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INDUSTRIAL AND MINING INVESTIGATIONS PTY LIMITEDIncorporated in the A.C.T.EXPLORATION LICENCE 4/61WEST COAST, TASMANIA**OPEN FILE**QUARTERLY RESUME

23.11.83 to 22.2.84

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CONTENTS

	<u>Page</u>
1. Summary	1
2. Personnel	1
3. Exploration - Minerals	2
3.1 Introduction	2
3.2 Stream Sediment Sampling	2
3.3 Geology and Heavy Mineral Sources	3
3.4 Outline of Tertiary Events	3
3.5 Sludge Sample Geochemistry	4
3.6 Future Exploration Proposals	6
4. Exploration - Gemstones	6
5. Main Creek Magnesite	6
5.1 Geostatistical Analysis	6
5.2 Metallurgical Research	6

Table 1: Stream Sediment Sample Locations,
Sample numbers 1 to 150 - Details.

Table 2: Stream Sediment Sampling,
Sludge Sample Analysis, Sample numbers 1 to 108.

Appendix 1: Penny, B.G., "IMI Stream Sediment Sampling Programme
Progress Report to December 22nd, 1983", December
1983.

Appendix 2: Canterford, J.H., "Production of Magnesia by the
Calcination/Carbon Dioxide Leach Process: Review of
Process Development", CSIRO Institute of Energy and
Earth Resources, Division of Mineral Chemistry,
October 1983.

Appendix 3: Canterford, J.H., "Production of High-Purity
Magnesia by the calcination/Carbon Dioxide Leach
Process: Summary of Process Development", CSIRO
Institute of Energy and Earth Resources, Division of
Mineral Chemistry, December 1983.

Map 1: EL 4/61, Sample Locations and Anomalous Values,
Stream Sediment Programme 83/84, C.H.C. Shannon,
March 1984 (2 sheets).

1. SUMMARY

Field work on the area was continuous during the quarter under review.

During the quarter, activities were concentrated on the:

- construction of new tracks;
- cutting of foot tracks to provide exploration access in the central portion of the licence area;
- cutting of grids for soil sampling in the central/western portion of the licence area;
- stream sediment sampling of the central and southern portions of the licence area;
- preparation by the CSIRO of reports summarising and reviewing process development in relation to metallurgical research of Main Creek magnesite by the CSIRO;
- commissioning of a consultant geologist to prepare a summary and review of the exploration on and the prospects of the area.

2. PERSONNEL

IMI's exploration personnel who were engaged on the area during the quarter included:

Henry Shannon, Senior Field Geologist
 Bruce Penny, Project Geologist
 Luke Vanzino, Field Geologist
 Peter Cover, Field Foreman
 Bonny Green, Field Assistant
 Casual field assistants

Contractors engaged on the area during the quarter included:

Analabs	- Assays
CSIRO	- Geostatistical analysis
John Dart	- Linecutting
John Dicker Investments Pty Ltd	- Earthmoving and track clearance
Peter Forwood	- Consulting Geologist
Hookway Aviation	- Helicopter Access.

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3. EXPLORATION - MINERALS

3.1 Introduction

Field work was in progress throughout the quarter with only minor inconvenience from the weather after December. The main project this season is a comprehensive stream sediment survey of the central and southern portions of the licence area. During the quarter, areas with reasonable road access and those with impossible helicopter access were sampled with areas in or adjoining open country deferred until a helicopter became available at the end of the quarter. Road construction work included the extension of the West Plain track to the Batty's bend area, and the Whyte Gauging Station track to the edge of open country. Gridding for soil sampling was begun in the Timbs Creek and Badger Plain areas, and foot tracks were cut from existing roads to the Badger Plain, Savage Creek, and Little Savage River areas.

3.2 Stream Sediment Sampling

After a critical review of the previous practice of sampling naturally settled silt bank material, it was decided to adopt a procedure whereby a pan concentrate was collected at each site, and also a sludge sample settled out from the interstitial fines found in the gravel used to prepare the pan concentrate.

To collect the pan concentrate a suitable trap site is important, but, to assist in standardisation, boulder bearing lag gravel traps are used, downstream of a plunge pool. Better trap sites could not be found consistently. To standardise sample size, a 5 litre fluid capacity dish is used. The sample collected is of either three heaped dish loads or, in sites deemed of greater importance, fifteen dish loads of gravel from which the larger stones are rejected. The procedure permits a practical rough measure of the abundance of heavy minerals, as well as their proportions in the catchment sampled.

The fines sample is prepared by decanting the thin mud washed out of the gravel into a large plastic bag, where it settles out into two layers. The watery top layer is poured off, then the sludge is collected taking care to reject the bottom portion likely to contain sand.

The advantage of this procedure in principle is that the fines would be expected to achieve equilibrium with the low flow metal content of the water, and on a consistent basis. Also, the possibility of getting a sample dominated by a local bank collapse is much reduced.

Table I shows details of stream sediment sample locations.

Table 2 shows assay results of sludge samples and brief comments on heavy mineral content.

Map 1 shows sample locations and anomalous values are indicated using the arbitrary criteria of (p.p.m.) Cu 150, Pb 40, Zn 200, As 10, Sn 10, Ni 150, W 10. The triangle denotes values of special interest.

3.3 Geology and Heavy Mineral Sources

Certain rock types are the logical source for particular heavy minerals: the Meredith Granite produces tourmaline and monazite; the serpentinites produce chromite. Oonah Formation type rocks produce fine grained almandine garnet and magnetite. Certain horizons in the greenschist belt produce magnetite and haematite, and one distinctive horizon produces abundant epidote.

The use of heavy mineral assemblages as tracers is complicated by the contributions of Tertiary gravel deposits, in particular, the sheet deposit of very mature gravel which appears to relate to the erosion surface developed in the Brown Plain area. Unlike the coarser gravel with many sandstone clasts found in the Savage River town area, the Brown Plain gravel contains chromite and cassiterite. Since the chromite presumably comes from a serpentinite source and all such sources are at some distance from the area, the cassiterite also could come from a distant source. Material from this gravel deposit, including gold, has been widely dispersed into the present day drainage, and needs to be allowed for before any inference can be made as to the contribution from local sources of heavy minerals.

3.4 Outline of Tertiary Events

1. The current hypothesis is that the Savage River town gravel and similiar gravels, eg, at sample site 53, are older than the basalt flows, and confined to channels in a fossil landscape of moderate relief. They are distinguished by relatively coarse boulders including sandstone and granite detritus. The original drainage appears to have been outwards from the Mt Meredith granite.
2. Basalt flows covered most of the area, establishing the sub-parallel courses of the Donaldson, Savage and Whyte Rivers; the Whyte River marking the abutment of the basalt against the Mt Meredith granite massif. The drainage pattern became entrenched well enough to keep re-establishing itself despite subsequent erosion surface developments.
3. The concordant plateau remnants at about 460m and 400m, which are partly on basalt, may be early post-basalt erosion surfaces. They lack distinctive sediments.

4. The gravel capped plateau remnants, which include Brown Plain, developed. They may represent separate surfaces concentrated at 200m+, 240m+ and 280m+, although some deformation of a single surface is possible (a gravel quarry at 435898 exposes dipping strata). The gravel appears to contain very little besides quartz and quartz tourmaline rock. It is mature but without being well rounded, and lacks material larger than about 15 cm. Associated with it are bodies of sand, and clay with macerated plant material indicating open water conditions.

A possible explanation is that the deposits are an infill of coastal lagoons. Some access to longshore drift could explain the ~~presence~~ of chromite in the heavy fraction. Perhaps the surface was initially a marine erosion surface establishing a plain cut partly on levelled bedrock and partly on filled valleys.

3.5 Sludge Sample Geochemistry

The samples provisionally considered anomalous usually form clusters with a number of features in common. They are discussed in groups below:

- 1. Sample 30 Sn 10 ppm
Trace anomaly in tin, probably not significant.
- 2. Sample 11 As 10 ppm
" 12 As 62 ppm
" 17 As 17 ppm
" 18 As 10 ppm

Anomaly in arsenic possibly related to gold. Paradoxically, the highest value (Sample 12) is from a gravel deposit of uncertain affinities.

- 3. Sample 70 Cu 235, Zn 280, Ni 155, As 60 ppm
Sample 71 Pb 55 ppm
Sample 87 Cu 270 ppm

These are all from major streams affected by mine tailings contamination.

- 4. Sample 13 Sn 25 ppm
Sample 15 Sn 15 ppm
Sample 48 Sn 10 ppm
Sample 49 Sn 16 ppm
Sample 54 Sn 22 ppm

These represent either in situ tin concentration in the Brown Plain gravel or concentrations in creeks draining the gravel area.

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- 5. Sample 44 Pb 85, Ag 0.4 ppm
- Sample 46 Pb 85 ppm

The lead responses may indicate stratigraphic control. In the case of sample 44, it is inferred that the lead value comes from bedrock.

- 6. Sample 61 Cu 210, Sn 13 ppm
- Sample 62 Sn 17 ppm
- Sample 105 Cu 185 ppm

Situated in a belt of strong magnetic anomaly with magnetic and haematite in the heavy minerals. The tin does not appear to derive from a Tertiary gravel source. The copper supports correlation with the Little Donaldson anomaly.

- 7. Sample 42 Pb 305, Zn 420, As 11 ppm

The highest lead and zinc values yet found in the licence area in stream sediments uncontaminated by mine drainage. Elevated Pb (25 ppm) in sample 37 downstream supports this anomaly.

- 8. Sample 52 Cu 315, Zu 200
- Sample 38 Cu 175
- Sample 102 Cu 185

The highest copper value in stream silts (sample 52) supported by downstream dispersion check (sample 38) and high value along strike (sample 102).

- 9. Sample 20 Zn 230 ppm

High zinc but unsupported by other elements possibly related to (3) - samples 44, 46, which are on the same stratigraphic horizon.

- 10. Sample 69 As 10
- Sample 95 As 69, Pb 45
- Sample 96 As 43
- Sample 107 As 15
- Sample 198 As 41

The arsenic anomalism in this area possibly indicates the true source of the Rocky River gold. The source may be in the divide area of the four small creeks which is in the eastern lobe of the large magnetic anomaly.

- 11. Sample 97 Sn 19, W 15

Possible minor mineralisation at the granite contact.

A progress report by B.G. Penny on the stream sediment sampling

programme to 22 December 1983 is annexed as Appendix 1.

3.6 Future Exploration Proposals

Soil sampling grids are proposed for prospects 6, 7, 8 and 10. The grid at Timbs Creek is being constructed.

4. EXPLORATION - GEMSTONES

The Exploration Licence was extended on 23 February 1984 to include gemstones.

During the quarter, however, preparations for helicopter access to target areas were made.

5. MAIN CREEK MAGNESITE

5.1 Geostatistical Analysis

This work, which is being conducted by the CSIRO, is continuing.

5.2 Metallurgical Research

In response to a request from the CSIRO, a consignment of approximately 100 kilograms of outcropping magnesite was collected and despatched for further bulk chemical analysis.

During the quarter the CSIRO released two reports (see Appendices 2 and 3) dealing with process development.

TABLE 1

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TABLE 1

STREAM SEDIMENT SAMPLE LOCATIONS - DETAILS

Sample Number	Creek/River	LOCATION		Remarks
		N	E	
1	Tributary of Timbs Creek	91.70	47.22	Small rocky section
2	Eight Mile Creek	92.27	47.93	Rocky creek bed
3	Tributary of Timbs Creek	91.22	45.10	" " "
4	Tributary of Brown Plains Creek	91.03	45.75	Small rocky section
5	Bowry Creek	97.23	47.34	Rocky creek bed
6	Bowry Creek	96.97	48.00	" " "
7	Timbs Creek	92.33	43.80	" " "
8	Tributary of Eight Mile Creek	91.65	46.65	" " "
9	Tributary of Savage River	06.42	53.61	Gravelly creek bed
10	" " "	07.43	53.62	Rocky creek bed
11	Alfords Creek	06.88	54.17	" " "
12	Fossil Creek - in road cutting at Alfords Creek	06.98	54.12	Coarser channel bases
13	Fossil Creek - in road cutting near sample 1.	91.70	47.30	" " "
14	Chinamans Creek	93.45	47.90	Coarse creek bed
15	Council Gravel Quarry - Little Plains	91.08	44.65	Possible channel bases
16	Tributary of Goodall Creek	92.43	48.78	Rocky creek bed
17	Alfords Creek	06.73	53.95	" " "
18	Tributary of Armstrong Creek	08.42	52.05	" " "
19	Armstrong Creek	08.52	52.00	" " "
20	Goodall Creek	92.42	49.20	" " "
21	Tributary of Hazelwood River	01.38	51.40	" " "
22	Armstrong Creek	10.05	53.10	" " "
23	Kaysers Creek	10.15	53.04	" " "
24	Little Hunter Creek	89.45	44.62	Gravelly Creek bed
25	Tributary of Little Hunter Creek	89.40	44.30	Rocky creek bed
26	Nine Mile Creek (No HM Sample)	93.45	49.59	" " "
27	Nine Mile Creek	93.79	49.49	" " "
28	Tributary of Pineapple Creek	16.33	52.90	" " "
29	Pineapple Creek	16.19	52.95	" " "
30	Tributary of Pineapple Creek	15.80	51.83	" " "

STREAM SEDIMENT SAMPLE LOCATIONS - DETAILS

Sample Number	Creek/River	Location		Remarks
		N	E	
31	Pineapple Creek	16.00	51.85	Rocky creek bed
32	Tributary of Whyte River	97.17	50.29	" " "
33	" "	96.85	50.45	" " "
34	Base of Sheetwash gravels - Rocky River track	91.40	48.24	Gravelly sands
35	Tributary of Whyte River	96.45	50.83	Rocky creek bed
36	" " "	96.00	50.95	Coarse creek bed
37	Timbs Creek	92.05	45.25	Rocky creek bed
38	" "	92.25	46.45	" " "
39	Tributary of Timbs Creek	92.13	46.42	" " "
40	" " "	92.45	45.95	" " "
41	Bracken Creek	92.28	46.20	" " "
42	Tributary of Timbs Creek	92.13	46.00	Coarse Creek bed
43	" " "	92.10	46.18	Coarse & rocky creek bed
44	Quarry on Corinna Road	94.25	48.85	Coarse gravels
45	" " "	94.05	48.83	" "
46	Breakneck Creek	88.58	49.35	Rocky creek bed
47	Hall Creek (Cataract Creek)	89.30	49.43	" " "
48	Quarry on Rocky River track	91.72	47.80	Coarse gravels
49	" " " "	91.72	47.80	" "
50	Tributary of Rocky River	87.93	50.98	Coarse creek bed
51	" " "	87.83	51.14	" " "
52	Eight Mile Creek	92.70	47.13	Rock bars
53	Base of surficial gravels - near sample 1	91.75	47.30	Coarse gravels
54	Graham Creek	91.75	48.62	Coarse creek bed
55	Tributary of Graham Creek	91.38	48.60	" " "
56	Tributary of Whyte River	91.73	49.22	" " "
57	Barren Creek	90.30	48.80	" " "
58	Eight Mile Creek	92.63	47.43	" " "
59	Chinamans Creek	93.03	47.30	" " "
60	Tributary of Timbs Creek	93.03	47.20	" " "

STREAM SEDIMENT SAMPLE LOCATIONS - DETAILS

Sample Number	Creek/River	Location		Remarks
		N	E	
61	Tunnelrace Creek	92.10	44.38	Coarse creek bed
62	Tributary of Timbs Creek	92.50	44.25	" " "
63	" " "	92.00	44.95	" " "
64	" " "	92.13	44.83	" " "
65	Tributary of Whyte River	00.88	51.95	" " "
66	" " "	00.75	51.85	" " "
67	Hall Creek (Cataract Creek)	89.40	49.65	" " "
68	Post Office Creek	92.00	49.82	Boulder bed
69	Wilsons Creek	90.65	49.25	Coarse gravels
70	Whyte River	01.35	51.78	Rocky Creek bed
71	Heazelwood River	01.38	51.40	" " "
72	Tributary of Goodall Creek	92.95	48.78	Coarse creek bed
73	Nine Mile Creek	94.37	49.34	Gravelly creek bed
74	Goodall Creek	93.25	48.88	Rocky creek bed
75	Tributary of Heazelwood River	02.90	51.80	Gravelly and rocky
76	Big Duffer Creek	02.08	48.48	Rocky creek bed
77	Tributary of Whyte River	89.10	48.65	Coarse creek bed
78	" " "	89.07	48.45	Coarse creek bed
79	Tributary of Bowry Creek	97.02	46.62	" " "
80	Bowry Creek	97.05	46.73	Rocky creek bed
81	Owen Meredith River	82.83	44.15	Point bar deposit
82	Paradise River	83.20	44.45	" " "
83	Tributary of Savage River	00.42	45.40	Rocky creek bed
84	" " "	00.08	45.75	Coarse creek bed
85	Lucy Creek	85.53	43.05	Gravelly creek bed
86	Nancy Creek	85.05	44.65	" " "
87	Main Creek	99.50	47.11	Point bar deposit
88	Tributary of Main Creek	99.35	47.20	Rocky Creek bed
89	Tributary of Whyte River	90.54	47.50	" " "
90	" " "	90.20	47.06	" " "

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STREAM SEDIMENT SAMPLE LOCATIONS - DETAILS

Sample Number	Creek/River	Location		Remarks
		N	E	
91	Tributary of Bowry Creek	95.35	47.40	Rocky creek bed
92	" " "	95.25	47.25	Rock crevices
93	" " "	96.70	46.75	Gravelly creek bed
94	" " "	95.75	47.15	" " "
95	Tributary of Rocky River	88.10	50.05	" " "
96	" " "	88.15	50.70	Rocky creek bed
97	Rocky River	87.10	52.72	Boulder & rocky creek bed
98*	Tributary of Whyte River	90.82	47.50	Rocky creek bed
99	Donelly Creek	92.80	46.85	Coarse creek bed
100*	Brown Plains Creek	90.90	45.75	" " "
101*	Little Hunter Creek	90.58	44.60	" " "
102*	Tributary of Whyte River	91.00	46.83	Rocky creek bed
103*	" " "	91.03	47.20	Gravelly creek bed
104*	Tributary of Little Hunter Creek	90.83	44.40	Coarse creek bed
105*	Tunnelrace Creek	91.25	44.12	Rocky creek bed
106*	Tributary of Timbs Creek	91.55	45.85	Coarse creek bed
107	Wilsons Creek	90.73	51.05	Rocky creek bed
108	Tributary of Wilsons Creek	90.64	50.65	Coarse creek bed
109	Tributary of Rocky River	87.25	51.12	" " "
110*	" " " (also known as "Eight Mile Creek)	87.12	51.65	Gravelly creek bed
111*	" " "	86.97	51.95	" " "
112	" " "	87.37	52.50	Rocky creek bed
113	McAuliffe Creek	11.15	49.50	" " "
114*	" " "	11.23	49.50	" " "
115	" " "	11.62	49.05	" " "
116*	Tributary of McAuliffe Creek	11.71	49.02	" " "
117*	McAuliffe Creek	11.60	48.93	" " "
118	Tributary of Whyte River	99.85	50.75	" " "
119*	Tributary of Chinamans Creek	93.98	46.98	Gravelly creek bed
120*	Donelly Creek	93.67	46.78	Rocky creek bed

013

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STREAM SEDIMENT SAMPLE LOCATIONS - DETAILS

Sample Number	Creek/River	Location		Remarks
		N	E	
D1 121*	Tributary of Savage River	96.00	44.73	Rocky creek bed
122	Longback Creek	96.26	44.08	" " "
123*	Tributary of Savage River	96.73	44.70	" " "
124*	" " "	95.00	43.73	" " "
125*	" " "	94.92	44.40	" " "
126*	" " "	94.91	44.58	" " "
127*	" " "	95.18	44.79	" " "
128	" " "	97.15	45.60	" " "
D2 129*	" " "	97.35	43.75	" " "
130*	" " "	97.38	44.30	" " "
131*	Tributary of Whyte River	99.10	52.12	" " "
(LSD1) 132*	Tributary of Little Savage River	05.95	47.35	" " "
133	Tributary of Whyte River	93.93	50.36	(No HM)
134	" " "	95.08	50.35	(No HM)
(LSD2) 135*	Tributary of Little Savage River	04.60	47.20	" " "
(LSD3) 136*	" " "	03.85	47.32	" " "
137*	Tributary of Whyte River	00.33	52.80	" " "
138*	" " "	00.43	52.82	" " "
(LSD4) 139*	Tributary of Little Savage River	05.18	47.25	Small waterfall
(LSD5) 140*	" " "	05.00	47.80	Rocky creek bed
(LSD6) 141*	Little Savage River	05.25	47.48	" " "
(LSD7) 142*	" " "	04.05	47.65	" " "
143*	Tributary of Rocky River	89.00	51.12	Gravelly creek bed
144*	" " "	88.95	51.20	" " "
145*	" " "	88.63	51.58	Rocky creek bed
146*	Wilson's Creek	89.93	51.31	Gravelly creek bed
147*	Tributary of Wilson's Creek	89.72	50.16	Rocky creek bed
148	Paradise River	84.47	52.05	" " "
149*	Tributary of Paradise River	84.65	52.20	" " "
150*	" " "	84.94	51.33	" " "

TABLE 2

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TABLE 2

STREAM SEDIMENT SAMPLING
SLUDGE SAMPLE ANALYSIS

Sample Number	Element (ppm)										Remarks	
	Cu	Pb	Zn	Sn	W	Ni	Mo	Ag	As	Ba		Au
1			NOT COLLECTED									
2			NOT COLLECTED									Minor gold
3			NOT COLLECTED									
4			NOT COLLECTED									Minor gold
5	70	15	160	4	x			x	6	57	IS	Magnetite
6	100	20	125	3	x			x	5	IS	IS	Magnetite
7	130	10	140	x	x			x	5	100	x	hematite
8	40	5	60	IS	IS			x	2	50	IS	
9	15	5	15	3	x			x	x	45	x	
10	20	5	30	7	x			x	2	60	IS	
11	20	10	25	5	x			x	10	80	IS	
12	55	20	40	6	x			x	62	25	x	
13	35	5	20	25	x			x	4	25	x	
14	20	10	35	5	x			x	4	70	IS	
15	x	x	5	15	x			x	4	15	x	
16	25	25	35	IS	IS			x	2	75	IS	
17	10	5	15	4	x			x	17	70	IS	Minor gold
18	40	10	70	4	x			x	10	IS	IS	
19	25	20	65	8	x			x	3	70	IS	Minor gold
20	80	10	230	4	x			x	5	IS	IS	Minor gold
21	15	10	30	x	x			x	9	60	IS	
22	20	15	35	8	x			x	9	70	IS	
23	30	20	55	x	x			x	x	60	IS	
24	65	30	75	IS	IS			x	7	85	IS	
25	10	20	15	3	x			x	3	60	IS	Minor gold
26	50	25	90	4	x			x	8	80	x	No HM sample taken
27	35	20	85	3	x			x	7	85	x	Gold
28	40	15	90	5	x			x	1	85	IS	
29	35	20	50	5	x			x	4	IS	IS	
30	30	15	110	10	x			x	5	100	IS	

STREAM SEDIMENT SAMPLINGSLUDGE SAMPLE ANALYSIS

Sample Number	Element (ppm)											Remarks
	Cu	Pb	Zn	Sn	W	Ni	Mo	Ag	As	Ba	Au	
31	45	20	90	x	x			x	4	80	IS	
32	25	10	55	x	x			x	7	60	x	
33	20	15	30	6	x			x	6	75	x	
34	x	x	5	6	x			x	x	10	x	
35	15	10	15	7	x			x	5	75	x	Pyrite
36	20	15	20	9	x			x	5	80	IS	
37	35	25	95	6	x			x	9	100	IS	
38	175	2	140	5	x			x	2	45	x	
39	120	25	130	x	x			x	2	30	x	Minor gold
40	55	20	100	4	x			x	2	80	x	Minor gold
41	80	10	85	8	x			x	x	40	IS	
42	115	305	420	x		60		IS	11	IS	IS	
43	120	10	115	x		40		x	5	45	IS	Minor gold
44	15	85	110	x		x		0.4	2	x	x	
45	10	x	10	x		x		x	x	x	x	
46	55	85	150	x		40		IS	5	110	IS	
47	85	20	215	x		40			3	135	IS	
48	5	x	15	10		5			x	IS	IS	
49	5	x	5	16		5			x	5	x	
50	15	20	35	x		15			9	55	x	
51	15	x	30	x		15			8	40	x	
52	315	30	200	3		60			3	125	IS	Minor gold
53	5	x	10	x		10			x	120	IS	
54	25	20	40	22		20			1	115	x	Minor gold
55	40	5	45	x		20			1	205	IS	Minor gold
56	65	10	185	x		55			x	45	IS	Minor gold
57	40	x	35	x		25			1	120	x	Minor gold
58	20	x	30	x		35			x	110	IS	Minor gold
59	45	5	50	x		35			x	IS	IS	Minor gold
60	55	5	50	x		40			1	IS	IS	Gold

STREAM SEDIMENT SAMPLINGSLUDGE SAMPLE ANALYSIS

Sample Number	Element (ppm)											Remarks	
	Cu	Pb	Zn	Sn	W	Ni	Mo	Ag	As	Co	Ba		Au
61	210	x	125	13		115			4		130	IS	hematite
62	80	15	95	17		75			x		150	IS	
63	30	15	95	x		75			4		IS	IS	
64	80	10	75	x		50			1		80	x	hematite
65	15	5	25	x	x	10	x		5		85	x	
66	15	5	35	x	x	20	x		2		IS	IS	
67	70	15	90	x		35			8		90	x	minor gold
68	25	15	45	x	x	25	x		8		IS	IS	minor gold
69	40	15	90	x	x	20	x		10	20	80	IS	magnetite/hematite
70	235	25	280	IS		155	x		60	75	150	IS	
71	55	55	115	IS		140			7	30	155	IS	
72	5	x	10	x		10			x	x	55	IS	pyrite
73	25	5	45	x		40			x	10	55	IS	gold
74	65	10	190	x		55			3	75	75	IS	hematite
75	15	15	30	x		15			6	15	120	IS	
76	70	10	90	x		35			7	55	85	IS	minor gold
77	40	5	45	x		30			x	25	130	IS	magnetite
78	35	5	30	x		20			x	20	110	IS	magnetite
79	50	5	65	x		40			4	35	130	IS	magnetite
80	70	15	110	x		40		0.1	4	60	70	IS	magnetite/minor gold
81	35	15	60	IS		30			4	20	125	IS	magnetite
82	40	5	60	x		35			2	20	120	IS	magnetite
83	95	10	130	x		75			1	45	200	IS	magnetite
84	85	30	115	x		60			2	40	115	IS	magnetite
85	55	15	80	x		35			x	15	100	IS	magnetite
86	85	20	120	x		45			x	40	125	IS	magnetite
87	270	10	75	x		105			4	60	50	IS	Main Creek (with more tails)
88	85	10	195	x		70			2	60	75	IS	
89	40	10	60	x		35			x	30	140	IS	
90	90	10	135	x		45			x	50	125	IS	

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STREAM SEDIMENT SAMPLING
SLUDGE SAMPLE ANALYSIS

Sample Number	Cu	Pb	Zn	Sn	W	Ni	Mo	Ag	As	Co	Ba	Au	Remarks
91	80	5	125	x		80			x	50	150	IS	Haematite, minor gold
92	65	10	105	x		55			2	45	165	IS	magnetite
93	95	20	155	x		75			x	60	160	IS	magnetite
94	75	15	120	x		65			x	45	120	IS	magnetite
95	30	45	80	x		20		0.2	69	20	90	IS	
96	30	35	35	x		10		0.2	43	15	80	IS	minor gold
97	15	15	15	19	15	10	x		9	x	35	IS	
98	50	15	65	x		40			1	40	180	IS	
99	65	10	175	x		65			x	30	80	IS	minor gold, epidote
100	70	20	80	x		40			2	25	105	IS	
101	20	5	15	x		10			x	x	130	IS	
102	165	15	120	9		30			x	25	45	IS	
103	35	10	80	x		50			x	40	110	IS	magnetite
104	135	5	85	x		60			4	50	55	IS	
105	185	5	145	x		120			2	65	120	IS	
106	50	15	100	x		45			x	25	55	IS	
107	10	x	20	x		15			15	x	55	IS	
108	15	20	30	x		10			41	10	50	IS	

APPENDIX 1

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APPENDIX 1

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INDUSTRIAL AND MINING INVESTIGATIONS PTY. LIMITED

STREAM SEDIMENT SAMPLING PROGRAMME

PROGRESS REPORT TO DECEMBER 22ND, 1983

B. G. Penny
December, 1983

1.

SUMMARY

A stream sediment sampling programme has been initiated in late 1983, with an emphasis on examining the heavy mineral assemblage. Sludge samples are also collected to assess the potential of elements not represented in the heavy mineral fraction. Results as yet are incomplete but the following observations can be made:-

- . In Brown Plains there are three coarse grained units present
 - The basal unit is a deep lead system which is essentially untested.
 - A sheetwash gravel overlies this. Testing so far suggests low grades of economic material, but further testing is needed to confirm this.
 - A surficial gravel overlies this and does not appear to have so much potential.

Earlier programmes may not have made these unit distinctions.

- . Gold in Nine Mile Creek may have its origins in a specific stratigraphic horizon within the Whyte Schist. To be followed up.
- . Tertiary sheetwash (and deep lead?) gravels are present south of but not north of the Rocky River. To be followed up.
- . The two magnetic anomalies crossing Timbs Creek may be caused by magnetite. Sludge samples suggest base metal anomalism and follow up work is required.
- . The Meredith Track magnetic anomaly yields pyrite in the heavy mineral concentrate. Sludge samples have a low base metal content. More work is needed.
- . Alford's Creek, including the deep lead are not interesting in heavy mineral content. However, there are anomalous arsenic values that may warrant follow up for gold.
- . Drainages from the east in the Armstrong Creek area are anomalous in arsenic and may be worth following up for gold.
- . Pineapple Creek contains little of interest in the heavy mineral concentrate. Further, sludge sample results to date are not encouraging.
- . Bowry Creek samples predictably contain magnetite. Sludge samples have elevated copper and zinc values which are also not unexpected.

TABLE OF CONTENTS

	<u>Page</u>
<u>SUMMARY</u>	1
<u>TABLE OF CONTENTS</u>	2
1. <u>INTRODUCTION</u>	3
2. <u>METHOD</u>	3
TRAPSITE CRITERIA	3
FACTORS AFFECTING MINERAL ASSEMBLAGE	4
3. <u>SAMPLING</u>	4
4. <u>POTENTIAL DIFFICULTIES</u>	5
5. <u>RESULTS AND DISCUSSION</u>	6
a. Browns Creek - Little Plain	7
b. Nine Mile Creek	11
c. Rocky River	12
d. Timbs Creek	12
e. Meredith Track Magnetic Anomaly	14
f. Alfords Creek	14
g. Armstrong Creek	15
h. Pineapple Creek	15
i. Bowry Creek	16

3.

1. INTRODUCTION

Previous stream sediment sampling in the Savage River area involved the collection of -80 mesh material from stream deposited silt banks. Unfortunately, although this method may be suitable for the detection of copper, lead and zinc, it is not suitable for the more erosion resistant minerals of tin, chrome, rare earths and precious metals.

Therefore, an intensive, detailed stream sediment sampling programme has been initiated, involving primarily the examination of the heavy mineral fraction which would contain the high specific gravity minerals of these commodities. In addition to collecting the heavy mineral fraction, a sludge sample (essentially interstitial silt) is collected as a more sophisticated (and reliable?) technique of sampling the -80 mesh fraction. Both base metals and very fine grained heavy minerals (particularly cassiterite - which is known to have a very fine grained component) which may otherwise be missed, would be detected in this fraction.

2. METHOD

An on the spot assessment is made of the drainage to determine the optimum sampling points (known as trapsites). Trap sites are essentially energy drop situations and are of the utmost importance in the obtaining of a correct sample. A suitable sample, in appearance, should contain all size ranges from clays and silts to large boulders.

TRAPSITE CRITERIA

In order of decreasing desirability, these are:-

- 1) Natural rock crevices in the drainage base, particularly where these oppose the water flow.
- 2) The downstream side of large boulders where eddy currents can be set up.
- 3) Rocky creek beds which essentially are a smaller more numerous version of 2).
- 4) Coarse gravelly creek beds which are a finer version of 3).

If at all possible, these should be combined with:

- a) The outwash side of a waterfall,
- b) The outer edge of the downstream side of a curve in the creek.

Heavy minerals, except in extreme energy situations, do not form part of the suspended load of a drainage. Movement is by

"saltation" - a process of bouncing along the base of the water flow. This process is more likely to occur during increased energy situations, i.e. flood periods. Therefore, when selecting a suitable trap site for sampling, areas within the present drainage bed, but outside the current water flow, should not be ignored.

FACTORS AFFECTING MINERAL ASSEMBLAGE

Heavy minerals tend to gravitate to the base of a loose sedimentary pile. Obviously, a sample from the drainage base is not always possible, and so the presumption that there is a continuous input of heavy minerals from the source area is necessary. If this is so, then, provided a suitable trap site is selected, a representative sample of the heavy mineral assemblage is possible.

Because of the variation in specific gravities of the heavy minerals, there is likely to be a downstream partitioning of the assemblage, i.e. the lighter heavy minerals are more prone to further movement downstream and less movement downwards through the sedimentary pile than the heavier heavy minerals.

Bearing this in mind, other factors which may affect the mineral assemblage are:

- 1. The distance from the heavy mineral source(s).
- 2. The number of trap sites between the sample site and the source(s). Trap sites closer to the source are more likely to contain a higher heavy mineral content.
- 3. The slope of the drainage. The steeper the slope, the more likely the heavy minerals will travel further.

3. SAMPLING

After selection of a suitable sample site, the sample material is excavated by shovel and then panned in a 5 litre pan. The heavy mineral residue is retained. From the first two pannings the silt laden water is decanted into a large plastic bag and allowed to settle. After settling, the water is decanted and the residue retained for assay.

Fifteen pannings per sample has been deemed sufficient to provide an adequate heavy mineral sample. This number of pannings was determined on the basis of laboratory requirements for quantitative assessment of the sample if required. If insufficient sample is obtained from 15 pannings, then this information is considered relevant and pertains to the lack of a suitable source in the headwaters of the drainage.

In some cases, only three pannings per sample were done. The

025

first four samples were for orientation and education and so only three pans per sample were required. The other three pan circumstances all involve limited material zones - being fossil creek exposures in road cuttings and channel bases (if discernable) in quarries in the Tertiary gravels.

It is not planned at this stage to submit all samples to the laboratory for quantitative assessment. A preliminary assessment will be done by field staff with the aid of a binocular microscope. Samples which prove to be interesting on that basis and require a better definition will be sent to the laboratory.

As a guide to the correct field identification, the first two samples were despatched to Analabs (Burnie) for a qualitative assessment of the heavy mineral assemblage. The results indicate the presence of chromite, cassiterite (red and brown-black) and magnetite. The determinations were qualitative, not quantitative.

4. POTENTIAL DIFFICULTIES

Possible problems that may affect the sampling (apart from the malevolent nature of the vegetation) are:-

- 1) Some drainages are too deep and too rapidly flowing in the appropriate trap sites to permit adequate sampling. Apart from personal danger in such situations, the sample tends to wash off the shovel before the sample can be transferred to the pan.
- 2) The technique is a once only method at each spot. Naturally, sampling depletes the heavy mineral content of a sample site and subsequent samples would be unrepresentative. (There is a certain amount of regeneration of sample sites but the length of time to totally restore a site is unknown - likely to be many years). This is particularly important to realize when panning creeks which have been panned in former years by prospectors.
- 3) In excessively steep valleyed creeks the influx of scree material can make the obtainable sample meaningless as the material will only come from a limited sample area.
- 4) If mining operations have been conducted upstream of the sample site, then the heavy mineral assemblage may be altered by the tailings from the mining operation. The same can be said of road making operations.
- 5) It is conceivable that some drainages may be water deficient later in the season. In this case, samples may have to be either re-sited or transported to an appropriate panning location.

- 6) Other problems may arise in the nature of the sample material. Excessive clay content and partial cementation cause the panning to be both time consuming and arduous.
- 7) Very fine heavy minerals may tend to be washed out with lighter material. In theory, this should be overcome by the collection of the silt sample.
- 8) Very fine heavy minerals tend to float when dry. If this situation arises the addition of a small amount of detergent will overcome the problem.

5. RESULTS AND DISCUSSION

For convenience, the stream sediment (and other) samples have been grouped into the following nine areas:-

- a. Browns Plain - Little Plain
- b. Nine Mile Creek
- c. Rocky River
- d. Timbs Creek
- e. Meridith Track Magnetic Anomaly (earlier referred to as Tin Anomaly area D).
- f. Alford's Creek
- g. Armstrong Creek
- h. Pineapple Creek
- i. Bowry Creek

The arrival of the binocular microscope has facilitated the assessment of heavy mineral concentrates from these areas. Not all samples have been thoroughly examined as yet, although most have been examined in a cursory fashion. The first impressions are that the technique is working sufficiently well to assist in lithology definition and prospect evaluation. A more detailed discussion will follow on an area by area basis.

Sludge samples from HM5 to HM41 (inclusive) were dispatched to Analabs for analysis for Cu, Pb, Zn, Ag, As, W and Sn. Results have been received for all elements except W and Sn.

Despite some differences in the range of lithologies sampled and in the type of sample taken, the values for copper and zinc appear comparable with those taken in previous work in EL 4/61 in which the -80mesh fraction of silt bank material was assayed. The lead values obtained appear to be more sensitive than the previous results and, therefore, of more value. Silver values are uniformly low and may reflect either a lack of silver in the area or a shortcoming of the technique.

In view of the ease of collection of the samples and the apparent merit of the results obtained, it is intended to continue collecting sludge samples. (Silver will not be

027

analysed). A discussion of the more significant results follows on an area by area basis.

a. Browns Plain - Little Plain

This is the most completely sampled and examined area in the programme.

Geologically, the area consists of 3 alluvial/eluvial units (excluding topsoil) which overlie the Whyte Schists. The heavy mineral response of each of these 3 units is quite different.

These units are:

- I. A tertiary ^{deposit?} deep of rounded but poorly sorted gravel and sand, with clasts of vein quartz, gneisen, quartz tourmaline rock and some sandstone is observable on Brown Plain at 473928 on the Corinna Road. It is part of a drainage network and is probably more extensive than the road cutting indicates (much more of the same type of gravel occurs at Savage River). The fossil channel, about 10 m wide, is exposed at two points 50 m apart.

The most obvious heavy minerals observable are:

- Tourmaline
- Corundum
- Monazite
- Pyrite (nodular) is occasionally present.

Note that the pyrite is interpreted as being an in-situ development. Further, there may be chromite and black cassiterite but these have not been detected as yet.

- II. Above the deep lead, and overlapping it onto a bedrock surface, is a sequence commencing with brown (lignitic?) clay and passing into alternating sand and clay. Some of the basal clay is sufficiently well bedded to indicate lacustrine conditions. A good exposure occurs on the Corinna Road at approximately 4491. The sequence may have been deposited in lakes marginal to basalt flows, but might be related to erosion surfaces that are later than the basalts in which case some coastal lagoon features would be expected in the sediments (H Shannon pers. comm.). This material will be examined for fossil evidence to support this theory.

For convenience, an overlying sheetwash gravel unit (Tertiary) has been included as part of the same unit. This gravel unit consists of medium to coarse sands and gravel up to small cobble size, generally sub-angular to sub-rounded. This has a variable thickness which appears to depend on the topography at the time of deposition and

the current topography.

The heavy mineral response from this unit (from gravel quarries in the area) is:

- Tourmaline
- Minor Corundum
- Monazite
- Red Cassiterite
- Chromite

There may also be black cassiterite present but this is more difficult to detect. The most obvious difference between this and the underlying deep lead sequence is the presence of red cassiterite. This implies that the source of the red cassiterite was not available to the deep lead system, and enhances the distinction between the two units.

III. Overlying this is another gravel sequence which, although compositionally similar, is noticeably angular. It has a thickness which does not appear to exceed 1m. There is a small component of this unit which is scavenged from the underlying Tertiary gravels.

The heavy mineral content of this unit is almost non-existent and what there is may be scavenged from the Tertiary gravels.

Stream sediment samples from drainages emanating from this area all have an assemblage similar to the sheet wash gravels. In addition, minor gold may or may not be present. (Absence of the gold is probably due to overworking by prospectors).

A surficial examination of the area reveals that gold prospectors have been active. Government reports suggest that exploration (and exploitation) commenced approximately 100 years ago. There are indications that it is still in progress, albeit illegally.

The most notable of these workings are some underground workings (see sketch map). There are a series of adits and a shaft, all of which appear to be seeking the deep lead material. The excavated material from these workings contains a reasonable proportion of rounded pebbles but these could be derived from either the deep leads or sheetwash material. It is, therefore, a point of conjecture as to which (if any) of these underground workings actually succeeded in exploiting the deep leads.

If these workings were successful in exploiting the deep

leads, it would be interesting to know the method of determining where to excavate. The adits may simply have been exploratory.

Further, if the deep leads were being exploited for gold, why weren't the workings more substantial? Possibilities which spring to mind are:

- i. insufficient gold
- ii. excessive water
- iii. cave-in problems

A further question which now arises is from which of these alluvial units does the gold originate? It is likely that the present drainage is reconcentrating gold into reasonable quantities. Prospectors in former years are reported to have done reasonably well out of working these modern alluvials, but less well out of the Tertiary gravels (including the deep leads). Certainly, the number of very recent excavations (small) suggests that there is still gold to be won from these modern alluvials.

Given that gold is generally present in all drainages and that deep leads may not always be exposed, then the most probable source of the gold is the sheetwash gravels. This does not deny the presence of gold in the deep leads. No sample of in-situ material from any of the three units has contained detectable gold and so the source question is still very much open.

In addition to gold, tin is also a commodity of economic interest.

An attempt was made in 1980 to systematically assess the tin/gold potential of the Tertiary gravels. The method was a grid based auger programme. No significant gold values were obtained, although values of up to 7,300 ppm tin were obtained. A follow up auger programme of the more interesting areas yielded only disappointing results. Several trenches were also excavated with disappointing results. It was concluded that anomalous values were randomly scattered and often associated with sediment from present day drainages (i.e., reworked Tertiary material). Exploration was therefore curtailed.

A re-assessment was made of earlier work and the current programme initiated. A brief examination of some of the auger sites suggests the possibility that the overlying angular gravels were not penetrated. In this circumstance, a low result is almost guaranteed.

Stream sediment samples, by their very nature, cannot be

considered in a quantitative, whereas the quarry samples (of Tertiary gravels) can (within the limits of the method). The largest amount of heavy mineral (total) from a quarry sample, is 2-4 gms from 15 litres of material. (This estimate is a ballpark figure and is derived from comparison to samples already weighed and the heavy mineral percentage determined). This gives a heavy mineral content of 50-100 ppm. Testing of various levels throughout the quarry on the Rocky River track suggests a fairly uniform heavy mineral content (for that area). Testing of different quarries suggests considerable variation in heavy mineral content from area to area.

It is difficult to ascertain the areal extent of the Tertiary gravels because of the masking effect to topsoil and the angular gravels. However, indications so far are that even if enough material was present, then the grade of mineralization so far indicated is not high enough nor consistent enough to permit exploitation.

However, it is still possible that richer pockets may exist - as indicated by the 1980 programme. Further, the possibility of a multi mineral deposit - gold, cassiterite, monazite and chromite (collectively) should not be ignored.

Another possibility, about which even less is known, is the deep lead system. Because of the lack of exposure, it is difficult to assess the potential of this unit. Most certainly, prospectors in former times did not significantly deplete any of its potential.

In order to test these possibilities, a well placed trenching programme (to overcome topographic problems) preceded by a geophysical (seismic?) programme should be able to delineate and test the deep leads and the sheetwash gravels.

A hand auger programme - using a sufficiently robust hand auger - would then be able to define the limits of the Tertiary gravels.

In terms of base metal potential, high lead values were detected in the 1980 programme. The conclusion drawn at that time was that this is a genuine bedrock anomaly - this still appears valid. A grid based hand auger programme (penetrating to the Whyte Schists) would adequately evaluate whether this was worth pursuing or not.

A stream sediment sludge sample from Goodall Creek (near Blackguards Hill) contains high zinc and copper values. The significance of this is not known but a stream sediment sampling programme upstream of this sample would

initially verify (or not) the anomaly and delineate areas for soil sampling.

In Little Hunter Creek, there is an elevated copper value. This may represent a normal copper response with a magnetite deposit (bearing in mind the minor chalcopyrite found in the Savage River magnetite - and that this creek drains a substantial magnetic anomaly). However, the magnetite content of the heavy mineral concentrate is quite low. This suggests a more interesting source. The magnetic anomaly is part of the Timbs Creek magnetic anomaly and any follow up exploration would naturally be done in conjunction with exploration in the Timbs Creek area.

Tin and tungsten values have not yet been received for the sludge samples. No comment can therefore be offered.

b. Nine Mile Creek

The Cape Copper mine is located in this creek and attempts were made to obtain stream sediment samples both upstream and downstream of this mine.

Initially, a downstream sample was attempted. A sludge sample was collected, but very little heavy mineral was detected. It was concluded that this was due to tailings from the mine masking the true alluvials of the creek. Further attempts at collecting a sample were tried further downstream. At no point between the mine and the Whyte River was a heavy mineral sample obtainable.

An upstream sample was then attempted. Once again, very little heavy mineral was obtainable (thus disproving the conclusion reached on the first attempt). However, significant gold was detected.

The absence of significant heavy minerals implies that this creek does not drain the Tertiary gravels. Therefore, gold must have an alternate source. This fits nicely with the theory (H. Shannon) of a gold bearing stratigraphic unit. Further, if this were so, then this may correlate with Golden Ridge and Specimen Ridge.

Follow up stream sediment sampling is recommended.

Naturally, the sludge sample below the mine has an elevated copper value. However, the copper value upstream is also higher than background (but not as high as downstream). Re-examination of the lithologies present in the creek yielded some pyritic shales and the copper may be associated with this.

A follow up programme for gold could also test the potential of copper. Rock chips could also be collected of the pyritic material and analysis for base metals and gold conducted on them.

c. Rocky River

This is a well known mineralised area. Several attempts have been made to exploit the area for gold. Both alluvial and underground mining have been attempted. The alluvial miners met with some success, but the underground operations do not appear to have been successful. Possibly they misinterpreted the geological controls of the gold mineralization.

Equally as well known is the magnetite deposits which pass through the area. These have been tested (for magnetite only) and been found to be of insufficient quality.

Currently, there is a dredging operation in progress downstream of the magnetite occurrence. This is owned and operated by P. Forrest, who has supplied samples of heavy mineral concentrate from his dredge (with the gold removed). The sample, naturally, has a significant magnetite and haematite content. Apart from this, it appears to have a typical Tertiary gravel assemblage.

Three samples have been taken of tributaries draining from the North into Rocky River and one sample of a tributary (Breakneck Creek) draining from the south.

One of the samples from the north is from the magnetite belt and the heavy mineral assemblage is mainly magnetite with very little else. The other two samples are beyond the magnetite belt and contain very little heavy mineral.

The sample in Breakneck Creek is also influenced by the magnetite belt. However, in addition to the magnetite and haematite, it also contains a typical Tertiary gravel type assemblage.

Although more testing is required in this area, it would appear likely that there are tertiary gravels to the south of Rocky River, but not to the north.

No sludge samples from this area have been dispatched for analysis as yet.

d. Timbs Creek

Alluvial gold has been won from this creek by prospectors in years gone by. Possibly the source of the gold is the Tertiary gravels. There is evidence of minor excavations and sluicing operations in the lower reaches of the Creek.

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There are two significant magnetic anomalies cut by this drainage system.

The western anomaly is the most intense. A heavy mineral sample obtained downstream of this anomaly yielded an abnormally large concentrate, which has been determined by laboratory analysis to be 82.4% haematite. All other samples from this drainage system are totally unlike this sample.

The obvious conclusion is that the haematite is connected with the magnetic anomaly - although not being magnetic, is unlikely to have caused it. If the anomaly was a magnetite anomaly, then more magnetite would have been expected in the heavy mineral concentrate. Sampling of other drainages emanating from the magnetic anomaly is required.

Samples from creeks draining the eastern magnetic anomaly all contain significant magnetite, implying that magnetite is the cause of the anomaly.

Heavy mineral concentrates from tributaries draining from the north do not contain a Tertiary gravel type assemblage, whereas all others do. Therefore, it can be concluded that the Tertiary gravels do not exist to the north, whereas they do to the south (Browns Plain).

Another feature of interest is that two samples contain significant epidote. Both of these samples are obtained from tributaries which are on either side of Timbs Creek, and align in the direction of the regional strike of the underlying strata. This probably means that one particular lithological unit is epidote rich.

Not all sludge samples have been assayed. However, sufficient results have been received to observe that:-

- I. The sample downstream of the western magnetic anomaly contains elevated copper and zinc values, whereas the sample immediately upstream of this anomaly is more subdued. It is probable that some base metal mineralization is associated with the anomaly. Follow up stream sediment sampling may further define the situation.
- II. There are high copper and zinc (and lead?) values from all drainages in the upper reaches of Timbs Creek (below the eastern magnetic anomaly). Not all results are yet to hand, and so the picture is still incomplete.

The most likely explanation for the anomalism is that there is some base metal mineralization associated with the magnetic anomaly. This can be easily tested by stream sediment sampling immediately upstream of the anomaly. One sample, considerably further upstream (Chinamans Creek) does have low

order base metal values.

If the base metal anomalism can be defined, then more detailed work in the form of a grid base soil sampling programme should follow.

e. Meredith Track Magnetic Anomaly

This area has earlier been referred to as Tin Anomaly Area D.

As yet, heavy mineral samples from this area have not been examined in detail. Field observations indicate the presence of significant pyrite (and minor pyrrhotite). Other heavy minerals noted were tourmaline and garnet. Most certainly, the Tertiary gravel type assemblage is absent.

One or two grey cassiterite crystals were noted and since the area is to be further investigated the significance of this should become more apparent.

Results from the sludge samples have indicated low base metal values. In consideration of the proximity to the granite, the tin and tungsten assays would naturally be of more interest. These results are still outstanding.

f. Alfords Creek

This area was investigated as a potential osmiridium bearing creek.

No osmiridium was observed in the heavy mineral concentrate. The assemblages obtained suggest that there is (or was) some Tertiary sheetwash gravels being drained by the creeks in the area.

There is a deep lead exposed in a road cutting at Alfords Creek. The material available from this deep lead is coarse sands. Unfortunately, the base of the channel is not exposed. The sandy nature of the material may represent some type of backwash material.

The mineral assemblage of the deep lead, like the deep lead exposed in the Corinna Road near Eight Mile Creek, is devoid of red cassiterite. This supports the concept proposed in the Browns Plain section that the deep leads are a separate entity available to the deep lead system.

Sludge samples from the area are all depressed for base metals. However, the deep lead and Alfords Creek both contain high arsenic values. It is possible that Alfords Creek has obtained its arsenic from the deep lead. Both samples were taken in Alfords Creek, both of which have high arsenic - one above the exposed deep lead and one below. The course of the deep lead may follow Alfords Creek, thus causing the upstream anomaly as well.

Because of the well known association of arsenic with gold, this anomalism should be pursued. Unfortunately, exploration would be difficult as it would involve testing the deep lead. Perhaps geophysics (seismic) followed by drilling could do this.

It would be advisable to bear in mind the proximity of this prospect to the lease boundary.

g. Armstrong Creek

Samples were obtained from this area to check the possibility of osmiridium.

Detailed examination of the heavy mineral concentrate has not been conducted as yet.

Field examination has revealed no osmiridium. Both of the southern samples contain detectable heavy minerals. In this group the drainage from the east contains significant magnetite suggesting some minor magnetite body further upstream. The assemblage for the other sample is as yet unknown.

The two samples to the north both contain very little heavy minerals.

Results from the sludge samples have been received. These indicate low order base metal values. However, in both groups of samples, the drainages from the east have elevated arsenic values. This suggests an arsenic enriched (and gold?) unit of the Whyte Schist.

Further sampling is required to define the source of the anomalism.

h. Pineapple Creek

Samples were taken both upstream and downstream of a basalt capping to check the possibility of Tertiary gravels being present under the basalt. (Pineapple Creek has exposed the base of the basalt).

Very little heavy mineral concentrate was obtained in the samples upstream. Samples downstream do contain significant heavy mineral concentrates. However, the bulk of the material (on field examination only) appears to be haematite. A more accurate assessment can be made later.

Sludge sample results from the area are uninspiring. If the tin and tungsten values are also low, then no further work would be the recommendation.

i. Bowry Creek

So far, only two samples have been taken from this system - in the vicinity of the well known magnetite occurrence. These samples were primarily for orientation purposes.

Predictably, there is a significant content of magnetite in the heavy mineral concentrate. The remainder of the heavy mineral has yet to be assessed but a Tertiary sheetwash gravel type assemblage would not be unexpected as there is a possibility of a minor occurrence of this unit in the headwaters of the system.

Sludge sample assays indicate elevated zinc and copper values. In view of the known association on minor base metals with the Savage River Iron Ore deposit, these values too, are not unexpected.

As time permits, more samples will be taken from this system.

B. G. Penny,
December, 1983.

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Institute of Energy and Earth Resources

Division of Mineral Chemistry

PRODUCTION OF MAGNESIA BY THE CALCINATION/CARBON DIOXIDE

LEACH PROCESS: REVIEW OF PROCESS DEVELOPMENT

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October 1983

Mineral Chemistry Communication

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CONTENTS

	<u>Page No.</u>
SUMMARY.....	1
INTRODUCTION.....	1
PRODUCT SPECIFICATIONS.....	3
THE SAVAGE RIVER MAGNESITE DEPOSIT.....	3
PROCESS SELECTION.....	4
THE CALCINATION/CARBON DIOXIDE LEACH PROCESS.....	6
Summary of Experimental Results.....	6
Ore Preparation.....	8
Magnesite Calcination.....	9
Calcine Grinding.....	12
Leaching.....	13
Liquid-Solid Separation.....	21
Intermediate Product Precipitation.....	21
Intermediate Product Recovery.....	21
Product Recovery.....	23
OPERATING STRATEGY.....	23
ACKNOWLEDGEMENT.....	24
REFERENCES.....	24
APPENDIX.....	27

PRODUCTION OF MAGNESIA BY THE CALCINATION/CARBON DIOXIDE
LEACH PROCESS: REVIEW OF PROCESS DEVELOPMENT

SUMMARY

The Division of Mineral Chemistry has carried out a collaborative project with Industrial and Mining Investigations Pty Ltd concerned with the development of a suitable route for the production of high-grade magnesia from Savage River magnesite. This report outlines the required product specifications and the factors taken into account in choosing the calcination/carbon dioxide leach process for detailed examination. Each of the major unit processes is briefly described, together with details of the optimum conditions derived from the laboratory-scale testwork. Magnesite calcination and calcine leaching are the two stages that need to be most closely controlled in order to maximize magnesium recovery while minimizing undesirable iron dissolution. The report concludes with a brief outline of an operating strategy for preparing two high-grade magnesia products.

INTRODUCTION

Magnesium oxide (magnesia) is the major constituent of a wide range of refractories used in virtually every form of high-temperature (>700°C) mineral processing. Various grades of magnesia are produced to meet specific refractory requirements. For the latter, both the physical and the chemical properties of the magnesia must fall within specific ranges. As a general rule, refractories in the most corrosive regions of the kiln, furnace, etc., must meet the most rigid chemical specifications in terms of minimum MgO and maximum Fe₂O₃ and B₂O₃ contents. In addition, the lime:silica (CaO:SiO₂) ratio must be about 2:1 to produce sufficient Ca₂SiO₄ for bonding purposes.

There are two major sources of magnesia - sea water (or brines) and minerals with high magnesium contents such as magnesite and dolomite. For each raw material, there are a number of alternative processing

routes. The choice between these routes depends upon many factors including location, desired product specifications and energy availability and costs, as well as raw materials grade and reserves. Production of magnesia from sea water suffers from high energy costs and the need to at least partly remove boron (sea water has a significant borate content). High-grade magnesite deposits can generally be readily upgraded into a high-grade concentrate by physical methods such as froth flotation, photometric sorting and reverse flotation, since most of the impurities (hematite, calcite, dolomite, quartz and layer silicates) occur as discrete entities. If the impurities are intergrown or occur as solid solutions with the magnesite, then physical beneficiation will not necessarily be satisfactory in maintaining product quality. In these two cases chemical dissolution techniques are required. These processes are also energy-intensive since it is necessary to calcine the magnesite to crude magnesia prior to chemical reaction as well as calcination of the purified magnesium salt to magnesium oxide.

A significant magnesite deposit has been delineated in the Savage River region of Tasmania and the CSIRO Division of Mineral Chemistry has collaborated with Industrial and Mining Investigations Pty Ltd (IMI) in mineralogical characterization of the orebody [1,2] as well as development of an appropriate processing route for high-grade magnesia [3-17]. Experimental work has now reached the stage where further development would necessitate the design, construction and operation of a pilot-scale plant on a continuous basis. Prior to this, proven ore reserves would need to be established by detailed drilling, etc., and a market evaluation carried out. The latter should consider both product grades* and production levels, taking into account the short- to medium-term over-supply position, depressed market and likely high cost of the product. This report summarizes the development work carried out to date.

*Discussions with both refractory manufacturers and users clearly indicates that in order to establish a commercially viable marketing position a range of products will be essential.

PRODUCT SPECIFICATIONS

Initially IMI requested that our process development work should be directed towards the production of very-high-purity magnesia, comparable to the top product produced by the Japanese manufacturer UBE. Thus the Division was requested to develop a process capable of producing magnesia with the following specifications from Savage River magnesite.

MgO	>	98.5%
Fe ₂ O ₃	<	0.05%
B ₂ O ₃	<	0.03%

The total production rate was initially set at 100 000 t/annum.

Following discussions between the author and Australian Industrial Refractories Pty Ltd (AIR), it became clear that the above specifications were too restrictive, particularly with respect to the Fe₂O₃ content. In addition, it seemed that the proposed total production rate was too high in terms of Australia's requirements and export prospects. On the basis of the discussions with AIR, it seems reasonable that processing of the Savage River magnesite should be broadly aimed at the production of the following three grades of magnesia.

		SRM1	SRM2	SRM3
MgO	(%)	>98.5	>97.0	>94.0
Fe ₂ O ₃	(%)	<0.10	<0.50	<2.00
B ₂ O ₃	(%)	<0.03	<0.03	<0.03

THE SAVAGE RIVER MAGNESITE DEPOSIT

On the basis of the mineralogical study on the limited quantity of diamond-drill core and surface samples presently available [12,18], the deposit can be described as massive, containing in excess of 50 million tonnes of ore containing about 80% magnesite, 10% dolomite and 10% silicates (mainly quartz). The dolomite occurs as discrete bands as well as being intimately mixed with the magnesite. As would be expected with the proposed origins of the deposit, the boron content of the magnesite is extremely low, typically being in the range 0.0002-0.0008% B₂O₃.

Since, as noted above, boron is an important impurity in refractory-grade magnesia, it can be readily appreciated that magnesia produced from the Savage River magnesite could be expected to be well within specification limits with respect to this element.

Iron, the other major undesirable impurity in refractory-grade magnesia, occurs in the Savage River magnesite in three major forms; as pyrite, in sheet silicate minerals, and as siderite (iron carbonate). The latter is the most significant in terms of both content and processing problems since it occurs as a solid solution in the magnesite. In the upper levels of the orebody, the bulk magnesite typically contains about 2% siderite but at depth the siderite content falls to about 1%.

Although the quartz, sheet silicates, pyrite and dolomite could be removed, at least partially, by a combination of physical processing techniques, this is not the case with the siderite because of its mode of occurrence. On the basis of the mineralogical study, it was concluded that production of refractory-grade magnesia from the Savage River magnesite would require chemical processing.

PROCESS SELECTION

Numerous chemical processes have been proposed for the production of pure magnesia from magnesite. Virtually all of these processes are characterized by the following major steps.

- Calcination of the magnesite to crude magnesia.
- Complete dissolution of the magnesium component of the crude magnesia.
- Recovery of an insoluble magnesium salt from the clarified leachate.
- Calcination of the magnesium salt to pure magnesia.
- Recovery, regeneration and recycling of the leachant.

Of the very wide range of proposed leachants, only the mineral acids (hydrochloric, nitric and sulphuric) and aqueous carbon dioxide (carbonic acid) can be considered commercially viable.

Processes using the mineral acids as leachants are characterized by complex solution purification and acid regeneration stages. In addition, there are substantial corrosion problems. Carbon dioxide

leaching appears to have a number of potential advantages. These include reduced corrosion problems, reduced dissolution of impurities and, most importantly, an acid plant is not required since the carbon dioxide required for leaching can be readily recovered from the magnesite and magnesium salt calcination stages. A major disadvantage of the carbon dioxide leach process is that the soluble magnesium salt, magnesium bicarbonate, has a much lower solubility than the corresponding chloride, nitrate and sulphate salts, requiring processing of large volumes of solution. In addition, the solubility of magnesium bicarbonate decreases with increasing temperature so that advantage cannot be taken of an increase in dissolution kinetics by increasing the leaching temperature. Magnesium bicarbonate solubility can be increased by operating at a high carbon dioxide pressure, but even so, carbon dioxide leaching has to be carried out with a low feed pulp density.* This means that the plant size must be substantially greater than those using the mineral acids to obtain the same overall production rate.

Of the numerous proposed magnesite dissolution routes, only hydrochloric acid leaching has been carried out on a significant commercial scale [19,20]. This no doubt relates to simpler metal separation and acid regeneration procedures compared with nitric and sulphuric acid systems. Carbon dioxide leaching has been practised commercially on a relatively small scale [21], although the process has attracted little interest over the last 20 years.

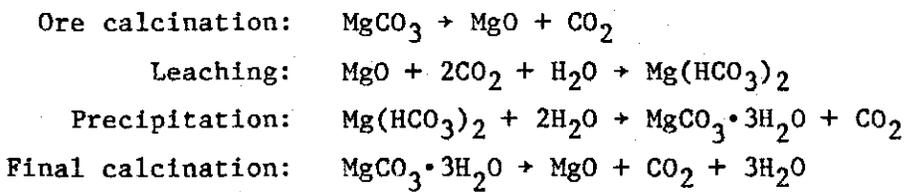
Despite the above limitations of the carbon dioxide leach process and the lack of current commercial practice, it was concluded that calcination followed by carbon dioxide leaching should be studied in detail as a potential method of producing high-purity magnesia from Savage River magnesite.

*Two to five percent solids, depending upon the Mg content of the feed, giving a maximum magnesium concentration of about 20 g/litre at 10°C, using an operating pressure of 1000 kPa carbon dioxide.

THE CALCINATION/CARBON DIOXIDE LEACH PROCESS

Figure 1 shows a simplified form of the proposed flowsheet for treating Savage River magnesite.* It includes the major metallurgical units but not many important chemical engineering steps such as heat recovery, dust handling, water purification and storage, and carbon dioxide handling. As a general comment, these latter units are "conventional" and are not discussed in this report.

At first sight, the calcination/carbon dioxide leach process involves some very simple chemistry. The reactions of the magnesite component of the feed can be summarized as follows.



As would be expected, the reactions, particularly leaching and precipitation, are considerably more complex than indicated above. In addition, the reactions of the gangue minerals must be considered. Leaching must be carried out in the presence of excess carbon dioxide in order to form soluble magnesium bicarbonate. If there is insufficient carbon dioxide, an insoluble basic magnesium carbonate will precipitate and this redissolves in the presence of excess carbon dioxide at a relatively slow rate.

SUMMARY OF EXPERIMENTAL RESULTS

With the exception of final product high-temperature calcination and densification, all major stages of the proposed flowsheet have been tested on the laboratory scale. In addition, leaching tests have been

*As discussed in the Appendix, alternative flowsheets were considered, particularly with respect to purification of the magnesium bicarbonate leachate. More importantly, the flowsheet is designed to produce the two highest grades of magnesia, viz., SRM1 and SRM2. As discussed below, production of the lowest grade of magnesia, SRM3, can probably be achieved without the need for the chemical dissolution and subsequent stages.

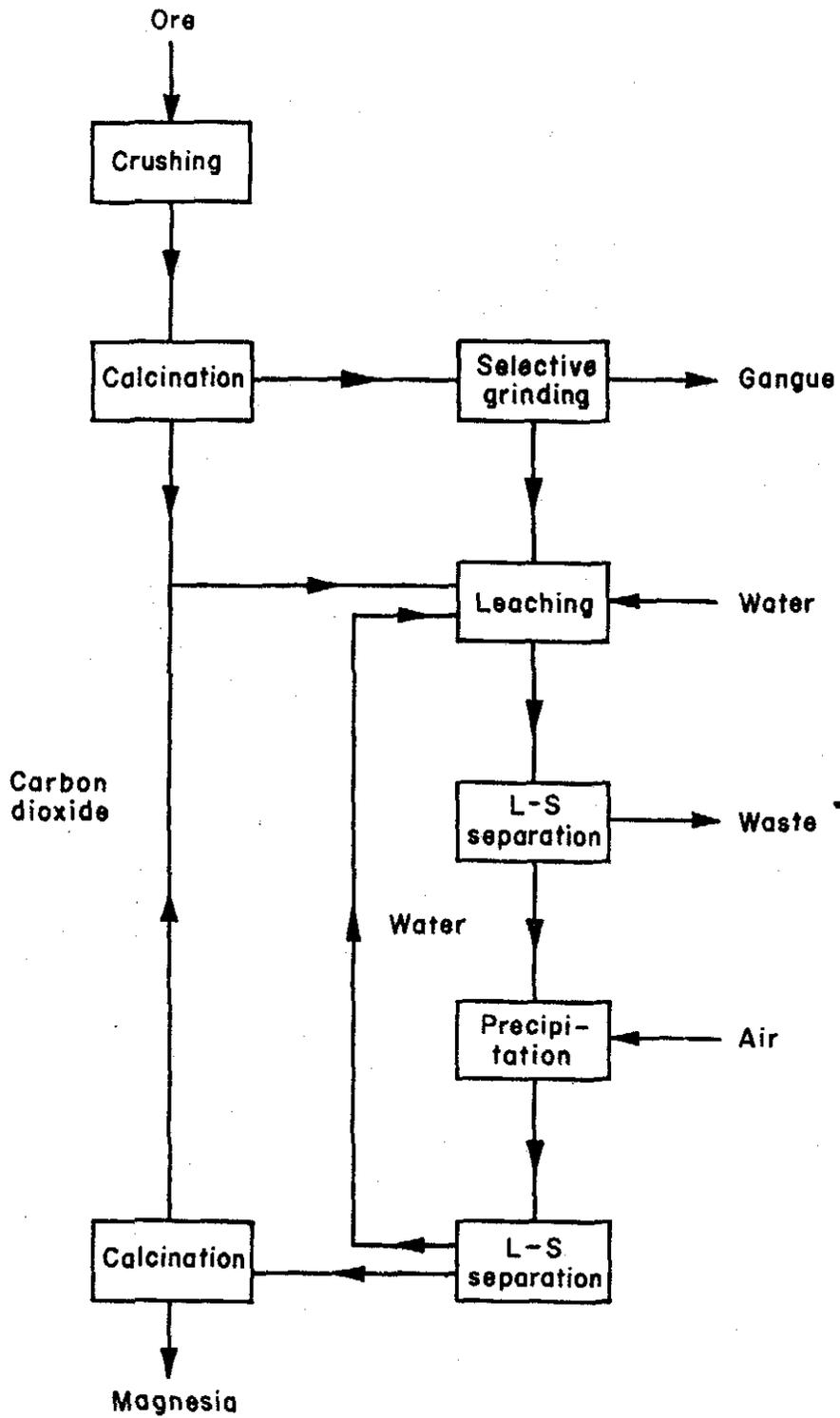


Fig. 1. Proposed flowsheet for the calcination/carbon dioxide leach process.

carried out on the pilot scale, some of the tests being carried out on a continuous basis. Most work has been directed towards the leaching stage since this is the least researched unit process.

Not unexpectedly, a number of problems were encountered during the study; most of these related to excessive iron dissolution. This problem is discussed in more detail in this report.

The experimental work clearly indicates that the proposed flowsheet is technically viable and is capable of producing the highest quality magnesia desired. Thus numerous samples of magnesia containing >99.0% MgO and <0.20% Fe₂O₃ have been prepared in the laboratory-scale tests. Apart from detailed continuous pilot-scale testing, areas that have not been studied in detail include capital and operating cost estimates and evaluation of refractory properties. All of these areas would have to be examined prior to commercial development.

Each of the major stages of the proposed flowsheet will be discussed below, with greatest detail directed towards the ore calcination and leaching stages. This is a reflection of the importance of these two stages on the overall viability.

ORE PREPARATION

As is the case with all processing routes, it is highly desirable to blend the ore to provide a feed as uniform as possible in both chemical and physical terms in order to reduce variations in processing behaviour while achieving maximum overall recovery. This can at least partly be achieved by careful control of the mining, crushing, grinding and concentration (pre-leach screening) stages.

Because the optimum calcination conditions vary with the magnesite/dolomite ratio of the feed, it will be essential to produce a feed with a "constant" magnesite/dolomite ratio. This ratio should be as high as possible, preferably greater than 9:1 since the optimum calcination temperature for dolomite is considerably higher than that of magnesite. It is considered that rejection of the dolomite is technically advantageous even though the overall magnesium recovery will be reduced. Thus mining will have to be on a "semi-selective" basis with rejection of high-dolomite ore. Use of stockpiling procedures will assist with the preparation of a uniform feed to the crushing circuit.

Mined ore needs to be crushed to a suitable size for efficient calcination. The crushed ore needs to be of a size which allows complete and uniform calcination; i.e., the feed needs to be of a size that allows complete and unrestricted evolution of the carbon dioxide. Although vertical shaft kilns are attracting some interest, directly fired rotary kilns are normally used for magnesite calcination.

Optimum crushing size is determined by the kiln characteristics but for magnesite should be $-50+15$ mm. Because of the hardness of the ore, crushing would probably be carried out in several stages with screening and recycling of oversize ore between each stage. This would ensure that there is not excessive particle size reduction.

MAGNESITE CALCINATION

In order to achieve an acceptable leaching rate, the crude calcine has to have as high a surface area as possible, consistent with maximizing the overall recovery rate. In simple terms, under-calcination leads to reduced recovery while over-calcination leads to a reduced leaching rate. In other words, there has to be a compromise between the recovery and leaching rates.

The formation of a suitable crude calcine is dependent upon particle size, retention time, temperature and atmosphere. Using a particle size consistent with the type of calcination kiln used, extensive testwork clearly indicates that calcination temperature is the most important of the above variables.* This is well illustrated by Figs. 2 and 3 which show the effects of calcination temperature on magnesium extraction for both magnesite- and dolomite-rich feeds. The difference in the behaviour of the two types of feed is also immediately apparent. The observations can be directly related to the measured surface areas of the calcines and the well established calcination behaviour of magnesite and dolomite [22].

For a directly fired rotary kiln in which the atmosphere above the solids is depleted in carbon dioxide by excess air, nitrogen and unburnt

*This comment only strictly applies to macrocrystalline magnesites such as the Savage River deposit. Work in these laboratories clearly indicates that with micro- or cryptocrystalline magnesites, calcination temperature is less critical in forming a reactive calcine.

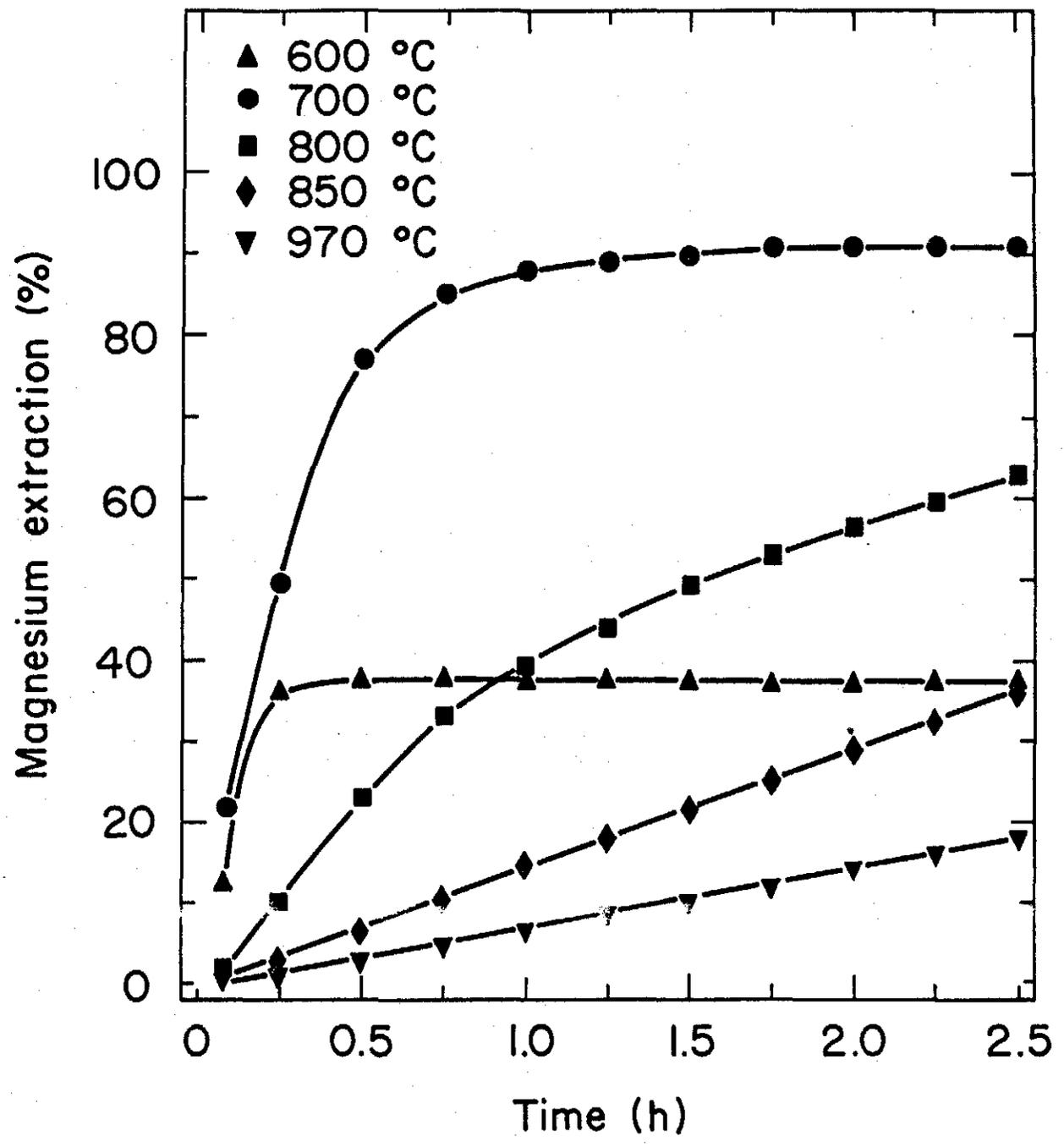


Fig. 2. Effect of calcination temperature on magnesium extraction. Magnesite-rich ore calcined for 1 h.

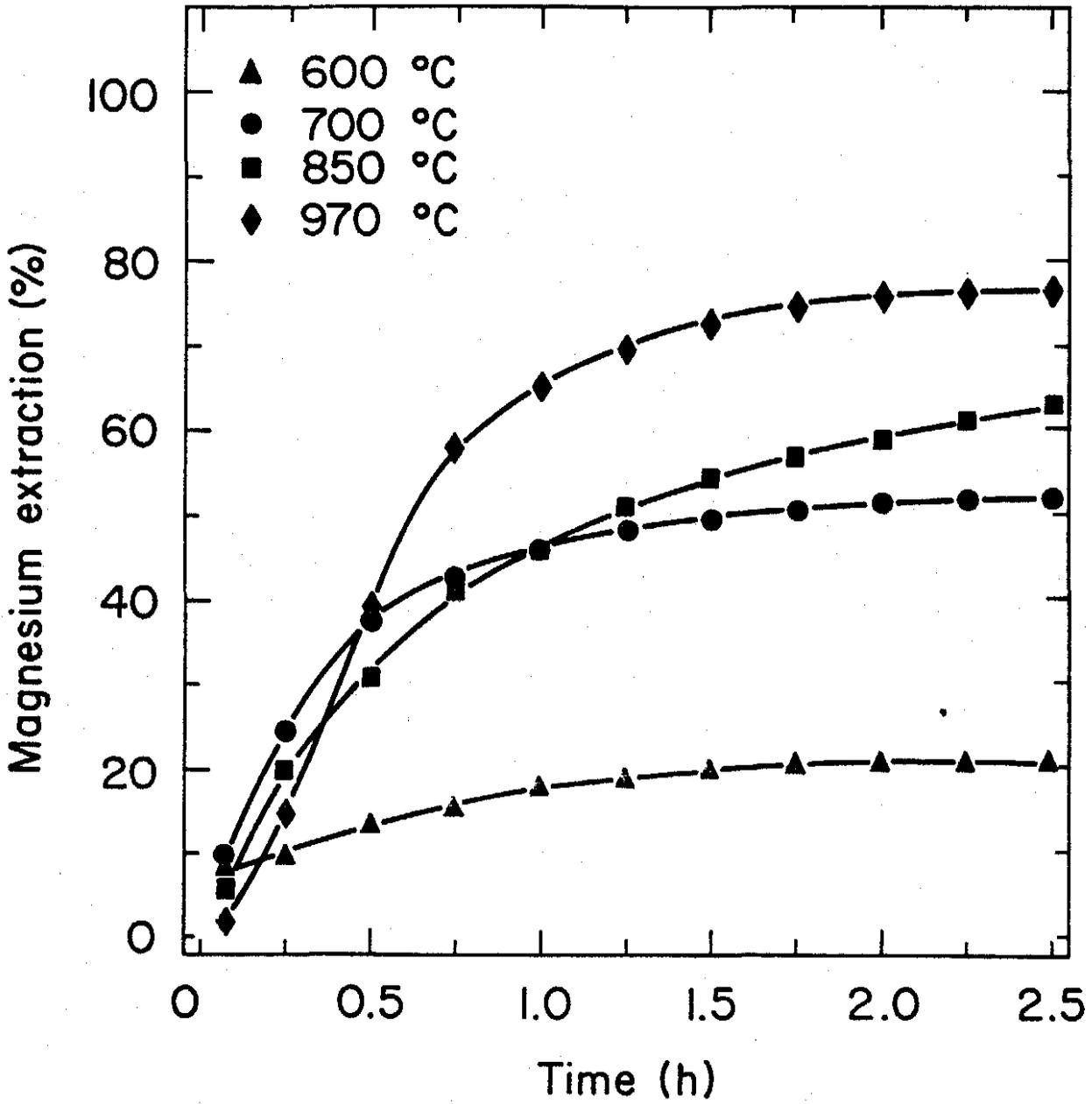


Fig. 3. Effect of calcination temperature on magnesium extraction.
Dolomite-rich ore calcined for 1 h.

hydrocarbons, optimum calcination conditions appear to be $720 \pm 20^\circ\text{C}$ for 2.0 ± 0.5 h. If an indirectly fired kiln was used, a somewhat higher calcination temperature ($760 \pm 20^\circ\text{C}$) would be required since the higher carbon dioxide atmosphere above the solids tends to suppress the calcination (decomposition) reaction. It is recommended that the surface area of the crude calcine be $>75 \text{ m}^2/\text{g}$, and that process control should incorporate regular surface area measurement.

As noted above, directly fired rotary kilns are normally used for calcination of magnesite, whether it be to produce a crude calcine for further processing or to form a refractory-grade magnesia from physically beneficiated magnesite. For the carbon dioxide leach process as applied to the Savage River magnesite, the use of a directly fired rotary kiln poses some problems. These relate to problems with temperature control, excessive temperatures in the region of the burner flame, and dilution of the carbon dioxide content of the off-gases. The implications of inadequate control and excessive temperature profiles are readily appreciated when the narrow optimum operating temperature range is considered. Although it is an advantage in terms of a reduction in calcination temperature, removal of carbon dioxide from above the solids, recovery, purification and recompression of the carbon dioxide for recycling to the leaching circuit (Fig. 1) is complicated by the presence of inerts in the atmosphere. These may constitute up to 90% by volume. Recovery of the carbon dioxide, as well as temperature control, using an indirectly fired rotary kiln would be more readily achieved. However, there are significantly greater engineering problems associated with their operation, and they have higher capital and operating costs. Overall, it is concluded that use of a conventional directly fired rotary kiln is the most appropriate.

CALCINE GRINDING

Following calcination, the crude calcine must be ground to a suitable size for leaching. Since the crude calcine ideally has a high surface area and a high porosity, a pre-leach particle size range of 100% -150 μm and 50% -40 μm will be adequate. Grinding of the feed to the leaching circuit is best carried out after calcination since during calcination there is a loss in weight of about 50%, a volume reduction

of about 10%, and significant decreases in both hardness and particle size. Thus both capital and operating costs are substantially reduced. Figure 4 compares Savage River magnesite and crude calcine, highlighting the above changes. The colour change is associated with oxidation of ferrous iron in the magnesite-siderite solid solution to ferric iron (hematite) in the crude calcine.

Another advantage of grinding after calcination is that the properties of the principal gangue mineral (quartz) are not radically changed during calcination so that grinding can be carried out on a selective basis with intermediate screening to remove the hard quartz.

Although it might be considered advantageous in terms of materials handling and dust control to carry out wet grinding of crude calcine as it is discharged from the rotary kiln, this leads to problems of excessive iron dissolution during leaching. Thus, grinding of the crude calcine should preferably be carried out on a dry basis. Provided leaching conditions can be chosen to reduce the amount of iron reporting in the clarified leachate, wet grinding of the crude calcine in recycled process liquor will, however, be more practical. This will facilitate introduction of the crude calcine into the leaching circuit but must be carried out with calcine that has already been cooled to ambient temperature. In addition, the time between preparation of the slurry prior to introduction into the grinding circuit and contact with carbon dioxide in the leaching circuit must be kept to a minimum (<1 h).

High-magnesia crude calcines prepared from the bulk ore samples provided for most studies to date have too high an iron content (3-6% Fe_2O_3) to produce SRM3 magnesia. However, recent preliminary tests indicate that, provided the raw magnesite contains <2% Fe_2O_3 , then calcination and selective screening alone can yield a product meeting SRM3 specifications.

LEACHING

The leaching rate and magnesium extraction from crude magnesia to form soluble magnesium bicarbonate is controlled by the following factors.*

*In addition to these factors, calcination conditions must be included. Thus the following discussion refers only to the leaching parameters.



Fig. 4. High-magnesite ore (left) and crude calcine (right) after heating to 800°C for 1 h.

- Pulp density
- Carbon dioxide pressure
- Agitation
- Temperature

Dissolution of crude magnesia derived from magnesite, particularly from that containing iron in solid solution, is complicated by the fact that a considerable amount of ferric iron also dissolves. Although this is contrary to "conventional" chemical theory since the leach slurry is alkaline (pH 7.5-9.0), it is apparent that a number of groups associated with the development of the carbon dioxide leach have also encountered this problem. The lack of success in overcoming the problems associated with this unexpected iron dissolution appears to be one of the main reasons for the non-commercial exploitation of the carbon dioxide leach process. Iron dissolution is affected by the above variables as well as the slake time and temperature.*

The effects of each of the leaching variables on the rate and extent of magnesium and iron dissolution are not independent of one another, making the determination of optimum leaching conditions complex, particularly in view of the fact that what is desirable in terms of the magnesium may be deleterious in terms of excessive iron dissolution. The effects of the leaching variables can be summarized as follows.

- Slake time and temperature - Increases iron dissolution, but does not affect magnesium dissolution.
- Pulp density - Does not affect the rate of dissolution of magnesium but is limited by the maximum magnesium concentration attainable. Iron dissolution increases rapidly with an increase in pulp density.
- Carbon dioxide pressure - Rate and extent of magnesium and iron dissolution both increase with an increase in the operating carbon dioxide pressure.
- Agitation - Substantial agitation is required both to keep the calcine particles in suspension and to provide adequate contact between the calcine and dissolved carbon dioxide. The rate of reaction between the magnesium oxide and carbon dioxide is

*Slaking is the reaction between the magnesium oxide and water to form magnesium hydroxide.

relatively rapid and it is essential to ensure that there is adequate dispersion of the carbon dioxide through the slurry.* Although this can be achieved by direct injection of the carbon dioxide into the slurry, preferably beneath the impeller, more efficient dispersion can be achieved with a Snyder sub-aerator. The sub-aerator has a pumping action that ensures homogeneous dispersion of the carbon dioxide throughout the slurry. The degree of agitation necessary to produce leaching kinetics that are independent of agitation are determined to a large extent by reaction vessel characteristics, including baffling, impeller type, impeller diameter to vessel diameter ratio, and vessel height to diameter ratio. However, general chemical engineering principles indicate that turbulent conditions are necessary, so that the reactor should have a Reynolds number greater than 20 000.

- Temperature - This is the most complex leaching variable, affecting the rate and extent of dissolution of both magnesium and iron. Provided that the "solubility" of magnesium bicarbonate is not exceeded, then an increase in temperature increases the rate of magnesium dissolution. The amount of iron dissolved generally decreases with increasing temperature but, more importantly, may decrease with increasing retention time. The temperature and rate at which this decrease occurs is dependent upon the other leaching conditions, particularly pulp density. The effects of temperature and pulp density on iron dissolution are well illustrated by Figs. 5 and 6.

The relationship between magnesium and iron dissolution is extremely complex, although in general it can be seen (Fig. 7) that the iron concentration increases with increasing magnesium concentration. Further evidence that iron dissolution is controlled, at least partly, by the magnesium concentration comes from the fact that the iron concentration is increased if the liquor used to make-up the calcine slurry also contains soluble magnesium.

In order to reduce capital and operating costs, leaching should be carried out under the following conditions.

*If there is insufficient agitation and carbon dioxide dispersion, the leach slurry becomes depleted in carbon dioxide with the result that an insoluble basic magnesium carbonate is formed.

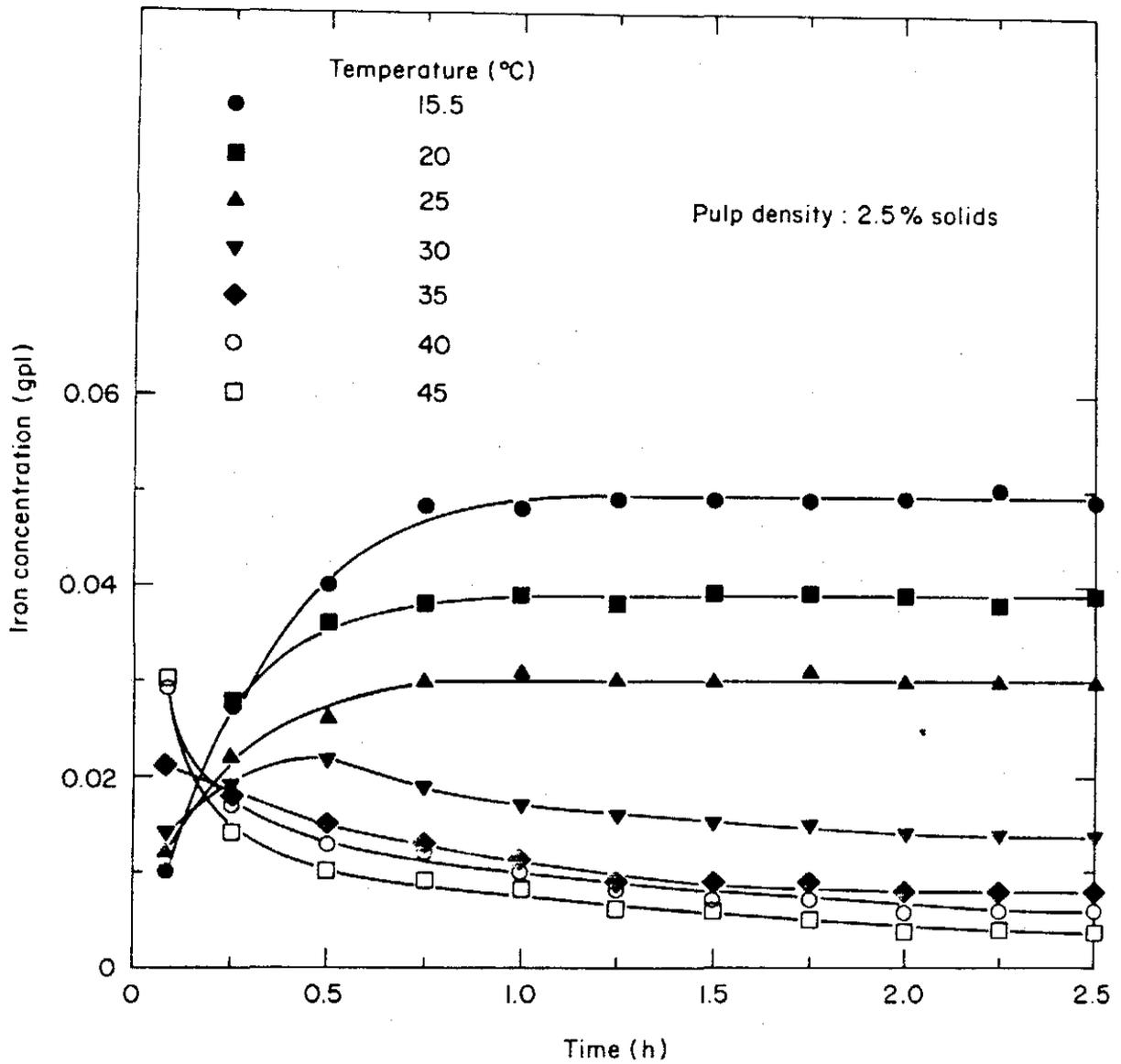


Fig. 5. Autoclave leach test data - effect of temperature on iron concentration. MAG 3 calcined at 700°C for 3 h, leached at 100 psig and 1200 rpm (0.5 h slake period).

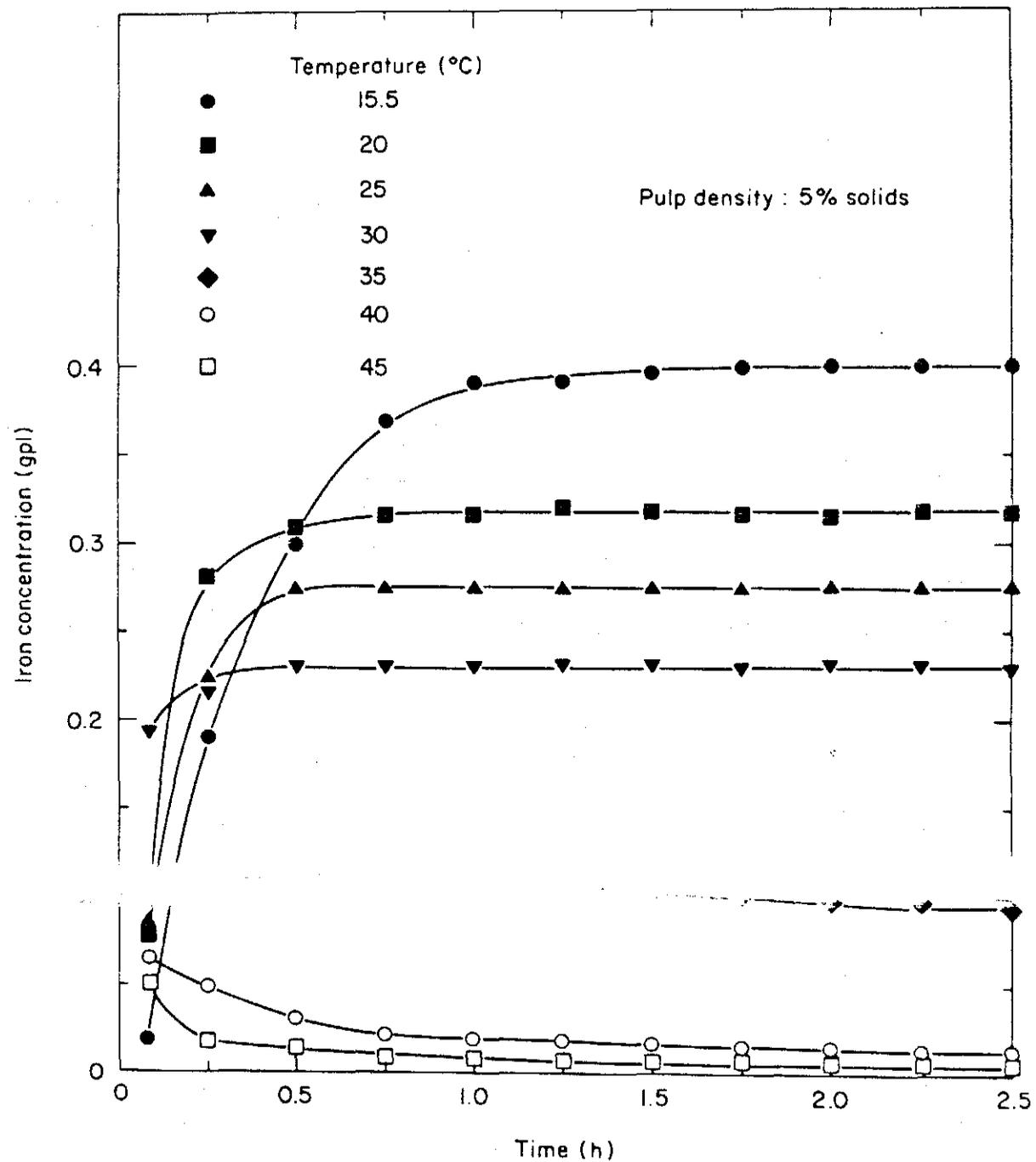


Fig. 6. Autoclave leach test data - effect of temperature on iron concentration. MAG 3 calcined at 700°C for 3 h, leached at 100 psig CO₂ and 1200 rpm (0.5 h slake period).

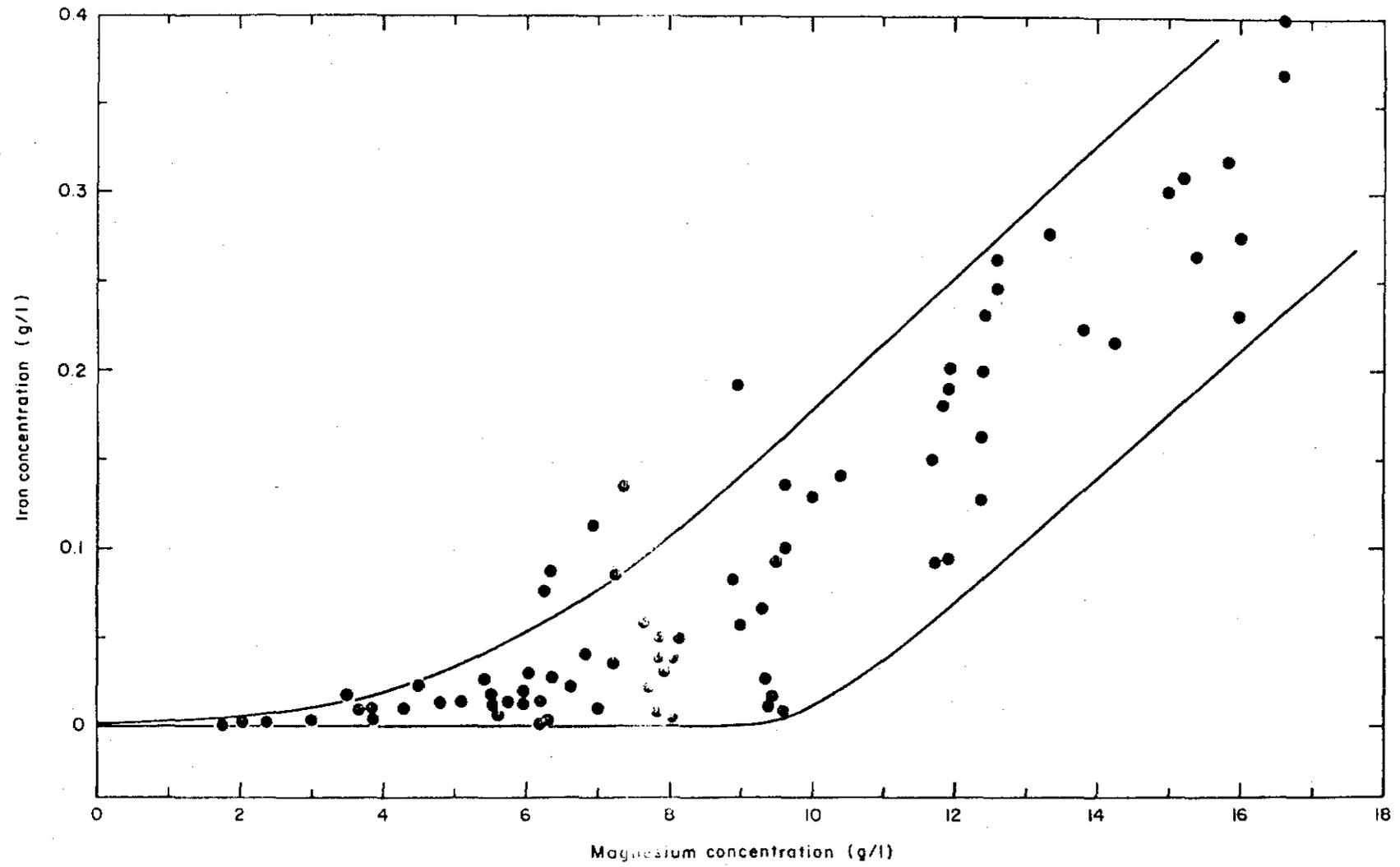


Fig. 7. Leach liquor composition: iron concentration as a function of magnesium concentration.

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<u>Maximum</u>	<u>Minimum</u>
Pulp density	Temperature
	Carbon dioxide pressure
	Agitation
	Retention time

For carbon dioxide leaching of crude magnesite derived from Savage River magnesite, reaction conditions are dictated by the maximum iron-to-magnesium concentration ratio that will ultimately yield a magnesite of the desired purity. An alternative way of establishing optimum leaching conditions is to consider the maximum iron concentration per unit magnesium concentration. The data in Table 1 give an indication of the compositions of the clarified liquors that will give a final magnesite product with a specified Fe_2O_3 content

Table 1. Maximum iron concentration as a function of magnesium concentration to yield magnesite with a given Fe_2O_3 content.

Liquor Mg content (g/l)	Liquor Fe content (g/l) for product containing x% Fe_2O_3			
	x = 0.01	x = 0.05	x = 0.10	x = 0.20
1.0	0.0001	0.0006	0.0012	0.0024
2.0	0.0002	0.0012	0.0024	0.0048
3.0	0.0004	0.0018	0.0036	0.0072
4.0	0.0005	0.0024	0.0048	0.0096
5.0	0.0006	0.0030	0.0060	0.0120
6.0	0.0007	0.0036	0.0072	0.0144
7.0	0.0008	0.0042	0.0084	0.0168
8.0	0.0010	0.0048	0.0096	0.0192
9.0	0.0011	0.0054	0.0104	0.0208
10.0	0.0012	0.0060	0.0120	0.0240

For MAG3 calcine formed at 700°C for 3 h and leached at 1200 rpm, using 100 psig carbon dioxide and a 0.5 h slake time at the leaching temperature, Table 1 gives the conditions that can be used to produce magnesite products SRM1 and SRM2 (< 0.10 and < 0.50% Fe_2O_3 , respectively). In each case, the conditions are such that maximum magnesium extraction is achieved; for this particular calcine it corresponds to 80 ± 2% of

the magnesium content of the calcine. It can clearly be seen that the conditions necessary to produce the higher grade product, SRM1, are much more restrictive than those that can be used to produce the less pure product, SRM2.

Table 2 gives the combination of leaching conditions needed to produce a specified product and provides the basis needed for capital and operating cost estimates and optimization.

LIQUID-SOLID SEPARATION

After the desired retention time, the soluble magnesium bicarbonate solution has to be separated from the leach residue. This must be carried out rapidly and under a carbon dioxide atmosphere in order to prevent undesirable precipitation of hydrated magnesium carbonate. Experimental work indicates that the solids settle rapidly without the need for flocculant addition. In commercial practice, pressure filtration would be used.

INTERMEDIATE PRODUCT PRECIPITATION

In order to carry out rapid and complete precipitation yielding a product that forms in the bulk of the solution and not as a coating on vessel walls, the clarified leachate should be heated to a temperature above 55°C. Under these conditions, hydromagnesite, $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$, precipitates. Although air can be sparged through the slurry to induce evolution of carbon dioxide and hence precipitation, this has the disadvantage of diluting the carbon dioxide-containing off-gases, which in turn makes carbon dioxide recovery and recycling more complex. Experiments carried out to date indicate that complete (>95%) precipitation can be achieved in less than 1 h.

INTERMEDIATE PRODUCT RECOVERY

The precipitated hydromagnesite can be recovered as a wet slurry by conventional clarification and filtration using, for example, a series of counter-current decantation thickeners. The filtrate (overflow) is subjected to a purification stage and returned to the leaching circuit.

Table 2. Leaching conditions required to meet SRM1 and SRM2 Fe₂O₃ specifications.*

SRM1			SRM2		
Pulp density (% solids)	Temp. (°C)	Time (h)	Pulp density (% solids)	Temp. (°C)	Time (h)
2.0	30.0	1.75	2.0	15.5	1.00
2.0	35.0	1.25	2.0	20.0	1.00
2.0	40.0	0.50	2.0	25.0	0.75
2.0	45.0	0.50	2.0	30.0	0.50
2.5	35.0	1.25	2.0	35.0	0.50
2.5	40.0	1.00	2.0	40.0	0.25
2.5	45.0	0.75	2.0	45.0	0.25
3.0	45.0	2.50	2.5	20.0	1.00
			2.5	25.0	1.00
			2.5	30.0	0.75
			2.5	35.0	0.75
			2.5	40.0	0.50
			2.5	45.0	0.25
			3.0	25.0	0.50
			3.0	30.0	0.50
			3.0	35.0	0.25
			3.0	40.0	0.25
			3.0	45.0	0.25

*SRM1 and SRM2 Fe₂O₃ specifications <0.10 and <0.50% respectively.

Leached at 100 psig carbon dioxide and 1200 rpm after 0.5 h slake at leaching temperature.

In order to reduce energy consumption in the product recovery stage, it will be essential to dewater the hydromagnesite product to as high a pulp density as possible, preferably >70% solids. This is probably best achieved by treating the solids (underflow) from the CCD circuit on a vacuum drum filter. A high pulp density will also reduce sticking problems in the feed introduction area of the rotary kiln used for final product calcination.

PRODUCT RECOVERY

Differential thermal and thermogravimetric analysis of hydromagnesite indicates that conversion to magnesium oxide occurs in two stages. Over the range 20-500°C, dehydration and dehydroxylation occurs, while above 500°C, carbon dioxide is evolved. It is recommended that intermediate product calcination be carried out in two stages, each in a rotary kiln. This will facilitate recovery and recycling of carbon dioxide since the bulk of the water is evolved as off-gases in the final calcination stage.

Refractory manufacture is not normally carried out by the magnesia producer since this requires a different blend of specialized technologies. In order to reduce problems with rehydration during storage prior to refractory manufacture, it will be essential to calcine the magnesia produced from Savage River magnesite at about 1800°C.

OPERATING STRATEGY

As discussed above, it is believed that a physical beneficiation can probably be used to produce the lowest of the proposed three grades of magnesia from Savage River magnesite. This would not involve additional processing circuitry since it is considered that all feed will need to be treated in order to reduce problems associated with the production of high-purity magnesia by chemical dissolution.

In order to minimize capital and operating costs, it is essential that the calcination/carbon dioxide leach process be carried out on a continuous basis. In particular, this will facilitate heat and water balance control, simplify carbon dioxide recovery and recycling, and

reduce problems associated with the unstable nature of the magnesium bicarbonate leach liquor.

While it might be advantageous to be able to produce both high-purity magnesias (SRM1 and SRM2) on a continuous basis, such an operating strategy would be too costly since it would involve duplication of much of the overall circuit.

Because of the nature of the proposed leaching and product recovery circuits, few difficulties can be expected when changing over from one set of operating conditions to the other. This is because only the leaching conditions need to be altered to change the product specifications. The calcination/carbon dioxide leach process involves two energy-intensive stages (feed and intermediate product calcination), in addition to heating a dilute slurry to a temperature in the range 30-45°C. Thus, heat recovery from the calcination stages must be efficient to supply the necessary energy for slurry temperature heating. In other words, the heat balance must be maintained within fairly tight limits. This means that it would be best to use the same leaching temperature for both grades of magnesia. Product grade would then be controlled by the pulp density and/or the retention time.

ACKNOWLEDGEMENT

Numerous helpful discussions with Dr Tom Biegler are gratefully acknowledged.

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APPENDIX

The unexpected observation of excessive ferric iron dissolution during leaching necessitated a wide range of studies directed towards development of an understanding of the mechanism of iron dissolution and of methods of removing the iron from the magnesium bicarbonate leach liquor. The results of these studies can be summarized as follows.

- The excessive iron dissolution is directly related to the physical state of the iron in the crude calcine, and hence the original magnesite feed. The iron is present in the crude calcine as hematite with a very high surface area.
- Iron dissolution occurs via the formation of a bicarbonato complex. The concentration of this ferric bicarbonato complex is controlled by the total bicarbonate concentration and the temperature of the leach slurry.
- The iron concentration of the final magnesium bicarbonate leach liquor can be reduced to an acceptable level by addition of aluminium sulphate to the initial leach slurry or to the clarified magnesium bicarbonate liquor. The soluble iron is coprecipitated as the insoluble synthetic mineral hydrotalcite, $[Mg_6Al_2(OH)_{16}CO_3 \cdot 4H_2O]$.
- Alternative methods of iron removal, including precipitation as ferric arsenate, ion exchange and solvent extraction, are not applicable because of the alkaline pH of the magnesium bicarbonate leach liquor.
- Although efficient removal of ferric iron could be achieved by precipitation of hydrotalcite, overall magnesia recovery was substantially reduced because of magnesium losses in the hydrotalcite. Better than 80% of the magnesium component of the hydrotalcite precipitate could be recovered either by dissolution of the precipitate in sulphuric acid or controlled calcination. Although both of these routes also resulted in recovery and recycling of the aluminium sulphate, the additional capital and operating costs would make these routes economically unattractive.

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CSIRO
Institute of Energy and Earth Resources
Division of Mineral Chemistry

PRODUCTION OF HIGH-PURITY MAGNESIA BY THE CALCINATION/CARBON
DIOXIDE LEACH PROCESS: SUMMARY OF PROCESS DEVELOPMENT

J.H. Canterford

December 1983

Mineral Chemistry Communication

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CONTENTS

	<u>Page No.</u>
TERMS OF REFERENCE.....	1
INTRODUCTION.....	2
CONCLUSIONS.....	4
FEEDSTOCK.....	5
PROCESS SELECTION.....	7
THE CALCINATION/CARBON DIOXIDE LEACH PROCESS.....	8
SUMMARY OF RESULTS.....	10
Ore Preparation.....	11
Magnesite Calcination.....	12
Calcine Grinding.....	17
Leaching.....	19
Liquid-Solid Separation.....	29
Intermediate Product Precipitation.....	29
Intermediate Product Recovery.....	30
Product Recovery.....	30
OPERATING STRATEGY.....	32
ACKNOWLEDGEMENTS.....	34
REFERENCES.....	35
APPENDIX.....	37

TERMS OF REFERENCE

To examine samples of magnesite from the Main Creek deposit near Savage River in Tasmania and endeavour to develop a satisfactory production route for premium grade magnesia suitable for refractory purposes.

INTRODUCTION

Early in 1979 Industrial and Mining Investigations Pty Ltd (IMI) requested the collaboration of the Commonwealth Scientific and Industrial Research Organization (CSIRO) on the mineralogical and metallurgical aspects of IMI's investigation of the potential development of a major deposit of magnesite said to occur in Exploration Licence No. 4/61 which is held by IMI in north-west Tasmania.

IMI indicated that, primarily, their project was based on the Japanese market and it would be necessary to have a premium grade product which would compete with the highest grade magnesia produced in Japan by the sea-water process. It was understood that it would be necessary also to have available a range of lower grade products but it was considered that, if the highest purity magnesia could be produced, the lower grades could readily be produced by changing processing conditions in the plant.

Initially, the following target specification was set by IMI for the most important components:

MgO	-	99.0% minimum
Fe ₂ O ₃	-	0.05% maximum
B ₂ O ₃	-	0.03% maximum

Subsequently, three other specifications were added to cover lower grades of magnesia. These specifications are as follows:

	<u>SRM 1</u>	<u>SRM 2</u>	<u>SRM 3</u>
MgO (%)	>98.5	>97.0	>94.0
Fe ₂ O ₃ (%)	<0.10	<0.50	>2.0
B ₂ O ₃ (%)	<0.03	<0.03	>0.03

Initially, IMI submitted a parcel of 5 magnesite samples described as diamond-drill core samples from the subject deposit. Later, additional samples described as samples of exposures of the deposit where it is cut by Main Creek, a tributary of the Savage River, were received from IMI and were included in the later stages of the programme.

In March 1979, a programme of research was commenced by CSIRO and has been carried on at intervals since then. This laboratory-scale research and the results obtained therefrom relate only to the samples provided by IMI.

This report summarizes the programme and the results obtained to date [1-15].

CONCLUSIONS

The samples of magnesite submitted by IMI have been studied and tested in the laboratory and reproducible results have shown that, on a laboratory scale, premium grade magnesia can be produced from those samples by the calcination/carbon dioxide leach process.

From the technical aspect, it is considered that the process warrants testing in a pilot plant.

FEEDSTOCK

Initially, five composite samples of roughly crushed ore were received, with each sample weighing approximately 50 kg. The approximate composition (%) of each sample was as follows.

Sample	MgO	CaO
MAG 1	26	23
MAG 2	44	2
MAG 3	41	4
MAG 4	42	4
MAG 5	37	10

Although boron contents of these samples were not determined, analysis of similar samples indicated traces only of boron (0.0002-0.0008% B₂O₃). The samples were described as composites of diamond-drill cores and were said to be indicative of a major deposit of magnesite with intermittent narrow bands of high-dolomite material.

MAG 1 was said to be indicative of the high-dolomite bands; MAG 2, MAG 3 and MAG 4 were representative of the major part of the drill intersections and MAG 5 had been taken from the narrow bands in which the magnesite contained above average amounts of dolomite.

After preliminary tests, more detailed research was undertaken on samples MAG 1 and MAG 3 as being

representative of the high-dolomite and high-magnesite samples, respectively.

This phase of the programme showed that it is desirable to have a plant feed which is low in dolomite (below 10%) and it was decided to base further research on sample MAG 3 which IMI considered to be the most likely to be indicative of the deposit as a whole.

Subsequently, a bulk sample was received which IMI described as a composite of several samples taken from exposures of the deposit where it is cut by Main Creek, a tributary of the Savage River. Test work on this bulk sample showed that metallurgically and mineralogically it is closely allied to MAG 3 and test results on this material could be directly compared to those achieved with MAG 3. This bulk sample was used for the larger-scale tests as well as for replicate tests to determine reproducibility.

PROCESS SELECTION

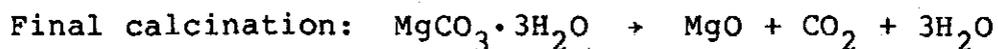
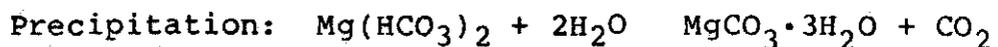
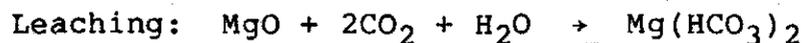
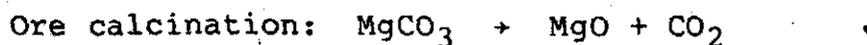
From a study of the material to be tested, an examination of all available literature on magnesite processing and observation of the methods currently in use, it became clear that a chemical leach process would be suited to the magnesite samples provided by IMI.

Following further study of the advantages and disadvantages of the various chemical processes which are, or have been, in use, it was concluded that calcination followed by carbon dioxide pressure leaching offered the best prospects for success in achieving the goal set by IMI. Accordingly, it was decided to base the research programme on the calcination/carbon dioxide leach process.

THE CALCINATION/CARBON DIOXIDE LEACH PROCESS

Figure 1 shows a simplified form of a proposed flow-sheet for treating Savage River magnesite. It covers the major metallurgical units but not many important chemical engineering steps such as heat recovery, dust handling, water purification and storage, and carbon dioxide handling. In general, these latter units are "conventional" items and are not discussed in the report.

At first sight, the calcination/carbon dioxide leach process involves some very simple chemistry. The reactions of the magnesite component of the feed can be summarized as follows.



As would be expected, the reactions, particularly leaching and precipitation, are considerably more complex than indicated above. In addition, the reactions of the gangue minerals must be considered. Leaching must be carried out in the presence of excess carbon dioxide in order to form soluble magnesium bicarbonate. If there is insufficient carbon dioxide, an insoluble basic magnesium carbonate will precipitate and this re-dissolves in the presence of excess carbon dioxide at a relatively slow rate.

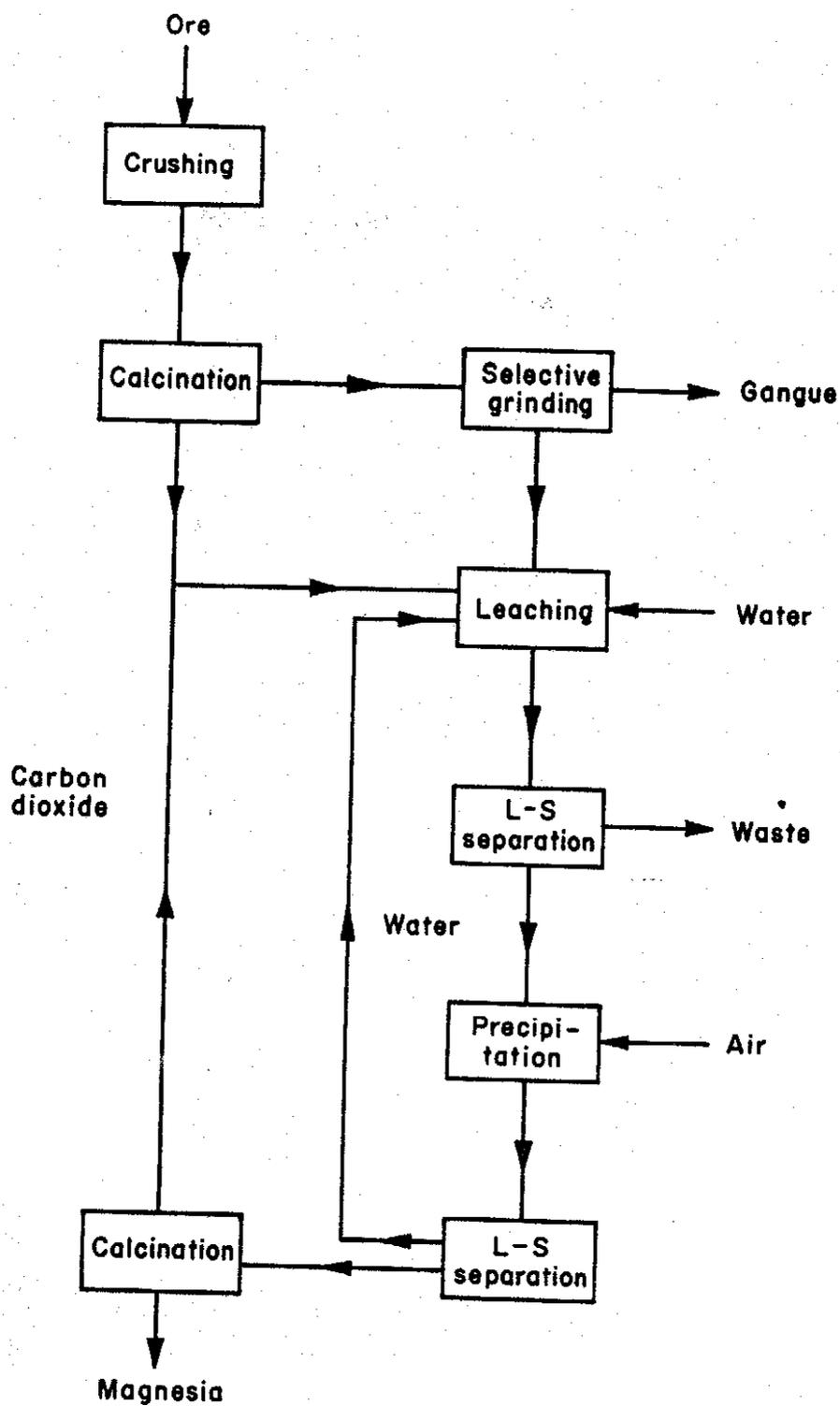


Fig. 1. Proposed flowsheet for the calcination/carbon dioxide leach process.

SUMMARY OF RESULTS

With the exception of high-temperature calcination and densification of the final product, all major stages of the flowsheet have been tested on a laboratory scale and reproducible results have been achieved. In addition, leaching tests have been carried out on a laboratory pilot scale, some of these tests being on a continuous-flow basis, using four 35-litre autoclaves in series.

In general, most of the work has been directed towards the leaching stage because this is the least researched unit of the process.

Not unexpectedly, a number of problems were encountered during the study, most of which related to excessive dissolution of iron. In dealing with this difficulty, various additives were introduced into the circuit. Alternatively, additional unit processes were also examined. Ultimately, the use of additives and/or additional stages were discarded on either technical or commercial grounds. The iron problem is discussed in more detail later.

The programme clearly indicated that the proposed flowsheet is technically viable and is capable of producing the highest quality of magnesia desired. Numerous samples of magnesia containing more than 99% MgO and less than 0.05% Fe₂O₃ have been prepared in the laboratory-scale tests.

More importantly, the analyses of samples of the magnesia produced showed them to contain 0.0002 to 0.001% B₂O₃.

Each of the major sections of the proposed flowsheet are discussed below with the most detail directed towards the ore calcination and leaching stages; this is a reflection of the importance of these two sections in the overall viability of the process.

ORE PREPARATION

In all processing routes it is highly desirable to provide a plant feed which, as nearly as possible, is uniform in chemical and physical terms so as to reduce variations in the process behaviour and to achieve maximum overall recovery.

Because the optimum calcination temperature for dolomite is considerably higher than that for magnesite, the optimum calcination conditions for the process vary significantly with the magnesite/dolomite ratio in the plant feed. Therefore, this ratio should be kept as high as possible, preferably greater than 9:1.

It is considered that rejection of most of the dolomite from the plant feed is technically advantageous and this should be done if it is practicable so to do, even if it entails some loss in the overall recovery of magnesium from the deposit. IMI has advised that they have had discussions

with Ore Sorters (Australia) Pty Ltd regarding their process for photometric ore-sorting and that Ore Sorters have said that their process would reject most of the dolomite from Savage River magnesite.

The plant feed needs to be crushed to a size which permits complete and uniform calcination, thereby allowing unrestricted evolution of the carbon dioxide. Although vertical shaft kilns are attracting some interest, directly fired rotary kilns are normally used for magnesite calcination.

Optimum crushing size is largely determined by the kiln characteristics but, for magnesite, it could be expected to be to the order of -50+15 mm. Because of the hardness of the ore, crushing would probably be in stages with screening and recycling of oversize ore between each stage.

MAGNESITE CALCINATION

In order to achieve an acceptable leaching rate, the crude calcine has to have as high a surface area as possible, consistent with maximizing the overall recovery rate. In simple terms, under-calcination leads to reduced recovery while over-calcination leads to a reduced leaching rate. In other words, there has to be a compromise between the recovery and leaching rates.

The formation of a suitable crude calcine is dependent upon particle size, retention time, temperature and atmosphere. Using a particle size consistent with the type of calcination kiln used, extensive testwork clearly indicates that calcination temperature is the most important of the above variables.* This is well illustrated by Figs. 2 and 3 which show the effects of calcination temperature on magnesium extraction for both magnesite- and dolomite-rich feeds. The difference in the behaviour of the two types of feed is also immediately apparent. The observations can be directly related to the measured surface areas of the calcines and the well established calcination behaviour of magnesite and dolomite [16].

For a directly fired rotary kiln in which the atmosphere above the solids is depleted in carbon dioxide by excess air, nitrogen and unburnt hydrocarbons, optimum calcination conditions appear to be $720 \pm 20^\circ\text{C}$ for 2.0 ± 0.5 h. If an indirectly fired kiln was used, a somewhat higher calcination temperature ($760 \pm 20^\circ\text{C}$) would be required since the higher carbon dioxide atmosphere above the solids tends to suppress the calcination (decomposition) reaction. It is recommended that the surface area of the crude calcine be $>75 \text{ m}^2/\text{g}$, and that process control should incorporate regular surface area measurement.

*This comment only strictly applies to macrocrystalline magnesites such as the Savage River deposit. Work in these laboratories clearly indicates that with micro- or cryptocrystalline magnesites, calcination temperature is less critical in forming a reactive calcine.

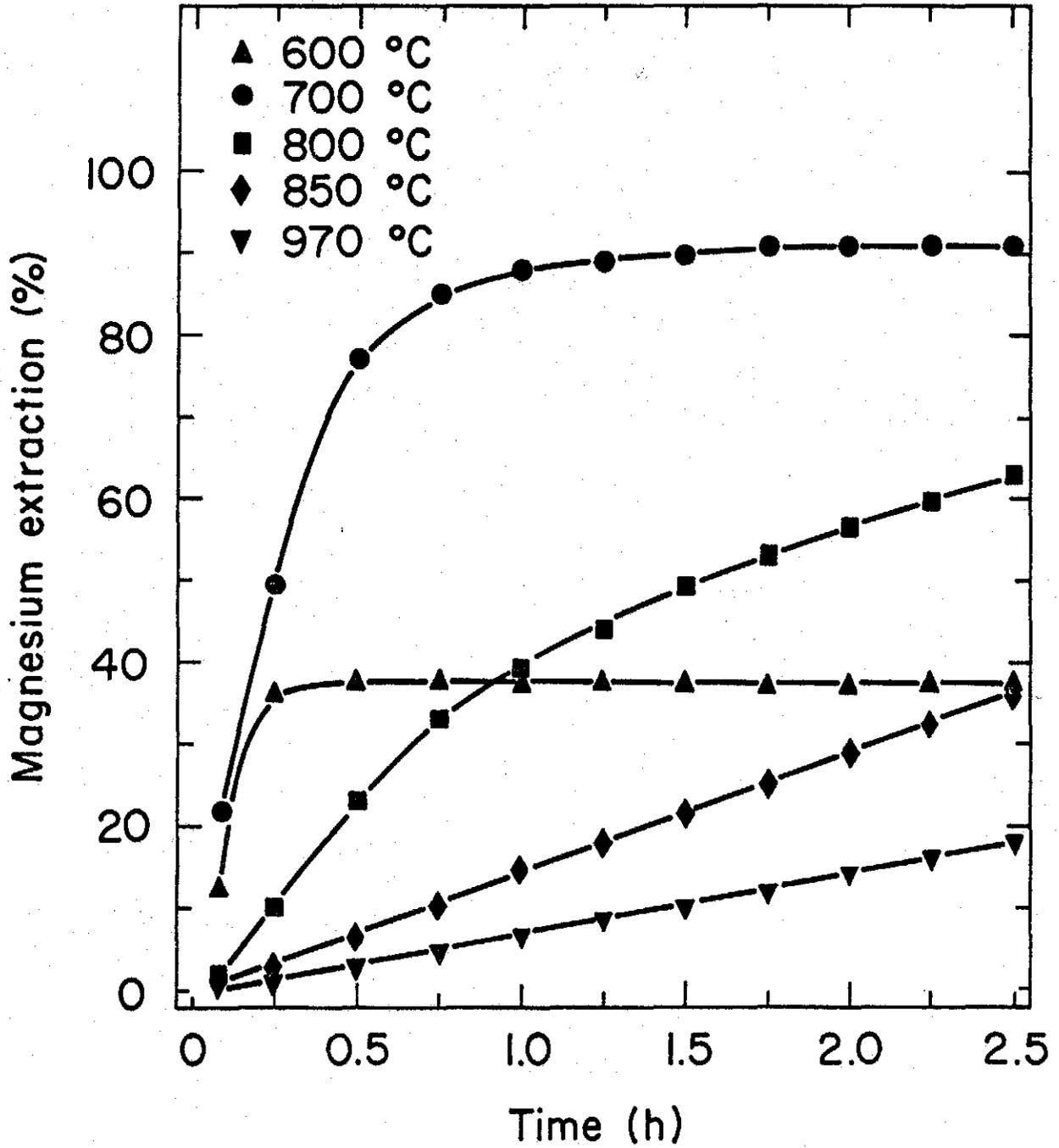


Fig. 2. Effect of calcination temperature on magnesium extraction. Magnesite-rich ore calcined for 1 h.

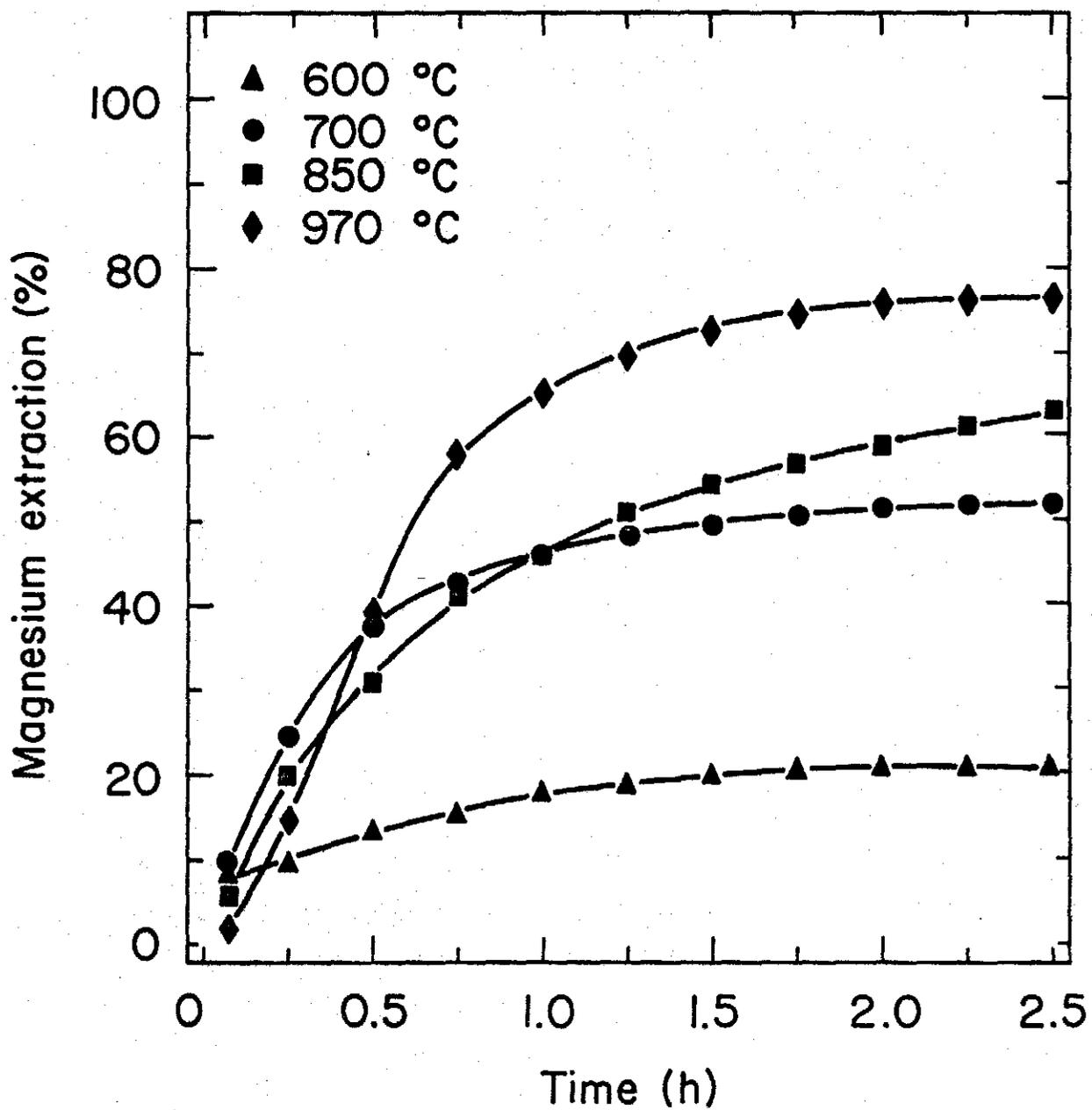


Fig. 3. Effect of calcination temperature on magnesium extraction. Dolomite-rich ore calcined for 1 h.

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As noted above, directly fired rotary kilns are normally used for calcination of magnesite, whether it be to produce a crude calcine for further processing or to form a refractory-grade magnesia from physically beneficiated magnesite. For the carbon dioxide leach process as applied to the Savage River magnesite, the use of a directly fired rotary kiln poses some problems. These relate to problems with temperature control, excessive temperatures in the region of the burner flame, and dilution of the carbon dioxide content of the off-gases. The implications of inadequate control and excessive temperature profiles are readily appreciated when the narrow optimum operating temperature range is considered. Although it is an advantage in terms of a reduction in calcination temperature, removal of carbon dioxide from above the solids, recovery, purification and recompression of the carbon dioxide for recycling to the leaching circuit (Fig. 1) is complicated by the presence of inerts in the atmosphere. These may constitute up to 90% by volume. Recovery of the carbon dioxide, as well as temperature control, using an indirectly fired rotary kiln would be more readily achieved. However, there are significantly greater engineering problems associated with their operation, and they have higher capital and operating costs. Overall, it is concluded that use of a conventional directly fired rotary kiln is the most appropriate.

CALCINE GRINDING

Following calcination, the crude calcine must be ground to a suitable size for leaching. Since the crude calcine ideally has a high surface area and a high porosity, a pre-leach particle size range of 100% -150 μm and 50% -40 μm will be adequate. Grinding of the feed to the leaching circuit is best carried out after calcination since during calcination there is a loss in weight of about 50%, a volume reduction of about 10%, and significant decreases in both hardness and particle size. Thus both capital and operating costs are substantially reduced. Figure 4 compares Savage River magnesite and crude calcine, highlighting the above changes. The colour change is associated with oxidation of ferrous iron in the magnesite-siderite solid solution to ferric iron (hematite) in the crude calcine.

Another advantage of grinding after calcination is that the properties of the principal gangue mineral (quartz) are not radically changed during calcination so that grinding can be carried out on a selective basis with intermediate screening to remove the hard quartz.

Although it might be considered advantageous in terms of materials handling and dust control to carry out wet grinding of crude calcine as it is discharged from the rotary kiln, this leads to problems of excessive iron dissolution during leaching. Thus, grinding of the crude calcine should preferably be carried out on a dry basis.

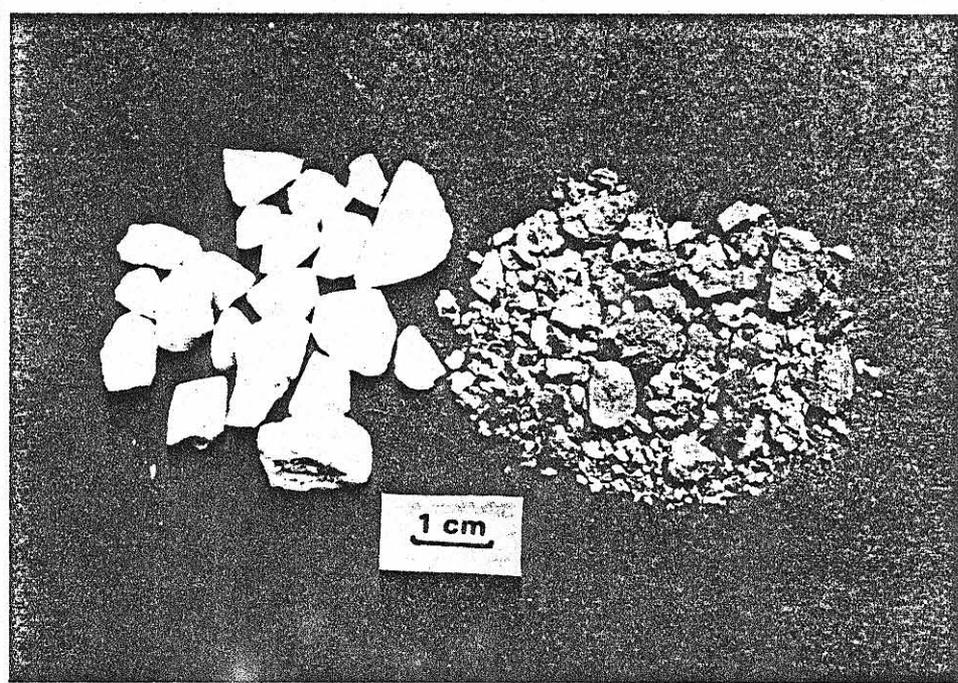


Fig. 4. High-magnesite ore (left) and crude calcine (right) after heating to 800°C for 1 h.

092

Provided leaching conditions can be chosen to reduce the amount of iron reporting in the clarified leachate, wet grinding of the crude calcine in recycled process liquor will, however, be more practical. This will facilitate introduction of the crude calcine into the leaching circuit but must be carried out with calcine that has already been cooled to ambient temperature. In addition, the time between preparation of the slurry prior to introduction into the grinding circuit and contact with carbon dioxide in the leaching circuit must be kept to a minimum (<1 h).

High-magnesia crude calcines prepared from the bulk ore samples provided for most studies to date have too high an iron content (3-6% Fe_2O_3) to produce SRM 3 magnesia. However, recent preliminary tests indicate that, provided the raw magnesite contains <2% Fe_2O_3 , then calcination and selective screening alone can yield a product meeting SRM 3 specifications.

LEACHING

The leaching rate and magnesium extraction from crude magnesia to form soluble magnesium bicarbonate is controlled by the following factors.*

*In addition to these factors, calcination conditions must be included. Thus the following discussion refers only to the leaching parameters.

- Pulp density
- Carbon dioxide pressure
- Agitation
- Temperature

Dissolution of crude magnesia derived from magnesite, particularly from that containing iron in solid solution, is complicated by the fact that a considerable amount of ferric iron also dissolves. Although this is contrary to "conventional" chemical theory since the leach slurry is alkaline (pH 7.5-9.0), it is apparent that a number of groups associated with the development of the carbon dioxide leach have also encountered this problem. The lack of success in overcoming the problems associated with this unexpected iron dissolution appears to be one of the main reasons for the non-commercial exploitation of the carbon dioxide leach process. Iron dissolution is affected by the above variables as well as the slake time and temperature.*

The effects of each of the leaching variables on the rate and extent of magnesium and iron dissolution are not independent of one another, making the determination of optimum leaching conditions complex, particularly in view of the fact that what is desirable in terms of the magnesium may be deleterious in terms of excessive iron dissolution. The effects of the leaching variables can be summarized as follows.

*Slaking is the reaction between the magnesium oxide and water to form magnesium hydroxide.

- Slake time and temperature - Increases iron dissolution, but does not affect magnesium dissolution.
- Pulp density - Does not affect the rate of dissolution of magnesium but is limited by the maximum magnesium concentration attainable. Iron dissolution increases rapidly with an increase in pulp density.
- Carbon dioxide pressure - Rate and extent of magnesium and iron dissolution both increase with an increase in the operating carbon dioxide pressure.
- Agitation - Substantial agitation is required both to keep the calcine particles in suspension and to provide adequate contact between the calcine and dissolved carbon dioxide. The rate of reaction between the magnesium oxide and carbon dioxide is relatively rapid and it is essential to ensure that there is adequate dispersion of the carbon dioxide through the slurry.* Although this can be achieved by direct injection of the carbon dioxide into the slurry, preferably beneath the impeller, more efficient dispersion can be achieved with a Snyder sub-aerator. The sub-aerator has a pumping action that ensures homogeneous dispersion of the carbon dioxide throughout the slurry. The degree of agitation necessary to produce leaching kinetics that are independent of agitation are determined to a large extent by

*If there is insufficient agitation and carbon dioxide dispersion, the leach slurry becomes depleted in carbon dioxide with the result that an insoluble basic magnesium carbonate is formed.

095

reaction vessel characteristics, including baffling, impeller type, impeller diameter to vessel diameter ratio, and vessel height to diameter ratio. However, general chemical engineering principles indicate that turbulent conditions are necessary, so that the reactor should have a Reynolds number greater than 20 000.

- Temperature - This is the most complex leaching variable, affecting the rate and extent of dissolution of both magnesium and iron. Provided that the "solubility" of magnesium bicarbonate is not exceeded, then an increase in temperature increases the rate of magnesium dissolution. The amount of iron dissolved generally decreases with increasing temperature but, more importantly, may decrease with increasing retention time. The temperature and rate at which this decrease occurs is dependent upon the other leaching conditions, particularly pulp density. The effects of temperature and pulp density on iron dissolution are well illustrated by Figs. 5 and 6.

The relationship between magnesium and iron dissolution is extremely complex, although in general it can be seen (Fig. 7) that the iron concentration increases with increasing magnesium concentration. Further evidence that iron dissolution is controlled, at least partly, by the magnesium concentration comes from the fact that the iron concentration is increased if the liquor used to make-up the calcine slurry also contains soluble magnesium.

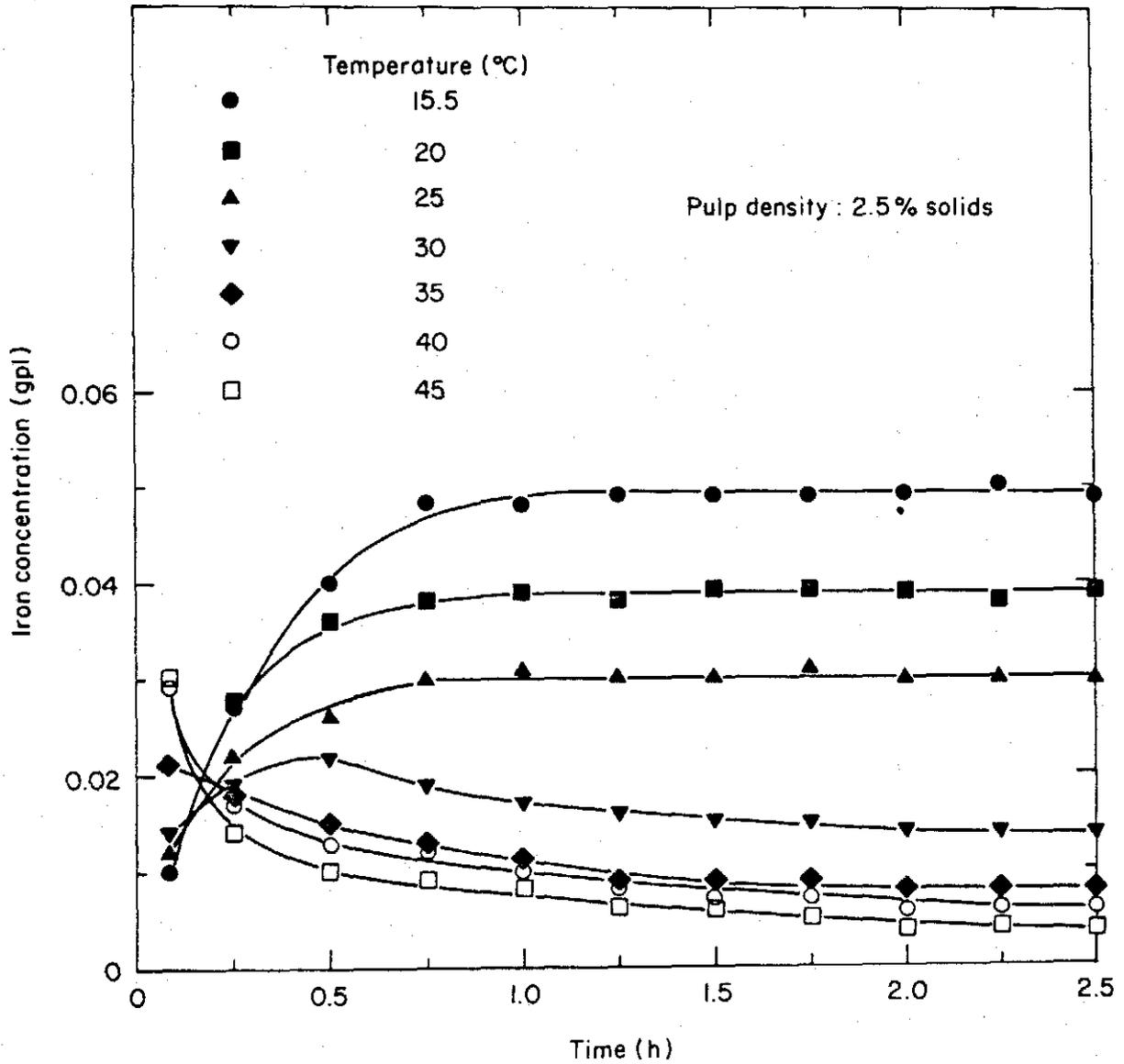


Fig. 5. Autoclave leach test data - effect of temperature on iron concentration. MAG 3 calcined at 700°C for 3 h, leached at 100 psig and 1200 rpm (0.5 h slake period).

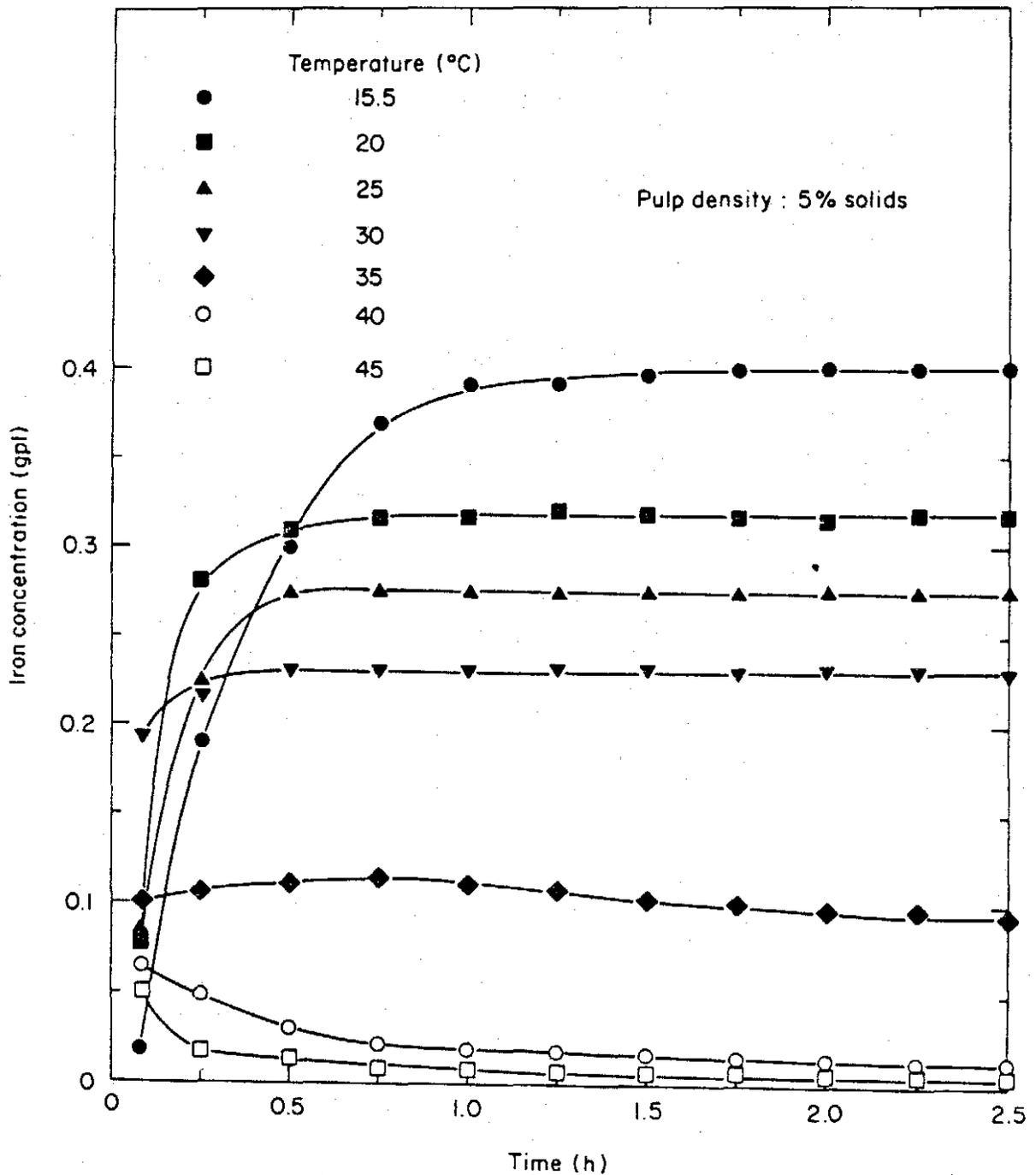


Fig. 6. Autoclave leach test data - effect of temperature on iron concentration. MAG 3 calcined at 700°C for 3 h, leached at 100 psig CO₂ and 1200 rpm (0.5 h slake period).

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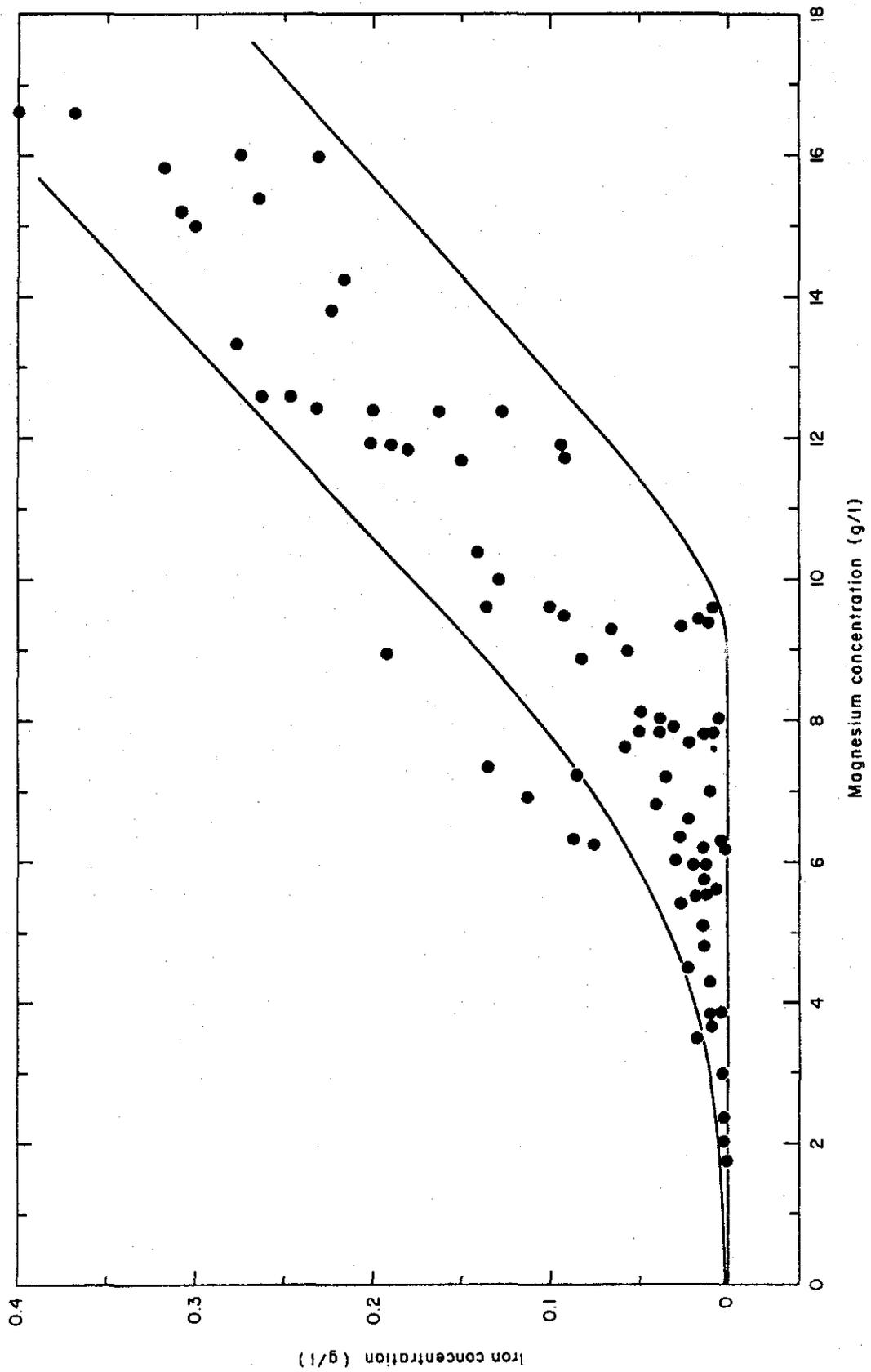


Fig. 7. Leach liquor composition: iron concentration as a function of magnesium concentration.

099

In order to reduce capital and operating costs, leaching should be carried out under the following conditions.

Maximum

Pulp density

Minimum

Temperature

Carbon dioxide pressure

Agitation

Retention time

For carbon dioxide leaching of crude magnesia derived from Savage River magnesite, reaction conditions are dictated by the maximum iron-to-magnesium concentration ratio that will ultimately yield a magnesia of the desired purity. An alternative way of establishing optimum leaching conditions is to consider the maximum iron concentration per unit magnesium concentration. The data in Table 1 give an indication of the compositions of the clarified liquors that will give a final magnesia product with a specified Fe_2O_3 content.

For MAG 3 calcine formed at 700°C for 3 h and leached at 1200 rpm, using 100 psig carbon dioxide and a 0.5 h slake time at the leaching temperature, Table 2 gives the conditions that can be used to produce magnesia products SRM 1 and SRM 2 (< 0.10 and $< 0.50\%$ Fe_2O_3 , respectively). In each case, the conditions are such that maximum magnesium extraction is achieved; for this particular calcine it corresponds to $80 \pm 2\%$ of the magnesium content of the calcine. It can

Table 1. Maximum iron concentration as a function of magnesium concentration to yield magnesia with a given Fe_2O_3 content.

Liquor Mg Content (g/l)	Liquor Fe content (g/l) for product containing x% Fe_2O_3			
	x = 0.01	x = 0.05	x = 0.10	x = 0.20
1.0	0.0001	0.0006	0.0012	0.0024
2.0	0.0002	0.0012	0.0024	0.0048
3.0	0.0004	0.0018	0.0036	0.0072
4.0	0.0005	0.0024	0.0048	0.0096
5.0	0.0006	0.0030	0.0060	0.0120
6.0	0.0007	0.0036	0.0072	0.0144
7.0	0.0008	0.0042	0.0084	0.0168
8.0	0.0010	0.0048	0.0096	0.0192
9.0	0.0011	0.0054	0.0104	0.0208
10.0	0.0012	0.0060	0.0120	0.0240

Table 2. Leaching conditions required to meet SRM 1 and SRM 2 Fe₂O₃ specifications.*

SRM 1			SRM 2		
Pulp density (% solids)	Temp. (°C)	Time (h)	Pulp density (% solids)	Temp. (°C)	Time (h)
2.0	30.0	1.75	2.0	15.5	1.00
2.0	35.0	1.25	2.0	20.0	1.00
2.0	40.0	0.50	2.0	25.0	0.75
2.0	45.0	0.50	2.0	30.0	0.50
2.5	35.0	1.25	2.0	35.0	0.50
2.5	40.0	1.00	2.0	40.0	0.25
2.5	45.0	0.75	2.0	45.0	0.25
3.0	45.0	2.50	2.5	20.0	1.00
			2.5	25.0	1.00
			2.5	30.0	0.75
			2.5	35.0	0.75
			2.5	40.0	0.50
			2.5	45.0	0.25
			3.0	25.0	0.50
			3.0	30.0	0.50
			3.0	35.0	0.25
			3.0	40.0	0.25
			3.0	45.0	0.25

*SRM 1 and SRM 2 Fe₂O₃ specifications <0.10 and <0.50% respectively. Leached at 100 psig carbon dioxide and 1200 rpm after 0.5 h slake at leaching temperature.

102

clearly be seen that the conditions necessary to produce the higher grade product, SRM 1, are much more restrictive than those that can be used to produce the less pure product, SRM 2.

LIQUID-SOLID SEPARATION

After the desired retention time, the soluble magnesium bicarbonate solution has to be separated from the leach residue. This must be carried out rapidly and under a carbon dioxide atmosphere in order to prevent undesirable precipitation of hydrated magnesium carbonate. Experimental work indicates that the solids settle rapidly without the need for flocculant addition. In commercial practice, pressure filtration would be used.

INTERMEDIATE PRODUCT PRECIPITATION

In order to carry out rapid and complete precipitation yielding a product that forms in the bulk of the solution and not as a coating on vessel walls, the clarified leachate should be heated to a temperature above 55°C. Under these conditions, hydromagnesite, $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$, precipitates. Although air can be sparged through the slurry to induce evolution of carbon dioxide and hence precipitation, this has the disadvantage of diluting the carbon dioxide-containing off-gases, which in turn makes carbon dioxide recovery and recycling more complex. Experiments carried

103

out to date indicate that complete (>95%) precipitation can be achieved in less than 1 h.

INTERMEDIATE PRODUCT RECOVERY

The precipitated hydromagnesite can be recovered as a wet slurry by conventional clarification and filtration using, for example, a series of counter-current decantation thickeners. The filtrate (overflow) is subjected to a purification stage and returned to the leaching circuit. In order to reduce energy consumption in the product recovery stage, it will be essential to dewater the hydromagnesite product to as high a pulp density as possible, preferably >70% solids. This is probably best achieved by treating the solids (underflow) from the CCD circuit on a vacuum drum filter. A high pulp density will also reduce sticking problems in the feed introduction area of the rotary kiln used for final product calcination.

PRODUCT RECOVERY

Differential thermal and thermogravimetric analysis of hydromagnesite indicates that conversion to magnesium oxide occurs in two stages. Over the range 20-500°C, dehydration and dehydroxylation occurs, while above 500°C, carbon dioxide is evolved. It is recommended that intermediate product calcination be carried out in two stages, each in a rotary kiln. This will facilitate recovery and recycling of

104

carbon dioxide since the bulk of the water is evolved as off-gases in the final calcination stage.

Refractory manufacture is not normally carried out by the magnesia producer since this requires a different blend of specialized technologies. In order to reduce problems with rehydration during storage prior to refractory manufacture, it will be essential to calcine the magnesia produced from Savage River magnesite at about 1800°C.

OPERATING STRATEGY

As discussed above, it is believed that physical beneficiation can probably be used to produce the lowest of the proposed three grades of magnesia from Savage River magnesite. This would not involve additional processing circuitry since it is considered that all feed will need to be treated in order to reduce problems associated with the production of high-purity magnesia by chemical dissolution.

In order to minimize capital and operating costs, it is essential that the calcination/carbon dioxide leach process be carried out on a continuous basis. In particular, this will facilitate heat and water balance control, simplify carbon dioxide recovery and recycling, and reduce problems associated with the unstable nature of the magnesium bicarbonate leach liquor.

While it might be advantageous to be able to produce both high-purity magnesias (SRM 1 and SRM 2) on a continuous basis, such an operating strategy would be too costly since it would involve duplication of much of the overall circuit.

Because of the nature of the proposed leaching and product recovery circuits, few difficulties can be expected when changing over from one set of operating conditions to the other. This is because only the leaching conditions need to be altered to change the product specifications. The calcination/carbon dioxide leach process involves two

energy-intensive stages (feed and intermediate product calcination), in addition to heating a dilute slurry to a temperature in the range 30-45°C. Thus, heat recovery from the calcination stages must be efficient to supply the necessary energy for slurry heating. In other words, the heat balance must be maintained within fairly tight limits. This means that it would be best to use the same leaching temperature for both grades of magnesia. Product grade would then be controlled by the pulp density and/or the retention time.

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- 109
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APPENDIX

The unexpected observation of excessive ferric iron dissolution during leaching necessitated a wide range of studies directed towards development of an understanding of the mechanism of iron dissolution and of methods of removing the iron from the magnesium bicarbonate leach liquor. The results of these studies can be summarized as follows.

- The excessive iron dissolution is directly related to the physical state of the iron in the crude calcine, and hence the original magnesite feed. The iron is present in the crude calcine as hematite with a very high surface area.

- Iron dissolution occurs via the formation of a bicarbonato complex.

The concentration of this ferric bicarbonato complex is controlled by the total bicarbonate concentration and the temperature of the leach slurry.

- The iron concentration of the final magnesium bicarbonate leach liquor can be reduced to an acceptable level by addition of aluminium sulphate to the initial leach slurry or to the clarified magnesium bicarbonate liquor. The soluble iron is coprecipitated as the insoluble synthetic mineral hydrotalcite, $[\text{Mg}_6\text{Al}_2(\text{OH})_{16}\text{CO}_3 \cdot 4\text{H}_2\text{O}]$.
- Alternative methods of iron removal, including precipitation as ferric arsenate, ion exchange and solvent

111

extraction, are not applicable because of the alkaline pH of the magnesium bicarbonate leach liquor.

- Although efficient removal of ferric iron could be achieved by precipitation of hydrotalcite, overall magnesia recovery was substantially reduced because of magnesium losses in the hydrotalcite. Better than 80% of the magnesium component of the hydrotalcite precipitate could be recovered either by dissolution of the precipitate in sulphuric acid or controlled calcination. Although both of these routes also resulted in recovery and recycling of the aluminium sulphate, the additional capital and operating costs would make these routes economically unattractive.

AMG REFERENCE POINTS ADDED

446109

EL 4/61
Sample Locations and
Anomalous values
Stream Sediment Programme 83/84
C H C Shannon, March 1984

Pyramid Hill

E.L. 4/61

SRM area
and
town lease

As 13

As 17

As 18

As 71
70 Cu, Zn, Ni, As

As 87

35300m E

MT. MEREDITH
Map 1 Sheet 1

112

