The MgO chemical market will continue to grow but only at a slow rate.

Market Strategy

Martin Marietta is very service oriented in refractories and this policy has paid dividends, as do not have to rely on competing on price alone. (Difficult to compete with Chinese on price.)

They get to know prospective customers' operations, trouble shoot and do R & D to develop a product and package to suit their needs. Suggests that if a company is not service oriented, they should not enter the MgO industry as one can not make profit selling MgO as a commodity against competition from China.

Using this market strategy, Martin Marietta has successfully sold refractories in the Western U.S.A. markets despite an US$80/tonne freight disadvantage compared with local refractory manufacturers (e.g. Washington, Oregon).

MgO Price

Chemical grade MgO average US$300/tonne.
High grade nodular MgO can fetch US$500-600/tonne.
If the price of MgO could be reduced to US$200/tonne, then market volume could be increased.

China has been dumping caustic calcined MgO in USA for US$125/tonne CIF. Martin Marietta compete with Chinese MgO in gunning mixes.

Competition is also felt in chemical and refractory grade market from imports from Yugoslavia, Greece, Spain, Netherlands, UK (little) and China.

Visit to Baymag, Calgary Head Office and MgO Operations at Exshaw

Meetings with Ron Moore, Vice-President Sales and Dorm Dalley, Operations Manager 4th July 1991

Refratechnic (Gottingen, Germany) purchased Baymag in 1978 to give them an alternative source of magnesite for refractory manufacture. Previously dependent on supply from Czechoslovakia and other European sources. Austrian magnesite has too high iron.

Baymag high purity crystalline magnesite deposit (120m thick horizon) is 220 km west from Exshaw (which is 95 km west of Calgary). Access is good except for last 26 km. Transport (36 tonne trucks x 18 trips per day) takes 4 hours mine to plant. Freight cost is Can. $10-11/tonne for 220 km haul. Developed open pit mine in 1982 and started calcination using refurbished cement plant at Exshaw (leased from Lafarge Cement). Important to keep capital cost low to enable competitiveness on market . Baymag start-up capital cost was $5 million. Operate 330 days/year.

The company has 107 employees. 72 work at the MgO plant, 21 in the fused magnesia plant, 2 staff at mine (balance contractors) and 22 in the Calgary head office.

Baymag sell only caustic calcined and fused magnesia. They can produce refractory grade, but requires two stage dead burning, have no quality advantage over competitors and also a freight disadvantage. Hence no competitive advantage over US refractory MgO producers.

Magnesia Markets

Mr Moore emphasised that marketing is of prime importance in the magnesia industry. Calcined product is difficult to ship in bulk as it forms lumps if it gets wet.

There is a glut of sintered, calcined and fused magnesia on the world market. Baymag has capacity for 15000 tpa fused magnesia, but can only sell 9-10,000 tpa due to oversupply.

China represents a formidable competitor on world magnesia markets. They have huge magnesite resources in Liaoning Province and 65 operating plants which collectively make a lot of product. A new port has been established at Ying Kon which is closer to the production facilities. The Chinese use their own ships for transport and trade by barter.

Caustic Calcined MgO Market

The world market for caustic calcined MgO is only about 700,000 tpa. Market estimates by Roskills etc. are always exaggerated. Baymag and most other producers always overstate their sales! Baymag sales are 60,000 tpa but report 100,000 tpa MgO.

The MgO market is small and highly specialised with many uses. New applications will be found but not often. Baymag has developed a new market to replace Na OH and sell MgO for US$385/tonne, but this market is small (only 1200 tpa).

Require technical support to achieve sales of MgO. Baymag is fortunate to have a large USA market close by. USA has few domestic suppliers although some refractory manufacturers are targeting the calcined market to compensate for sales decline.

Environmental Markets

Lot of speculation about growth of environmental markets for MgO. The chemistry of MgO is good for many environmental applications and it works well (gas scrubbing and acid neutralisation).

Development of markets for MgO is more of an engineering problem than a technical problem. Need to invest in equipment to test applications and then convince industry of benefits. This is a costly, slow and painful process.

Most MgO is sold as a raw material which is processed by another party to meet users specifications. This is a value added market but there are a lot of failures.

The MgO market for environmental markets is sluggish and sporadic. Ron Moore cannot see any major breakthrough in this market for a long time. Baymag has been trying to build up this market for 8 years without much success.

There is no assurance that MgO will secure a large market base in environmental applications. It wont displace lime (which is much cheaper) in SO_2 gas scrubbing especially if there is a market for byproduct gypsum (used for plasterboard).

Refractory grade markets are competitive and some MgO producers are switching some capacity to caustic calcined product for the environmental market.

Baymag Operations

4 week stockpile of 6" magnesite is kept at plant. Crush to 1" in jaw crusher. Calcine at 800°C for 2-7 hours in a 10'x315' rotary kiln. Screen calcine to 12, 20 and 70 Tyler mesh - 70 mesh is ground to - 325 mesh (possibly to - 400 mesh) in a ball mill. Dust is removed from the rotary kiln (important) as it can choke the flame and reduce kiln capacity. This represents 15-40% of magnesia. The dust is removed from a stack by electrostatic precipitator (expensive).

It takes a long time to establish optimum operating kiln conditions. Many variables - length of flame, T, slope, rotating speed by trial. Product is tested every 20 minutes at various stages of calcination. Production rate is 22 kph $MgCO_3$ -> 11tph MgO. Produce 15 grades of calcined product. Grade 95.5 - 97% MgO. Also produce to customer specifications as required.

The composition of the dust recovered from the stack (electrostatic precipitator) cannot be controlled. It includes variable amounts of calcined and raw magnesite (from cold end of kiln). Some of the dust is sold but most is recycled through the kiln.

Rotary Kiln

1932 vintage. Gas fired. Cheap gas is key factor in viability. Problem with S if use oil. 10' x 315'. Vertical chains half way along kiln accelerates decrepitation. 225 tonnes magnesite in kiln, 2' deep bed. 5 sections in kiln. Calcination takes place between 2nd and 3rd section (not 1-2 near flame entry) 4 and 5 sections are heat-up zone at end where magnesite is introduced.

Quality Control

There are 12 sample points between the mine and the bagging of product. This is a simple process but essential. Quality control is important for customer. Product is light burned not caustic calcined. Temperature used is 807°C (900°C chain temperature).

Some hard burned MgO is produced in batches. Kiln is rotated at slower speed and higher temperature. The hard burned magnesia is used for neutralisation of strong acid. Would have exothermic reaction if used caustic calcined MgO (too reactive).

Sizing and screen analysis, and surface area BET and Iodine Number tests are carried out in the Baymag laboratory on site.

- $\frac{1}{2}$" + 12 mesh calcined MgO is processed through a hammer mill.
+$\frac{1}{2}$" product used to be sold to steelworks for fluxing.
Calcined product slakes readily so must be protected from moisture.
Dead burned MgO (96) can't be slaked.
Light burned MgO slake time generally 24 hours but depends on water temperature. Exothermic reaction, so must always add product to water not vice versa.

Specifications for 3 grades of light burned MgO 30, 56 and 96 are attached.

Transport

Product is transported in either 1 tonne bulka bags or in 25kg bags (animal feed). None is shipped in bulk. Average customer requires 2-300 tpa MgO. Baymag owns a 114 rail car fleet. No backloading is possible. Two customers send their own rail cars.

Fused Magnesia

The fused magnesia production facility (commissioned Sept 1989 at capital cost Can. $20 million) is 4km from the calcining plant. The plant is highly automated and has a capacity of 20,000 tpa refractory grade fused magnesia. Sells for US$1,100/tonne. The fused MgO has too high Fe for electric grade (US $2,000/tonne). The pilot plant which cost Can. $250,000 could produce 7,000 tpa.

Baymag considers QMC will not be able to service debt on fused magnesia plant. Customers don't like changing supply unless there is a very good reason. It will take QMC a long time to build up a market base as consumers take long time for decision to purchase new product.

Views on Australian Magnesite Projects

Mr Moore visited Kunwarara operations to assess its potential for success. Over $160 million has been spent and concern was expressed about QMAG being able to sell sufficient refractory grade magnesia and fused magnesia to service debt and generate profit. If QMAG fails, he thought Radex could run the project for a while, but diagnosis was for financial failure due to product distribution and marketing difficulties.

He was also doubtful about the viability of the Arthur River magnesite project in the short to medium term. Australian operations will have problems with distribution due to distance from major markets. Baymag also has distribution problems, but much less than Kunwarara or Arthur River.

Arthur River

The calcined product from the Amdel tests is too reactive for general chemical use. Should calcine more to reduce reactivity and CO_2 content.

Baymag MgO has a L01 of 1% or 2%. Arthur River MgO needs to be reduced from 6-7% L01 to less than 2.5% even if this reduces reactivity. Surface areas of 30-40 m^2/g are fine for many markets.

Suggests we heat to 900°-1000° for longer retention time (hard to believe this!).

Should do some tests on citric acid and acetic acid reactivity. Also tests with dilute HCl solutions.

Baymag considers that it is highly unlikely that the Arthur River magnesite project could be developed for many years. Kunwarara prior development is another factor.

Baymag is not interested in a joint venture on the Arthur River magnesite project.

1. Location - too far from markets. Hence distribution problems.

2. Peculiarities of market. Environmental markets will not be driven by MgO producers unless engineering services provided.

3. Baymag is a small privately held company with no history of joint ventures.

Recommends

1. Retain tenements so long as holding cost is reasonable.

2. Complete market analysis.

3. Adopt a wait and see strategy - 10-15 years.

Baymag offered to carry out tests on samples of calcined product provided and will report results.

Offered to send flow sheet for Exshaw operation. Natural gas in Alberta is very sour due to high sulphur content. No MgO is used for removal of S despite MgO being available locally (30 km distant). May be sizeable market for MgO if S removal is legislated but this could be many years off.

Baymag Advice to CRA

If get into MgO business, start with minimum investment in modest plant to survive. If build an expensive plant initially this is recipe for disaster (possible scenario for QMC).

If CRA can land bulk magnesite along the North American coast for $50-60/tonne and calcine near the market, it would still be more expensive (2x) than Baymag, competitive with Steetley and Pechiney and cheaper than Greek and Spanish magnesia.

Currently there are not many markets big enough for a CRA size operation in North America. MgO has a lot of uses and can be substituted for other alkalis, especially caustic soda which is now very expensive (usually $Mg(OH)_2$ displaces Na OH (not MgO). $Mg(OH)_2$ however is expensive to transport.

Baymag Opinion of Arthur River Magnesite

1. Tasmania location may cause a distribution problem for MgO as too far from markets. China has no distribution problem as they use their own ships for zero value and backload wheat.

2. Considering the oversupply of calcined, dead burned and fused magnesia on world markets, if QMAG comes on stream, then it will be a long time before the market can support another new producer.

Other Points

- Landed cost of crude magnesite in USA is US$50/tonne minimum, which is twice the cost of Baymag crude.

- Potential conversion of MgO to slaked $Mg(OH)_2$ to replace NaOH or $Ca(OH)_2$ introduces a formidable engineering problem. This possibility is talked about a lot, but market development will be difficult.

VISIT TO STANFORD RESEARCH INSTITUTE

MEETING WITH DR EUGENE THIERS, BUSINESS MANAGER - METALS AND MINING, SRI INTERNATIONAL

MgO market is static at best, except environmental. Possible markets include acid neutralisation, gas scrubbing and steel industry. Need to engineer markets by conducting trials for specific applications.

MgO may be too soluble for some applications eg. MgS04 or other soluble compound may not be desirable by-product in some applications.

Soda ash from Green River, Wyoming is now being successfully promoted as substitute for caustic soda on world markets following increased price of NaOH.

DISCUSSION WITH DR ADRIAN SMITH, ASINCO HOLDINGS INC., NORTH VANCOUVER GEOCHEMICAL AND ENVIRONMENTAL CONSULTANT - 8/7/91

Believes QMC may have difficulties next 2 years in establishing profitable operations due to time required for the establishment of high volume markets in the highly competitive magnesia industry. Adrian has been advising Tony Grey on recent problems with Pancontinental Mining.

Considers QMC is capable of producing best quality dead burned and caustic calcined magnesia in the world.

The MgO market is affected by the ability of companies to defer the implementation of environmental legislation by "buying time" through political favours. No companies will spend more than absolutely necessary on environmental controls and some influence the timing of enforcement of standards and limits. This is a major factor in delaying growth in demand for CaO, NaOH and MgO.

There is no shortage of MgO available on world markets.

7. Company Correspondence

STEETLEY MAGNESIA PRODUCTS LIMITED
Hartlepool Works
P.O. Box 8, Hartlepool
Cleveland TS24 0BY
Telephone: 0429 267071
Telex: 58649 Fax: 0429 266600

STEETLEY

942080

Our Ref.: DRW/SAC

Date: August 22, 1991

Dr. Norman Shepherd,
CRA Ltd.,
55 Collins Street,
Melbourne 3001,
AUSTRALIA.

Dear Norman,

I am pleased to hear you found our meeting useful. I trust the remainder of your trip was successful.

I would ask you to bear with me for a little while. I am about to undertake a three week trip to the far east. Unfortunately we have no plans to visit Australia while we are in the area!

When I return I will submit a proposal based on preliminary evaluation of your samples. I don't expect to be able to do this before the end of October however. I hope this does not give you a problem.

Thanks for the invitation to visit you. I would be pleased to accept should I ever have business in Australia.

Yours sincerely,

David Wilson

D.R. Wilson
Technical Manager

File 1-15-9

942081

DAMPIER SALT (OPERATIONS) PTY. LIMITED
AUSTRALIAN COMPANY NUMBER 008 668 234
177A ST. GEORGE'S TERRACE PERTH WA 6000 AUSTRALIA

PO BOX 7073
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MARKETING:
TELEX: AA187221
FACSIMILE: (61) (9) 327 2298

JUL 8 15:49

RECEIVED

6 August 1991

Fax: 03 658 3707

[redacted]
Senior Project Manager
CRA Limited
55 Collins Street
MELBOURNE

Dear Norm,

Thank you for your letter of 2 August, 1991 addressed to Kevin Wellisch.

Please note that Kevin is no longer with this company, and as Dampier Salt Technology Department will be closing in the near future, I have passed your correspondence on to our Managing Director, Mr Brian Horwood, for noting.

As a point of interest, Steetley had previously contacted Dampier Salt in respect of magnesium production in the mid 70s and while samples were taken for bench-scale testing, this work was never pursued.

From our own studies there are some technical barriers to readily obtaining high quality magnesium clinker from sea water brine, which I believe does not confront the Israelis.

Regards,

J N McARTHUR
General Manager - Technology

ab12578

Baymag
800, 10655 Southport Road S.W.
Calgary, Alberta, Canada T2W 4Y1
Tel: (403) 271-9400
Telex 03-827731
Telefax (403) 271-0010

July 24, 1991

VIA TELEFAX
(03) 658-3707

nc

CRA Services Limited
Melbourne 3001, Australia

Attention: Mr. Alex Zadnik

Dear Alex:

Thank you for taking the time to visit us in Calgary on July 4th. I am leaving for my annual vacation today and have not received the laboratory analysis on the sample Dr. Shepherd left. I will be writing my report on our visit on my return in mid August.

Yours truly,

per: Arlene Wyeth

Ronald A. Moore
Vice President, Sales

RAM/ad

NATIONAL
MAGNESIA CHEMICALS
Division of National Refractories & Minerals Corporation

942083

July 22, 1991

FAX: 011-61-3-6583451
HARD COPY MAILED

CRA Services Limited
GPO Box 384D
Melbourne 3001, Australia

Attention: Alex Zadnik

Dear Alex:

Our July 5, 1991 meeting was very helpful to us and much appreciated.

Our plan is to be the major supplier of magnesia chemicals in the environmental markets. As discussed, we will require the availability of a reliable, consistent high reactivity calcine at competitive prices to complement our seawater/dolomite based products out of Moss Landing, California.

We expect rapid growth in usage of magnesia chemicals over the next 3 - 5 years. The majority of the growth will be in acid neutralization and heavy metals removal or recovery. Two large markets in FGD (SO_2) and Superfund Site Remediation will be developing in this time period, but the rate of development is more difficult to project.

The majority of our current projects are in the Western United States and Texas/Louisiana. $Mg(OH)_2$ slurry has obvious shipping limitations although we are supplying one major copper company in New Mexico 9,000 TPY (dry weight equivalent). Many large users, however, will either have or install slaking capabilities to handle high reactivity calcine. At present we utilize our MAG PLUS Grade 30/40.

National is developing most of these larger potentials and this positions us well to obtain the early calcine requirements. This large developing usage will bring in competition from many sources. As we discussed, the Chinese are expected to be the major cost competitor.

National would be very interested in representing your product line in North America. We are rapidly developing the application technology required to make major markets. It would obviously expand our practical territory beyond the Western North American market and gulf areas. Some larger accounts in our existing market areas will require large volume of good quality calcined natural magnesite to remain competitive.

National has the only experience with $Mg(OH)_2$ on handling the off-gases from copper smelters in large volume but it is associated with wet scrubbers. The major copper smelters we are aware of are wet scrubbers in the U.S.A. Most of these use CaO to neutralize the effluent and the resulting contaminated gypsum simply impounded. There is environmental pressure to correct this which would then bring $Mg(OH)_2$ into a strong market position. Some simply consume their weak acid by leaching of oxide ores.

We have not worked with anyone on dry baghouse operations using $Mg(OH)_2$ for the copper industry. We are the major supplier to a company that promotes dry baghouse applications for MgO in the foundry industry. We would certainly be interested in discussions with your subsidiaries on such an application.

National Refractories & Minerals Corporation is a privately held company of about $170 million in sales. Prior to 1985, we were Kaiser Refractories, a division of Kaiser Aluminum & Chemical Corporation. We will put together a packet of information on our company that will be helpful.

Sincerely,

Gary A. Tyler
Manager

GAT/jl

cc: J. E. Allen
C. T. Caves
R. L. Coatney
J. C. Hartman
T. H. Mathis
C. C. Smith

A SUMMARY REVIEW OF NATIONAL REFRACTORIES

National Refractories & Minerals Corporation began as a new company in January, 1985 with its management and an investment bank purchasing most of the North American plants and assets previously operated by the Kaiser Refractories Division of Kaiser Aluminum & Chemical Corporation. The company is structured with an Employee Stock Ownership Plan (ESOP), and 44% of the common stock is held currently by 1500 employees. National ranks in sales among the top four U.S. producers.

Facilities include a dolomite facility, a seawater magnesia plant, two basic refractory plants, a clay/alumina plant, and a preformed shape conversion facility. There is a wholly-owned subsidiary in Canada, and our company maintains an extensive research and product development center in Pleasanton, California.

National Refractories produces basic brick and monolithics, clay-alumina brick and monolithics and preformed shapes. It also produces Scorialit mold powders for continuous casters in North America under an exclusive licensing agreement with Metallurgica G.m.b.H. of West Germany.

The company has much of its raw materials base secured, being self-sufficient in clays, 65% sufficient in MgO and holding favorable contracts for imported bauxite and chrome ore.

The company conducts an active overseas business with a worldwide network of licensees and agents in 23 countries. There are technical licensee agreements currently with five foreign refractory companies and technology has been purchased from four non-U.S. companies so the company can keep abreast of the latest refractory product developments worldwide.

Diversified Sales

National Refractories also includes two sales divisions, National Magnesia Chemicals and National Mineral Products, the former selling chemical-grade magnesia and the latter selling a variety of high purity dolomitic products.

Unique Combination of Assets

The combination of employee ownership, concentration on research and development and an enviable raw material position enables National Refractories to sell proprietary products of the highest quality at a competitive price throughout the world. This is possible because in the buy-out National Refractories left behind the non-profitable plants and streamlined operations at the remaining facilities.

National Refractories maintains a leading position in research and product development, to keep pace with the ever-evolving new industrial processes in steelmaking, cement and other basic industries. National Refractories personnel have created or modified approximately 250 products since 1985. The intense product development approach has resulted in 25% of revenues being generated from products that did not exist five years ago. Research and development spending averages approximately 3% of sales.

One Kaiser Plaza, Oakland, California 94612 Telephone 415/452-8711 Mail: P.O. Box 24040, Oakland CA 94623-1040

SPC is Implemented

Statistical process control (SPC) has been implemented at all plants; and customers such as Bethlehem Steel, LTV Steel, Inland Steel, PPG and Alcoa have ranked our plants among the top for SPC techniques. The Mexico, Missouri plant has been rated by Bethlehem Steel and Alcoa as the best in SPC implementation for clay-alumina refractories. Effective SPC has meant the product rejection rates are the lowest in company history. Employees are also actively participating in Quality Circles at the plants and the research facility.

Service to Customers

National Refractories' sales have grown 35% from 1985 to 1988, and are forecasted to grow at a rate above the industry average through 1991. With a competitive cost structure due to our raw materials position, efficient facilities network and the Employee Stock Ownership Plan spirit, National Refractories is strongly positioned to be a leader in the supply of innovative, cost effective products and services on a world-wide basis.

At the heart of our strength in the marketplace is the commitment of our people to produce quality products which solve the refractory problems of our industrial customers. Every employee has a personal stake in seeing National Refractories prosper, and all segments of our operations understand that to excel we must constantly satisfy our customers and develop long-term relationships with them. To that end, we have a company slogan: "Better Refractories From People Who Care."

Better Refractories From People Who Care™

NATIONAL
REFRACTORIES & MINERALS
P.O. Box 24040, Oakland, CA 94623-1040
One Kaiser Plaza, Oakland, CA 94612
415/452-8700

CRA Limited
Incorporated in Victoria.
55 Collins Street, Melbourne 3001, Australia.

File: 1-A5-9

7 August 1991

Mr Ron Moore
Vice President - Sales
Baymag
800, 10655 Southport Road SW
Calgary, Alberta T2W 4YI
Canada

Dear Ron

Alex Zadnik and I are very appreciative of the time you spent with us on our visit to Calgary. We both learned a lot from the frank and open discussions on our Tasmanian magnesite project and the visit to your Exshaw operations.

We were very pleased you and Christine could join us for dinner at the Westin Hotel. It was also great to catch up with my friends, Maire and Hugh Jones. I do apologise for my state of health which prevented me from participating in the Calgary Stampede spirit. Normally I am not as subdued, but as it turned out I had pneumonia and was told on my return that I should have been hospitalised.

Your letter of July 24 was received and we look forward to the results of your laboratory analysis. With the high silica content, would there be any advantage in trying to upgrade the product by screening? This may not be necessary considering the major applications we would be targeting are environmental where impurities are not so important.

As I mentioned during our discussions, the calcination tests must be treated as being very preliminary and much more work needs to be done to optimise kiln conditions to yield a reactive product suitable for specific industrial applications. This is where a cooperative arrangements with a company such as Baymag with the technical and commercial expertise would be invaluable. We would very much like to build on the excellent understanding we have established with Baymag through you interest and support.

942088

Alex and I also appreciated your sound advice regarding the lag between industry expectations and realisations in the market place. The need for strong technical/economic input to the development of new markets was also noted. As you pointed out, you have been in the industry for a long time and your experience over these years in delays in achieving forecast market growth must be taken into account.

Please convey our regards to Dorm Dalley. We were most impressed with the operation he was managing. We would do well to model any plant for Tasmania on your Exshaw plant. Nothing fancy (hence inexpensive), but efficient and with good quality and production control.

Ron, we look forward to hearing from you on your return from vacation. Again, our sincere thanks for all your help.

Yours sincerely

Norman Shepherd   Alex Zadnik

Norman Shepherd & Alex Zadnik

cc: A Zadnik

NS/WL 8/8/91

CRA Limited
Incorporated in Victoria
55 Collins Street, Melbourne 3001, Australia.

File: 1-A5-9

5 August 1991

Mr Brian Coope
Leeds Mineral Services Group
304A Upper Richmond Road
London SW1A 7JG
England

Dear Brian

Alex Zadnik and I appreciated the opportunity to meet with you on 28 June, 1991 to discuss potential market opportunities for caustic calcined magnesite from our Arthur River magnesite project in Tasmania.

At this stage, it is apparent that we need to do a lot more calcination test work to tailor product to meet industry requirements. Unfortunately, CSIRO is not available to undertake this technical work on account of contractual arrangements with QMC on the Kunwarara magnesite project in Queensland.

When we have resolved the problem of finding a laboratory with the requisite expertise in calcination and characterisation of magnesia (chemical and physical properties), we may need your assistance to identify markets and determine product specifications for specific applications.

You indicated that there was a study proposed on "An Environmental Audit for the Base Metals Industry" and sponsors were being sought. Would you be able to advise us of the details of this study, as it should be of interest to CRA?

Next time you are in Australia, I hope you will have the time to visit us in Melbourne.

Yours sincerely

Norman Shepherd

Norman Shepherd
Senior Project Manager

Telephone (03) 658 3333 GPO Box 384D Melbourne 3001, Australia Telex AA30108 Telegrams Conrio Facsimile (03) 658 3707

CRA Limited
Incorporated in Victoria
55 Collins Street, Melbourne 3001, Australia

File: 1-A5-9
1-H5-9

2 August 1991

Mr Kurt Riffel
Managing Director
Thyssen Sonnenberg GMBH
Worthstrasse 110
4100 Duisburg 1
Germany

Dear Kurt

It was a pleasure to meet with you again! I do sincerely apologise for our very late arrival, and hope it did not cause any inconvenience.

Alex Zadnik and I appreciated the time you and your colleague Karl-Heinz von der Heiden made available to discuss our nickel and magnesia projects and other commodities of possible interest.

As we progress with investigations on the Honeymoon Well nickel project, we will be pleased to keep in touch. At this stage, we are confident that a unique high quality nickel concentrate can be produced from the low-medium grade ore discovered to date. Exploration is continuing on a number of highly prospective targets within the Honeymoon Well project area to increase reserves.

I still keep in touch with my Barrack colleagues (especially Andrew Simpson) when I visit Western Australia. I understand the operation is going well and there are encouraging signs of an increase in silicon price.

Should you or Karl-Heinz be in Australia, we would be delighted if you could visit us in our Melbourne office.

Yours sincerely

Norman Shepherd

Norman Shepherd
Senior Project Manager

cc: A. Zadnik

CRA Limited
Incorporated in Victoria.
55 Collins Street, Melbourne 3001, Australia.

File: 1-A5-9

2 August 1991

Mt Tore Vralstad
Norsk Hydro a.s.
PO Box 200
N-1321 Stabekk
Oslo NORWAY

Dear Mr Vralstad

Alex Zadnik and I appreciated the time you made available on 27 June for discussion on magnesium metal production and markets.

I have asked our geologists to determine potential reserves of high grade magnesite which could satisfy your specifications for Mg plant feedstock. I will contact you when I have this information. I hope we can offer an alternative, competitive source of supply to China. If we are confident that your specifications and long term tonnage requirements can be supplied economically, samples of the magnesite will be forwarded for your evaluation.

Your comments regarding the potential suitability of Yaamba magnesite (Peabody) for metal production were noted. We will make some discreet enquiries and advise you of our findings.

It will be interesting to see how Pancon-QMC fare with their bold investment in refractory grade magnesia products. In recent months, Pancon has been divesting of its major assets to reduce debt levels. I do hope they are making the right decisions.

Next time you are in Australia, I hope you will be able to visit our Melbourne office.

Yours sincerely

Norman Shepherd

Norman Shepherd
Senior Project Manager

cc: A Zadnik

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File: 1-A5-9

2 August 1991

Mr Hans-Jakob Henrich
Managing Director
Otavi Minen AG
Mergenthalerallee 19-21
D-6236 Eschborn
Frankfurt/Main
Germany

Dear Mr Henrich

It was a pleasure to meet up with you again! Alex Zadnik and I appreciated the time you made available, knowing that you had urgent preparations to complete for an important board meeting later in the day.

We had most informative discussions with Hans Bohm and are very grateful for his advice on magnesia markets. Hans pointed out that although Otavi traded mainly in dead burned and fused magnesia for for the refractory market, the company could be interested in caustic calcined magnesia.

As you are aware, CRA has a very large crystalline magnesite resource in Tasmania located within 50 kilometres of a deep water port. Preliminary tests suggest that the magnesite can be readily calcined at about 750°C for less than half an hour to yield a highly reactive product.

CRA is basically a large metals mining company and does not have any experience in the processing or marketing of magnesia. We recognise that market pull is essential for the resource to be developed. Hence we would welcome a joint venture partner who could provide the necessary technical and market expertise to develop the project.

Telephone (03) 658 3333 GPO Box 384D Melbourne 3001, Australia Telex AA30108 Telegrams Conzinc Facsimile (03) 658 3707

I enclose some information on the magnesite resource and very preliminary calcination tests. More testwork is required to optimise the calcination conditions to produce a reactive product to satisfy specific market requirements.

We thank you and your colleague, Mr Bohm once again for the opportunity to discuss the Arthur River magnesite project, and look forward to possible cooperation in the future.

Should you plan to visit Australia, we would be delighted to meet you at our office in Melbourne.

Yours sincerely

Norman Shepherd
Senior Project Manager

att.

CRA Limited
Incorporated in Victoria
55 Collins Street, Melbourne 3001, Australia

File: 1-A5-9

2 August 1991

Dr David Taylor
Sales and Marketing Manager
ICI Chance and Hunt
Alexander House Commercial Gate
Runcorn
Cheshire WA7 2UP
England

Dear David

I wish to thank you for the time you made available to meet with Alex Zadnik and myself on 24 June 1991. We appreciated the insight you provided on markets for caustic calcined magnesia.

It appears unlikely that the animal feed and fertiliser market will provide a basis for development of our Tasmanian magnesite deposit.

You mentioned during our discussions that it would be more appropriate for us to communicate with another branch of ICI which is involved in alkali chemicals and would be able to advise on product specifications and potential markets for caustic magnesia in environmental applications. We would appreciate if you could provide contact details so that we can get in touch with this ICI Division. We may be interested in providing samples of our calcined product for testing and characterisation by your laboratories.

I look forward to hearing from you soon.

Yours sincerely

Norman Shepherd
Senior Project Manger

cc: A Zadnik

CRA Limited
Incorporated in Victoria.
55 Collins Street, Melbourne 3001, Australia.

942095

File: 1-A5-9

2 August 1991

Mr David Wilson
Technical Manager
Steetley Magnesia Products Limited
PO Box 8
Hartlepool
Cleveland TS24 OBY
England

Dear David

I appreciated your making time available to meet with Alex Zadnik and myself at Teeside Airport on June 24, 1991.

We found the discussion most useful and now have a much better understanding of calcined magnesia markets and the formidable competition from Chinese imports in the lower quality segment of the market. I have referred your possible interest in bitterns from the Dampier Salt operations in Western Australia for high quality magnesia production. Should you wish to follow this up please contact:

Mr Kevin Wellisch
P.O. Box 7073
Cloisters Square
Perth WA 6000

I would be interested to have some comments from you on the calcined magnesia samples which I left with you. The magnesite was calcined at 770°C for 15 minutes. It is not fully calcined and still has 7-8% residual CO_2. The magnesia contains a considerable amount of silica which may be able to be screened if necessary to upgrade the product.

I would appreciate if you could provide a technical evaluation of the product with some indication of possible markets which we may be able to target. Advice on whether the magnesite requires more complete calcination would be welcome. I enclose some results from the preliminary calcination tests undertaken at the AMDEL Laboratory in Adelaide for your information.

942096

Should the caustic magnesia be of interest to Steetley, we would be pleased to discuss possible marketing arrangements and equity participation in the project.

We would be very pleased to meet you in our Melbourne office should you plan to visit Australia.

Yours sincerely

Norman Shepherd
Senior Project Manager

cc: A Zadnik

CRA

942097

CRA Services Limited
Incorporated in Victoria
55 Collins Street, Melbourne 3001, Australia

19 July 1991 By fax: (0015-1-408) 633 2904

Mr. Gary A. Tyler
Manager
National Magnesia Chemicals
P.O. Box 30
Moss Landing, CA 95039
USA

Dear Gary,

I would like to thank Thomas Caves and yourself for making the time available to see me in San Francisco on 5th July.

I trust I was able to explain to you CRA's interests in the Tasmanian magnesite project, as well as our longer term objectives, to form a collaborative relationship with people in the industry who have a good understanding of the customer expectations and the market characteristics. Certainly we would like to continue to explore with you any areas of common interest and mutual benefit for our two companies in respect to natural magnesite derived products.

One area where you may already have had specific experience is in the use of MgO or $Mg(OH)_2$ in metal smelter baghouses. One of our subsidiary companies is currently assessing alternatives to lime and caustic soda for capturing sulphur, zinc and lead fumes arising from a copper smelting process. If you have specific experiences in this area and are interested in following up, please let me know.

I would also be interested to know more about National Magnesia Chemicals and the National Refractories and Mineral Corperation. Any recent literature and annual reports you could send me would be appreciated. Likewise, please let me know if I can provide you with further information about the CRA Group and the Tasmanian magnesite project. In particular we would be happy to send you natural magnesite samples for testing and evaluation if you thought this would be useful.

Finally should you or your colleagues be visiting Australia we should certainly like to see you in Melbourne.

Yours sincerely,

Alex Zadnik

Alex Zadnik
General Manager - Business Development
Resource Commercialisation

Telephone (03) 658 3333 Correspondence GPO Box 384D Melbourne 3001 Australia Telex Conno AA30108 Facsimile (03) 658 3707

CRA Limited
Incorporated in Victoria
55 Collins Street, Melbourne 3001, Australia

942098

File: 1-A5-9

2 August 1991

Mr Kevin Wellisch
Dampier Salt Limited
PO Box 7073 - Cloisters Square
Perth WA 6000

Dear Kevin

I have recently returned from an overseas trip with Alex Zadnik on a mission to gather technical and commercial information on nickel concentrates and caustic magnesia.

We met with Steetley Magnesia Products Limited in Hartlepool, England. They are more interested in the higher quality end of the magnesia market, so did not show too much enthusiasm for our Arthur River calcined product.

I mentioned the potential for quality magnesia to be produced from Dampier Salt bitterns and this was of much more interest. If you think this is worthwhile following up, please contact:

Mr David Wilson - Technical Manager
Steetley Magnesia Products Limited
PO Box 8
Hartlepool, Cleveland TS24 OBY
England

Some of the highest quality magnesia is produced from brines in Israel. I do not know how this would compare with WA bitterns which are probably much more concentrated. This quality of magnesia commands a premium price.

Have now settled down in Melbourne, but taking some time to forget the beautiful weather in the west.

Best regards

Norman Shepherd
Senior Project Manager

cc: A Zadnik

AMDEL CALCINATION TEST PROGRAMME

Caustic Calcined Magnesia

Introduction

A calcination test programme was undertaken at Amdel Laboratories, Adelaide, South Australia in May 1991 with the objective of determining kiln operating conditions to produce a highly reactive magnesia from samples of Arthur River magnesite.

Three magnesite samples from the Pinner Prospect were tested. They had the following compositions (%):

Sample	MgO	CaO	Fe_2O_3	Al_2O_3	SiO_2	CO_2
A	41.1	4.12	1.31	0.13	3.43	50.6
B	39.0	2.99	0.88	0.06	8.92	49.2
C	41.6	1.22	0.53	0.11	7.72	48.0

Samples A and B are composites prepared from drill core. Sample C is a composite from boulders in the Pinner pit.

Differential Thermal Analysis

A differential thermal analysis showed that the magnesite decomposed in the range 570°C to 710°C. However, the magnesite component of the dolomite in the sample decomposed at 710-780°C, while the $CaCO_3$ decomposed at 925-960°C (Refer Figure 1).

Muffle Furnace Tests

Laboratory muffle furnace tests were carried out using 150 gram samples of magnesite crushed to minus 6.3 mm.

Weight Loss - Temperature - Time Curves

Results show calcination is slow below 700°C. At 800°C and 900°C most of the weight loss occurs in the first 30 minutes. Refer Figure 2. There was no sign of decrepitation or other size degradation of the product.

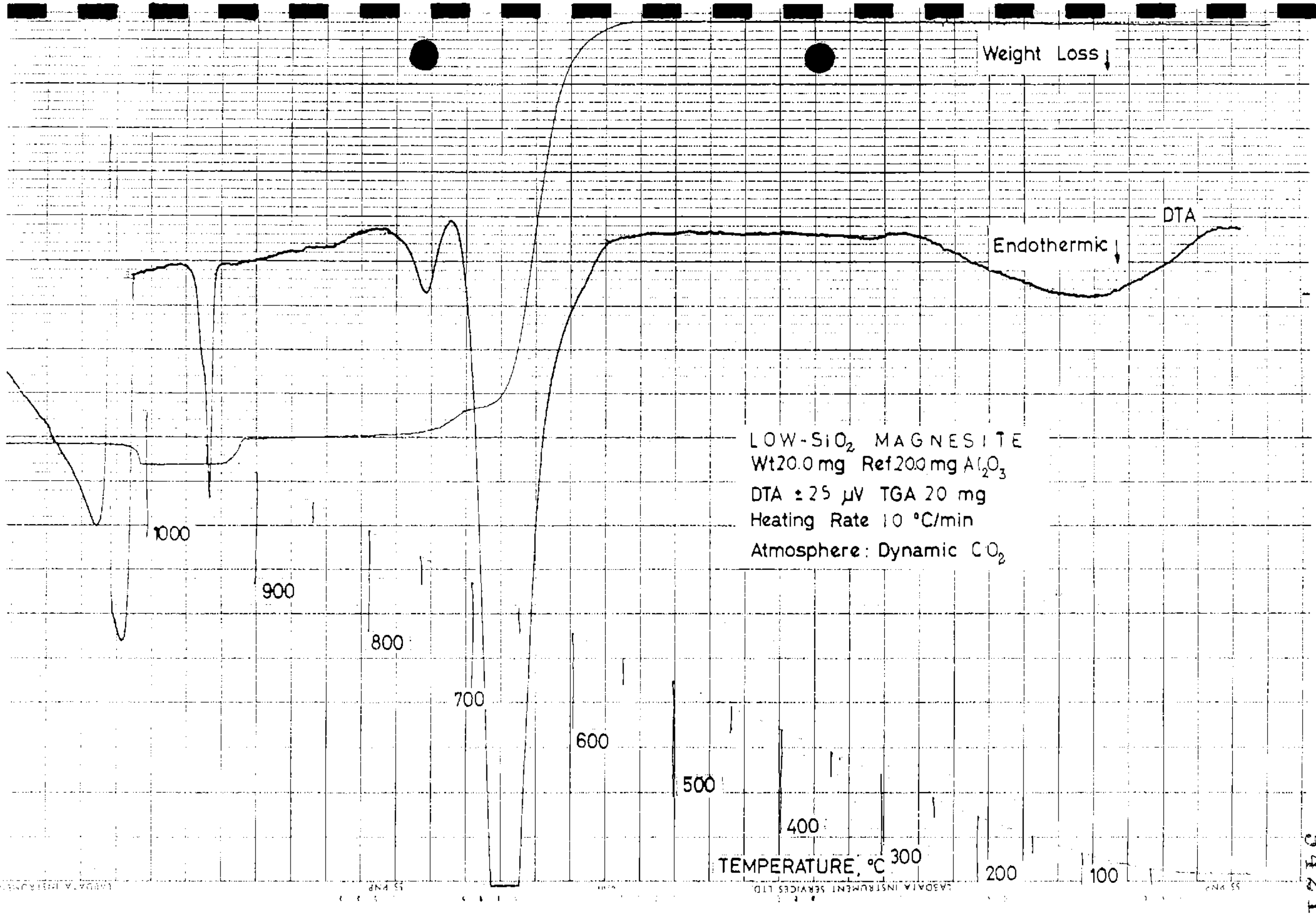
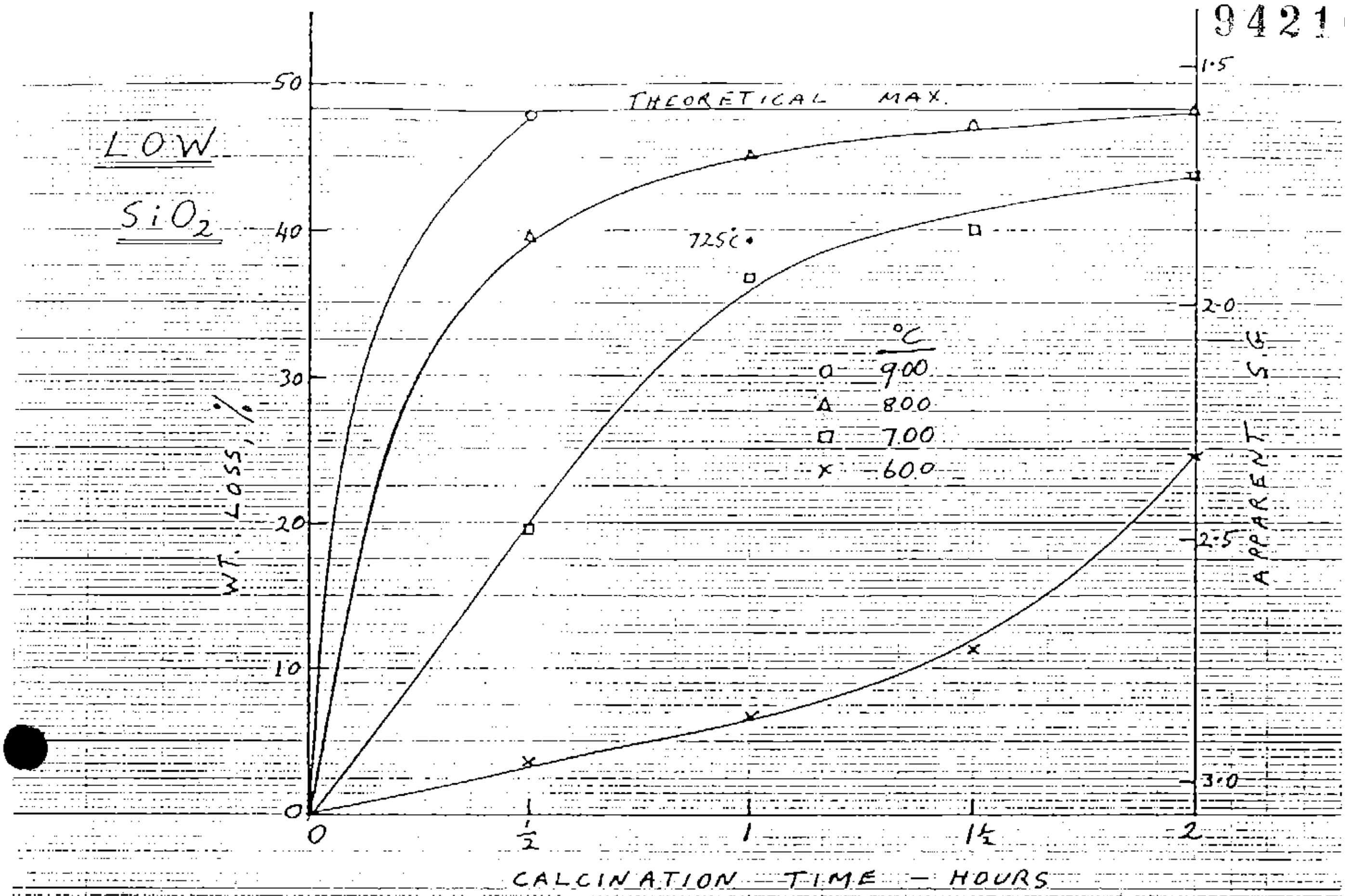


FIGURE 1: THERMAL ANALYSIS OF LOW SILICA MAGNESITE IN CO_2 ATMOSPHERE



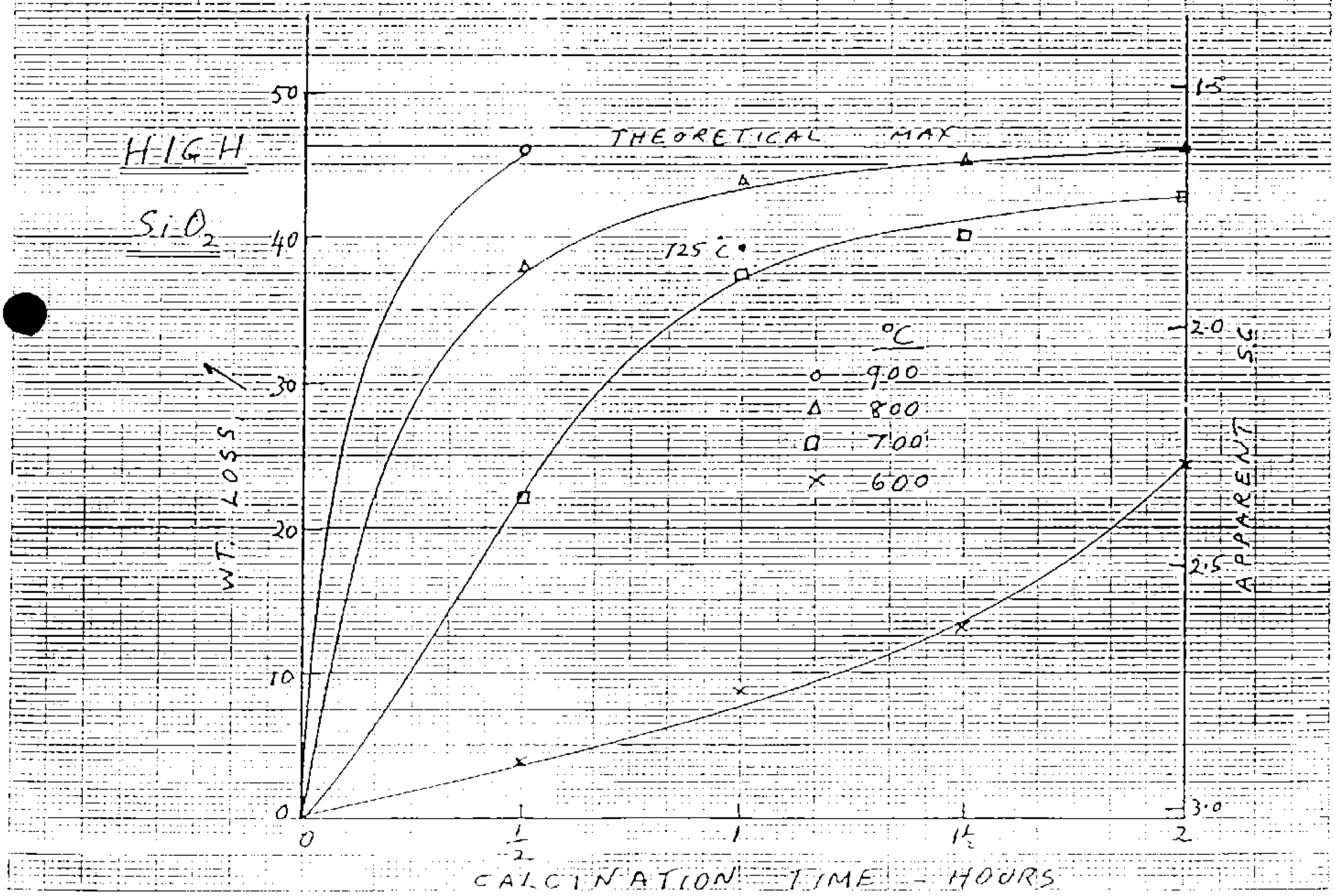


FIGURE 2: WEIGHT LOSS AS A FUNCTION OF TIME

Effect of Temperature

Magnesite samples were calcined for one hour at temperatures ranging from 500°C to 700°C and for shorter times at 725°C and 750°C. Iodine numbers were determined to indicate reactivity of the calcined product. Results of the tests are presented in Table 1. It is apparent that the samples were insufficiently calcined to yield meaningful results and further tests are required for longer times at around 750°C to produce a saleable product.

Effect of Calcination Time

Magnesite samples were calcined at 700°C for 0.5 - 2.0 hours. The iodine number decreased after one hour, even though the degree of calcination increased with time. Results are presented in Table 2.

Effect of Feed Size

The effect of feed size on reactivity was determined by calcining a series of size ranges. Results are listed in Table 3. These show the weight loss decreased as the particle size increased. However, the finest particle size did not yield the highest iodine number. This may indicate that it is easy to over calcine the very fine material.

Surface Area

A selection of products with high iodine numbers was submitted for BET surface area determinations and reactivity tests. Surface area results are presented in Table 4.

These results show surprising differences to the iodine numbers. The highest surface area was obtained at 775°C. Acid reactivity tests confirmed that 775°C produced the most reactive product.

Acid Reactivity

Acid reactivity was determined by reacting finely ground calcine with 0.1N sulphuric acid (pH ≈ 1.26) containing about 10 ppm each of copper and zinc as sulphates. An initial amount of 5 grams of solids was added to 2 litres of acid in an agitated beaker and the pH was allowed to stabilise. Further additions of around 0.5 gram each were made until the pH reached 7.5 within a 2 hour period. In some of the tests the pH rose to 9 or above because only a very small excess (<0.1 g) of calcine addition was sufficient to cause this to happen. The total weight of solids required was taken as a measure of reactivity, with the lowest weight representing the highest activity. These results are listed in Table 4 and show that the most reactive calcines were produced at 775°C. The residual carbonates in the calcine did not cause any bubbling or frothing due to their relatively low reactivity compared with the oxide product.

In the initial batch of reactivity tests, a liquor sample was taken every 30 minutes and analysed for Mg, Cu and Zn. These results are listed in Table 5. The rate of increase of pH in each sample was a function of the rate of addition of calcine only. It does not indicate the relative reactivity of the sample. For each sample the magnesium dissolved was in excess of 95%. The relationship between pH and the amounts of copper and zinc remaining in solution are illustrated graphically in Figure 3. All the copper was precipitated by pH 7 and all the zinc by pH 9 to 9.5.

Rotary Kiln Calcination

Calcination was carried out in a propane fired rotary kiln, 3.6 m long and 0.23 m internal diameter. Labyrinth seals were provided at each end of the kiln to minimise ingress of air. Air was drawn through the kiln using an induced draft fan.

The speed of rotation was fixed at 2 rev/min and the slope was varied to alter the residence time.

The kiln was operated at steady conditions for a time in excess of the total residence time in the kiln. Product was then collected for analysis, surface area determination and acid reactivity tests. There was no noticeable size degradation of the magnesite during calcination and very little dust was removed from the kiln (about 200 g/h for 15 kg/h feed rate). The product was quite weak and could be broken manually and hence would be easy to crush. However, no noticeable degradation occurred during handling of the product and presumably it could be transported without degradation.

The first series of kiln tests used low silica magnesite (Sample A) crushed to pass 12.7 mm. The calcination conditions used were 800°C with a residence time in the hot zone of about 25 minutes, 775°C/25 minutes and 775°C/40 minutes. These conditions were based on the best results obtained in the laboratory. Shorter residence times were investigated because there is a long heating up time in the kiln which effectively increased the total calcination time. The results of tests on the products are listed in Table 6.

The Mg0 contents in these products were higher than in any of the laboratory tests and hence the products had been calcined to a greater extent. The surface areas were lower than the best laboratory ones, but it is significant that the highest surface area corresponded to the lowest Mg0 content. This suggested that a better result may be obtained with a shorter residence time or a lower temperature.

On the other hand, the acid reactivities for all of the kiln samples were better than for the best laboratory samples. Copper and zinc contents of the solutions after 2 hours were each less than 0.2 ppm.

The second series of kiln tests used the surface magnesite samples (C) crushed to pass 12.7 mm. The calcination conditions were chosen with the aim of decreasing the amount of calcination taking place. The conditions used were 700°C C/40 minutes, 750°C/25 minutes, 750°C/15 minutes and 775°C/15 minutes. The results of these tests are also listed in Table 6.

In the test at 700°C the product was undercalcined as evidenced by the low MgO and high CO_2 contents. At 775°C the product was overcalcined. Each test at 750°C gave a product with a surface area in excess of 90 m^2/g with a high Mg0 and low CO_2 content.

On the basis of these results, it was decided to process all of the remaining surface and high silica magnesite at 750°C/15 minutes.

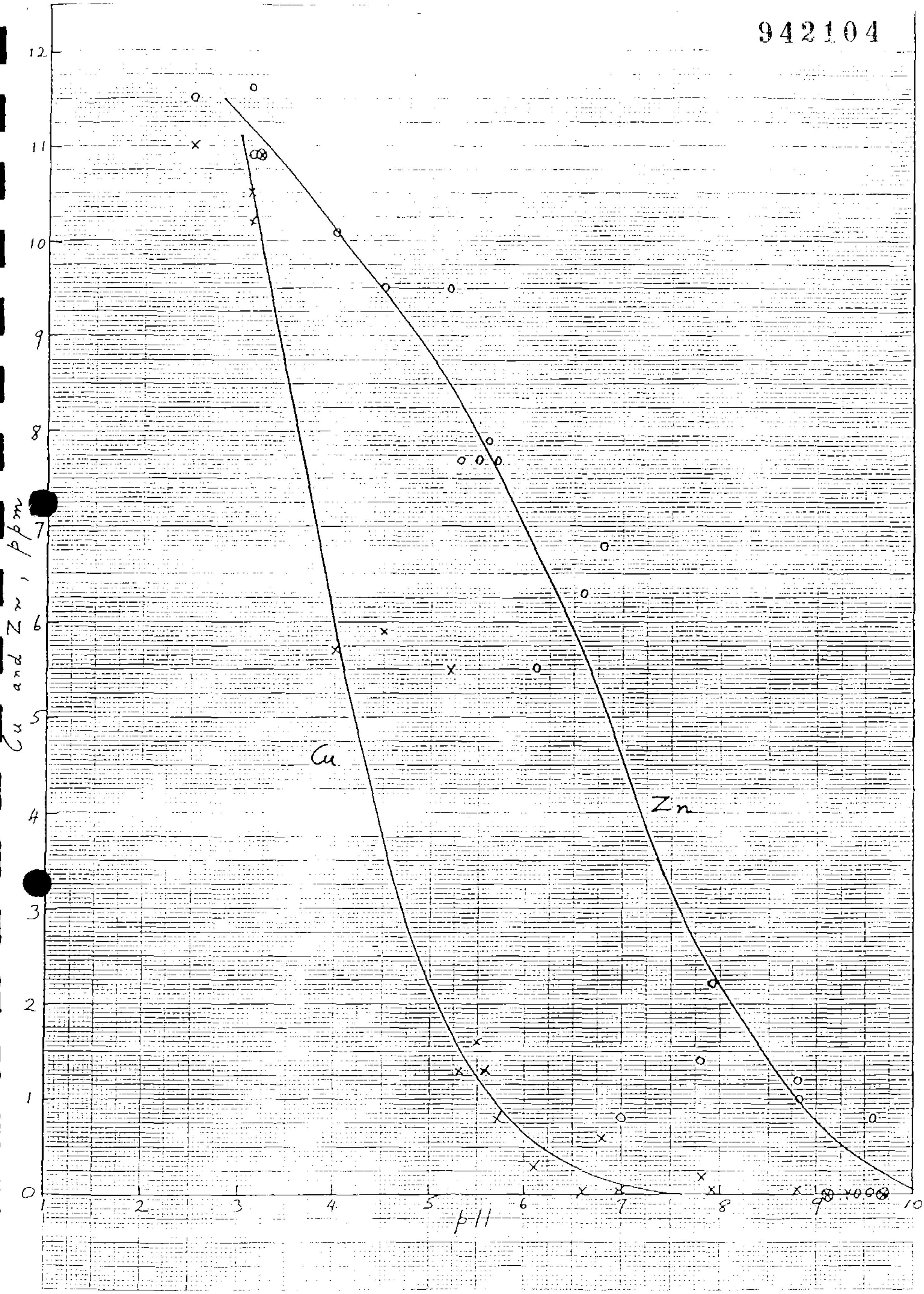


FIGURE 3: METAL PRECIPITATION AS A FUNCTION OF pH

Production Runs

The two feed materials (Sample B and C) were processed in separate campaigns using feed rates of around 15 kg/h.

The results of tests on the products are listed in Table 5. The results for the surface material were virtually identical to those obtained in Test 6 (see Table 6). The results for the high silica material (Sample B) were not as good as for the surface material (Sample C). This indicates that either the conditions used were not optimum for the material, or that it has a lower inherent reactivity.

By comparison of the two MgO and CO_2 assays in Table 7, it would appear that the high silica (Sample B) magnesite was undercalcined and that more CO_2 should have been removed.

However, if the assays for the high silica sample are compared with those in Table 1 for calcination at 775°C for 40 minutes (conditions which gave the highest surface in laboratory tests), it would appear that the kiln product was over calcined. This could only be resolved by kiln trials with the high silica material at a series of conditions.

Acid reactivity tests confirmed that both products were very reactive and that the weight of surface material required was less than that for the high silica magnesite. In both cases, almost 100% of the magnesia was dissolved.

Reactivity may be a function of the quantity of $CaCO_3$ present in the magnesite. This does not decompose during calcination and does not appear to react with the acid during reactivity trials. The low silica magnesite (Sample A) had the highest lime content (4.12% CaO), followed by the high silica magnesite (Sample B) [2.99% CaO], while the surface material (Sample C) contained only 1.22% CaO.

Throughout the laboratory testwork, the high silica magnesite was more reactive than the low silica magnesia. The kiln production runs show that surface magnesite sample is the most reactive.

Conclusions from Calcination Tests

1. A minimum calcination temperature of 700°C is required to obtain a reasonable decomposition rate. However, a temperature in excess of 710°C is required to decompose the $MgCO_3$ content of the dolomite, while the $CaCO_3$ decomposes about 925°C.

2. The magnesite can be calcined to form a very reactive product with a surface area of 75 to 95 m^2/g which reacts very quickly with acidic liquors, including very weak acids with pH values of 5 and above. Heavy metals such as copper and zinc can be virtually completely precipitated from solution in a very short time.

3. The reactivity appears to be highest when the $CaCO_3$ content is lowest.

4. The optimum calcination conditions in a rotary kiln are approximately 750°C with a residue time of 15 to 25 minutes in the hot zone. The time may vary with the overall length of kiln and the amount of time the magnesite spends at temperatures about 650°C during heating up.

TABLE 1: EFFECT OF TEMPERATURE ON IODINE NUMBER

Temp °C	Time min	Wt Loss %	MgO %	CO_2 %	Iodine No. -2 mm	Iodine No. Fines
Sample A						
500	60	1.5	39.9	49.5	5	-
550	60	4.9	41.7	47.8	20	-
600	60	6.7	47.5	43.6	35	-
650	60	29.2	58.0	32.4	85	-
700	60	36.7	62.6	23.2	105	105
725	60	39.1	63.9	18.0	95	100
750	40	37.5	61.7	20.0	85	-
750	50	41.8	68.0	14.4	85	-
750	60	44.2	74.5	10.3	90	90
775	40	39.7	64.6	16.8	100	-
Sample B						
500	60	1.5	40.7	48.0	5	-
550	60	5.5	42.0	46.3	15	-
600	60	8.8	46.4	40.1	50	-
650	60	25.3	53.0	32.0	75	0
700	60	37.5	61.2	18.8	115	120
725	60	39.9	62.4	13.7	105	115
750	40	37.1	60.8	16.6	110	-
750	50	39.8	63.7	12.5	100	-
750	60	42.8	66.5	8.3	105	105
775	40	40.7	64.5	10.8	100	-

TABLE 2: EFFECT OF CALCINATION TIME AT 700°C ON IODINE NUMBER

Time/Hours	Wt. loss %	Iodine No.
Sample A		
0.5	19.5	50
1.0	36.7	105
1.5	40.1	95
2.0	43.9	85
Sample B		
0.5		
1.0	22.0	70
1.5	37.5	115
2.0	40.1	105
	42.8	105

TABLE 3: EFFECT OF FEED SIZE ON IODINE NUMBER
(700°C - 1 HOUR)

Feed Size mm	Wt. loss %	Iodine No.
Sample A		
-0.5	41.8	80
-6.3	36.7	105
-12.7+6.3	36.0	105
-19+12.7	31.5	95
-25+19	31.1	85
Sample B		
-0.5	41.5	95
-6.3	37.5	115
-12.7+6.3	35.7	95
-19+12.7	36.8	85
-25+19	34.2	

TABLE 4: SURFACE AREA MEASUREMENTS AND ACID REACTIVITIES

Product	Iodine No.	Surface Area m^2/g	Acid Reactivity wt of solids, g
Sample A			
700°C, 1 h, -6.3 mm	105	65	7.80
725°C, 1 h, -6.3 mm	95	53	-
750°C, 1 h, -6.3 mm	90	50	-
775°C, 40 min, -6.3 mm	100	91	6.75
700°C, 1 h, -12+6.3 mm	105	75	7.70
700°C, 1 h, -0.5 mm	80	43	-
LR1, -6.3 mm	nd	62	8.25
Sample B			
700°C, 1 h, -6.3 mm	115	63	8.00
725°C, 1 h, -6.3 mm	105	71	-
750°C, 1 h, -6.3 mm	105	60	-
775°C, 40 min, -6.3 mm	100	92	6.45
700°C, 1 h, -12+6.3 mm	95	88	7.95
700°C, 1 h, -0.5 mm	95	44	-

TABLE 5: ACID REACTIVITY - SOLUTION ASSAYS

Sample	Time min	Mg	Cu	Zn	pH
		<----------- Analyses, ppm ------------>			
Acid liquor	-	-	11.4	11.3	1.26
LS 700°C, 1 h -6 mm	30	1420	1.3	7.7	5.3
	60	380	0.2	1.4	7.8
	90	1400	<0.2	<0.2	9.0
	120	1390	<0.2	<0.2	9.3
LS 775°C, 1 h -6 mm	30	1330	10.9	10.9	3.2
	60	1360	5.5	9.5	5.2
	90	1350	<0.2	6.3	6.6
	120	1360	<0.2	2.2	7.9
LS 700°C, -12+6 mm	30	1310	11.0	11.5	2.5
	60	1380	5.9	9.5	4.5
	90	1350	0.6	6.8	6.8
	120	1340	<0.2	<0.2	9.7
LR1, 700°C	30	1370	5.7	10.1	4.0
	60	1370	1.3	7.9	5.6
	90	1380	0.3	5.5	6.1
	120	1360	<0.2	<0.2	8.5
HS 700°C, 1 h -6 mm	30	1420	<0.2	0.8	7.0
	60	1430	<0.2	<0.2	9.6
	90	1420	<0.2	<0.2	9.8
	120	1420	<0.2	<0.2	10.0
HS 775°C, 40 min	30	1350	10.2	10.9	3.1
	60	1370	0.8	7.7	5.7
	90	1380	<0.2	1.2	8.8
	120	1350	<0.2	0.8	9.6
HS 700°C, -12+6 mm	30	1380	10.5	11.6	3.1
	60	1410	1.6	7.7	5.5
	90	1370	<0.2	1.0	8.8
	120	1360	<0.2	<0.2	9.6

LS = Low silica, Sample A. HS = High silica, Sample B

TABLE 6: KILN CALCINATION RESULTS

Test No	<----------1st Series	---------->		<-------------- 2nd Series	------------------>		
	1	2	3	4	5	6	7
Feed		Sample A				Sample C	
Temperature, °C	800	775	775	700	750	750	775
Residence time, min	25	25	40	40	25	15	15
Reactivity, g solids	5.60	5.85	6.50	-	-	-	-
Surface area, m^2/g	57	70	56	83	92	96	72
Analyses, %							
MgO	77.7	74.8	77.5	67.2	77.2	76.8	79.8
CaO	7.55	7.25	7.90	2.38	2.24	2.15	2.36
Fe_2O_3	2.24	2.30	2.16	0.89	0.87	0.89	0.94
Al_2O_3	0.30	0.20	0.19	0.18	0.18	0.18	0.14
SiO_2	6.60	6.75	7.35	11.6	13.4	14.1	13.9
CO_2	8.30	10.7	8.00	18.7	7.50	7.00	3.65

TABLE 7: KILN PRODUCTION RUNS

Sample	Sample B (High Silica)	Sample C (Surface)
Temperature, °C	750	750
Residence time, min	15	15
Reactivity, g solids	6.40	5.95
Surface area, m^2/g	78	94
Analyses, %		
MgO	67.8	76.2
CaO	4.41	2.12
Fe_2O_3	1.41	0.84
Al_2O_3	0.05	0.06
SiO_2	16.3	13.0
CO_2	8.20	7.05