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THE SAVAGE RIVER MAGNESITE DEPOSIT

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M.T. Frost

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CONTENTS

	<u>Page No.</u>
1. INTRODUCTION	1
2. THE GEOLOGY OF NORTH WEST TASMANIA	2
3. THE SAVAGE RIVER MAGNESITE	5
4. A DESCRIPTION OF THE MAGNESITE AND RELATED ROCKS	6
4.1 Carbonate which is Predominantly Magnesite	6
4.1.1 Fine-grained Magnesite	6
4.1.2 Cryptocrystalline Pale Yellow Magnesite	6
4.1.3 White Marble	7
4.1.4 Coarse-grained Magnesite	7
4.2 Carbonates which are a Mixture of Dolomite and Magnesite	7
4.2.1 Patchy Magnesite	7
4.2.2 Brecciated Magnesite	7
4.3 Carbonate Predominantly Dolomite	7
5. SAMPLING THE MAGNESITE ORE-	8
6. STUDIES OF POLISHED SECTIONS USING THE SEM AND OPTICAL MICROSCOPE	24
6.1 The Advantages of a Backscattered Electron Detector	24
6.2 The Features of the Magnesite	24
6.3 The Features of the Dolomite	25
6.4 Replacement of Quartz	26
6.5 The Associated Schists	26
6.6 Minor Element Distribution	26
7. STUDIES OF THIN SECTIONS USING AN OPTICAL MICROSCOPE ..	27

8. QUANTITATIVE ASSESSMENTS OF THE QUALITY OF THE
MAGNESITE ORE 27
8.1 X.R.D. Method for the Analysis of Carbonates 27
8.2 The Determination of the Amount of Non-carbonate
Minerals 29
8.3 The Quality of the Magnesites 29

9. QUANTITATIVE ELECTRON MICROPROBE ANALYSES 32
9.1 Experimental Methods 32
9.2 An Analysis of the Carbonate Compositions 33
9.3 The Chlorites and Talcs 34

10. QUALITATIVE SPECTROGRAPHIC ANALYSIS 57

11. BORON LEVELS IN THE SAVAGE RIVER MAGNESITES 57

12. THE EXTENT AND QUALITY OF THE ORE BODY 59
12.1 The Size of the Ore Body 59
12.2 The Purity of the Magnesite 60

13. THE ORIGINS OF THE SAVAGE RIVER MAGNESITE DEPOSITS 60

14. CONCLUSIONS 67

15. PROPOSALS FOR FURTHER STUDIES 68

APPENDIX 1 106

APPENDIX 2 108

REFERENCES 112

APPENDIX 3. -- SEPARATE (attached to back)
Cost Estimate of MAGNESITE PROJECT ----- SEPARATE.

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THE SAVAGE RIVER MAGNESITE DEPOSIT

1. INTRODUCTION

This report describes the geology and mineralogy of the Savage River magnesite deposit. The deposit is situated in a remote area of north west Tasmania. Very thick rain forest covers the area and there are no all weather roads accessing the deposit, although the Savage River magnetite mine is situated a few kilometres to the north, resulting in there being a town and good roads relatively close by. Therefore, access is one major problem in the commercial exploitation of the magnesite. Another problem arises from the nature of the ore. There is about two percent Fe in the lattice of the magnesite, and this must be removed to obtain high grade MgO. Also, there is often abundant dolomite quartz, and to a lesser extent talc and chlorite, intimately associated with it. It was because of the mineralogical complexity of the ore, that Industrial and Mining Investigations, the leaseholders, sponsored Dr J.H. Canterford's research program within this division. This work is nearly complete and has proved very successful in developing a method for extraction of MgCO₃ (M.C.C. 302 and preceding reports).

The emphasis of this report is on the geology and mineralogy of the ore body and the aims are to provide more detailed information on the quality and quantity, and insight into the genesis of the ore body. Very little has been published on the geology of the magnesite. Apart from brief descriptions of its discovery, only Urquhart (1966) has attempted to describe the ore in detail. Since then two bore holes have been drilled, each over 1000' deep, and the core samples have provided an invaluable source for detailed mineralogical investigations. Some work has been carried out by the author on the associated magnesite ore body at Arthur River, and what has been done indicates that this deposit is very similar in nature. Some preliminary work has been carried out on the S. Australian and N.S.W.'s deposits, and this will be very briefly reported here. The author wishes to thank Industrial and Mining Investigations, and in particular Mr M. Edyvean for his help in providing samples, and in arranging an excursion to the site of the deposit.

2. THE GEOLOGY OF NORTH WEST TASMANIA

The interpretation of the geology of the area about Savage River is very uncertain, partly due to the complexity of the geology, but primarily due to the dense rain forest and high rainfall which generates a deep weathering zone with few outcrops. A large area of North West Tasmania is considered Precambrian, mainly from the fact that the oldest fossiliferous beds overlying it are the Middle Cambrian of the Dundas Group. The Precambrian in this area is divided usually into two main groups. The first is a sequence of regionally metamorphosed deformed schists and quartzites, and the second a sequence of sandstones, slates and mudstones which are less deformed. One of the more highly metamorphosed sequences occurs as an 8 km wide belt, stretching 115 km NNE from the south west coast to the north coast (Fig. 1). Gee (1967a and 1967b) proposed the name Arthur Lineament for this belt of rocks. The schists in the south west, that belong to the Greenschist facies, are known as the Whyte schists and their petrography and texture have been described in detail by Spry (1962, and 1964). Close to the northern end of the narrow metamorphosed belt, similar rocks named the Keith metamorphics (McNeil, 1960) are found. To the north of the Arthur Lineament, the Rocky Cape Group consists of 6000 m of shales, siltstones and quartzites. Unconformably on this group lie the lower Cambrian Smithton dolomites. Gee (1967b) extended these dolomites south to include the Savage dolomites which occur a few kilometres north west of Corinna. The Rapid River dolomites, situated very close to the northern magnesite outcrop at Arthur River, are also correlated with the Smithton dolomites. To the south-east of the Arthur Lineament, over 4500 m of similar slates, greywackes and quartzites are named the Burnie formation. Spry considered that the more metamorphosed rocks were older, and that they were separated from the younger Precambrian by a major metamorphic event that was named the Frenchman orogeny. The evidence for this is uncertain. It is mainly based on an unconformity between the 'older' and 'younger' in the area south-east of Artist Hill (Spry and Zimmerman, 1959), and from the detailed study of tectonic style showing significant differences. The argument for the two being contemporaneous rests on their very similar lithologies, namely thick

alterations of quartz sandstones and pelites. Also, the subdivision based on the degree of deformation is not conclusive, as it is observed as gradational in areas along the Pieman River gorge (Spry 1962) and also in the Whyte schists about the Central Savage iron ore deposit (Urquhart, 1966).

The alternative interpretation proposes that the Rocky Cape and Burnie formations and the rocks within the Arthur Lineament represented a single Precambrian geosyncline of the same age. During or at the end of the Precambrian, a major orogenic period, compressed the Whyte and Keith schists, producing their major isoclinal folding, and downfaulted the less competent block against the resistant formations to the south east.

The associated igneous rocks of the region introduce further complications and uncertainties. A major ultrabasic complex, the Heazelwood complex, lies just to the north east of Savage, and Rubenach (1974) considered this was emplaced in Cambrian times. The extensive Devonian granite at Meredith lies directly south of this and both abut against the eastern side of the Arthur Lineament. Small pyroxenite bodies are associated with the magnesite at Arthur River. In addition, an extensive series of amphibolite lenses and sheets occurs within the Whyte schists. Spry (1962), for example, describes seven dykes close to the Pieman River which cut the Whyte schists and which appear less metamorphosed than the schist itself. Urquhart (1966) describes in detail how the extensive and enigmatic magnetite lenses are always closely associated with the amphibolite bodies. The amphibolite schistosity is usually, but not always, conformable with the Whyte schists, running nearly vertically down the Arthur Lineament in the Savage River area. Urquhart also describes a narrow amphibolite lens extending south from Bowry Creek (Fig. 2). Gee (1967b) considered that similar amphibolites within the Keith metamorphics were equivalent to the Coree dolomites which were intruded syntectonically in the early period of the Penguin orogeny, which occurred between Precambrian and Cambrian periods.

Coree
X
dolomites

The geology of the Savage River magnetite deposits may be important in considering the genesis of the magnesite. The iron ore is considered to be Precambrian from the fact that the magnetite and associated amphibolites lie within the Whyte schists. An intrusive igneous origin

however, would make it possible for this ore to be intruded as late as very early Cambrian times. The central deposit, a few kilometres to the north of the magnesites consists of vertically discontinuous lenses of massive and layered magnetite and pyrites, one kilometre thick, within the foliated amphibolites (also Coleman 1975). The magnetite and associated rocks have undergone at least one joint period of deformation and metamorphism during the Penguin orogeny, and another during the Devonian Tabberabberan orogeny. The deposit is at present being studied extensively, hopefully to shed more light on the geological history of this area. What Urquhart's original studies and the extensive mining and exploration about the orebodies show is that, apart from the extensive iron deposition, there is a minor but still substantial gabbroic body lying to the east and concordant with the schist, and that there are regions of metasomatism about the ore. Serpentinite is abundant, and Urquhart delineates a wide zone of carbonate metasomatism close to the Central orebody. In addition, substantial additional dolomite horizons are found, both along the Savage River and in core samples south of the main magnesite deposit.

This then is the geological setting for the magnesite deposits of north west Tasmania. The geological history may be summarized as follows:

- a) The deposition of a thick sequence of geosynclinal Precambrian sediments. The more highly metamorphosed sediments are considered tentatively by most geologists to be older.
- b) The development of the Arthur Lineament, either during or after the Precambrian period.
- c) Minor ultrabasic and basic intrusions in the Savage and Arthur River areas, which occurred during very late Precambrian or early Cambrian times.
- d) The deposition of extensive dolomite during early Cambrian times.
- e) The intrusion of the adjacent Heazelwood ultrabasic complex.
- f) The emplacement of the adjacent Devonian granites.
- g) Further mild metamorphism during the Tabberabberan orogeny.

It will be shown in Section 13 that the presence of substantial carbonate deposits in the Arthur Lineament may have important consequences in the interpretation of the geology of the area.

3. THE SAVAGE RIVER MAGNESITE

Figure 2 illustrates how the magnesite is situated in relation to the Whyte schists and magnetite deposits. The differentiation into psammatic and pelitic schists is due to Urquhart (1966). Urquhart also mapped a narrow lens of amphibolite, concordant to the general foliation of the schists, which extends south from Bowry Creek. Figure 3 illustrates the extent of the surface magnesite found along Main Creek which is a minor stream off Savage River. Rowe (1963) was first to recognize that the 'dolomite was' in fact, magnesite. Urquhart (1966), in his description of the magnesites of the Savage River area was first to map the outcrop and Figs. 2 and 3 are based on his published maps. A visit to the Main Creek outcrop was made by the author with Mr M. Edyvean, Chief Geologist for Industrial and Mining Investigations, and a set of surface samples was collected. Mapping is made very difficult by the thick rain forest that covers the area. Outcrops are restricted to the river banks which cut the magnesite and, because of this, the relationship of the magnesite to the country rock is obscure. The locations of two boreholes, M.C.1 and M.C.2 are shown on Fig. 3. D.D.H. M.C.1 produced substantial dolomite for the first 134' which was followed by 32' of talc schist. However, the D.D.H. M.C.2 gave only 61' of dolomite and schist before the main orebody. Hand samples 2-5 were mainly dolomite and from these data the boundary between magnesite, and dolomite and talc schist was constructed (see Fig. 3). Both boreholes failed to reach the end of the magnesite. In fact, the higher purity magnesite was encountered at depth. Therefore the western border of the deposit is uncertain.

Samples 14-17 were found to be mainly magnesite. These may be very close to the westerly boundary of the orebody and if this is so, and assuming both drill holes had reached the end of the orebody, the western margin would be close to that shown in Fig. 3. However, the true western margin could be a hundred metres or even more to the west. A trench, due west from the river, half-way between M.C.1 and M.C.2, would determine this very important margin. Urquhart does define a small magnesite lens off to the west of the most southerly bend of the stream, shown in Fig. 3. If this is part of the main ore body then the

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westerly border would be extended considerably. There is no evidence that the magnesite continues north. Extensive mining and drilling about the Central iron orebody, to the north of Main Creek, indicate the common occurrence of dolomite amongst schist and amphibolite. Dolomite outcrops all along the Savage River just north of the Central deposit, but no magnesite has been found. To the south, along Bowry Creek and in boreholes to the south of Bowry Creek, horizons of magnesite have been recognized. There may be large, as yet undiscovered, lenses of magnesite, forming a semi-continuous ore body from Bowry Creek to Main Creek, but until more drilling is undertaken, it is impossible to verify due to the dense vegetation.

4. A DESCRIPTION OF THE MAGNESITES AND RELATED ROCKS

D.D.H. M.C.1 was studied in detail. A brief description of the borehole samples is presented in Table 1 and for Main Creek samples in Table 2. A summary of the changes in rock types down the 1023' drill hole is presented in Table 3. The various varieties of carbonates are illustrated in Fig. 41.

In hand samples, dolomite can be distinguished easily from magnesite by colour, with the dolomite always found to be dark grey. Various varieties of carbonate can be distinguished from the hand samples. These types are based on crystallinity and variations in dolomite and magnesite.

4.1 CARBONATE WHICH IS PREDOMINANTLY MAGNESITE

4.1.1 Fine-grained Magnesite

This type of magnesite represents the most common form. The rock tends to break conchoidally and is a very pale grey.

4.1.2 Cryptocrystalline Pale Yellow Magnesite.

Some samples tend to resemble the 'bone magnesites' found associated with basic igneous rock alterations (see Section). When cut they are very smooth, dense, and are very pale yellowy grey.

4.1.3 White Marble.

On certain horizons, the magnesite appears very pure, massive and white. This type of magnesite is most abundant at horizons near 900 ft.

4.1.4 Coarse-grained Magnesite.

Unusually, magnesite may be found with crystals up to 1 cm across and very white in colour.

4.2 CARBONATES WHICH ARE A MIXTURE OF DOLOMITE AND MAGNESITE

4.2.1 Patchy Magnesite.

Commonly occurring magnesites at Savage River contain small quantities of dolomite and silicates. Sometimes, these are minor patches within magnesite which are predominantly dolomitic. But there are some horizons that extend over many feet where substantial quantities of dolomite occur with magnesite. Figure 41 shows a typical example. Irregular magnesite areas, up to 1 cm wide, are separated by much darker dolomite. These borders are about 2 mm wide and appear to merge into the lighter grey magnesite. Most magnesite areas appear very finely crystalline, but occasionally the magnesite is much coarser grained (1 mm wide with crystals).

4.2.2 Brecciated Magnesite.

Similar to the patchy magnesite, but it occurs in more angular patches (Fig. 41) and the size distribution of the magnesite fragments is much greater. A rare carbonate type.

4.3 CARBONATE PREDOMINANTLY DOLOMITE

A clearly defined carbonate in hand specimen (Fig. 41). Very dark grey, this carbonate occurs in well defined bands within the sequence. Dolomites are usually fine- to medium-grained with semi-conchoidal fracturing.

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5. SAMPLING THE MAGNESITE ORE

Samples were collected along Main Creek, as shown in Fig. 3, and are described in Table 2. Vegetation is very dense and soil is very thick. As a result, surface samples were very difficult to obtain. The two D.D.H'S M.C.1 and M.C.2, which are shown in Figs. 2 and 3, were sampled every 3 ft and D.D.H. M.C.1 is described in Table 1. Small polished sections of samples every 10 ft and at points of interest have been made. (Samples with polished sections are marked in Table 1.)

Several other diamond-drill holes have been made, mainly south of the Main Creek area. Their positions are indicated in Fig. 2. Table 4 details the extent of these deposits. Appendix 1 presents bulk analyses of ore samples.

Several samples from the Arthur River deposit in the north have been obtained. Polished sections from this deposit have also been made.

Table 4. Details of the D.D.H's other than the two main drill holes at Main Creek.

D.D.H.	Description
R.T.A.E. No. 1	Carbonate at 606-620' and 624-639'. Assay in Appendix
D.D.H. 28	Carbonate at 499-505' and 521-530'
D.D.H. 29	Carbonate from 481-488', 503-510', and 546-600' (end of hole)
D.D.H. 46	Magnesite-rich carbonate from 550-610' and 656-664' (end of hole)
D.D. 14	Dolomite layers at 257-278', 282-285 1/2', 302 1/2 to 303', and 439-442'.

Table 1. Description of core samples from D.D.H. M.C.1. The * denotes a polished thin section has been made. The MF number refers to the polished section made.

10'	Dark grey, fine-grained dolomite, sharply in contact with white coarsely grained carbonate. MF37.
17'	Dark grey, fine-grained dolomite. Wide veins over 1 cm wide of lighter carbonate which is coarser grained. MF37.
30'	Dark grey, fine-grained dolomite. Veins of lighter carbonate (up to 1 cm across). MF37.
33'	Dark grey dolomite. Thick veins, over 3 mm wide of coarse-grained white dolomite. MF38.
39'	Dark grey dolomite. Medium grained. Patches of white carbonate. MF38.
50'	Dark grey, fine-grained dolomite. MF38.
55'	Dark grey, fine-grained dolomite. Small patches of white carbonate. MF39.
57'	Dark grey, coarsely grained dolomite. MF39.
60'	Dark grey dolomite with veins of white carbonate. MF39.
62'6"	Sharp boundary between dark grey, coarsely grained dolomite and silicate- (mainly talc) rich rock. MF40.
63'	Talc-rich rock. Includes small areas of dolomite.
65'	Silicate rock - a talc schist interbedded with dark carbonate. MF40.
68'	Medium grey, coarse-grained dolomite. No veins. MF40.
71'	A talc schist with small areas of dolomite. MF41.
73'	Dark grey, coarsely crystalline dolomite.* MF41.
73'6"	Talc schist. There are small areas of carbonate.
77'	Grey, medium-grained dolomite. MF41.
80'	Dark grey, coarsely crystalline dolomite. MF42.
83'6"	Dark grey, coarsely crystalline carbonate with a thick (1 cm) vein of white carbonate. MF42.
84'	White, coarse-grained carbonate sharply against dark coarsely grained dolomite. MF42.

- 013
- 87' Dark grey dolomite with patches of coarsely crystalline white carbonate. Some silicates (talc). MF43
- 90' Mixture of white coarsely crystalline carbonate with dark grey, coarsely crystalline carbonate. MF43.
- 93'6" Dark grey, coarsely grained dolomite intimately mixed with patches of white carbonate and talc. MF43.
- 94' Light grey, coarse-grained carbonate. MF44.
- 97' Light grey, coarse-grained carbonate. MF44.
- 100' Medium grey, coarsely crystalline carbonate. MF44.
- 103'6" Dark grey, fine-grained massive dolomite. MF45.
- 113' Light grey, coarse-grained carbonate. Grey carbonate mixing with white carbonate. MF45.
- 115' White, coarsely crystalline carbonate with patches of grey carbonate and veined. Some silicates present between the two carbonates. MF45.
- 118' Talc schist.
- 124' Chlorite schists. Little carbonate.*
- 127' Dark grey patches of carbonate. One corner consists of a very white, coarse-grained carbonate. MF46.
- 130' Medium-grained, light grey carbonate. MF46.
- 133' Weathered, yellowish dolomite. Fine-grained. MF46.
- 145' Yellowish white, fine-grained carbonate.
- 156' Talc schist.
- >176' Chlorite-talc schist.
- <199' Chlorite schist with 2 mm carbonate veins. Sporadically passing through schist.
- 199' Yellow, coarsely crystalline, patches of quartz a few cm across. MF47
- 200' Talc schist. A white rock. Much coarsely crystalline carbonate. MF47.
- 210' Yellow, very fine-grained carbonate. MF47.
- 215' Yellow, weathered carbonate, coarsely crystalline. MF48.

- 220' Yellowish white, fine-grained carbonate. Diffuse patches of darker material. MF48.
- <221' Pale, yellowish white, fine-grained carbonate with abundant veins passing through in all directions. MF48.
- 221' Light yellowish grey, coarsely crystalline carbonate. MF49.
- 224' Light grey, fine-grained carbonate with veins of coarsely crystalline carbonate. Veins surrounded by yellow carbonate, very fine-grained. MF49.
- 229' Yellowish white, very fine-grained carbonate. Some diffuse patches of darker material. MF49.
- 240' Chlorite schists.
- 255' White crystalline carbonate. MF50.
- 257' Light grey, homogeneous fine-grained marble.* MF50.
- 259' Very fine-grained, homogeneous white carbonate. MF50.
- 264' White, fine-grained carbonate. Light, yellowish-white, very fine-grained with lenses of coarse-grained light-coloured carbonate. MF51.
- 275' White or yellowish grey carbonates. MF51.
- 278' Yellowish white, very fine-grained carbonate with several patches of dark, coarsely crystalline dolomite. MF52.
- 281' Medium grey carbonate. MF52.
- 282' Yellowish white carbonate with diffuse patches of darker carbonate. MF52.
- 285' A white and dark grey (dolomite) carbonate junction. Coarsely crystalline. MF53.
- 296' Yellowish white carbonate. Patches of very fine yellow carbonate and the whiter patches are more coarsely crystalline. MF53.
- 305' Light grey, fine-grained carbonate. MF54.
- 308' Medium grey, homogeneous, fine-grained carbonate. MF54.
- 312' Medium grey, homogeneous, fine-grained carbonate. MF55.
- 325' Very fine-grained, whitish grey carbonate. MF56.
- 320' Talc schist. Partly a fine-grained dark dolomite.

- 015
- 323' Light grey, medium grained carbonate.
- 328' Light grey, fine-grained marble. MF55.
- 331' Light grey, very fine-grained, homogeneous carbonate. MF57.
- 333' Medium grey, homogeneous carbonate.
- 334' Light grey, medium-grained, homogeneous carbonate. MF57.
- 339' Light grey, homogeneous carbonate, usually very fine-grained. MF57.
- 343' Light grey, very fine-grained, homogeneous carbonate. MF58.
- 345' Light grey, homogeneous marble. MF58.
- 353' Light grey, fine-grained, homogeneous carbonate. MF58.
- 356' Greyish white, fine-grained, homogeneous marble. MF59.
- 360' Medium grey marble. Light grey, fine-grained, homogeneous carbonate.
- 363' Light grey, fine-grained, homogeneous carbonate.
- 366' Greyish white, fine-grained, homogeneous marble. MF57.
- 368' Light grey, fine-grained carbonate. Brecciated appearance. Irregular patches about 3 mm wide separated by pale, white carbonate. MF60.
- 369' Light grey, very fine-grained carbonate. MF60.
- 376' White to yellowish grey, fine-grained marble. MF60.
- 377' White, fine-grained marble. MF61.
- 386' Light grey, fine-grained, homogeneous carbonate. MF61.
- 381' Light, yellowish grey, fine-grained carbonate. MF63
- 393' Light grey, fine-grained carbonate. MF63.
- 396' White to grey carbonate.* Some areas are silicate-rich and are much darker. Sharp contact between the carbonate and silicate areas. MF63.
- 396(1) Silicate brown rock with patches of white carbonate. MF63.
- 396(2) Predominantly silicate rock with vein of white carbonate running through. Yellowish white, medium-grained, with one part over 1 cm wide and much whiter. MF64.

- 016
- 396(4) Dolomite giving way to magnesite (white) gradually.* Border consists of rounded bleb 3 mm across, surrounded by dark material. Dark material is probably dolomite. The rounded blebs are carbonate. MF64.
- 396(5) Dark grey dolomite with predominantly brown silicates.
- 396(6) Silicate rock. Bands along cleavage of white carbonate. MF65.
- 399' Chlorite schist with veins of carbonate.*
- >408' Silicate-rich rock with abundant carbonate. MF65.
- 422' Light grey, fine-grained carbonate. MF66.
- 423' Light grey, coarsely crystalline carbonate (dolomite). MF66.
- 424' Dark grey, fine-grained carbonate. MF66.
- 426' Dark grey, fine-grained carbonate., with 1 cm wide white carbonate veins. MF67.
- 427' White, homogeneous carbonate.
- 430' Dark grey carbonate with very white veins passing through. Veins are diffuse. MF67.
- 431' Dark, medium coarse-grained dolomite. MF67.
- 450' Dark grey dolomite, fine-grained. MF71.
- 451' Dark grey dolomite. White veins plus one large coarse vein 2 m wide. MF71
- 457' Dark grey, fine-grained dolomite. MF71.
- 430' Dark grey dolomite with thin white veins passing through.
- 463' Dark grey, fine-grained dolomite. Some white patches. MF72.
- 467' Grey, fine-grained, homogeneous carbonate. Some fine white veins. MF72.
- 470' Dark grey dolomite. White veins passing through. MF72.
- 474' Mixture of silicate and carbonate. Silicates as irregular lenses. Carbonates as medium coarse-grained carbonate. MF73.
- 481' Dark grey carbonate on one side; on other, light grey carbonate with even white veins passing through. Junction sharp between the two. MF73.
- 487' Light grey, fine-grained carbonate.

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- 491' White to pale grey, fine-grained carbonate. MF74.
- 499' White to pale yellow, fine-grained, homogeneous carbonate. MF74.
- 501' Light grey to yellow carbonate. MF74.
- 504' Light grey, fine-grained carbonate. MF75.
- 507' Whitish grey, fine-grained, homogeneous carbonate.* MF75.
- 513'6" White, fine-grained carbonate.* MF76.
- 514' Light grey, fine-grained carbonate.
- 530' White carbonate with grey patches.
- 531' Grey carbonate with distorted reticular patchwork of darker carbonate.* MF76.
- 538' Very fine-grained, light grey, with lighter white veins less than 1 mm across. Veins fade after a few cm. MF76.
- 543' Dark grey dolomite.
- 547' Dark grey dolomite.
- 548' Light grey, very fine-grained, homogeneous carbonate. Small area of dolomite on edge. MF77.
- 551' Light grey carbonate. MF77.
- 555' Light grey, very fine-grained, homogeneous carbonate. MF78.
- 558' Light grey, fine-grained carbonate. MF78.
- 564'6" Grey, coarsely crystalline carbonate. Thin white vein passing through middle. MF79.
- 567' Light grey carbonate with some areas of darker dolomite.
- 576' Light grey, fine-grained carbonate. Diffuse veins of dark grey carbonate. MF79.
- 578' Yellowish grey, very fine-grained, with darker grey diffuse borders of carbonate. MF80.
- 579' Very light grey, very fine-grained, homogeneous carbonate. MF80.
- 586' Light grey, fine-grained, homogeneous carbonate.* MF80.
- 589' Dark grey carbonate. Pyrites very abundant, occurring as elongated crystals 1 mm long aligned along cleavage. MF81.

- 596' Light grey, fine-grained carbonate. MF81.
- 598' Light grey, coarse-grained carbonate. MF81.
- 598'1" Light grey, medium coarse-grained carbonate. MF82.
- 601' White, very coarse-grained. Dark patches of coarse-grained dolomite. MF82.
- 603' Heterogeneous. Whitish grey carbonate, as irregular areas 1 cm across, are surrounded by diffuse thin edges of dark dolomite. Dolomite is fine grained. White is coarser. At one end there is a much darker carbonate. MF82.
- 606' Coarse, light grey carbonate. MF83.
- 609' Dolomite-rich. Patchy white to grey, fine-grained. Some silicates present. MF83.
- 616' Light grey, fine-grained carbonate. MF83.
- 617' Light grey carbonate, fine-grained.
- 623' Light grey, fine-grained with veins of coarsely crystalline carbonate diagonally accross sample. MF84.
- 625' Dark grey, fine-grained carbonate sharply abuts against brown silicate- (chlorite?) rich edge. MF84.
- 634' Light grey, fine-grained marble. MF84.
- 644' Medium grey, fine-grained carbonate. Patches bordered by thin (1 cm irregular grains) diffuse darker carbonate. MF85.
- 649' Light grey, fine-grained carbonate with dolomite. MF86.
- 656' Talc-chlorite schist. Little evidence of carbonate.* MF86.
- 669' Deformed chlorite schist. Microfolds visible. MF86.
- 677'6" Light grey, homogeneous, fine-grained carbonate with thin veins. There is a lens of coarse-grained white carbonate. MF87.
- 686'a Brown chlorite schist. MF87.
- 686' Light grey, fine-grained, homogeneous carbonate. MF88.
- 699'6" White, fine-grained carbonate. Diffuse coarsely crystalline areas of darker carbonate in an irregular band. MF88.
- 701' Pure white, fine-grained carbonate. A few fine white veins. MF89.

- 702' Pure white carbonate, fine-grained.
- 705' Pure white, fine-grained carbonate with a few white veins. MF89.
- 709' Patchy. Bottom part fine-grained, light grey carbonate. Upper part, much darker carbonate. All fine-grained. MF89.
- 714' Dark dolomite, fine-grained. MF90.
- 726' Patches of white carbonate, somewhat uneven, with thin zones of darker dolomite. Crack with recrystallized white, coarse-grained carbonate. Then the rock has cracked again across the vein with subsequent recrystallization. MF90.
- 729' The same as 726'. Rounded areas 1-2 cm across surrounded by thin diffuse areas. MF91.
- 731'6" The same as 729'. Not so patchy. MF91.
- 742' The same patchy texture as 729'. MF91.
- 755' The same patchy form as 729'. MF92.-
- 758' Grey carbonate. Vein of coarsely crystalline white material. Some areas patchy as 729'. MF92.
- 767' A silicate/carbonate contact. Carbonate is coarse-grained. Silicate, pinkish to grey. MF93.
- 768' Chlorite schist. MF93.
- 771' White, coarsely crystalline carbonate. MF93.
- 778' Light grey, homogeneous, fine-grained carbonate. MF94.
- 781' White, fine-grained carbonate. MF95.
- 784' Light grey, fine-grained carbonate. Patches of diffuse veins, 4 mm wide, of dark, coarse dolomite. MF95.
- 789' The same patchy form as 726'. Irregular patches, 0.5 mm to 0.9 mm across, of light grey carbonate surrounded by narrow diffuse darker carbonate. MF96.
- 791' White, homogeneous carbonate. Diffuse veins of darker carbonate. MF96.
- 797' The same patchy form as 726'. MF96.
- 800' Light grey, fine-grained, homogeneous carbonate. MF97.
- 801' White, fine-grained, homogeneous carbonate. MF97.

- 820
- 805'6" White, coarse-grained carbonate. Fine-grained. MF97
- 806'6" White, fine-grained mainly, homogeneous carbonate. With diffuse patchy area of dolomite. MF98.
- 807' Light grey, fine-grained, homogeneous carbonate. With 1 mm coarse-grained veins running in a patchwork through the rock. MF98.
- 817' White, coarse-grained carbonate. A few fine-grained patches.
- 820' Pure white carbonate. MF99.
- 825' Light grey, mainly fine-grained carbonate with some dolomite present. A little pyrites. MF99.
- 826' White carbonate, fine-grained.
- 827' Light grey, fine-grained carbonate.* MF99.
- 828' White, homogeneous, fine-grained carbonate. MF100.
- 830' White, fine-grained carbonate.* MF100.
- 833' Pale white, fine-grained, homogeneous carbonate. MF101.
- 837' Light grey carbonate. Patches coarse-grained. Some veining. MF101.
- 841' White, fine-grained carbonate. MF101.
- 845' Light grey, fine-grained carbonate. MF102.
- 847' Patchy carbonate texture, as 726'.* MF102.
- 851' White, fine-grained carbonate.*
- 852' White, fine-grained carbonate. MF102.
- 856' White, coarse-grained carbonate. MF103.
- 857' White carbonate, fine-grained. MF103.
- 864' White and coarse-grained carbonate. MF103.
- 865' Very light grey, fine-grained carbonate. MF104.
- 870' White, fine-grained, homogeneous carbonate. MF104..
- 876' Light grey, fine-grained carbonate with thin white veins. MF105.
- 881' White carbonate with a few darker patches. MF105.

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- 886' White carbonate mainly. One side merges into a darker grey carbonate. MF105.
- 890' White, very fine-grained carbonate with some veining. MF106.
- 897' Very light grey, very fine-grained carbonate. MF897
- 899' White, fine-grained carbonate. MF106.
- 900' White with ill-defined patches of darker fine-grained carbonate. MF900
- 903' Yellowish white carbonate. Very fine-grained. Veins of white carbonate running through. MF107.
- 906' White, fine-grained carbonate. MF107.
- 908' Whitish grey marble, very fine-grained. MF108.
- 910' Mainly white with patches of white and grey carbonate. Fine-grained. Diffuse patches as 726'. MF108.
- 911' White and very coarse-grained (crystals nearly 1 cm wide) carbonate. MF108.
- 914' Light grey carbonate with very coarse-grained carbonate veins. MF109.
- 916' Very fine-grained, light grey patchy carbonate. MF109.
- 917' White, fine-grained carbonate. MF109.
- 921' White carbonate. Coarsely crystalline darker particles. White veins. MF111.
- 926' White, fine-grained marble with areas of diffuse grey carbonate. MF111.
- 928' Light grey, fine-grained carbonate. MF111.
- 932' White, fine-grained carbonate with whiter fine veins. MF112.
- <936' Silicate-carbonate boundary sharply defined. Chlorite with light grey, coarse carbonate. MF112.
- 936' Chlorite schist, fine-grained.*
- 938' White marble with a few patches coarser grained. MF113.
- 939' Silicate rock, mainly talc schist.
- 940' White, fine-grained marble. Diffusely patchy. MF113.
- 946' Patches of white surrounded by grey carbonate. As 726'. MF113.

- 949' Patchy carbonate, as 946'.* MF114.
- 950' White and usually very coarse-grained although there are some areas darker and much finer grained. MF114.
- 951' Light grey, fine-grained with white veins, less than 1 mm across. MF114.
- 952'6" Light grey, fine-grained and slightly patchy carbonate. MF115.
- 955' Light grey, very fine-grained, homogeneous marble. MF115.
- 959' Whitish grey, slightly heterogeneous, fine-grained carbonate. MF116.
- 960' Light grey, coarse-grained carbonate, with darker diffuse patches.
- 961' White, very fine-grained and homogeneous carbonate. MF116.
- 969' Greyish white, coarse-grained, adjacent to fine-grained, dark grey carbonate. MF117.
- 974' Light grey, fine-grained carbonate with white veins. MF117.
- 976' Fine-grained, white marble.* MF117.
- <981' White, very fine-grained, homogeneous marble. MF118.
- 983' Whitish yellow, fine-grained with small veins.
- 991' Light grey, fine-grained, patchy carbonate. MF118.
- 993' Patchy, as 946'. Fine-grained, light grey. Patches of darker carbonate. MF118.
- 996' Fine-grained marble. Many fine veins cutting each other. Some smaller areas coarse-grained. MF119.
- <999' A silicate band.* Some carbonate in the silicate. MF119.
- <1001' Very fine, white, with a few diffuse coarser-grained dark grey carbonate patches. MF119.
- 1001' White, coarse-grained, with some silicates present. MF120.
- 1011' Chlorite schist with thin veins (2-3 mm) of carbonate.* MF120
- 1020' Dark grey, dolomite, fine-grained. MF120.
- 1021' Brecciated. Irregular fragments of white carbonate set in a dark carbonate matrix. MF121.
- 1021(a) Chlorite schist with carbonate veins. MF121.

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1021(b) Chlorite schist with carbonate veins.*

1023' White, very coarse-grained carbonate. MF122.

Table 2. Description of samples collected along banks of the Main Creek
(see Fig. 3).

1. Medium grey. Schistose to some extent. MF31.
2. Brecciated rock. Yellow stained. MF31.
3. Dark grey brecciated carbonate. Groundmass dark. Lighter uneven grains of carbonate 1 cm to 0.21 cm wide. Diffuse into the groundmass. MF31.
5. Highly weathered grey, fine-grained carbonate. MF32.
6. Light grey, coarsely crystalline carbonate. MF32.
7. Coarsely crystalline carbonate. Whitish grey. MF32.
8. Very fine-grained yellowish carbonate. Parallel veins through dark grey carbonate. MF33.
9. Fine-grained, yellowish-grey carbonate. Brecciated with fine darker veins separating the 0.5 to 1.0 cm irregular carbonate areas. MF33.
10. Light, yellowish, fine-grained carbonate. With contact of coarse vein of carbonate. MF33.
12. Fine-grained carbonate with broad band of well crystallized carbonate. Yellowish white. Veins of coarse carbonate. MF34.
13. Very coarse-grained, white carbonate on one bed. Fine-grained carbonate in the other.
14. Fine-grained, yellowish grey carbonate. MF35.
15. Fine-grained, yellowish carbonate. MF35.
16. Very light yellow, very fine-grained magnesite. One edge is very coarsely crystalline quartz. MF 35.
17. Quartzite.

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Table 3. Summary of the succession of rock types in D.D.H M.C.1.

0-145' Predominantly dolomite. Bands of schist.
Magnesite scarce.

145-210' Schist with sporadic carbonate bands

210-240' Yellow fine-grained magnesite. Abundant minor veins

240-250' Schist

250-270' Light-grey, fine- to medium-grained magnesite

270-285' Band of dolomite at 285'

285-335' Medium-grey magnesite

335-395' Light-grey, fine-grained magnesite

395-410' Schist with dolomite

410-422' Light-grey magnesite

422-470' Mainly dark grey dolomite. Abundant minor veins

470-475' Schist

475-530' White fine-grained magnesite

530-550' Dark-grey dolomite

550-590' Light-grey magnesite

590'	Dark-grey, pyrite-rich band
590-600'	White, coarse-grained magnesite
600-610'	Predominantly dolomite
610-625'	Light-grey, fine-grained carbonate
625-660'	Dark-grey carbonate
660-690'	Schist
690-710'	White, fine-grained magnesite
710-715'	Predominantly dolomite
715-760'	Patchy magnesite
760-770'	Schist
770-795'	Light-grey to white. Bands of patchy magnesite
795-936'	White to light-grey magnesite, occasional patchy magnesite, minor veins at 810'
936-955'	Schist and then layers of patchy carbonate
955-1000'	Light-grey magnesite
1000-1020'	Schist
>1020'	White magnesite with bands of dolomite

6. STUDIES OF POLISHED SECTIONS USING THE SEM AND OPTICAL MICROSCOPE

6.1 THE ADVANTAGES OF A BACKSCATTERED ELECTRON DETECTOR

A Jeol JSM25S with an annular solid state backscattered detector was used to examine the mineralogy of these rocks (Frost et al., 1981). Imaging using backscattered electrons rather than secondary electrons has considerable advantages. The signal is much more compositionally sensitive than the image produced by secondary electrons so that very small variations in composition can be observed, which can be measured by X-rays only by counting for considerable periods. For example the zoning observed in the dolomites represent changes in Mg:Fe of less than 1%. Using high beam currents and 30 KV it is possible to examine compositional variations with extreme sensitivity. In fact the method is so sensitive it becomes very difficult to determine what cations are changing. To do so requires the user to move the sample from the SEM to the microprobe and step scan for long periods across the same grains. But to pin point the same areas is difficult because the detector on the probe is not as sensitive. Moreover, high beam currents and high KV's tend to destroy dolomite, when a spot focus is used, and this makes precise measurements of Ca, Mg and Fe more difficult. Studies that have been undertaken all suggest that the zoning observed is due to Mg and Fe interchanging, rather than Ca replacing either Mg or Fe. When examining the backscattered electron images, it should be remembered that the signal is proportional to $\sum w_i \zeta_i$, where w and Z are the weight fraction and backscattered electron coefficient of the i-th element in the compound. The values of ζ 's in the region Mg to Fe increase roughly proportionally to their atomic number. So dolomite is brighter than magnesite, and Fe-rich magnesite brighter than pure magnesite. It so happens that the signal from dolomite and quartz is about the same, although they can be distinguished when they occur as adjacent grains. FeS₂ grains are very bright.

6.2 THE FEATURES OF THE MAGNESITE

Magnesite that is fine grained is usually very uniform in composition but has been found to be slightly more Fe-rich about grain

boundaries (Fig. 4). The magnesite ore is rarely pure and usually contains a proportion either quartz and dolomite, dispersed as irregular patches (Figs. 5 to 7) or as veins. Sometimes it is found as a predominantly homogeneous phase but containing Fe-rich laths (Fig. 8). Rhythmic zoning is found in some samples. Figure 9 shows a band of more Fe-rich magnesite that has developed along a dolomite magnesite interface. Figure 10 shows granular anhedral magnesite grains that are more Fe-rich than the surrounding magnesite and which shows rhythmic zoning. Rhythmic zoning is particularly well shown in Figs. 11 and 12.

6.3 THE FEATURES OF THE DOLOMITE

The dolomite is surprisingly heterogeneous. Grains that occur isolated within the magnesite, over 100 μm across, are often full of magnesite inclusions, which as far as can be determined have a slightly different composition to the magnesite outside (Fig. 13). Larger areas of dolomite are mottled in appearance but contain fewer if any magnesite inclusions. They are often associated with quartz and again their borders are very irregular (Fig. 14). The mottled nature is caused probably by small variations of the Mg/Fe ratio ($<0.5\% \text{FeCO}_3$) rather than any variation in the (FeMg)/Ca ratio. As the temperature drops under conditions of equilibrium, it would be expected that Ca enrichment occurs in the dolomite, and Ca-impoverishment in the associated magnesite. If Ca replaced Mg the reverse shading would be found, i.e. the edges of the grains would be brighter. But if Ca replaced Fe the darker phase would appear on the outside. Figure 15 shows more clearly the zoning of Fe and Mg in dolomite. The light grey contains very little Fe but the darker grey contains about 1-2%. The very dark grey phase showing cleavage is chlorite. Figure 16 details this dolomite. Small blebs of Fe-rich magnesite and laths of talc are also present. This sample of dolomite shows clearly that zoning of Fe and Mg occurs.

Extensive replacement of the dolomite for magnesite is observed universally. Figures 17(a) and (b), 18(a) and (b) and 19(a) and (b) illustrate replacement features. The boundaries between dolomite and magnesite are very irregular, with many rounded indentations. Veins and irregular patches of magnesite occur within the dolomite and the edges have the same structure, appearing as if the magnesite is absorbing the

dolomite. Individual grains and areas of dolomites are sometimes surrounded by magnesite. It would appear that the Ca is being removed along the cracks between crystals and grains. It should be pointed out that these three sets of photomicrographs are deliberately set at very high contrast, which emphasises any subtle compositional variations in the dolomite, but loses as a consequence detail within the magnesite which appears black. Therefore, the mottling observed is due to very small changes in Mg/Fe ratio.

6.4 REPLACEMENT OF QUARTZ

Quartz is by far the most abundant non-carbonate present in the magnesite. It is frequently found to occur as clouds of particles within the magnesite (Figs. 20 and 21). Their outline can be interpreted as there being once a solid single crystal, which was replaced by magnesite and the clusters of small ~10 μm particles represent the remnants of larger crystals.

6.5 THE ASSOCIATED SCHISTS

These mainly consist of chlorite, quartz and carbonate. Figure 22 (a) and (b) illustrates a well foliated variety with chlorite interleaved with magnesite and dolomite. The bright, small, rounded areas are apatite. A less well foliated schist is illustrated in Fig. 23. Chlorite, talc, and quartz are associated together with magnesite dispersed in irregular areas. There is some evidence that suggests that the carbonates within the schists were present before the rock was subjected to the last period of deformation producing foliation.

6.6 MINOR ELEMENT DISTRIBUTION

Ti occurs as abundant small inclusions in isolated zones within the schists (Fig. 23). P occurs in apatite as very irregularly distributed grains (Fig. 25). Pyrites is scattered freely through both carbonates and schists, and in some horizons is abundant. It never appears to have been replaced and Fig. 24 shows a replacement structure with pyrites originally crystallising about a round crystal which has been replaced subsequently, leaving the pyrites ring. Sometimes pyrites contains minor amounts of Ti and Fig. 26(a) and (b) illustrates Ti-zoning in a

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large grain of pyrites. Cu and Zn have been found within the pyrites as small isolated grains.

7. STUDIES OF THIN SECTIONS USING AN OPTICAL MICROSCOPE

A very typical fine grained granular magnesite is shown in Fig. 27, although this equigranular texture may become coarser grained (Fig. 37). Often there are a network of slightly coarser grained veins, either of dolomite or magnesite within the homogeneous magnesite (Fig. 28). Patches of much coarser grained carbonate are also common Figs. 29, 30, 36 and 38. Coarse grained quartz and dolomite and chlorite and carbonate are often found associated (Figs. 31 and 32). Sometimes the carbonate is found deformed into microfolds (Fig. 33) and on other occasions irregularly granular (Fig. 35). Quartz occurs as both irregular patches and as definite veins through the carbonate (Fig. 34).

The intermingling schists are predominantly composed of chlorite and quartz with minor amounts of talc and carbonate (Fig. 39). The borders between dolomite and schist are usually sharp, but on a small scale, the carbonate and chlorite and talc are found intimately associated (Fig. 40).

8. QUANTITATIVE ASSESSMENTS OF THE QUALITY OF THE MAGNESITE ORE

8.1 X.R.D METHOD FOR THE ANALYSIS OF CARBONATES

Quantitative modal analyses of the carbonates by X-ray diffraction methods were carried out on over 50 samples of ore by I. Madsen and I. Palmer.

A Philips PW 1310/20 X-ray generator was used, run at 40 kV 40 mA, and fitted with a normal focus Cu target tube, a PW 1050/25 diffractometer fitted with graphite monochromator and 1° divergence and receiving slits.

Samples were prepared using 0.6 g of sample and 0.6 g of corundum ($\alpha\text{-Al}_2\text{O}_3$). They were carefully weighed and mixed, by grinding, in a

Sieb Technik mill (small W.C. vessel) for 2 min. The samples were then side-mounted in a cavity holder and tapped gently into place. Pressing or scraping was avoided to ensure a minimum of preferred orientation.

Integrated peak intensities and backgrounds were measured on the internal standard and on each of the carbonate minerals. The Miller indices and limits of integration for each peak are shown below.

Peak	hkl	2 θ min.	2 θ max.
Corundum	012	25.00	26.00
Dolomite	104	30.00	31.70
Magnesite	104	31.90	31.70

At each of the 2 θ limits, background counts of 20s. were taken. The peak intensities were integrated between these limits by setting the timer to infinity and simultaneously starting the counter and the 2 θ scan (at a constant rate of 0.5° 2 θ /min. At the upper limit, both scanning and counting were stopped and the total counts recorded. Net peak intensities were calculated using the formula

Net counts = integrated peak counts - (bgnd₁ + bgnd₂)

$$\times \frac{\text{peak int. time}}{\text{total bgnd time}}$$

Concentrations of each of the three minerals were calculated using the formula

$$\frac{X}{X_s} = \frac{1}{k} \frac{I}{I_s}$$

where X = concentration of unknown

X_s = concentration of internal standard (α -Al₂O₃)

I = net peak intensity of unknown

I_s = net peak intensity of internal standard

k = a constant of proportionality determined from known samples and synthetic standards. (Different k values are calculated for each mineral.)

Peak intensities are usually affected by variations in mass absorption coefficient. However, since an internal standard method was used, this effect is cancelled as variations in mass absorption coefficients will affect the internal standard and analytical peaks equally. The same is true of any variations in sample packing density.

8.2 THE DETERMINATION OF THE AMOUNT OF NON-CARBONATE MINERALS

About 500 mg of finely crushed ore was carefully weighed and placed in a platinum crucible. The ore was then heated in a muffle furnace at $770 \pm 10^\circ\text{C}$ to constant weight (about 60 min). The sample was then cooled for 30 min in a desiccator and again weighed to determine loss of weight on ignition. The residue was then transferred to a beaker by washing with distilled water. The total volume was adjusted to 25 ml. Using a pH-meter and a magnetic stirrer, 2M hydrochloric acid was titrated to obtain a pH of 2.0 for 20 min. whilst stirring at room temperature. The sample was then filtered through a millipore filter (0.6 μm BDWP 025-00), and washed with water. The filter paper and residue was transferred to a watchglass and dried at 105°C to constant weight. Table 5 presents the mean weight percent of magnesite, dolomite and non-carbonates and their standard deviations for samples of ore from Savage River. Core samples are all from D.D.H. M.C.1.

8.3 THE QUALITY OF THE MAGNESITE

Table 5. Presents a summary of the modal analysis data. The mean and standard deviations are computed from all samples below the first dolomite band from D.D.H. M.C.1., i.e., from below 133' (Number of samples, 54).

	Mean (wt.%)	σ
Magnesite	66.2	28.1
Dolomite	24.2	23.0
Silicates	9.1	10.7
Total	99.5	

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Table 6. Weight percent of magnesite, dolomite and non-carbonates for samples of ore from Savage River. (Figures in parentheses are repeats.)

Sample	Magnesite	Dolomite	Non-carbonates
Main Creek, No. 1			12
Main Creek, No. 9			3
10'	0(0)	94(98)	1
17'	0(0)	94(100)	1
30'	0(0)	96(95)	3
38'			89
50'	0(0)	91(94)	7
57'	0(0)	88(103)	5
62'	2(0)	17(20)	80
68'	3(2)	91(86)	12
73'	5(4)	90(86)	8
80'	1	98	8
87'	5(4)	85(81)	9
94'	2(2)	93(83)	11
100'	6	90	23
113'	1	84	16
127'	3	91	12
133'	12	80	7
176'	67	17	34
199'	61	13	35
210'	86	10	4
215'	92	14	10
221'	79	18	4
229'	84	13	3
235'	84	12	9
259'	81	11	9
278'	55	36	5
285'	22	70	5
305'	77	12	9
312'	70	23	4
320'	83	13	10
334'	71	13	8
345'	79	10	4
356'	76	14	5
376'	93	12	3(3)
393'	74	21	2
396'	31	26	30
<408'	32	38	38
423'	19	75	2
450'	0	52	40

Table 6 (cont.)

Sample	Magnesite	Dolomite	Non-carbonates
470'	0	83	8
487'	82(76)	7(18)	1(3)
499'	77	8	13
504'	81	10	2
513'	69(78)	20(20)	2(1)
547'	16	58	26
551'	97(97)	13	5
555'	97	1	0
561'	97	3	1
567'	78	17	3
578'	86	11	7
579'	83	6	-
598'6"	83	3	15
601'	1	96	3
609'6"	9	60	32
625'	82	11	0
634'	77	9	7
646'	78	19	5
649'	20	66	28
715'	16	74	4
750'	80	13	4
775'	78	25	8
781'	82	8	4
787'	74	15	5
797'	71	17	5
805'6"	80	22	3
825'	51	47	5
828'	81	16	3
833'	65	29	1
852'	87	7	3
867'	78	16	1
890'	98	2	3

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Table 6 presents the details of the proportions of magnesite, dolomite and non carbonates from 54 samples taken from D.D.H. M.C.1. Figures 42 and 43 illustrate how the proportions of the carbonates and non carbonates vary. These data and figures show that dolomite and silicates are nearly always present in significant amounts, and the proportions of non-carbonates tend to fall slightly with depth but dolomite-rich bands occur throughout the sequence. Even if the magnesite were to be mined by carefully separating the dolomite and chlorite schists by visual inspection, there would be about 10% dolomite and non carbonate present in the resulting ore. X.R.D. analysis of the non carbonate residues showed them to consist of predominantly quartz in the main magnesite horizons, with talc and chlorite in the associated schists.

9. QUANTITATIVE ELECTRON MICROPROBE ANALYSES

9.1 EXPERIMENTAL METHODS

Analyses were performed using an automated JXA-50A electron microprobe. Standards used were for Mg, a magnesite from Austria, for Ca a wollastonite, for Fe synthetic Fe_2O_3 , and pure Mn. Other elements were analysed but not found present were Na, Al, Si and Zn. Cu, Ni and Cr were found present but in very low concentrations. Counting times were usually 40s. on peak and backgrounds for each element, and the relative errors at 95% confidence limits on measured concentrations from the algorithm given by Ancey (1977) are as follows:

% relative error at 95% confidence limits

	Magnesite	Dolomite
Mg	0.3	0.5
Ca	31.0	0.15
Fe	1.5	4.0
Mn	30	6.0

The magnesite and dolomite analyses are presented in Table 7. Analyses of the carbonates from Arthur River are presented in Table 8, and Table 9 presents the silicate analyses.

The element C cannot be measured on an electron microprobe. Therefore, the cations Mg, Ca, Fe and Mn are measured and O and C are determined by difference. O and C are then proportioned in the ratio 3 to 1. Totals are determined by summing the weight fractions of MgO, CaO, FeO and MnO from the determined weight fractions of the cations, and the amount of CO₂ determined by the ratio-method.

9.2 AN ANALYSIS OF THE CARBONATE ANALYSES

The electron microprobe analyses of magnesite indicate that they contain normally about 2% FeCO₃ in the main magnesite ore body. The cryptocrystalline, yellowish magnesite and the medium grey magnesites contain up to 3% FeCO₃, and the whiter, marble-like samples between 0.5 to 1% FeCO₃. Magnesite grains, included in relatively large dolomite grains in what is basically a magnesite-rich rock, have lower Fe contents than the magnesites found in the main bulk of the rock. These may have exsolved, probably from the dolomite. Magnesite is frequently zoned (Fig. 4) and this zoning invariably replaces Mg with Fe and Mn. Zoning is found even in the cryptocrystalline varieties on some occasions, but compositional variations rarely exceed about 1% FeCO₃. Often Fe-rich magnesite is found as isolated crystals within the main magnesite, and in these cases the Fe may reach 5 to 6% (see Fig. 8). In some instances, clusters of Fe-rich magnesite crystals occur, with Fe-rich centres and Fe-poor surrounds (Fig. 10). The margins are sharp between the two compositions. On other occasions rhythmic zoning is observed (Fig. 11) and then the boundaries are both sharp and gradational, with compositions again varying by about 3% FeCO₃.

Ca is much lower than Fe in the magnesites (on average 0.14% CaCO₃). In typical magnesites it rarely exceeds 0.1% CaCO₃ and is not correlated with FeCO₃ content. The highest value measured was 0.4%. Mn ranges from about 0.1% in low-Fe varieties to 0.8% MnCO₃ in Fe-rich varieties, and oftens exceeds Ca.

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Dolomite associated with the main magnesite deposit contains usually less than 1% FeCO_3 and 0.1% MnCO_3 , much less than the co-existing magnesite. In the main dolomite zone (0 III 130') the magnesite has been found to contain 3-4% FeCO_3 . A ternary plot of co-existing dolomites and magnesites is shown in Fig. 44. Rosenberg (1967) describes the subsolidus relationships between dolomite, magnesite and ankerite (Fig. 45) at 450°C and 2 to 3 Kb. but gives no tie lines between co-existing $(\text{MgCa})\text{CO}_3$ and $(\text{MgFe})\text{CO}_3$. A narrow one-phase region running along the MgCO_3 - FeCO_3 is described as a disordered solid solution and this region contains a few percent of CaCO_3 . It is likely that under the more slowly cooling conditions experienced in nature, this Ca would order into the dolomite phase, so explaining why the Savage River magnesite contains so little Ca. The dolomite boundary maintains constant Ca content while replacing Mg for Fe. If the tie lines are drawn equidistantly along the dolomite and siderite borders of the dolomite-siderite phase area, then the Fe content of the siderite will always be significantly higher than in the co-existing dolomite. Raising the temperature swings the 3-phase area clockwise, but it is unlikely that the contraction of the dolomite-siderite phase area would be reduced to the extent of affecting low-Fe solid solutions. No estimates of either temperature or pressure can be attempted in this case, because the Fe and Mn is relatively high compared with Ca, and no data are available for such compositions.

Figure 46 demonstrates how the composition of magnesite varies with depth. There is a definite trend towards purer magnesite with increasing depth. The two dolomite-rich bands contain magnesite with significantly higher Fe and Mn.

9.3 THE CHLORITES AND TALCS

As would be expected, the talc and chlorites found associated with the magnesite are very Fe and Ca poor varieties. The chlorite is a typical chlinochlore showing small variations in Fe content. The talc also has a typical chemistry, with little variation from the ideal formulae of $\text{Mg}_6\text{Si}_8\text{O}_{20}(\text{OH})_4$.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mg	0.1428	0.1421	0.1497	0.2566	0.2631	0.1322	0.2272
Ca	0.1870	0.1921	0.1748	0.0069	0.0020	0.2098	0.0002
Fe	0.0023	0.0023	0.0060	0.0399	0.0385	0.0022	0.0908
Mn	0.0008	0.0001	0.0005	0.0031	0.0033	0.0170	0.0045
MgO	0.2367	0.2356	0.2482	0.4255	0.4262	0.2192	0.3767
CaO	0.2616	0.2688	0.2446	0.0010	0.0027	0.2936	0.0002
FeO	0.0029	0.0029	0.0077	0.0514	0.0495	0.0219	0.1169
MnO	0.0010	0.0001	0.0006	0.0040	0.0042	0.0029	0.0058
Total	0.9917	0.9941	0.9919	0.9951	1.0012	1.0066	0.9965

No. of ions on the basis of three O atoms.

Mg	0.5366	0.5347	0.5609	0.9135	0.9349	0.5051	0.8336
Ca	0.4261	0.4384	0.3973	0.0015	0.0042	0.4860	0.0003
Fe	0.0037	0.0037	0.0008	0.0619	0.0595	0.0283	0.1450
Mn	0.0013	0.0001	0.0097	0.0049	0.0052	0.0038	0.0073
$\sum n_i$	0.9677	0.9769	0.9687	0.9818	1.0038	1.0232	0.9862

- (1) Dolomite, 57', MF 39.
- (2) Dolomite, 57', MF 39.
- (3) Dolomite, 57', MF 39.
- (4) Magnesite, 62', MF 40.
- (5) Magnesite, 62', MF 40.
- (6) Dolomite, 62', MF 40.
- (7) Fe-rich magnesite, MF 40.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.I. (cont.)

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Mg	0.2409	0.2425	0.1258	0.1241	0.2350	0.1383	0.1374
Ca	0.0005	0.0010	0.2060	0.2046	<.0000	0.2238	0.2126
Fe	0.0069	0.0678	0.0146	0.0198	0.0695	0.0706	0.0083
Mn	0.0049	0.0027	0.0012	0.0024	0.0031	0.0015	0.0003
MgO	0.3995	0.4021	0.2087	0.2058	0.3897	0.5276	0.2278
CaO	0.0007	0.0014	0.2882	0.2863	0.0007	0.5178	0.2975
FeO	0.0887	0.0872	0.0188	0.0254	0.0988	0.0175	0.0107
MnO	0.0063	0.0035	0.0015	0.0030	0.0040	0.0025	0.0004
Total	0.9975	0.9974	0.9958	0.9968	0.9951	1.0171	1.0069

No. of ions on the basis of three O atoms.

Mg	0.8726	0.8767	0.4801	0.4749	0.8547	0.5276	0.5218
Ca	0.0011	0.0023	0.4765	0.4749	<0.0000	0.5178	0.4898
Fe	0.1087	0.1067	0.0243	0.0329	0.1216	0.0175	0.0137
Mn	0.0079	0.0043	0.0020	0.0040	0.0050	0.0025	0.0005
$\sum n_i$	0.9903	0.9900	0.9829	0.9867	0.9813	1.0654	1.0258

(8) Magnesite, 62', MF 40.

(9) Magnesite, 65', MF 40.

(10) Dolomite, 65', MF 40.

(11) Dolomite associated with Fe-rich magnesite, 67', MF 40.

(12) Magnesite, 67', MF 40.

(13) Dolomite, 68', MF 40.

(14) Dolomite, 199', MF 47.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Mg	0.1341	0.2674	0.2729	0.2707	0.2703	0.2719	0.1351
Ca	0.2160	0.0015	0.0006	0.0003	0.0003	0.0003	0.1978
Fe	0.0068	0.0316	0.0274	0.0200	0.0204	0.0204	0.0046
Mn	0.0004	0.0017	0.0008	0.0008	0.0007	0.0007	0.0006
MgO	0.2224	0.4435	0.4526	0.4489	0.4483	0.4509	0.2240
CaO	0.3022	0.0021	0.0008	0.0004	0.0006	0.0005	0.2767
FeO	0.0088	0.0407	0.0352	0.0257	0.0312	0.0262	0.0060
MnO	0.0005	0.0022	0.0010	0.0010	0.0010	0.0009	0.0008
Total	1.0054	1.0003	1.0019	0.9956	0.9954	0.9969	0.9930

No. of ions on the basis of three O atoms.

Mg	0.5100	0.9458	0.9616	0.9511	0.9500	0.9553	0.5107
Ca	0.4980	0.0032	0.0013	0.0007	0.0006	0.0007	0.4533
Fe	0.0113	0.0487	0.0420	0.0306	0.0312	0.0312	0.0076
Mn	0.0007	0.0026	0.0012	0.0012	0.0010	0.0011	0.0010
$\sum n_i$	1.0200	1.0003	1.0061	0.9836	0.9828	0.9883	0.9726

- (15) Dolomite, 199', MF 47.
 (16) Magnesite, 199', MF 47.
 (17) Magnesite, 199', MF 47.
 (18) Magnesite, 200', MF 47.
 (19) Magnesite, 200', MF 47.
 (20) Magnesite, 200', MF 47.
 (21) Magnesite, 210', MF 47.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(22)	(23)	(24)	(25)	(26)	(27)	(28)
Mg	0.2700	0.1358	0.2741	0.1357	0.2757	0.2795	0.1345
Ca	0.0007	0.2154	0.0008	0.2140	0.0007	0.0012	0.2076
Fe	0.0325	0.0076	0.0206	0.0071	0.0216	0.0222	0.0054
Mn	0.0009	0.0003	0.0010	0.0005	0.0008	0.0007	0.0004
MgO	0.4478	0.2251	0.4545	0.5155	0.4572	0.4635	0.2230
CaO	0.0010	0.3013	0.0012	0.4931	0.0010	0.0017	0.2905
FeO	0.0418	0.0097	0.0296	0.0091	0.0278	0.0286	0.0069
MnO	0.0012	0.0004	0.0013	0.0010	0.0011	0.0009	0.0006
Total	1.0023	1.0068	1.0009	1.0054	1.0014	1.0055	0.9993

No. of ions on the basis of three O atoms.

Mg	0.9544	0.5161	0.9638	0.5155	0.9684	0.9814	0.5098
Ca	0.0015	0.4965	0.0018	0.4931	0.0010	0.0017	0.4774
Fe	0.0500	0.0125	0.0352	0.0117	0.0309	0.0318	0.0089
Mn	0.0015	0.0005	0.0015	0.0009	0.0011	0.0009	0.0007
$\sum n_i$	1.0074	1.0256	1.0023	1.0212	1.0014	1.0158	0.9968

(22) Magnesite, 210', MF 47.

(23) Dolomite, 210', MF 47.

(24) Magnesite, 235', MF 50.

(25) Dolomite, 235', MF 50.

(26) Magnesite, 257', MF 50.

(27) Magnesite, 264', MF 51.

(28) Dolomite, 264', MF 51.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.I. (cont.)

	(29)	(30)	(31)	(32)	(33)	(34)	(35)
Mg	0.1394	0.2827	0.1347	0.2770	0.2780	0.1337	0.2794
Ca	0.2113	0.0007	0.2122	0.0013	0.0002	0.2073	0.0010
Fe	0.0035	0.0145	0.0056	0.0103	0.0217	0.0036	0.0237
Mn	0.0002	0.0006	0.0004	0.0006	0.0009	0.0005	0.0010
MgO	0.2312	0.4688	0.2233	0.4594	0.4643	0.2217	0.4634
CaO	0.2957	0.0010	0.2970	0.0018	0.0002	0.2901	0.0014
FeO	0.0045	0.0207	0.0072	0.0132	0.0279	0.0059	0.0305
MnO	0.0003	0.0009	0.0006	0.0007	0.0012	0.0008	0.0013
Total	1.0052	1.0034	1.0027	0.9966	1.0051	0.9974	1.0063

No. of ions on the basis of three O atoms.

Mg	0.5279	0.9883	0.5112	0.9681	0.9825	0.5065	0.9818
Ca	0.4852	0.0014	0.4886	0.0027	0.0002	0.4763	0.0014
Fe	0.0057	0.0220	0.0092	0.0156	0.0301	0.0059	0.0339
Mn	0.0003	0.0009	0.0007	0.0009	0.0012	0.0008	0.0013
$\sum n_i$	1.0191	1.0126	1.0097	0.9873	1.0140	0.9895	1.0184

(29) Dolomite, 267', MF 51.

(30) Magnesite, 267', MF 51.

(31) Dolomite, 312', MF 55.

(32) Magnesite, 312', MF 55.

(33) Magnesite, 314', MF 55.

(34) Dolomite, 312', MF 55.

(35) Magnesite, 320', MF 55.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(36)	(37)	(38)	(39)	(40)	(41)	(42)
Mg	0.1341	0.1372	0.2745	0.2680	0.1399	0.1300	0.1322
Ca	0.2079	0.2160	0.0026	0.0009	0.2222	0.2101	0.2172
Fe	0.0066	0.0061	0.0122	0.0192	0.0047	0.0043	0.0062
Mn	0.0006	0.0003	0.0002	0.0006	0.0002	0.0003	0.0005
MgO	0.2224	0.2275	0.4553	0.4444	0.5316	0.2156	0.2192
CaO	0.2908	0.3022	0.0036	0.0013	0.5119	0.2940	0.3040
FeO	0.0085	0.0078	0.0157	0.0246	0.0078	0.0055	0.0080
MnO	0.0007	0.0004	0.0003	0.0008	0.0004	0.0004	0.0006
Total	0.9999	1.0077	0.9960	0.9929	1.0136	0.9962	1.0041

No. of ions on the basis of three O atoms.

Mg	0.5086	0.5209	0.9608	0.9420	0.5316	0.4935	0.5029
Ca	0.4783	0.4975	0.0054	0.0019	0.5119	0.4836	0.5011
Fe	0.0109	0.0100	0.0185	0.0293	0.0078	0.0070	0.0102
Mn	0.0009	0.0005	0.0004	0.0009	0.0004	0.0006	0.0008
$\sum n_i$	0.9987	1.0289	0.9851	0.9741	1.0517	0.9847	1.0150

(36) Dolomite, 330', MF 55. Small grain in magnesite.

(37) Dolomite, 330', MF 55.

(38) Magnesite, 356', MF 59. Within large dolomite grain.

(39) Magnesite, 356', MF 59. Outside large dolomite crystal.

(40) Dolomite, 356', MF 59.

(41) Dolomite, 356', MF 59.

(42) Dolomite, 356', MF 59.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(43)	(44)	(45)	(46)	(47)	(48)	(49)
Mg	0.2759	0.2726	0.1368	0.2733	0.2725	0.1364	0.2693
Ca	0.0006	0.0013	0.2188	0.0008	0.0019	0.2133	0.0004
Fe	0.0239	0.0244	0.0028	0.0250	0.0228	0.0005	0.0238
Mn	0.0008	0.0009	0.0004	0.0012	0.0007	0.0050	0.0008
MgO	0.4576	0.4520	0.2269	0.4532	0.4518	0.2263	0.4466
CaO	0.0008	0.0018	0.3062	0.0011	0.0027	0.2984	0.0006
FeO	0.0308	0.0314	0.0036	0.0321	0.0294	0.0064	0.0306
MnO	0.0011	0.0011	0.0005	0.0016	0.0009	0.0007	0.0010
Total	1.0028	1.0005	1.0075	1.0013	0.99981	1.0047	0.9965

No. of ions on the basis of three O atoms.

Mg	0.9702	0.9595	0.5193	0.9620	0.9585	0.5177	0.9482
Ca	0.0012	0.0028	0.5036	0.0017	0.0041	0.4908	0.0009
Fe	0.0366	0.0374	0.0046	0.0383	0.0350	0.0082	0.0365
Mn	0.0013	0.0014	0.0007	0.0020	0.0011	0.0009	0.0012
$\sum n_i$	1.0093	1.0011	1.0282	1.0040	0.9987	1.0176	0.9868

(43) Magnesite, 350', MF 59.

(44) Magnesite, 350', MF 59.

(45) Dolomite, 350', MF 59.

(46) Magnesite, 350', MF 59.

(47) Magnesite, 350', MF 59.

(48) Dolomite, 350', MF 59.

(49) Magnesite, 363', MF 59.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.I. (cont.)

	(50)	(51)	(52)	(53)	(54)	(55)	(56)
Mg	0.1340	0.2759	0.2715	0.1339	0.1373	0.1329	0.2684
Ca	0.2200	0.0005	0.0004	0.2161	0.2171	0.2016	0.0005
Fe	0.0033	0.0197	0.0238	0.0023	0.0020	0.0037	0.0370
Mn	0.0001	0.0001	0.0008	0.0003	0.0003	0.0002	0.0014
MgO	0.2222	0.4575	0.4502	0.2221	0.2276	0.2205	0.4450
CaO	0.3078	0.0006	0.0006	0.3023	0.3038	0.2821	0.0007
FeO	0.0043	0.0253	0.0306	0.0030	0.0026	0.0048	0.0475
MnO	0.0001	0.0001	0.0010	0.0004	0.0003	0.0003	0.0018
Total	1.0058	0.9999	0.9985	1.0027	1.0063	0.9929	1.0032

No. of ions on the basis of three O atoms.

Mg	0.5091	0.9680	0.9553	0.5081	0.5204	0.5030	0.9508
Ca	0.5069	0.0010	0.0009	0.4971	0.4993	0.4625	0.0010
Fe	0.0055	0.0300	0.0364	0.0038	0.0033	0.0062	0.0570
Mn	0.0001	0.0002	0.0012	0.0005	0.0004	0.0004	0.0021
$\sum n_i$	1.0216	0.9992	0.9938	1.0095	1.0243	0.9721	1.0109

- (50) Dolomite, 366', MF 59. Traces of Ni and Cr detected.
 (51) Magnesite, 363', MF 59.
 (52) Magnesite, 363', MF 59.
 (53) Dolomite, 363', MF 59. Associated with magnesite of (73).
 (54) Dolomite, 363', MF 59. Close to (75).
 (55) Dolomite, 363', MF 59. Small ?? in magnesite.
 (56) Magnesite, 363', MF 59. Centre of Fe-rich crystals.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(57)	(58)	(59)	(60)	(61)	(62)	(63)
Mg	0.1344	0.1314	0.2674	0.2788	0.1340	0.1389	0.2770
Ca	0.2112	0.2154	0.0006	0.0013	0.2200	0.2127	0.0006
Fe	0.0022	0.0039	0.0164	0.0208	0.0033	0.0052	0.0213
Mn	0.0002	0.0003	0.0007	0.0010	0.0001	0.0003	0.0008
MgO	0.2229	0.2179	0.4434	0.4623	0.2222	0.2299	0.4594
CaO	0.2956	0.3014	0.0009	0.0018	0.3078	0.2976	0.0008
FeO	0.0032	0.0050	0.0211	0.0268	0.0043	0.0067	0.0274
MnO	0.0002	0.0004	0.0009	0.0013	0.0001	0.0004	0.0010
Total	0.9998	1.0008	0.9907	1.0042	1.0058	1.0064	1.0023

No. of ions on the basis of three O atoms.

Mg	0.5093	0.4992	0.9387	0.9784	0.5091	0.5278	0.9726
Ca	0.4852	0.4963	0.0013	0.0027	0.5069	0.4891	0.0012
Fe	0.0037	0.0064	0.0250	0.0318	0.0055	0.0086	0.0325
Mn	0.0003	0.0005	0.0013	0.0015	0.0001	0.0006	0.0012
$\sum n_i$	0.9985	1.0024	0.9663	1.0144	1.0216	1.0261	1.0075

- (57) Dolomite, 365', MF 59.
 (58) Dolomite, 366', MF 59.
 (59) Magnesite, 366', MF 59.
 (60) Magnesite, 366', MF 59.
 (61) Dolomite, 366', MF 59.
 (62) Dolomite, 377', MF 61.
 (63) Magnesite, 377', MF 61.

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Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(64)	(65)	(66)	(67)	(68)	(69)	(70)
Mg	0.1341	0.2741	0.1334	0.1338	0.1269	0.2709	0.2601
Ca	0.2073	0.0008	0.2129	0.2254	0.2056	0.0020	0.0004
Fe	0.0048	0.0225	0.0049	0.0006	0.0047	0.0180	0.0344
Mn	0.0004	0.0008	0.0004	0.0003	0.0012	0.0024	0.0040
MgO	0.2224	0.4551	0.2219	0.2219	0.2104	0.4492	0.4312
CaO	0.2900	0.0011	0.2979	0.3154	0.2876	0.0028	0.0006
FeO	0.0062	0.0290	0.0064	0.0008	0.0061	0.0232	0.0443
MnO	0.0005	0.0010	0.0005	0.0004	0.0016	0.0031	0.0052
Total	1.0033	1.0008	1.0016	1.0078	0.9910	0.9967	0.9956

No. of ions on the basis of three O atoms.

Mg	0.5084	0.9646	0.5064	0.5085	0.4818	0.9519	0.9231
Ca	0.4764	0.0018	0.4902	0.5195	0.4731	0.0043	0.0009
Fe	0.0079	0.0345	0.0082	0.0010	0.0078	0.0276	0.0531
Mn	0.0006	0.0012	0.0007	0.0005	0.0020	0.0037	0.0063
$\sum n_i$	0.9933	1.0021	1.0055	1.0295	0.9647	0.9875	0.9834

(64) Dolomite, 381', MF 61.

(65) Magnesite, 381', MF 61.

(66) Dolomite, 386', MF 61.

(67) Dolomite, 420', MF 67.

(68) Dolomite, 520', MF 67.

(69) Magnesite, 443', MF 67.

(70) Magnesite, 467', MF 72.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(71)	(72)	(73)	(74)	(75)	(76)	(77)
Mg	0.2654	0.2726	0.1334	0.2734	0.2694	0.2698	0.1359
Ca	0.0003	0.0008	0.2064	0.0003	0.0009	0.0180	0.2065
Fe	0.0359	0.0159	<0.0000	0.0147	0.0156	0.0005	0.0109
Mn	0.0041	0.0009	0.0023	0.0008	0.0009	0.0017	0.0023
MgO	0.4407	0.4521	0.2212	0.4535	0.4467	0.4474	0.2246
CaO	0.0004	0.0011	0.2888	0.0010	0.0012	0.0007	0.2889
FeO	0.0462	0.0204	0.0000	0.0189	0.0223	0.0232	0.0140
MnO	0.0053	0.0012	0.0029	0.0001	0.0012	0.0022	0.0029
Total	1.0013	0.9954	0.9954	0.9950	0.9922	0.9941	1.0033

No. of ions on the basis of three O atoms.

Mg	0.9415	0.9562	0.5051	0.9583	0.9454	0.9481	0.5152
Ca	0.0006	0.0016	0.4739	0.0002	0.0018	0.0011	0.4763
Fe	0.0554	0.0242	0.0000	0.0224	0.0238	0.0278	0.0181
Mn	0.0064	0.0015	0.0038	0.0012	0.0014	0.0027	0.0038
$\sum n_i$	1.0039	0.9835	0.9828	0.9821	0.9724	0.9797	1.0134

(71) Magnesite, 467', MF 72.

(72) Magnesite, 547', MF 79. Contains also 0.04 Cr₂O₃.

(73) Dolomite, 547'. Irregular small grain. MF 79.

(74) Magnesite, near dolomite of (23) 547', MF 79.

(75) Magnesite, 564.5', MF 79. Contains 0.02% Cr₂O₃.

(76) Magnesite, 564.5', MF 79. Close to (25).

(77) Dolomite, 564.5', MF 79.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.I. (cont.)

	(78)	(79)	(80)	(81)	(82)	(83)	(84)
Mg	0.2705	0.1246	0.2730	0.2741	0.2719	0.2759	0.2738
Ca	0.0008	0.2154	0.0009	0.0009	0.0011	0.0008	0.0005
Fe	0.0157	0.0036	0.0176	0.0168	0.0131	0.0131	0.0142
Mn	0.0009	0.0008	0.0007	0.0009	0.0122	0.0114	0.0110
MgO	0.4485	0.2068	0.4528	0.4545	0.4510	0.4576	0.4540
CaO	0.0011	0.3014	0.0013	0.0012	0.0016	0.0011	0.0001
FeO	0.0202	0.0047	0.0227	0.0216	0.0169	0.0168	0.0183
MnO	0.0012	0.0010	0.0009	0.0012	0.0157	0.0147	0.0142
Total	0.9931	0.9944	0.9965	0.9973	0.9976	1.0025	1.0005

No. of ions on the basis of three O atoms.

Mg	0.9492	0.4744	0.9583	0.9615	0.9576	0.9703	0.9634
Ca	0.0016	0.4973	0.0019	0.0018	0.0024	0.0016	0.0001
Fe	0.0240	0.0060	0.0269	0.0257	0.0201	0.0200	0.0218
Mn	0.0014	0.0013	0.0010	0.0015	0.0190	0.0177	0.0172
$\sum n_i$	0.9762	0.9790	0.9881	0.9905	0.9991	1.0096	1.0025

(78) Magnesite, 564', MF 79.

(79) Dolomite, 547', MF 79.

(80) Magnesite, 547', MF 79.

(81) Magnesite, 547', MF 79.

(82) Magnesite, 625', MF 85.

(83) Magnesite, 625', MF 85.

(84) Magnesite, 625', MF 85.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.I. (cont.)

	(85)	(86)	(87)	(88)	(89)	(90)	(91)
Mg	0.2815	0.1428	0.1489	0.2801	0.2789	0.2673	0.2791
Ca	0.0000	0.1905	0.1890	<0.0000	<0.0000	0.0001	0.0005
Fe	0.0153	0.0063	0.0057	0.0148	0.0140	0.0145	0.0166
Mn	0.0052	0.0081	0.0088	0.0055	0.0036	0.0032	0.0012
MgO	0.4669	0.2368	0.2468	0.4645	0.4625	0.4433	0.4629
CaO	0.0000	0.2666	0.2645	<0.0000	0.0001	0.0001	0.0007
FeO	0.0197	0.0080	0.0074	0.0191	0.0180	0.0187	0.0213
MnO	0.0068	0.0105	0.0114	0.0071	0.0046	0.0042	0.0015
Total	1.0051	0.9993	1.0045	1.0036	1.0010	0.9904	1.0018

No. of ions on the basis of three O atoms.

Mg	0.9870	0.5403	0.5622	0.9822	0.9770	0.9389	0.9776
Ca	<0.0000	0.4371	0.4329	0.0001	0.0001	0.0002	0.0011
Fe	0.0234	0.0103	0.0094	0.0226	0.0213	0.0222	0.0252
Mn	0.0081	0.0136	0.0148	0.0085	0.0055	0.0050	0.0018
$\sum n_i$	1.0185	1.0013	1.0193	1.0134	1.0039	0.9663	1.0057

(85) Magnesite, 625', MF 85.

(86) Dolomite, 625', MF 85.

(87) Dolomite, 625', MF 85.

(88) Magnesite, 644', MF 85.

(89) Magnesite, 644', MF 85.

(90) Magnesite, 644', MF 85.

(91) Magnesite, 649', MF 86.

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864052

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(92)	(93)	(94)	(95)	(96)	(97)	(98)
Mg	0.1460	0.1335	0.2753	0.2745	0.2789	0.2841	0.2851
Ca	0.1789	0.2021	0.0005	0.0013	0.0003	<0.0000	<0.0000
Fe	0.0048	0.0053	0.0159	0.0168	0.0053	0.0043	0.0060
Mn	0.0004	0.0005	0.0007	0.0009	0.0007	0.0006	0.0008
MgO	0.2421	0.2215	0.4565	0.4552	0.4624	0.4711	0.4728
CaO	0.2504	0.2828	0.0007	0.0018	0.0004	<0.0000	<0.0000
FeO	0.0062	0.0068	0.0205	0.0217	0.0068	0.0056	0.0077
MnO	0.0005	0.0001	0.0010	0.0012	0.0009	0.0008	0.0001
Total	0.9903	0.9946	0.9974	0.9978	0.9947	0.9988	1.0007

No. of ions on basis of three O atoms.

Mg	0.5480	0.5085	0.9649	0.9630	0.9721	0.9887	0.9928
Ca	0.4072	0.4642	0.0011	0.0027	0.0006	0.0004	0.0000
Fe	0.0079	0.0088	0.0243	0.0257	0.0081	0.0065	0.0091
Mn	0.0007	0.0002	0.0012	0.0014	0.0011	0.0009	0.0012
$\sum n_i$	0.9638	0.9817	0.9915	0.9928	0.9819	0.9965	1.0091

- (92) Dolomite, 664'5", MF 79. Contains many small grains of magnesite.
 (93) Dolomite, 664'5", MF 79.
 (94) Magnesite, 664'5", MF 79.
 (95) Magnesite, 664'5", MF 79.
 (96) Magnesite, 781', MF 95.
 (97) Magnesite, 781', MF 95.
 (98) Magnesite, 784', MF 95.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(99)	(100)	(101)	(102)	(103)	(104)	(105)
Mg	0.2837	0.2746	0.2811	0.2907	0.2899	0.2858	0.1452
Ca	<0.0000	<0.0000	0.0007	0.0006	0.0006	0.0018	0.2113
Fe	0.0058	0.0136	0.0032	0.0027	0.0024	0.0026	0.0005
Mn	0.0007	0.0006	0.0008	0.0005	0.0005	0.0007	0.0006
MgO	0.4704	0.4554	0.4662	0.4821	0.4808	0.4739	0.2408
CaO	<0.0000	<0.0000	0.0009	0.0008	0.0008	0.0025	0.2956
FeO	0.0074	0.0175	0.0041	0.0035	0.0031	0.0034	0.0006
MnO	0.0008	0.0008	0.0010	0.0007	0.0007	0.0010	0.0008
Total	0.9992	0.9952	0.9962	1.0040	1.0003	1.0004	1.0086

No. of ions on the basis of three O atoms.

Mg	0.9879	0.9016	0.9784	1.0100	1.0073	0.9943	0.5487
Ca	0.0000	0.0001	0.0014	0.0012	0.0012	0.0038	0.4842
Fe	0.0087	0.0207	0.0048	0.0041	0.0036	0.0040	0.0007
Mn	0.0010	0.0010	0.0012	0.0008	0.0008	0.0011	0.0011
$\sum n_i$	0.9976	0.9834	0.9858	1.0161	1.0129	1.0032	1.0347

(99) Magnesite, 787', MF 95.

(100) Magnesite, 787', MF 95.

(101) Magnesite, 847', MF 102.

(102) Magnesite, 914', MF 109.

(103) Magnesite, 914', MF 109.

(104) Magnesite, 938', MF 113.

(105) Dolomite, 940', MF 113.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(106)	(107)	(108)	(109)	(110)	(111)	(112)
Mg	0.1343	0.2892	0.1354	0.2848	0.2859	0.1381	0.1435
Ca	0.2077	0.0006	0.2085	0.0004	0.0006	0.2144	0.2158
Fe	0.0009	0.0021	0.0004	0.0033	0.0035	0.0000	0.0001
Mn	0.0009	0.0007	0.0003	0.0010	0.0011	0.0000	0.0013
MgO	0.2228	0.4796	0.2245	0.4722	0.4741	0.2291	0.2380
CaO	0.2906	0.0008	0.2917	0.0006	0.0008	0.2999	0.3020
FeO	0.0012	0.0028	0.0005	0.0043	0.0045	0.0000	0.0002
MnO	0.0012	0.0009	0.0004	0.0012	0.0014	0.0000	0.0004
Total	0.9967	1.0025	0.9975	0.9990	1.0004	1.0035	1.0097

No. of ions on the basis of three O atoms.

Mg	0.5087	1.0049	0.5124	0.9910	0.9950	0.5231	0.5430
Ca	0.4769	0.0012	0.4785	0.0009	0.0012	0.4922	0.4953
Fe	0.0015	0.0032	0.0006	0.0051	0.0053	<0.0000	0.0002
Mn	0.0015	0.0011	0.0005	0.0015	0.0017	<0.0000	0.0005
$\sum n_i$	0.9886	1.0104	0.9920	0.9985	1.0032	1.0153	1.0390

- (106) Dolomite, 940', MF 113.
 (107) Magnesite, 940', MF 113.
 (108) Dolomite, 940', MF 113.
 (109) Magnesite, 940', MF 113.
 (110) Magnesite, 940', MF 113.
 (111) Dolomite, 957', MF 116.
 (112) Dolomite, 957', MF 116.

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.I. (cont.)

	(113)	(114)	(115)	(116)	(117)	(118)	(119)
Mg	0.2877	0.2832	0.2744	0.2866	0.1335	0.2797	0.1487
Ca	0.0006	0.0006	0.0007	0.0056	0.2141	0.0010	0.2054
Fe	0.0043	0.0034	0.0054	0.0058	0.0020	0.0052	0.0019
Mn	0.0002	0.0003	0.0008	0.0007	0.0000	0.0003	0.0003
MgO	0.4771	0.4697	0.4550	0.4753	0.2215	0.4638	0.2462
CaO	0.0009	0.0008	0.0009	0.0008	0.2996	0.0013	0.2874
FeO	0.0056	0.0044	0.0070	0.0074	0.0025	0.0067	0.0025
MnO	0.0003	0.0003	0.0011	0.0009	0.0000	0.0003	0.0004
Total	1.0021	0.9974	0.9907	1.0021	1.0002	0.9953	1.0008

No. of ions on the basis of three O atoms.

Mg	1.0008	0.9858	0.9578	0.9981	0.5067	0.9751	0.5601
Ca	0.0014	0.0012	0.0014	0.0012	0.4927	0.0020	0.4698
Fe	0.0066	0.0052	0.0083	0.0087	0.0033	0.0079	0.0031
Mn	0.0004	0.0004	0.0013	0.0011	0.0000	0.0004	0.0005
$\sum n_i$	1.0092	0.9926	0.9688	1.0091	1.0027	0.9854	1.0335

(113) Magnesite, 959', MF 116.

(114) Magnesite, 959', MF 116.

(115) Magnesite, 960', MF 116.

(116) Magnesite, 960', MF 116.

(117) Dolomite, 960', MF 116.

(118) Magnesite, 960', MF 116.

(119) Dolomite, 960', MF 116.

055

864056

Table 7. Magnesite and dolomite analyses from D.D.H. M.C.1. (cont.)

	(120)
Mg	0.1432
Ca	0.2126
Fe	0.0006
Mn	0.0000
MgO	0.2375
CaO	0.2975
FeO	0.0007
MnO	0.0000
Total	1.0074

No. of ions on the basis of three O atoms.

Mg	0.5416
Ca	0.4875
Fe	0.0009
Mn	0.0000
$\sum n_i$	1.0300

(120) Dolomite, 960', MF 116.

056

864057

Table 8. Analysis of magnesite from Arthur River.

	(1)	(2)	(3)	(4)	(5)	(6)
Mg	0.2771	0.2927	0.2792	0.2715	0.2709	0.1145
Ca	0.0004	0.0003	0.0003	0.0003	0.0002	0.2152
Fe	0.0122	0.0025	0.0084	0.0189	0.0191	0.0036
Mn	0.0014	0.0008	0.0011	0.0001	0.0011	0.0009
MgO	0.4605	0.4854	0.4630	0.4502	0.4656	0.2153
CaO	0.0005	0.0004	0.0004	0.0004	0.0024	0.2897
FeO	0.0158	0.0032	0.0108	0.0270	0.0278	0.0052
MnO	0.0019	0.0010	0.0015	0.0002	0.0016	0.0015
Total	0.9982	1.0062	0.9972	0.9953	1.0060	0.9943

No. of ions on the basis of three O atoms.

Mg	0.9713	1.0157	0.9744	0.9530	0.9852	0.4925
Ca	0.0008	0.0007	0.0006	0.0006	0.0004	0.4763
Fe	0.0186	0.0037	0.0127	0.0288	0.0330	0.0067
Mn	0.0022	0.0012	0.0018	0.0002	0.0020	0.0019
$\sum n_i$	0.9929	1.0213	0.9895	0.9826	1.0206	0.9774

- (1) Magnesite from Arthur River deposit, MF 127.
- (2) Magnesite from Arthur River, MF 127. Dark area. Surface sample.
- (3) Magnesite from Arthur River, MF 127. Taken from lighter areas. Surface sample.
- (4) Magnesite from Arthur River, MF 127. Taken from light areas. Surface sample.
- (5) Magnesite from Arthur River, JW 16.
- (6) Dolomite from Arthur River, JW 16.

Table 9. Analyses of silicates associated with the magnesite from Savage River.

	(1)	(2)	(3)	(4)
Si	0.1228	0.1388	0.2639	0.2822
Al	0.0960	0.1106	0.0014	0.0012
Fe	0.0108	0.0124	0.0022	0.0158
Mn	0.0001	0.0000	0.0000	0.0000
Mg	0.1738	0.1918	0.1763	0.1752
Ca	0.0052	0.0020	0.0002	0.0004
Na	0.0004	0.0003	0.0004	0.0002
SiO ₂	0.2627	0.2970	0.5646	0.6038
Al ₂ O ₃	0.1831	0.2089	0.0026	0.0023
FeO	0.0139	0.0159	0.0029	0.0203
MnO	0.0002	0.0000	0.0000	0.0000
MgO	0.2883	0.3180	0.2924	0.2906
CaO	0.0073	0.0029	0.0003	0.0005
Na ₂ O	0.0005	0.0005	0.0005	0.0002
Total	0.7559	0.8432	0.8633	0.9178

No. of ions

Si	2.8320	4.0000	2.8590	4.0000	7.896	7.9393	7.989	8.0000
Al	1.1680		1.1410		0.0432		0.0110	
Al	1.1570		1.2292		-		0.0250	
Fe	0.1256		0.1282		0.0333		0.2248	
Mn	0.0015	6.0102	0.0000	5.9588	0.0000		0.0000	
Mg	4.6316		4.5634		6.0967	6.1483	5.3732	5.636
Ca	0.0838		0.0294		0.0040		0.0077	
Na	0.0107		0.0086		0.0143		0.0052	

- (1) Chlorite. MF 38. Thin 10-15 μm laths of chlorite in dolomite.
- (2) Chlorite. MF 38. Another lath.
- (3) Talc. 39' MF 38.
- (4) Talc. 62' MF 40.

058

864059

Table 9. Analyses of silicates (cont.)

	(5)	(6)	(7)	(8)
Si	0.1335	0.1317	0.1307	0.3038
Al	0.1037	0.1032	0.1028	0.0006
Fe	0.0053	0.0053	0.0047	0.0057
Mn	0.0001	0.0002	0.0001	<0.0000
Mg	0.1930	0.1925	0.1918	0.1935
Ca	0.0004	0.0001	0.0002	0.0001
Na	0.0001	0.0000	0.0002	0.0000
SiO ₂	0.2856	0.2817	0.2797	0.6499
Al ₂ O ₃	0.1960	0.1950	0.1942	0.0012
FeO	0.0068	0.0068	0.0061	0.0073
MnO	0.0001	0.0002	0.0001	0.0001
MgO	0.3200	0.3928	0.3181	0.3210
CaO	0.0005	0.0001	0.0003	0.0018
Na ₂ O	0.0002	0.0000	0.0003	0.0000
Total	0.8093	0.8031	0.7987	0.9813

No. of ions

Si	2.7328	4.0000	2.837	4.0000	3.2360	4.0000	8.0020	8.002
Al	1.2672		1.168		0.7640		-	
Al	1.0410		1.1517		1.8840		0.0178	
Fe	0.0687		0.0572		0.0589		0.0753	
Mn	0.0009	6.113	0.0020	6.0056	0.0014	7.442	0.0001	5.986
Mg	5.0000		4.7933		5.4874		5.8912	
Ca	0.0005		0.0013		0.0031		0.0018	
Na	0.0009		0.0000		0.0069		0.0000	

(5) Chlorite, 57' MF 39.

(6) Chlorite, 57' MF 39.

(7) Chlorite, 57' MF 39.

(8) Talc. 210', MF 47.

Table 9. Analyses of silicates (cont.)

	(9)	(10)
Si	0.2819	0.2801
Al	0.0006	0.0010
Fe	0.0044	0.0170
Mn	0.0002	0.0002
Mg	0.1802	0.1721
Ca	0.0000	0.0001
Na	0.0005	0.0002
SiO ₂	0.6031	0.5993
Al ₂ O ₃	0.0012	0.0019
FeO	0.0057	0.0218
MnO	0.0003	0.0003
MgO	0.2989	0.2854
CaO	0.0000	0.0002
Na ₂ O	0.0001	0.0002
Total	0.9091	0.9091

No. of ions

Si	8.0000	8.0000	8.0080
Al	-	-	-
Al	0.0179		0.0293
Fe	0.0627		0.2441
Mn	0.0035	5.995	0.0029
Mg	5.9093		5.6861
Ca	0.0000		0.0023
Na	0.0016		0.0060

(9) Talc, 200', MF 47.

(10) Talc. Adjacent to Fe-rich magnesite of Analysis (120).

10. QUALITATIVE SPECTROGRAPHIC ANALYSIS

A qualitative spectrographic analysis was performed by the Australian Mineral Development Laboratories on the Samples at 360' and 855' for D.D.H. M.C.1. The results are as follows

Sample No.	Heavy trace (0.1 to 1%)	Trace (0.01 to 0.1%)	Faint trace (0.001 to 0.01)	Very faint trace (0.0001 to 0.001%)
360'	Ca, K	Mn, Al, Pb, Na	Cu, Zn, Li	Ni, Sc
855'	Si, Fe	K, Mn, Na	Al, Li, Pb, Zn, Cu, B	Sc

It is surprising that no Fe was detected in the 360' sample and that no Cr was detected in either sample. The Al, K and Na are associated probably with minor amounts of mica and feldspar. No Pb-rich minerals have yet been observed. Li and B cannot be detected on the electron microprobe, but see the next section.

11. BORON LEVELS IN THE SAVAGE RIVER MAGNESITES

In view of the importance of the B concentration in magnesite, 15 samples of ore were determined for B quantitatively by E.S. Pilkington. About 10 g of rock was crushed, and 200-300 mg of this was then decomposed with sodium peroxide sintering, dissolved and acidified, and the boron extracted with ethyl hexanediol. Curcumin was used to develop a colour for the spectrophotometric determination. Analyses are presented in Table 10, and are within 20% at levels <1 $\mu\text{g/g}$, 10% at 1 $\mu\text{g/g}$, 5% at 10 $\mu\text{g/g}$ and 3% at levels about 100 $\mu\text{g/g}$.

These results show that the level of B in both magnesite and dolomite is very low. In the case of the eight magnesite-rich (>80%

magnesite) samples, the amount never exceeded 6 µg/g. The 601' sample of dolomite was found to be significantly higher at 38 µg/g. The 649' sample, rich in talc schist and a mixture of both dolomite and magnesite is anomalously high. But detailed mineralogical investigations of this sample could not identify any B-rich mineral. Qualitative spectrographic analyses (see Section 10) also detected B in one sample, but again at very low levels.

Table 10. B determinations for samples taken from D.D.H. M.C.1.

Sample	B (µg/g)	Description of sample
221'	4.4	Mainly magnesite. Trace of silicates and some dolomite.
264'	4.7	Mainly magnesite. Minor dolomite.
376'	1.2	Predominantly magnesite.
504'	0.9	Predominantly magnesite.
555'	0.3	Predominantly magnesite.
578'	1.5	Predominantly magnesite.
625'	1.2	Mainly magnesite with a little dolomite.
700'	5.9	Magnesite with traces of Predominantly magnesite.
950'	1.3	Predominantly magnesite.
17'	3.6	Predominantly dolomite.
30'	1.4	Predominantly dolomite.
62'	0.8	Predominantly dolomite.
100'	0.9	Predominantly dolomite.
601'	38	Predominantly dolomite.
649'	236	Dolomite: magnesite 3:1. 30% silicates.

12. THE EXTENT AND QUALITY OF THE ORE BODY

12.1 THE SIZE OF THE ORE BODY

The exact size of the ore body is very uncertain. Both bore holes (M.C.1 and M.C.2) prove that the magnesite extends over an area of 400,000 square feet (37160 metres squared). But the width and the relative positions of the various lithological divisions are not the same in both bore holes (see details in Appendix 2). For example, the main dolomite and schist horizon, which extends down to about 200' in D.D.H. M.C.1, is found to be only 61' in D.D.H. M.C.2. Also, the second major dolomite horizon at about 420' in M.C.1, is not found at all in the core samples of M.C.2. Because neither boreholes reached the termination of the carbonate, and because the strike and dip is both uncertain and variable, the westerly extension of the ore is very uncertain. But the North-South extension is even more uncertain. There is no evidence to suggest that the magnesite extends any distance North of M.C.1 (Fig. 2). Extensive drilling about the central Savage River magnetite deposit has found no further magnesite. Outcrops at Bowry Creek and magnesite horizons found in bore holes to the south suggest the possibility that the ore may extend to the south, but it may occur as a series of isolated lenses, rather than a continuous deposit from Main Creek. More precise boundaries of the magnesite can only be obtained by a further drilling program. A bore hole sunk between M.C.1 and M.C.2, 200 m to the W, and a bore hole 400 m S of M.C.2 would be most valuable in this respect. With these reservations in mind, an estimate of the reserves can be made.

Carbonate intersection	III	37160 m ² .
North-south extension	III	500 m.
Total volume	=	18,580,871 m ³ .
MgCO ₃ content.	80%	
Density of MgCO ₃		3 gm/cm ² or 3 tonnes/m ³ .

Estimated reserve III 44.6 m tonnes.

As already stated the most uncertain figure in this estimate is the North-south extension. The lower limit, restricting the extension to

063

about the distance between bore holes, is about 250 m, which would halve the reserves. It is considered that the most likely range of reserves is between 30 and 45 million tonnes.

12.2 THE PURITY OF THE MAGNESITE

An interesting and significant find of this work is that the amount of Fe in the magnesite varies with depth (Fig. 46). Close to the surface Fe in rock which is predominantly magnesite reaches values of about 3% FeCO₃. Close to the termination of drilling at 1000', the Fe content has fallen to less than 1% FeCO₃. Also magnesite found in rocks which are predominantly dolomite contains up to 15% FeCO₃. No data has been collected on variation of FeCO₃-magnesite along the strike.

The economic implications of these findings are uncertain. They do suggest that a grade of magnesite that would contain less than 1% FeCO₃ could be mined without chemical beneficiation, from the deep horizons.

13. THE ORIGINS OF THE SAVAGE RIVER MAGNESITE DEPOSIT

Three main modes of formation have been considered.

- (1) By sedimentary processes.
- (2) By CO₂-metasomatism.
- (3) By Mg-metasomatism.

Urquhart (1966) favoured an origin by Mg-metasomatism, mainly on the grounds that the magnesite was concordant with the adjacent metasediments, and that the impurities found in the deposit were different from those expected from a sedimentary sequence. However, a sedimentary origin should not be dismissed out of hand. The concordance with adjacent metasediments would just as much favour a sedimentary deposition of magnesite. Although generally concordant, rocks from the two bore holes indicate that major features of the sequence do not continue over distances of more than 100 m. In particular the major dolomite and schist horizons cannot be matched in both cores. There is no magnesite a few kilometres to the north and only sporadic magnesite and dolomite, which occurs on several horizons, is found to the south. Unless complex

064

faulting is proposed, the sedimentary sequence, depositing either the magnesite or dolomite, must have been in the form of a discordant lenses, with the area of carbonate deposition extending and contracting considerably over relatively short periods of time. Such an environment might produce periods of high evaporation, with resulting magnesite deposition, in a manner similar to that now producing the dolomites and magnesites of the Coorong Area, in South Australia (von der Borch and Lock (1979)).

It is also of significance that extensive magnesite deposits of Precambrian age occur in South Australia. At Port Germein Gorge and in the Mundallio area magnesite occurs as thin (about 1 m) beds associated with dolomites, cherts and quartzites (King, 1956). In the Copley and Witchelina areas magnesite beds are traceable for more than 30 km and range in thickness up to 1 m (Forbes, 1955). There was therefore during Precambrian times, an adjacent area with geological and climatic conditions conducive to magnesite deposition. Such conditions extended over a very wide area, for similar deposits of approximately the same age occur in Manchuria (Nishihara, 1956), North Korea (Shevelev, 1978) and Russia (e.g. Sidorenkov (1964)). It is very plausible to conclude therefore, that Precambrian or early Cambrian Tasmania could have had a similar environment, that allowed the deposition of a sequence of both magnesite, shale and dolomite.

Although in no way conclusive, some of the petrographic features of the magnesite suggest a primary origin without in situ replacement. Although the magnesite can be found as a medium or coarse grained carbonate, the original petrography appears to be one of a uniform, very fine grained rock, which has subsequently partially recrystallised, forming regions of more coarsely crystalline material. Any theory which involves replacement of dolomite to produce magnesite, should consider this petrographic evidence.

However, the sedimentary hypothesis becomes increasingly difficult to accept when more detailed comparisons are made. From the field evidence available, the Savage River deposit is laterally very short and vertically very extensive, compared with other unequivocal sedimentary deposits of magnesite. The composition of the magnesites from Savage River differ in the amounts of minor elements from those of other

065

environments, is different, as the data of Table 10 shows. Here a typical Savage River magnesite is compared with samples from Mundallio Creek and Copley, and from the magnesite found at Young in N.S.W. This later deposit is clearly a product of conversion of an ultra basic igneous rock by low temperature CO₂-rich water. An analysis of a further South Australian sample from Balcanoona Station, which is considered to be of metasomatic origin is also presented (Johns, 1963). Both the sedimentary magnesites from South Australia have very low Fe and Mn, and higher Ca than the Savage River carbonate (the mean was found to be 0.00143 atoms of Ca). With low grade metamorphism, similar to that encountered at Savage, the Ca would probably exsolve as a separate coexisting dolomite phase, which would leave a very pure magnesite. Two samples are not sufficient to be sure that these differences are constant throughout the South Australian deposit. But the data does point to possible significant differences. The magnesite from Young is chemically very distinct, with Ca as the only significant impurity. But the magnesite from Balcanoona Station contains similar amounts of Ca and Fe (though much less Mn) and even the zoning is typical to that found in Tasmania. There are very few published analyses of magnesite using electron microprobes, which analyse cations within the lattice, rather than bulk composition. Dabitziias (1980) analysed magnesite and dolomite from the Vavdos magnesite deposit in Greece. These show relatively high Ca and low but very variable Fe and Mn. In addition significant amounts of Na, Si and Al were also found. Dabitziias considered that these magnesites originated from ascending CO₂-rich solutions. This work suggests that these magnesites are also geochemically distinct but much more work is required to characterise the geochemistry of magnesites, before definitive statements can be made.

What is considered to be the most important evidence supporting a metasomatic genesis, is found in the observed replacement structures in the associated dolomite horizons, and in the trend towards Fe-poor magnesites at depth. The dolomite in particular shows instability, apparently being replaced by magnesite. For example, Figs. 17 to 19 show a series of dolomite grains with indented borders, and irregular patches of magnesite enclosed in the dolomite. In addition the dolomite

Table 11. Analyses of magnesites from other localities.

	(1)	(2)	(3)	(4)
Mg	0.2827	0.2850	0.2791	0.2917
Ca	0.0028	0.0025	0.0015	0.0015
Fe	0.0050	0.0020	0.0013	0.0002
Mn	<0.0000	0.0001	0.0068	0.0000
MgO	0.4738	0.4749	0.4736	0.4838
CaO	0.0039	0.0035	0.0020	0.0021
FeO	0.0072	0.0029	0.0187	0.0003
MnO	<0.0000	0.0002	0.0011	0.0000
Total	1.0022	1.0014	1.0066	1.0040

No. of ions on the basis of three O atoms.

Mg	0.9952	0.9952	0.9987	1.0122
Ca	0.0059	0.0053	0.0031	0.0032
Fe	0.0085	0.0034	0.0221	0.0004
Mn	<0.0000	0.0002	0.0013	0.0000
$\sum n_i$	1.0096	1.0041	1.0252	1.0158

- (1) Magnesite from Mundallio Creek, S. Australia.
- (2) Magnesite from Copley, S. Australia.
- (3) Magnesite from Balcanoona Station, S. Australia.
The Fe/Mg ratio varies over the sample and can be double the figure quoted.
- (4) Magnesite from Young, N.S.W.

Savage River magnesites have on average 0.00143 ions of Ca per three O atoms.

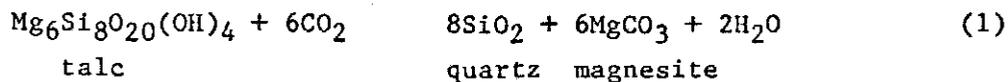
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appears zoned. Figures 15 and 16 for example shows the magnesite to have penetrated along cracks encircling small dolomite areas. The borders of each dolomite zone is Fe-deficient, so that the mechanism by which dolomite is replaced appears to be first the removal of the small (about 2% FeCO₃) amount of Fe within the dolomite, and second the removal of the Ca itself.

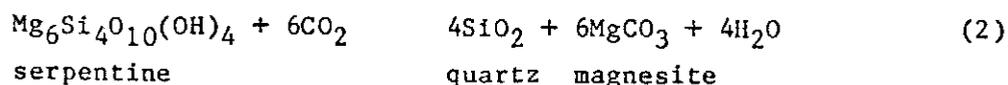
The main dolomite zone may represent the original dolomite, partly replaced by magnesite. The small amount of Fe-rich magnesite found in this zone, may now have compositions close to the magnesite that first formed in the metasomatic processes, and the preferential removal of Fe from the dolomite into solution could be a source of the extra Fe found in the associated magnesite. Alternatively, this Fe-rich magnesite was present in the original dolomite and was affected by the metasomatism only by the removal of Fe 5-10% FeCO₃.

Other details of the transformation of original dolomite are as uncertain. The laths of Fe-rich magnesite found in the magnesite beneath the dolomite and illustrated in Fig. 8, may be pseudomorphs after talc, although such transformation would require the complete removal of silica. Also, clusters of small quartz grains, illustrated in Figs. 20 and 21, again are probably a replacement structure after talc or chlorite. From equation (1), talc would alter to about equal volumes of quartz and magnesite, and this proportion corresponds approximately to that observed.

The whole deposit is within the quartz-magnesite stability field. Talc and chlorite are found associated with the dolomite that lies on top of the magnesite, and within the schist bands in the main sequence of the magnesite ore body. Therefore, the main composition of ore body lies within the system MgO-SiO₂-CO₂-H₂O and the two reactions,



and



describe very closely the phase boundaries about the quartz magnesite field, neglecting the effect of the small amounts of Fe present. As Johannes (1970 and 1969) described, the quartz magnesite field represents the lowest temperature field above 10 mol. % CO₂. The magnesite-talc, magnesite-quartz phase boundaries rises from about 370° to only 430°C with 80 mol. 1/2 CO₂. With the addition of dolomite, the boundary of the Ca-rich equivalent system, lies about 50°C higher (Winkler, 1967). The boundary also lies about 40°C higher for every additional 1000 Kb. hydrostatic pressure. At very low CO₂ values quartz and magnesite alter to serpentine. Talc and chlorite are only found in the main dolomite at the surface and in the schist bands within the magnesite. The predominant assemblage is that of magnesite, quartz and dolomite.

The most likely mechanism by which this Mg-metasomatism arose, is through the percolation of MgCl₂-rich solutions; a mechanism first proposed by Petraschetz (1932). This mechanism is preferred to that of a transformation by CO₂-metasomatism for reasons discussed in detail by Johannes (1970). Johannes considered that on the basis of the low solubilities of carbonates at moderately high temperatures, the removal of Ca would require enormous quantities of solvent. The high chloride concentrations in geothermic brines, and the occurrence of halide crystals in fluid inclusions indicates the ubiquitous occurrence of chloride solutions. Cationic exchange of Ca by Mg through salt solutions was found to be very rapid and very economical regarding solvent volumes. Johannes showed that the Ca:Mg ratio of the solution in equilibrium with dolomite or magnesite, changed only slightly with considerable variation in both total and CO₂-pressures, but increased rapidly with increasing temperature, between 250 and 350°C. This means that an increase in temperature promotes the transformation of dolomite into magnesite with the same Ca/(Ca + Mg) ratio in the acting solution. From experiments on rates of reactivity, Johannes considered that equilibrium was reached quickly, if solutions were allowed to migrate through the solid phases, and such rapid rates of reaction may help to explain the fine grained texture of the bulk of the magnesite.

As is illustrated in Fig. 46 there is a trend towards purer, Fe and Mn-poor magnesites with depth. Johannes has studied the equilibrium

compositions of the magnesite-siderite solid phase and the associated solutions. The relative compositions are highly dependent on temperature. Magnesite with less than 10% $FeCO_3$, at temperatures above $300^\circ C$ at an hydrostatic pressure of 1 Kb. and at a salt concentration of 1.0 molar, is in equilibrium with a solution which always contains more Fe. It was also concluded that a solution that reacts with dolomite at $350^\circ C$ to give magnesite, becomes relatively Fe-rich. Johannes experimental work also suggest that a metasomatic introduction of a predominantly Mg-rich salt solution, which contained small amounts of $FeCl_2$, would be expected to form Fe-rich magnesites at higher (cooler) horizons and Mg-rich magnesites at depth. This trend is shown in the Slovakian Jelsava Magnesite (Friedrich, 1951) where the FeO content falls from 3.8% at 300 m to 2.9% FeO at 450 m. Thus it is concluded that an explanation for a chemical trend across the whole ore body can be expressed in terms of one metasomatic process. There is no evidence to suggest that the Fe content would vary in a similar way through a thick sedimentary sequence of magnesites. Therefore, to obtain such trends, it would be necessary to add another stage, i.e. a metasomatic chemical adjustment, to the genesis of this deposit. The simpler metasomatic theory must be considered the most likely on the evidence so far procured. There remains the problem of the origin of the Mg-rich chloride solutions. The source is very uncertain. The serpentinites associated with the magnetite deposit to the North, the reported pyroxenite associated with the magnesites at Arthur River, and the Haezlewood ultrabasics, suggest possible sources, but this problem must at the moment remain unsolved. In addition, the transformation of dolomite implies the removal of large quantities of Ca, probably in the form of $CaCl_2$. There is no geological evidence that this Ca has formed other Ca-rich minerals locally, and it must be concluded that it has been removed completely from this region as an hydrothermal solution. Also, the significance of the relative proportions of Fe and Mn in coexisting magnesites and dolomites is not known, because of lack of detailed experimental work on the appropriate region of the $CaCO_3 - MgCO_3 - FeCO_3 - H_2O$ system at different hydrostatic and CO_2 -pressures.

The geological significance of the Savage River magnesites has not been discussed. It has been emphasised elsewhere how uncertain is the

070

geology of the area, and in particular how tenuous is the evidence for the more highly metamorphic rocks of the Arthur Lineament to be older than those of the Rocky Cape or Burnie formation. One major difficulty in subdividing the Precambrian is the very similar lithologies between the rocks within the Arthur Lineament and those to each side. Now all evidence suggests that the succession of Precambrian rocks in north west Tasmania contained practically no limestones until Cambrian or near Cambrian times (Spry, 1962). Both in the Zeehan-Corinna and Burnie Rocky Cape areas for example, over 14,000' of slates and quartzites are found with no dolomites. But at the beginning of the Cambrian succession, at almost every locality, there is a thick sequence of dolomite. It has already been pointed out, that just to the west of the Arthur Lineament, there are found the Savage River dolomites. It is very plausible to suggest therefore, that the Savage River magnesites that were once dolomites themselves, represent further outcrops of the Cambrian Savage River dolomites, and that the rocks of the Arthur Lineament are therefore of the same age as the Precambrian and early Cambrian succession to the North and West. In a similar way, the magnesites at Arthur River may be metasomatised Arthur River dolomites, again of early Cambrian age.

14. CONCLUSIONS

- 14.1 Ore reserves are at the moment ill-defined but must be at least 40 m tonnes. Selective mining of the white magnesite and the darker dolomite and schist, would produce an ore containing about 80% magnesite, 10% dolomite and 10% silicates (mainly quartz). The Fe-content of the magnesite would be about 3% initially but would decrease to less than 1% at depth (>900').
- 14.2 The magnesite is considered to have been derived by Mg-metasomation of dolomite. The solution carrying the Mg was most likely a dilute chloride solution. The temperature of formation was probably less than 400°C, with a CO₂ pressure of between 15 and 60 mol.% CO₂.

14.3 It is suggested tentatively that the magnesite deposit and the associated Whyte schists are not lower Precambrian, but upper Precambrian or even early Cambrian. The Precambrian succession continued throughout the period, depositing a thick series of quartzites, shales and mudstones. At the end of the Precambrian and during early Cambrian times a thick sequence of dolomites were deposited. The early members of this sequence are represented by the Savage and the Arthur River dolomites, to the north west of the Arthur Lineament, and the Savage River magnesites, inside the Arthur Lineament. A major crystal movement resulted in the down-throw and the metamorphism of these rocks within the Arthur Lineament. Subsequently, the dolomites within the Arthur Lineament were almost completely changed to magnesites.

15. PROPOSALS FOR FURTHER STUDIES

- 15.1 The Arthur River magnesites need to be investigated in more detail. In this locality there are outcrops of pyroxenite and it would be of interest to study the relationship between this ultra-basic rock and the magnesites.
- 15.2 A mineralogical investigation of the Cambrian dolomites of the area may provide evidence, one way or the other, for possible association with the Savage River magnesites and dolomites.
- 15.3 A detailed mineralogical study of other magnesite deposits in Australia may provide very important information to the understanding of these rocks. In particular the sedimentary deposits of South Australia, and the metasomatic magnesites of N.S.W. should be studied. It should be emphasised that the mineralogical techniques are unusual. Our backscattered electron detector permits a view of carbonate mineralogy hitherto rarely seen. And the amount of detailed electron microprobe work has so far been extraordinarily small.

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- 15.4 An experimental investigation into the system $\text{CaCO}_3 - \text{MgCO}_3 - \text{FeCO}_3 - \text{H}_2\text{O}$, in the area $(\text{CaMg})\text{CO}_3 - \text{MgCO}_3 - 20\% \text{FeCO}_3$. This should be conducted at differing pressures. In particular the compositions of coexisting $(\text{CaMgFe})\text{CO}_3$ and $(\text{MgFe})\text{CO}_3$ would be of great interest.
- 15.5 Further drilling would delineate the main magnesite ore body much more precisely. The positions of two bore holes are suggested in Section 12.

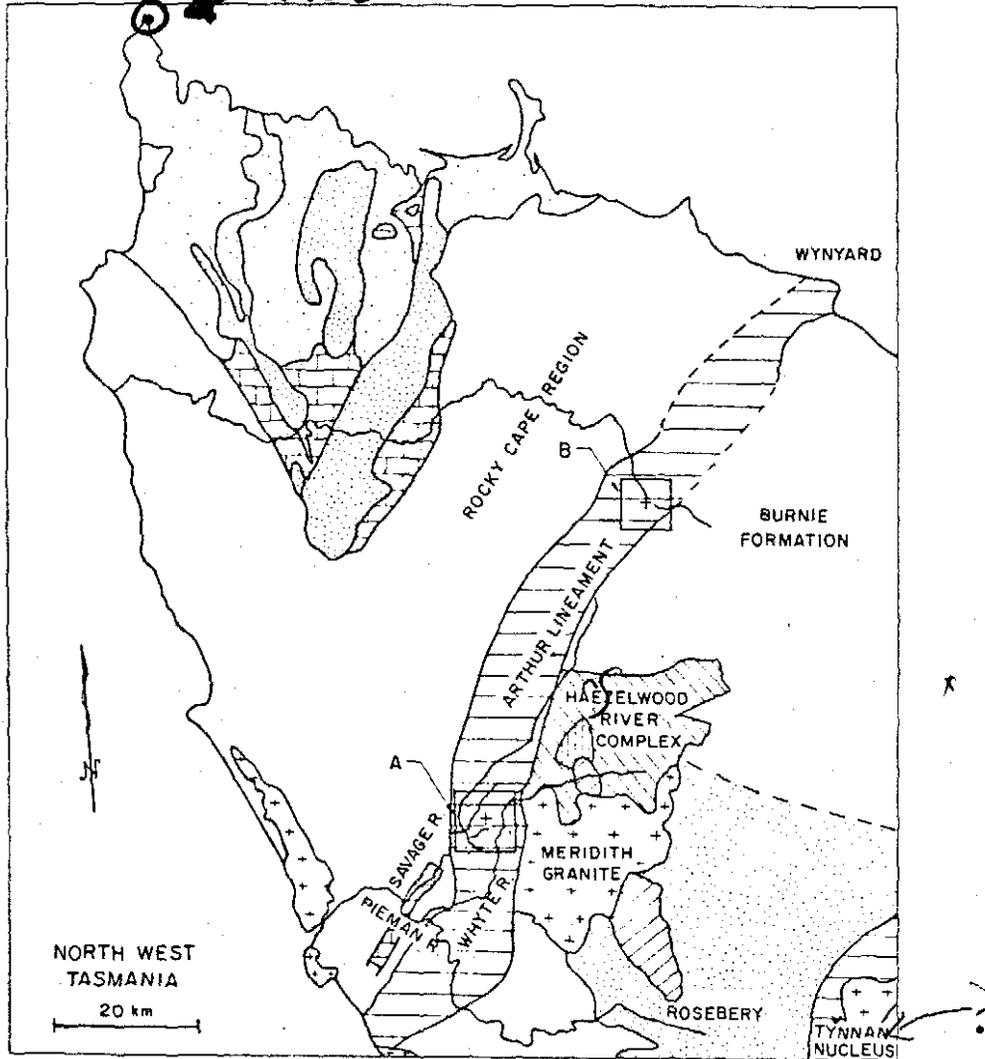
Fig. 1. The general geology of north west Tasmania. ^{post} ~~Pre~~-Devonian rocks are not included. The Savage River magnesites are found in the Block A and those from Arthur River in Block B.

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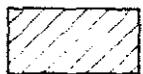
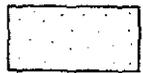
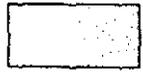
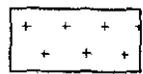
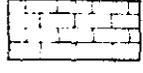
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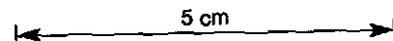
AMG REFERENCE POINTS ADDED

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LEGEND

	DEVONIAN MUDSTONES	IGNEOUS ROCKS	
	UNDIFFERENTIATED CAMBRIAN		CAMBRIAN ULTRA-BASICS SERPENTINITES
	UPPER CAMBRIAN GREYWACKES		DEVONIAN GRANITES
	LOWER CAMBRIAN DOLOMITES		THE SAVAGE RIVER MAGNESITE
	PRECAMBRIAN SILTSTONES AND QUARTZITES		THE ARTHUR RIVER MAGNESITE
	PRECAMBRIAN SCHISTS		

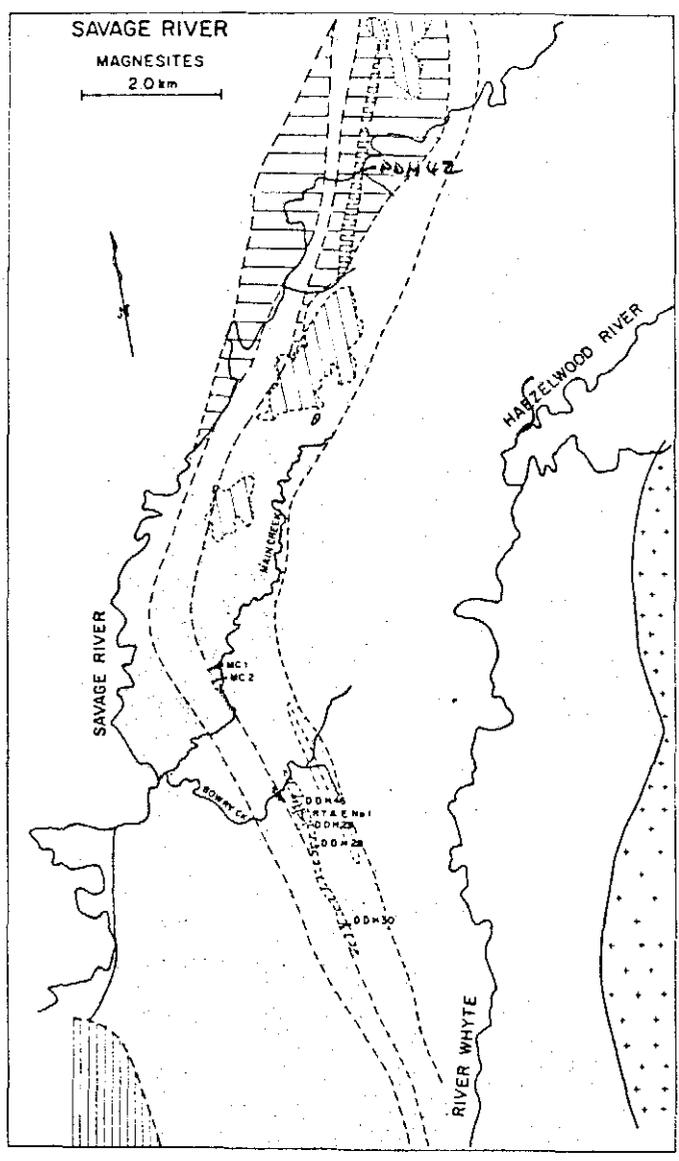


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Fig. 2. The geology of the area about Savage River. This map is based on the work of Urquhart (1966). In particular, Urquhart divides the Whyte schists into two types. The known surface outcrops of magnesite are indicated, as are the boreholes that have recorded magnesite. The magnetite deposits are also shown. Strike follows the general direction of the Whyte schists and dips are generally near vertical and towards the east.

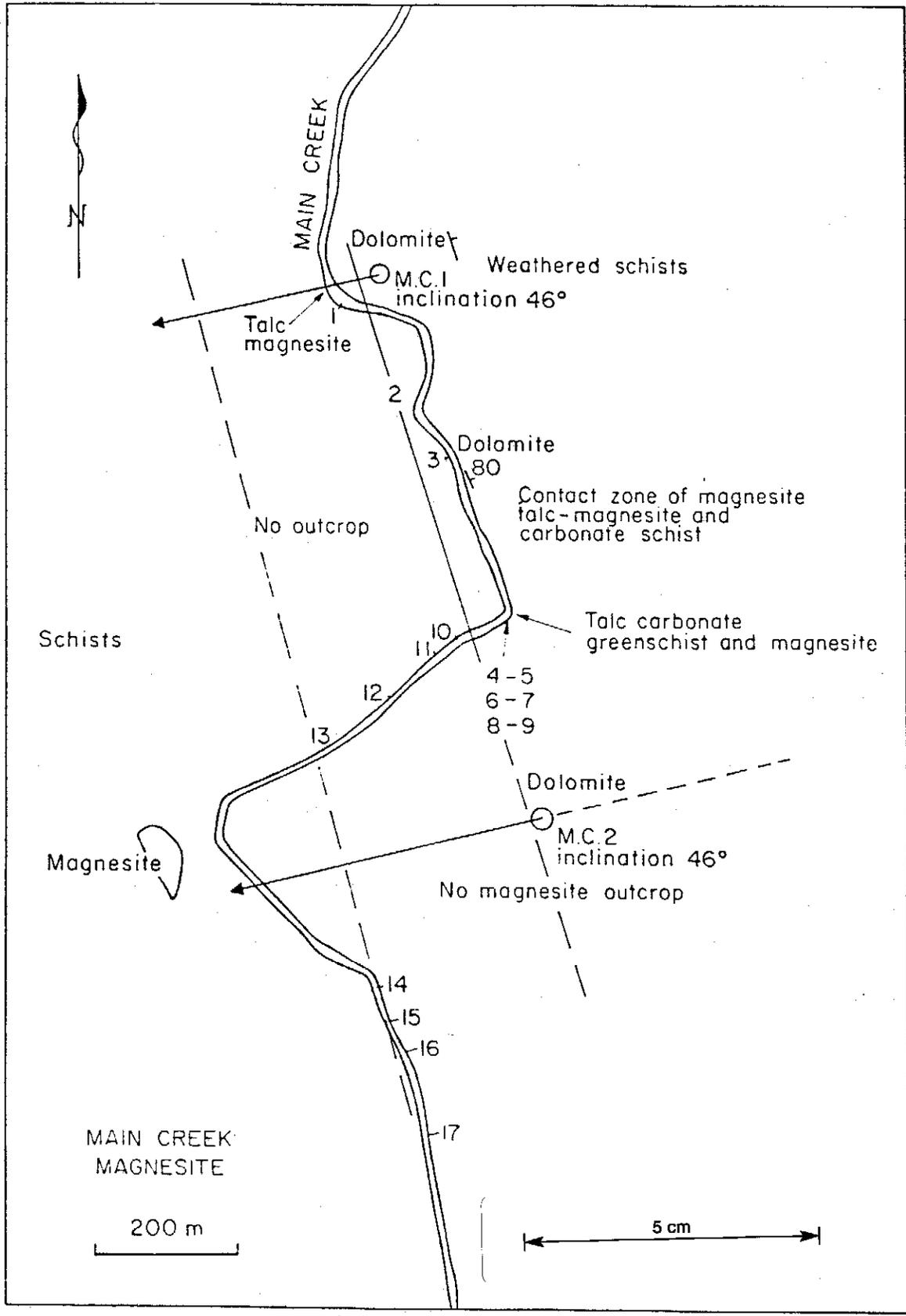


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LOWER CAMBRIAN		AMPHIBOLITES
UPPER PRECAMBRIAN		CORINNA SLATES
LOWER PRECAMBRIAN		WHYTE SCHISTS
		PSAMMATIC PELITIC
IGNEOUS ROCKS		
TERTIARY		BASALT
DEVONIAN		MERIDITH GRANITE
PRECAMBRIAN		MAGNESITE (<i>melasomalite?</i>)
		MAGNETITE

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Fig. 3. The geology of the Main Creek area, after Urquhart (1966). The Position and inclination of the two bores, the points where surface samples were collected, and the position and minimum width of the magnesite ore are shown.



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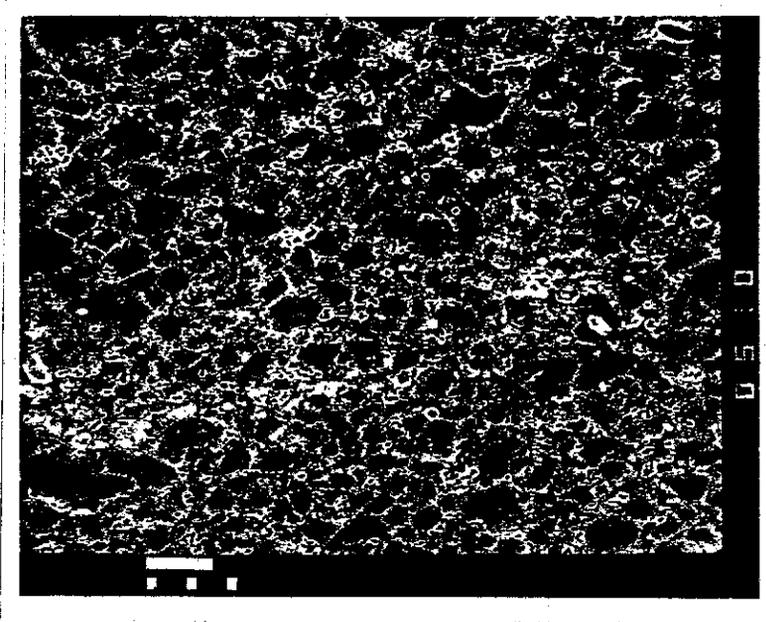


Fig. 4. Moderately fine grained magnesite showing Fe-rich borders about crystal edges. The bright small grains are quartz. The bar is 100 μ m MF 58, 340'.

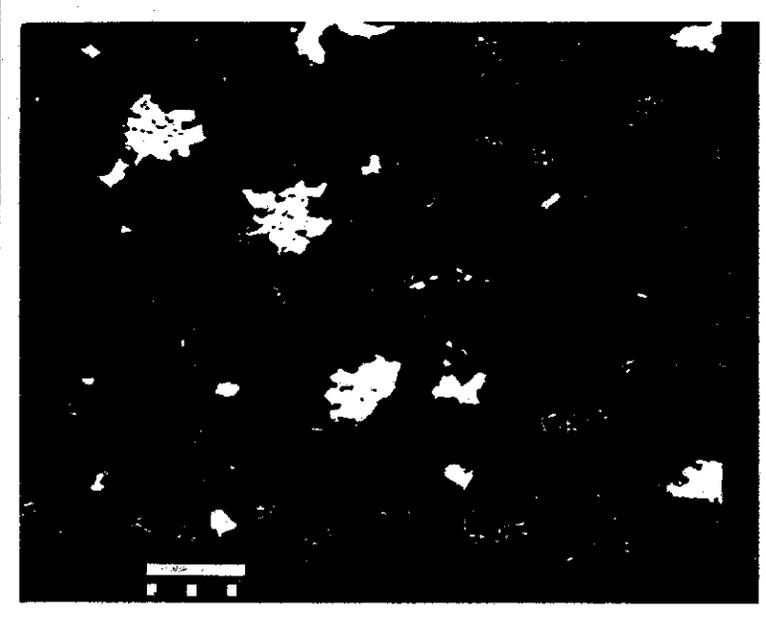


Fig. 5. A typical distribution of small irregular blebs of dolomite dispersed in homogeneous magnesite. Note how irregular the dolomite grains are. MF 58, 340'.

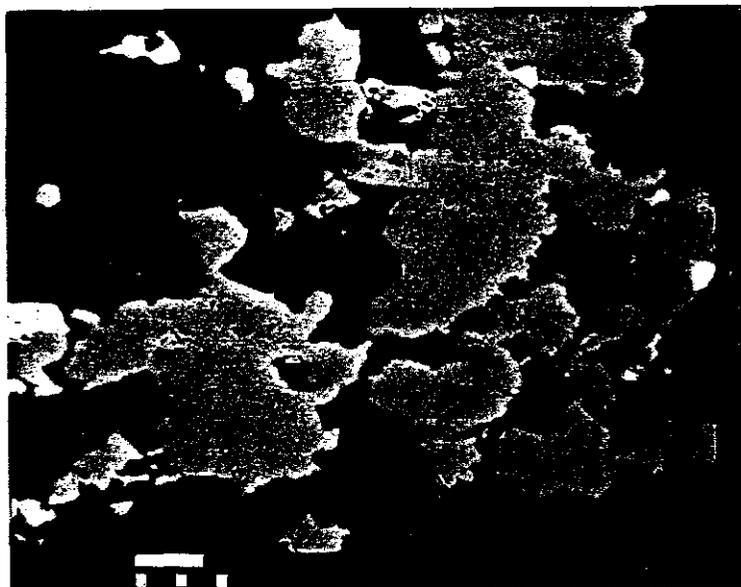


Fig. 6. Quartz is usually dispersed as small irregular grains within the magnesite. On occasion it occurs more plentifully as in this micrograph. It also commonly occurs as thin veins in the carbonate. The very bright grain is FeS_2 . MF 58, 340'. The bar is 100 μm .

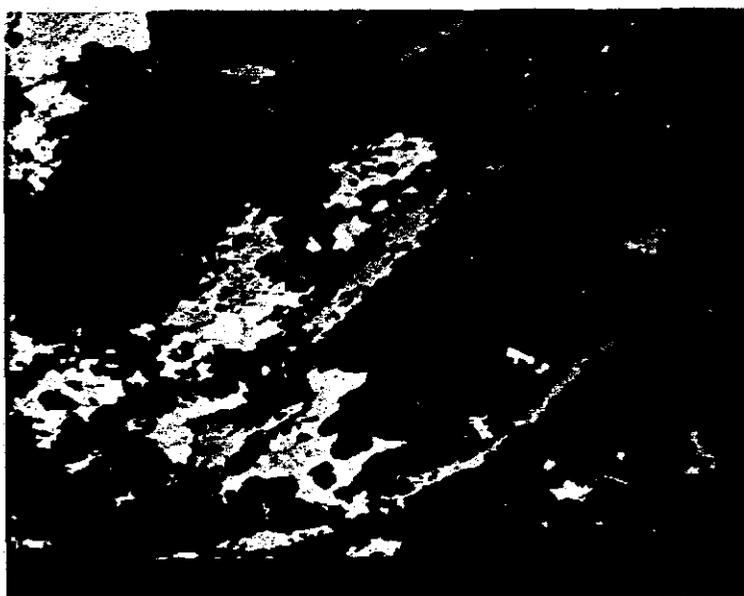


Fig. 7. Typical veining and inclusions of quartz and dolomite in magnesite. The long thin veins of uniform and slightly darker grey are quartz and the more mottled, very irregular and anhedral brighter areas are dolomite. Black is magnesite. MF 58, 340'.

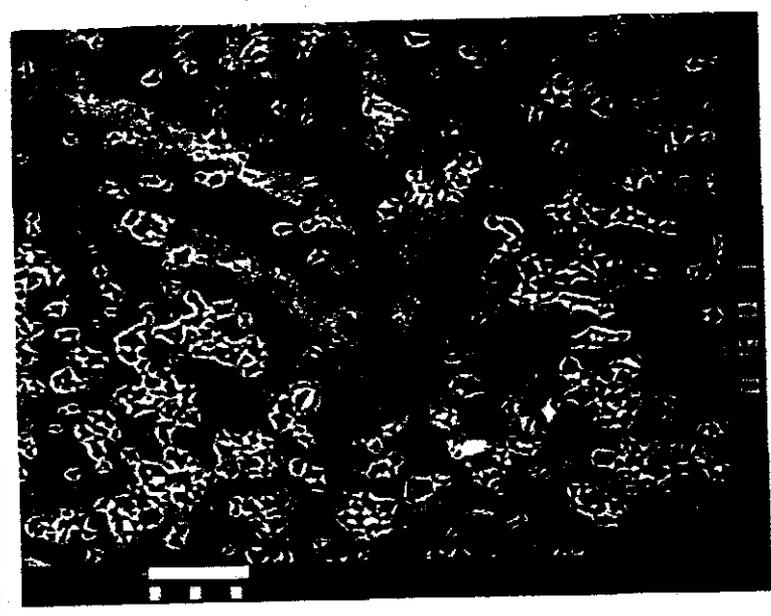


Fig. 8. Magnesite containing Fe-rich laths. These contain about 2% more FeCO_3 than the surrounding carbonate. MF 58, 340'. Bar represents 100 μm .

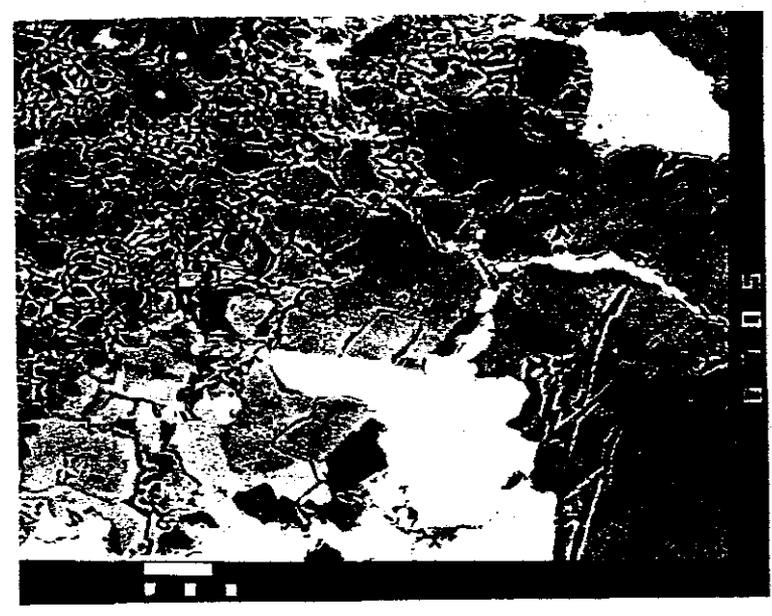


Fig. 9. Strongly zoned magnesite about dolomite (white). The light grey Fe-rich (5%) magnesite has formed rhythmically zoned areas about the dolomite. The main bulk of the magnesite seen on the top left corner has lower Fe and is homogeneous. MF 58, 340'. Bar represents 100 microns.



Fig. 10. Grains of Fe-rich magnesite in Fe-poor magnesite (dark grey). The centres of the grains are poor in Fe than their borders. Rhythmic zones, is evident as well. The surrounding magnesite is not homogeneous with some patches darker (lower Fe) than others. MF 127, Arthur River magnesite. The bar represents 100 μ m.

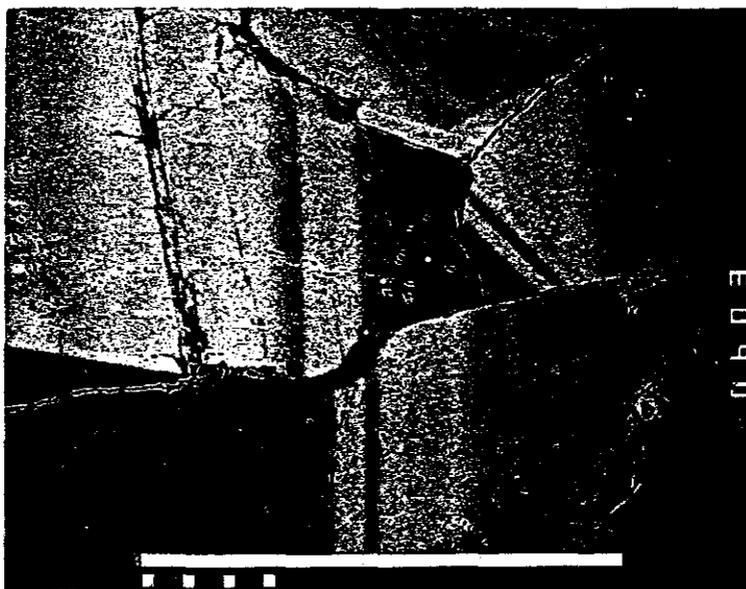


Fig. 11. An excellent example of rhythmic zoning in magnesite. Composition changes from about 4-5% FeCO_3 to 2% FeCO_3 (dark). MF 127. Arthur River magnesite. The bar represents 1000 μ m.

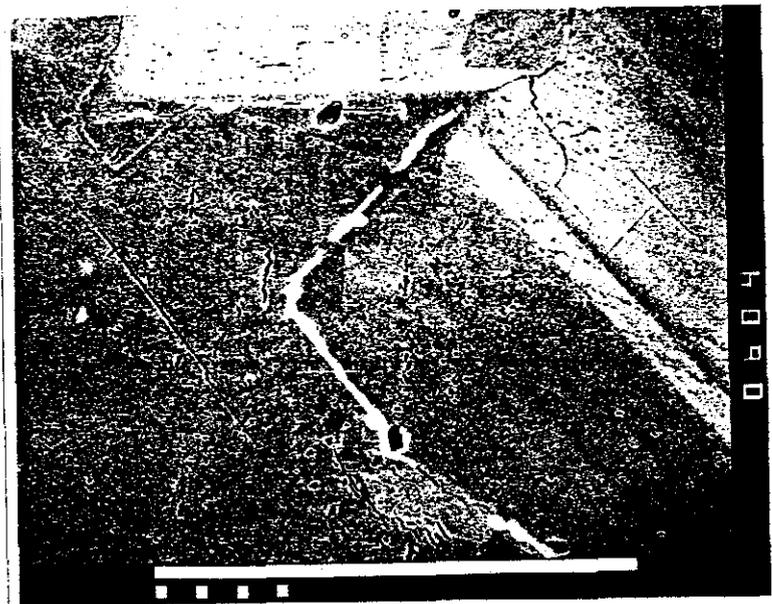


Fig. 12. Rhythmic zoning in magnesites. The grain is very close to the ore shown in Fig. 11. The white phase outlining one area is calcite, which must have precipitated much later than the magnesite itself. MF 127. Arthur River. The bar represents 1000 μ m.

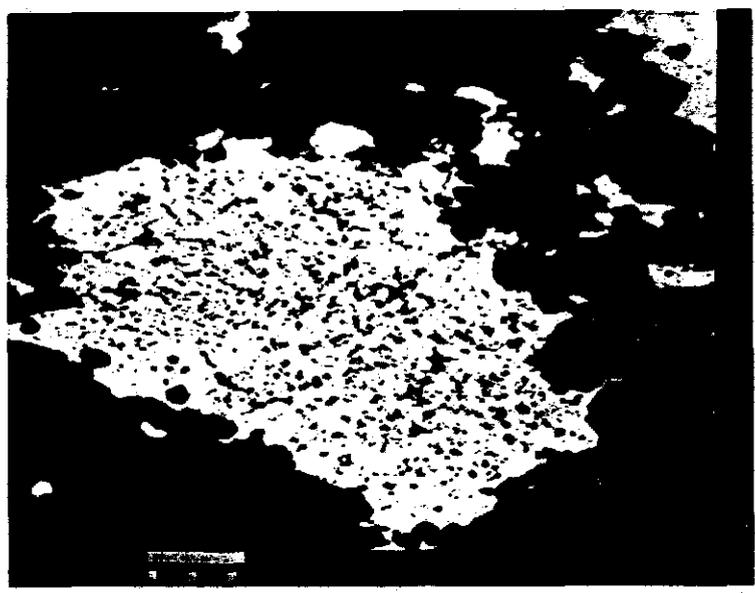


Fig. 13. A large isolated grain of dolomite showing many small magnesite inclusions. The borders are invariably very irregular and appear to have been replaced partially. MF 58, 340'. The bar represents 100 μ m.

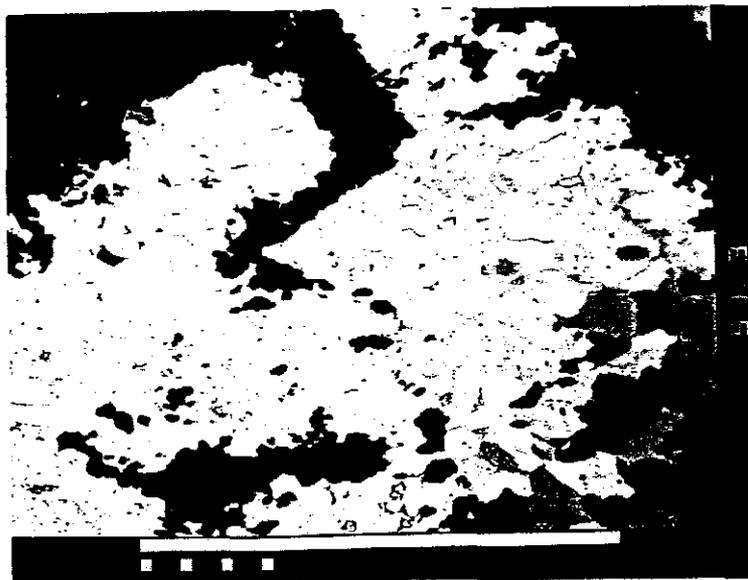


Fig. 14. An area of dolomite. Notice the mottled appearance of the dolomite in contrast to the even grey of the quartz grains located towards the bottom right hand side. The black is magnesite. MF 58, 340'. The bar represents 1000 μ m.

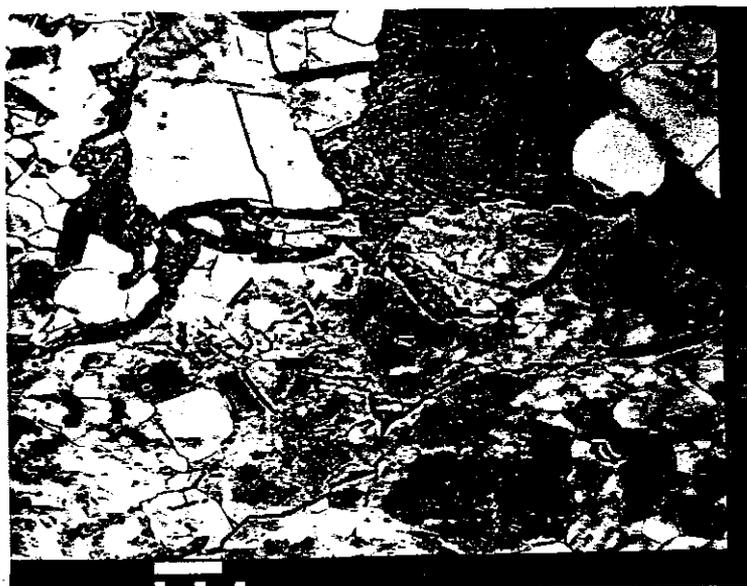


Fig. 15. Fe-Mg zoning in dolomite. The light grey areas are free of Fe whereas the mottled darker grey areas contain Fe up to about 2%. Chlorite occurs at the top of the figure as dark grey laths. MF 33, surface outcrop. Bar represents 100 μ m.

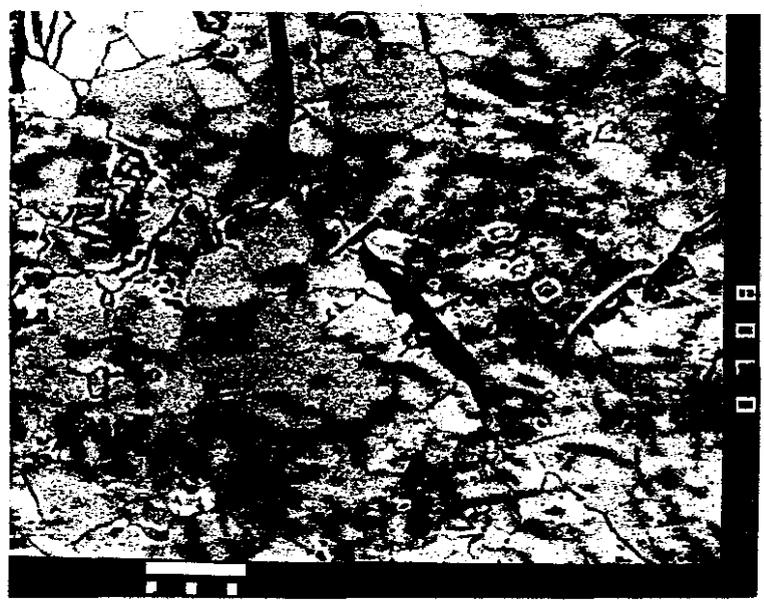


Fig. 16. Zoned dolomite. The mottled appearance of the dolomite from light to dark grey is due to Fe/Mg zoning, with Fe richer in the lighter areas. The very dark laths are talc. MF 33 surface sample no. 8. Bar represents 100 μ m.

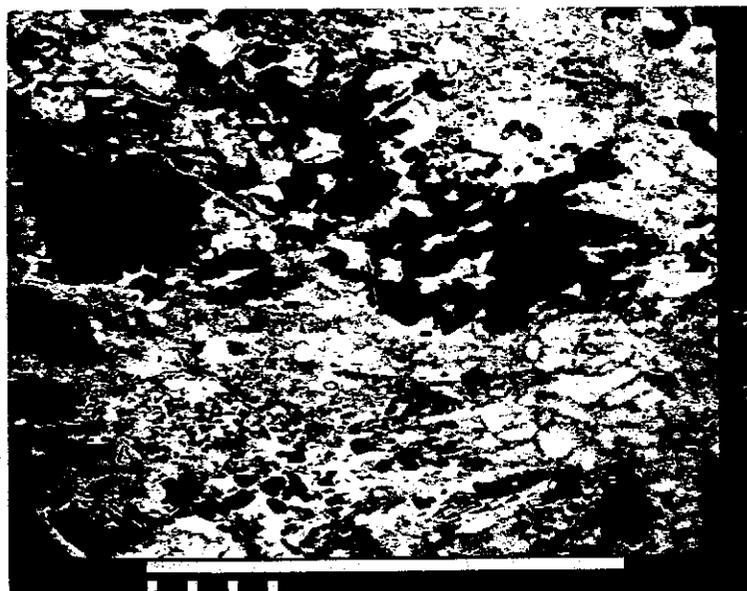


Fig. 17(a). Dolomite appears mottled (light grey) and shows replacement by magnesite (black). 17(b) is a detail of 17(a). Individual dolomite crystals or grains are surrounded by magnesite. The mottling is due to variations in Mg/Fe ratio in the dolomite. MF 127, Arthur River. Bar represents 1000 μm and 100 μm respectively.

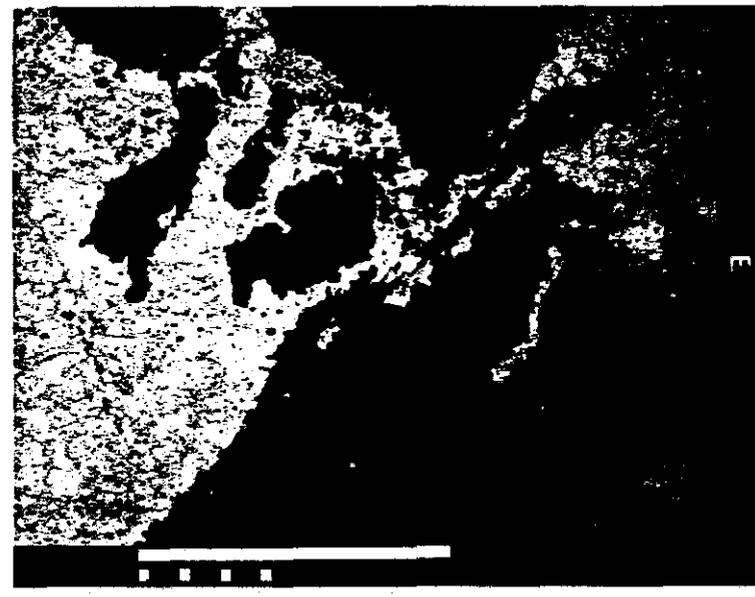
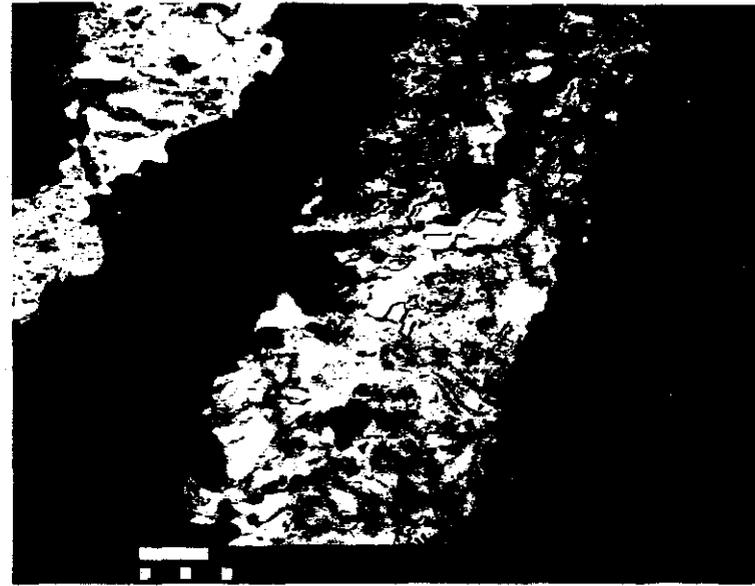


Fig. 18(a). Dolomite (mottled light grey) showing replacement features with magnesite (black). 18(b) is a detail of 18(a) showing how the dolomite appears to be in the process of being replaced by magnesite. Surface dolomite sample, MF 33 (No. 8). Bar represents 1000 μ m and 100 μ m respectively.

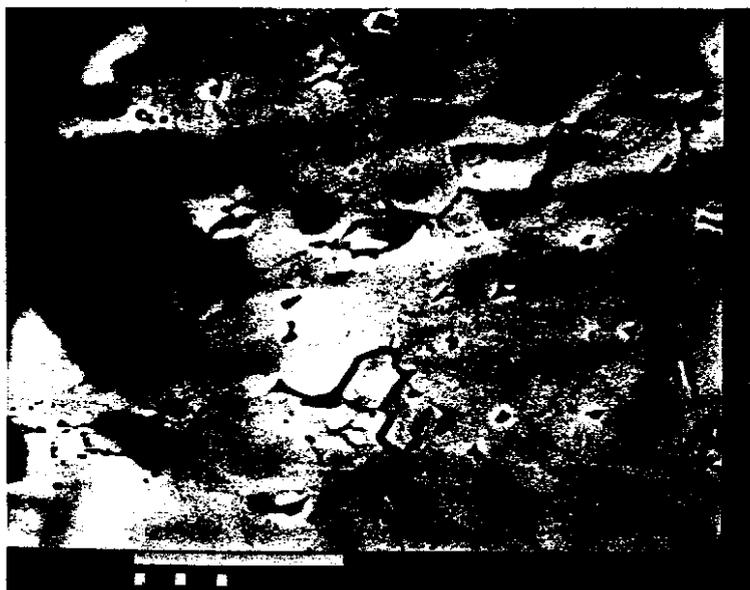


Fig. 19(a). Dolomite and magnesite. The dolomite (grey) appears to be in the process of being replaced by magnesite (black). Mottling is due to variations in Fe/Mg ratio. 19(b) is a detail of 19(a). The bar represents 100 μm . MF 33, surface sample No. 8.

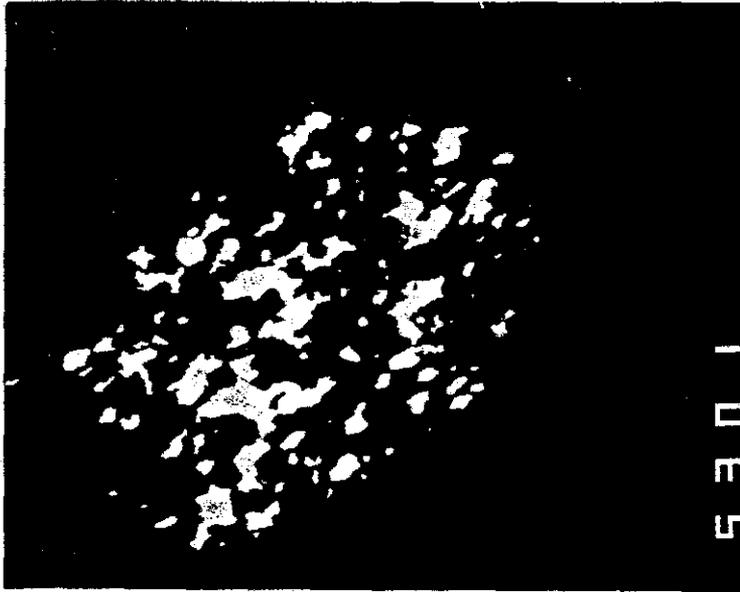


Fig. 20. Quartz (light grey) in magnesite (dark grey). The quartz may once have been a subeuhedral single crystal which has been replaced by magnesite. x 130. MF 102, 847'.



Fig. 21. Quartz (light grey small grains) forms a cluster of small crystals in magnesite (dark grey), close to a large dolomite crystal (light grey and mottled). Bar represents 100 μm . MF 102, 847'.

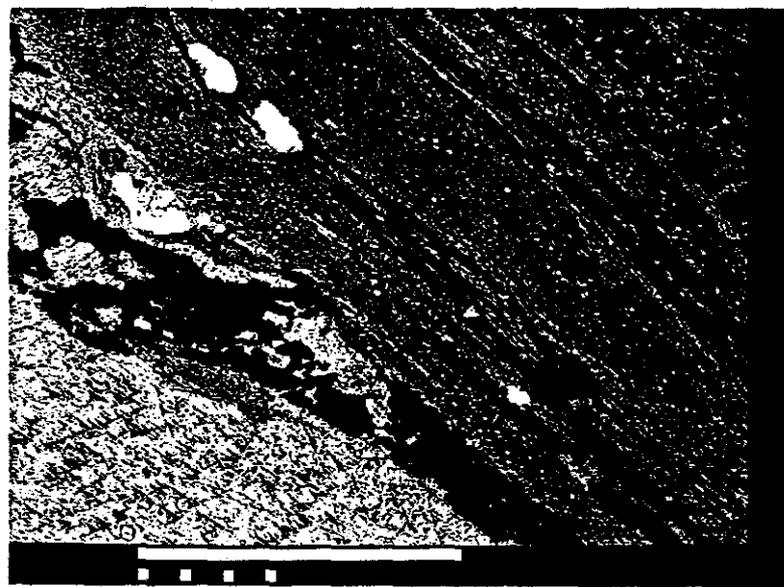
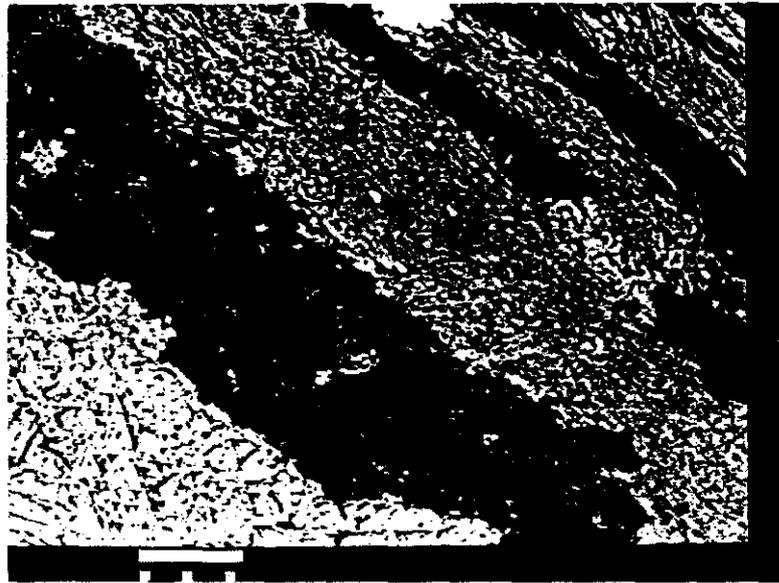


Fig. 22(a). Chlorite schist. Chlorite (dark grey) foliated with magnesite (black). Dolomite (med. grey) at the bottom left hand corner. The bright (white) areas are apatite. Bar represents 1000 μ m. 22(b) a detail of 22(a) showing the magnesite, which is particularly rich in Fe, zoned slightly. Bar represents 100 μ m. MF 41, 77'.

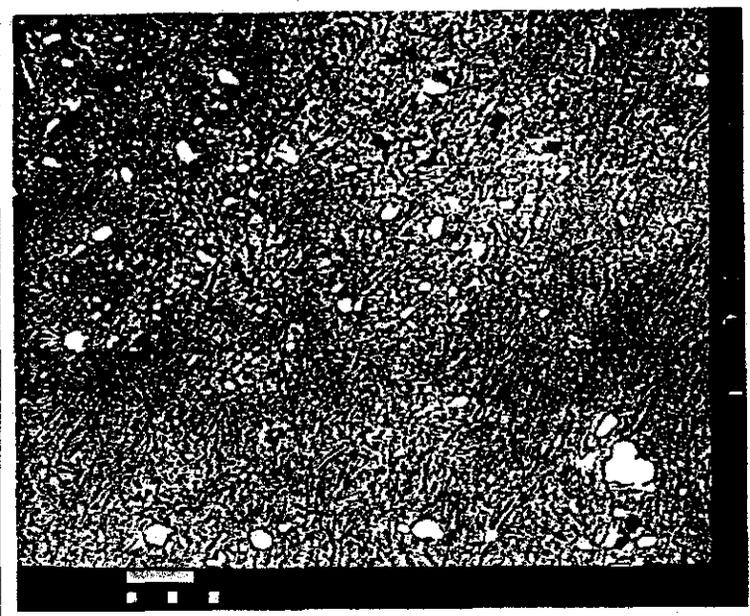


Fig. 23. Chlorite (grey) schist containing abundant small grains of rutile (white). 989'. Bar represents 100 μ m.

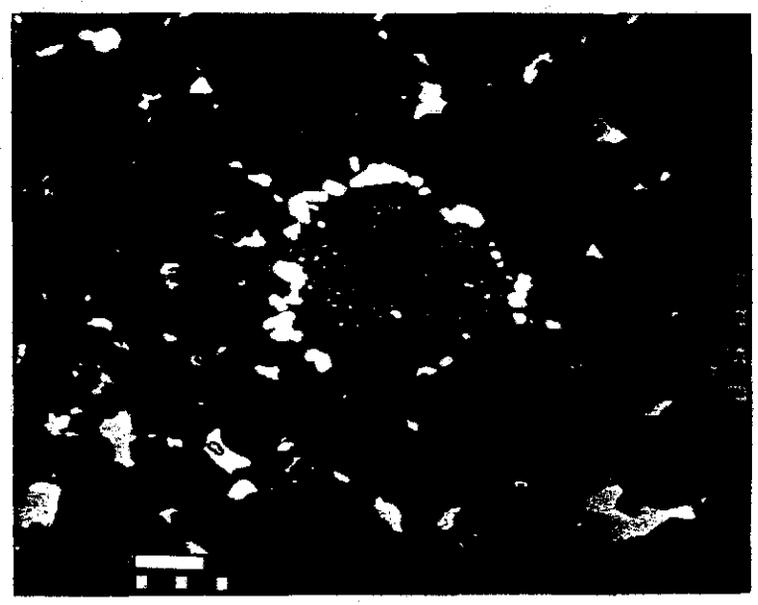


Fig. 24. A ring of pyrites (white) in magnesite (black). Originally there was once another round grain on which the pyrites crystallised, and this grain has subsequently been replaced by magnesite, leaving the pyrites intact. Quartz is scattered in the magnesite. Bar represents 100 μ m.

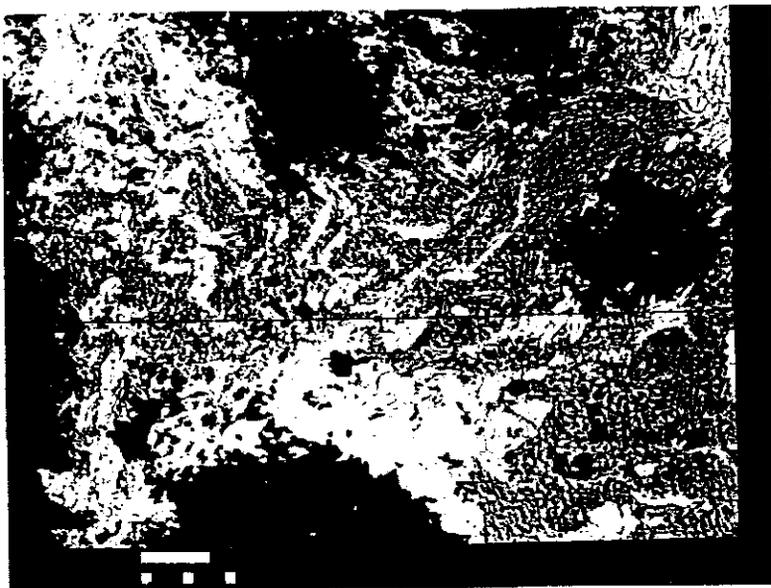


Fig. 25. Small bent talc laths (light grey) are associated with chlorite (darker grey) and more granular quartz (light grey). The quartz is mainly associated with the large apatite grains (white) and in the area at the top right hand corner. The magnesite (black) occurs as irregular areas between the silicates. MF 93, 768'. Bar represents 100 μ m.

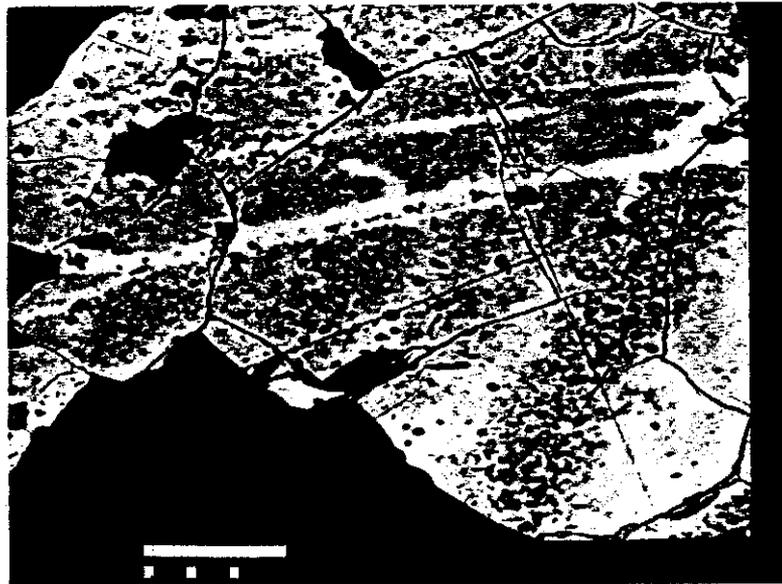
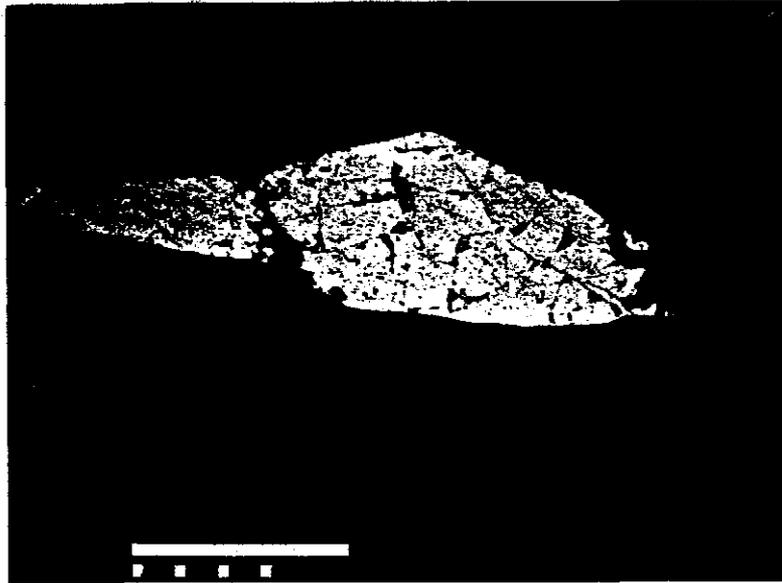


Fig. 26(a). A large pyrites grain (grey) in magnesite (black).
 26(b). Shows details of the Ti zoning in the pyrites. Many pyrites grains found in other horizons do not show Ti-zoning. Bar represents 1000 μ m and 100 μ m respectively.

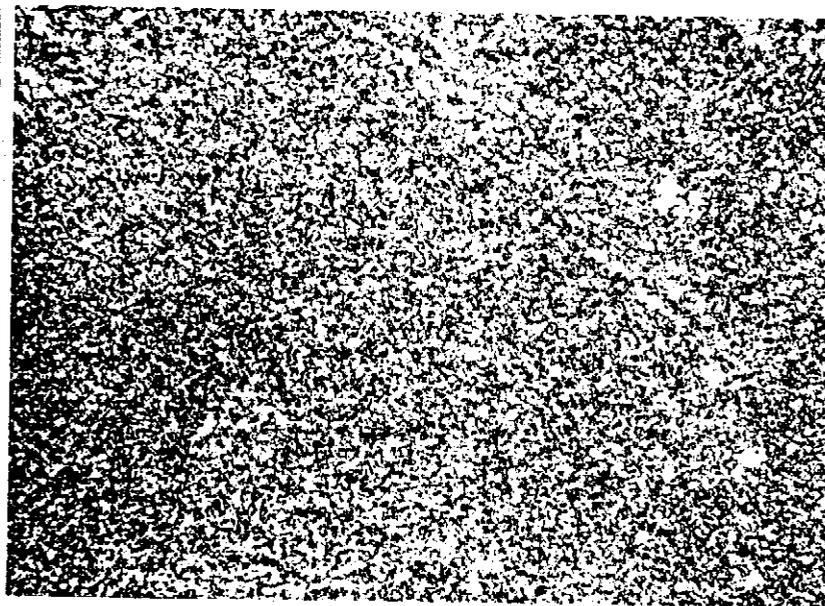


Fig. 27. A typical fine grained magnesite. 386', M.C.1. x 30.

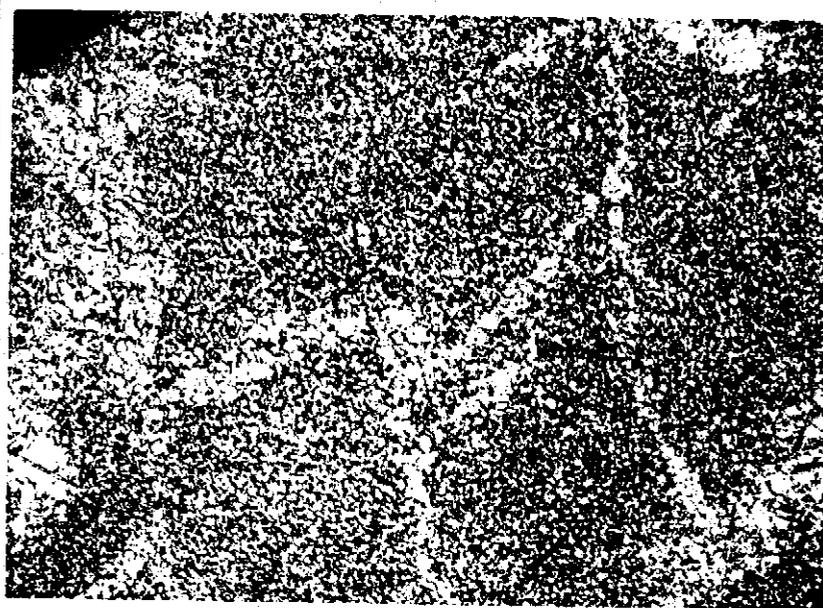


Fig. 28. A fine grained magnesite showing growth of coarser grained carbonate. 257', M.C.1. x 30.



Fig. 29. Coarse and fine grained magnesite. The boundary is sharp between the two. 513', M.C.1. x 30.

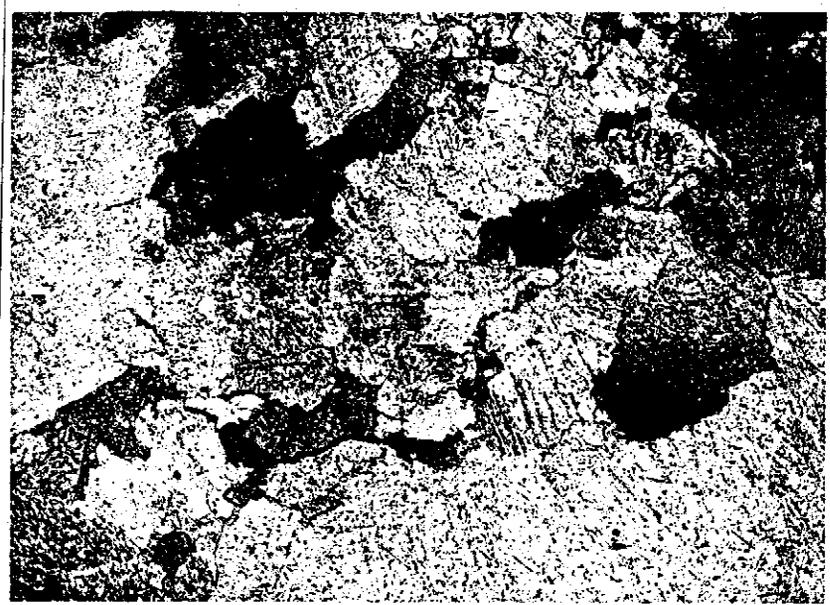


Fig. 30. Coarsely crystalline carbonate (mainly dolomite). 73', M.C.1. x 30.

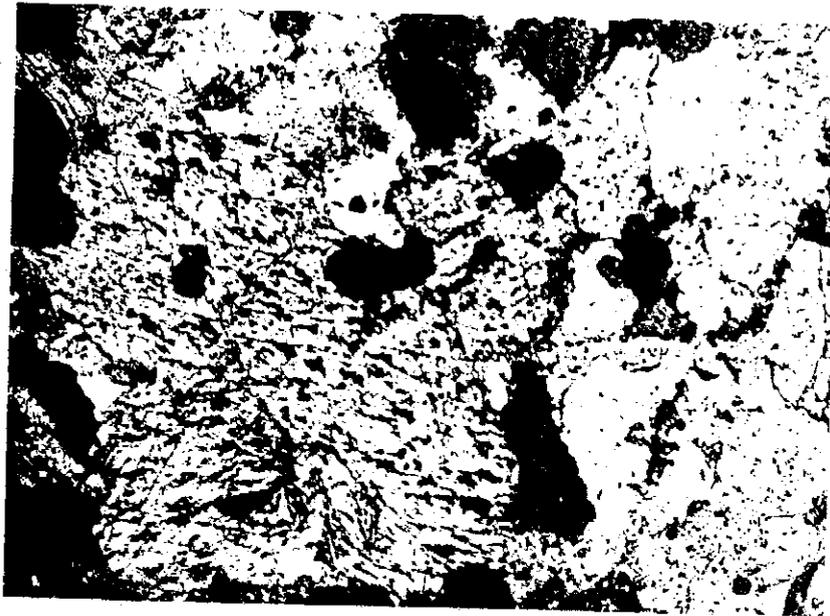


Fig. 31. Very coarsely crystalline carbonate against coarse quartz.
548', M.C.l. x 30.



Fig. 32. Coarsely grained carbonate with small foliated grains of talc.
989', M.C.l. x 30.



Fig. 33. The magnesite probably recrystallised and at the same time was subject to deformation. This photomicrograph shows folding in a predominantly magnesite rock. 669', M.C.1.

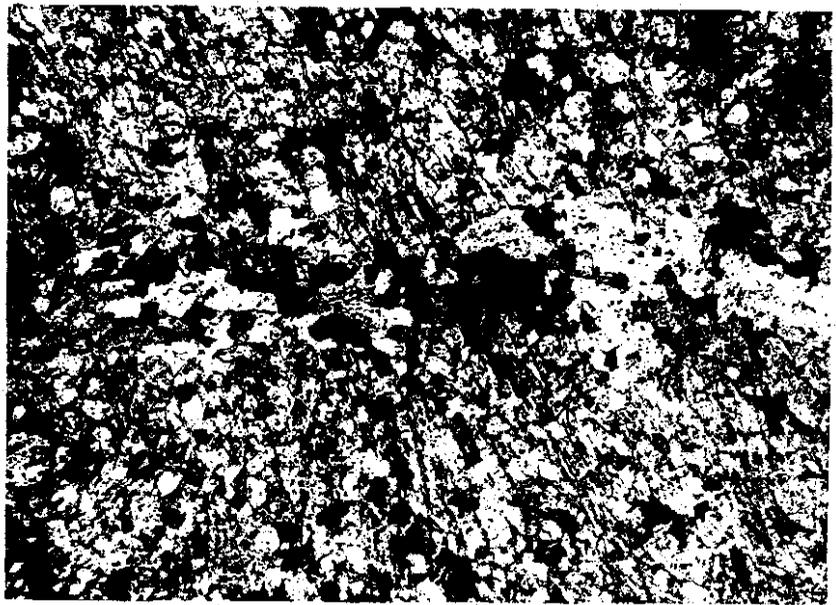


Fig. 34. A vein of quartz through magnesite. The magnesite is coarse grained. 316', M.C.1. x 30.

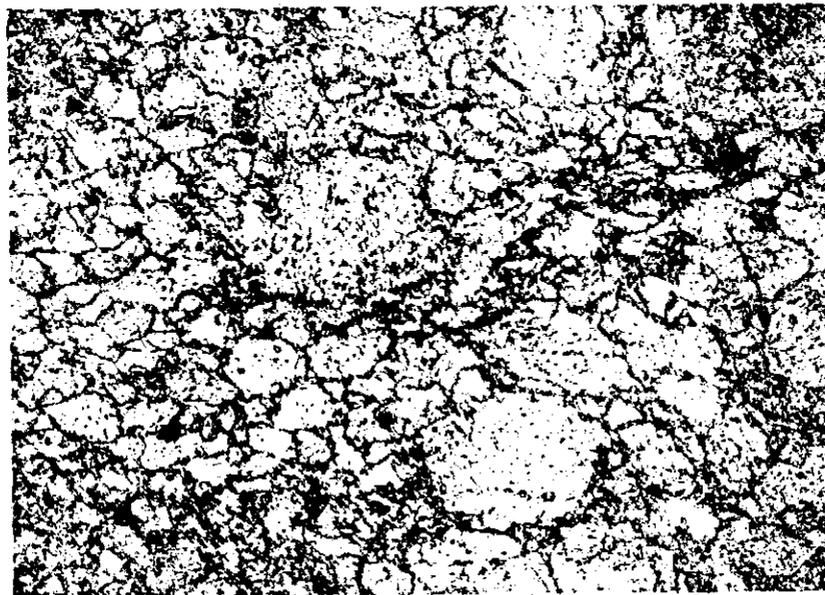


Fig. 35. Granular textures in the carbonate. 827', M.C.I. x 30.



Fig. 36. Coarse grained dolomite. 84', M.C.I. x 30. Nicols crossed.

093

864100

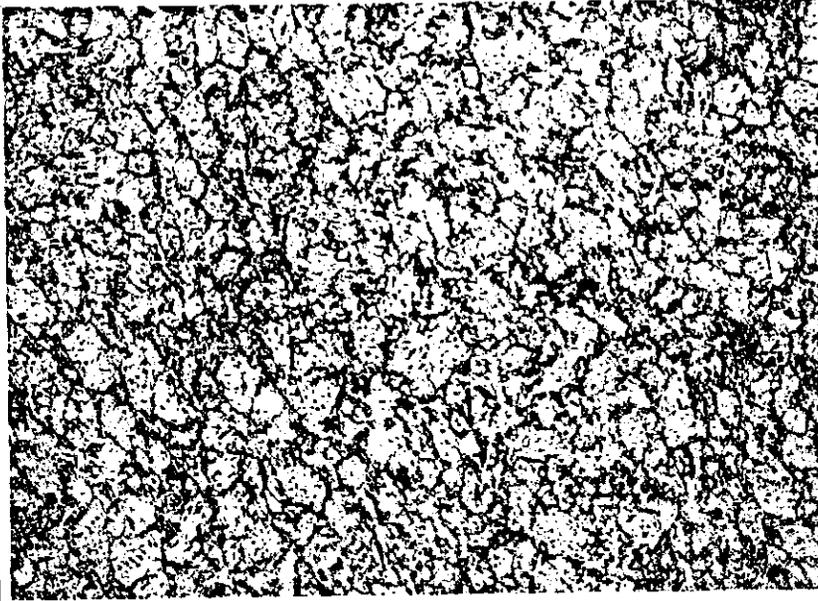


Fig. 37. Equi-granular, moderately coarse grained carbonate. 830'. M.C.1. x 30.

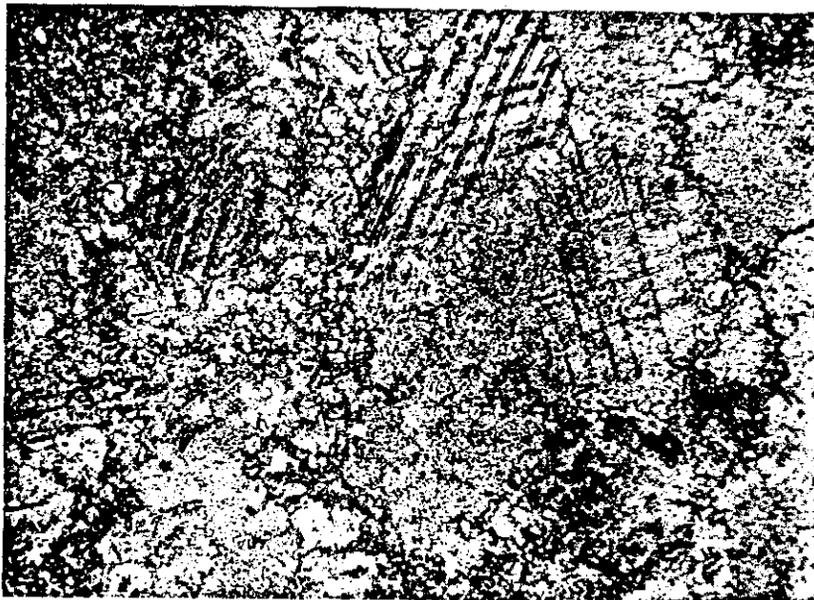


Fig. 38. Very coarsely crystalline carbonate. 779', M.C.1. x 30.



Fig. 39. Chlorite talc schist. A fine grained mixture mainly of chlorite with a little talc and quartz. Foliation is marked in hand specimens. 124', M.C.I. x 30.

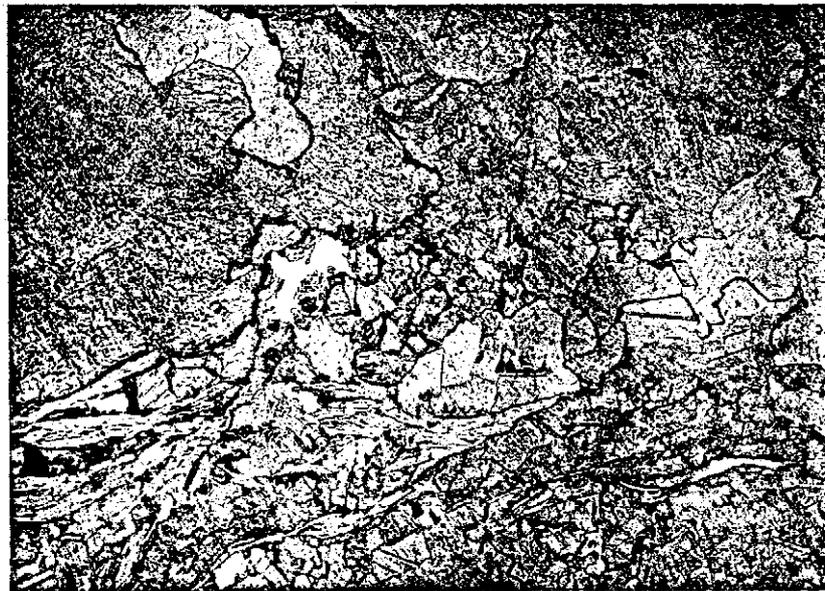


Fig. 40. Dolomite with chlorite (curved with well developed cleavage). 84', M.C.I. x 30.

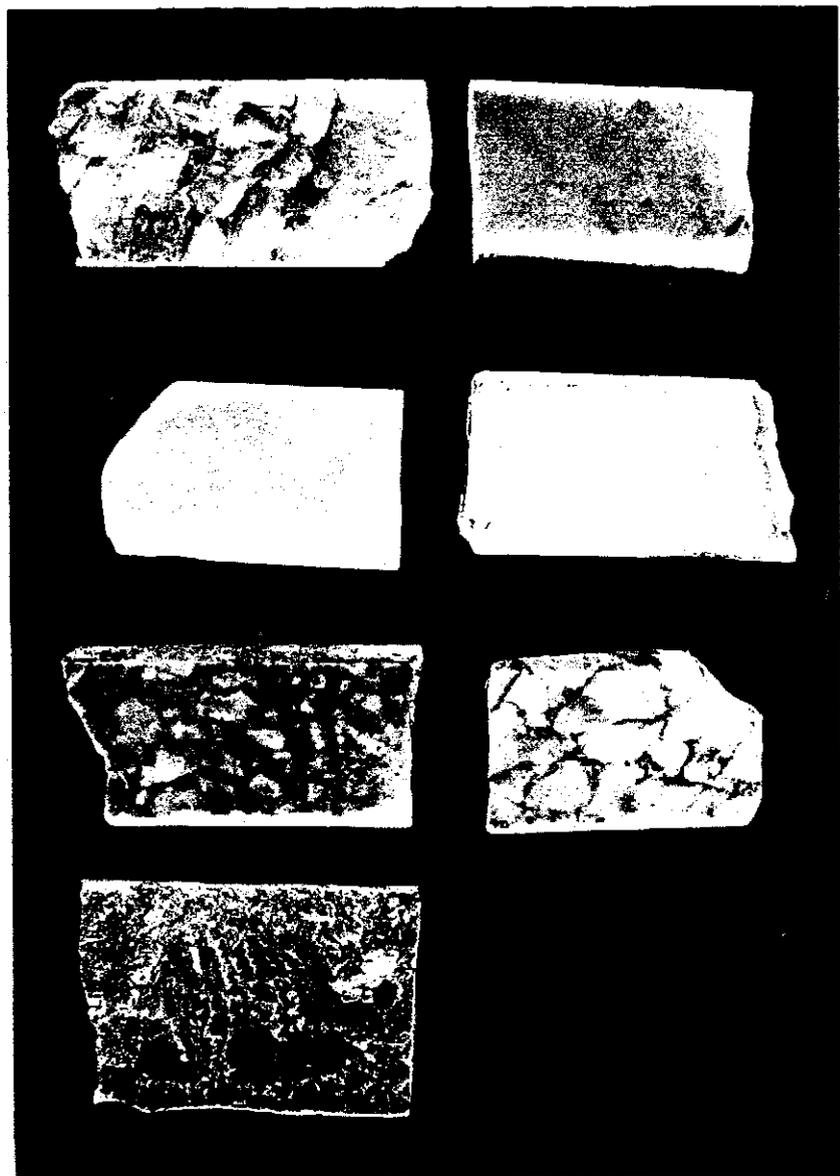
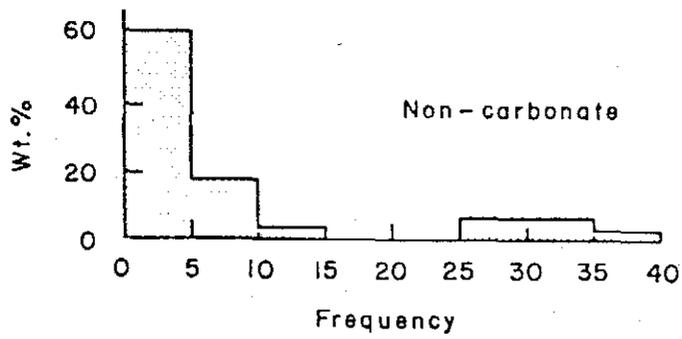
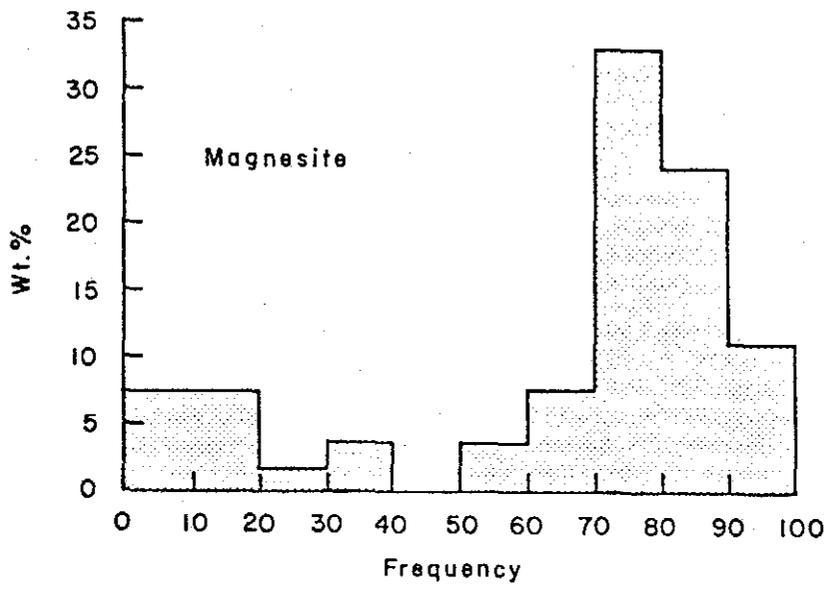
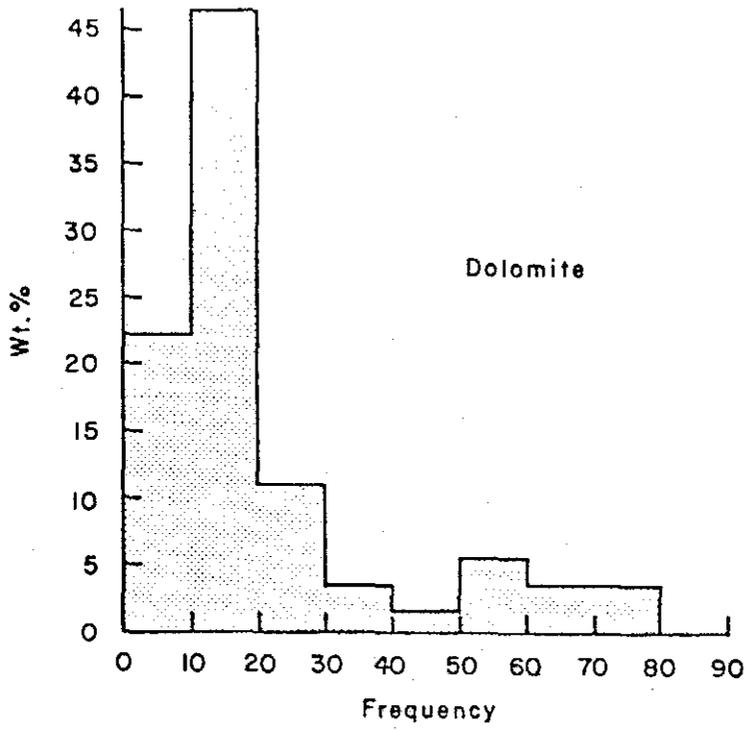


Fig. 41. Photographs of the various carbonate types. Top left, coarse grained pure magnesite. Top right, fine medium quality, medium grained magnesite. Second from top, left, pure fine grained, marble magnesite. Second from top, right, purest marble magnesite. Third from top, left, brecciated magnesite. Whiter areas magnesite, darker dolomite. Third from top, right, patchy magnesite (about 720'). Bottom, dark almost pure dolomite.

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Fig. 42. A set of frequency diagrams illustrating the distribution of the proportions of magnesite, dolomite and non-carbonates in samples of D.D.H. M.C.1.



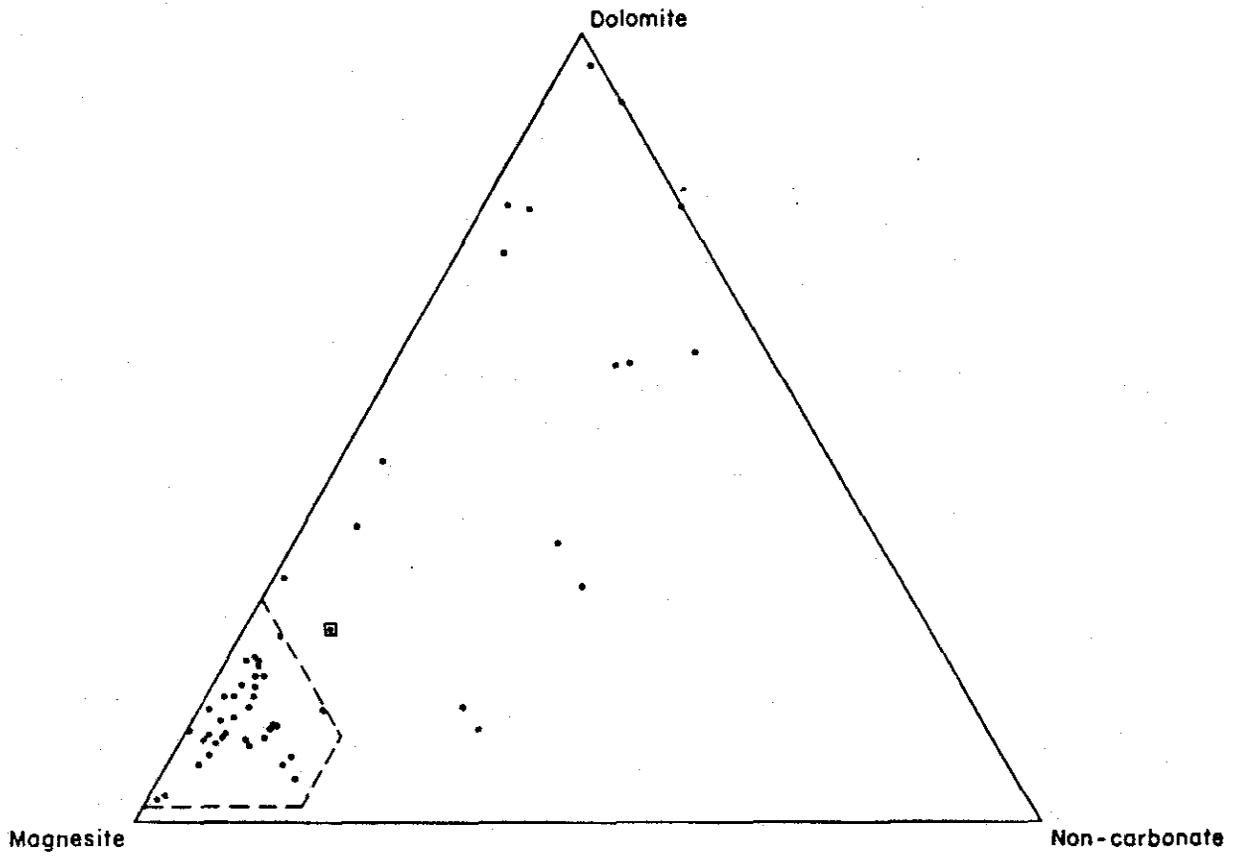


Fig. 43. A ternary diagram illustrating the proportions of magnesite, dolomite and non-silicates in the D.D.H. M.C.1.

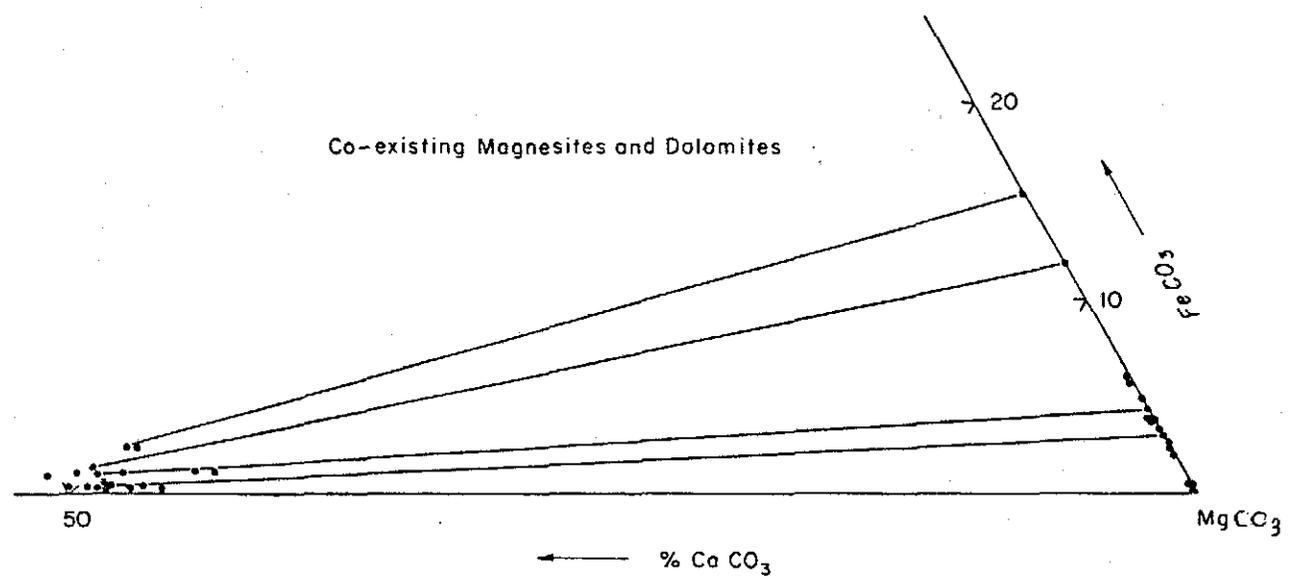


Fig. 44. Part of the ternary diagram $(CaMg)CO_3-FeCO_3-MgCO_3$ showing the compositions of coexisting dolomites and magnesites. Not all the tie lines are shown.

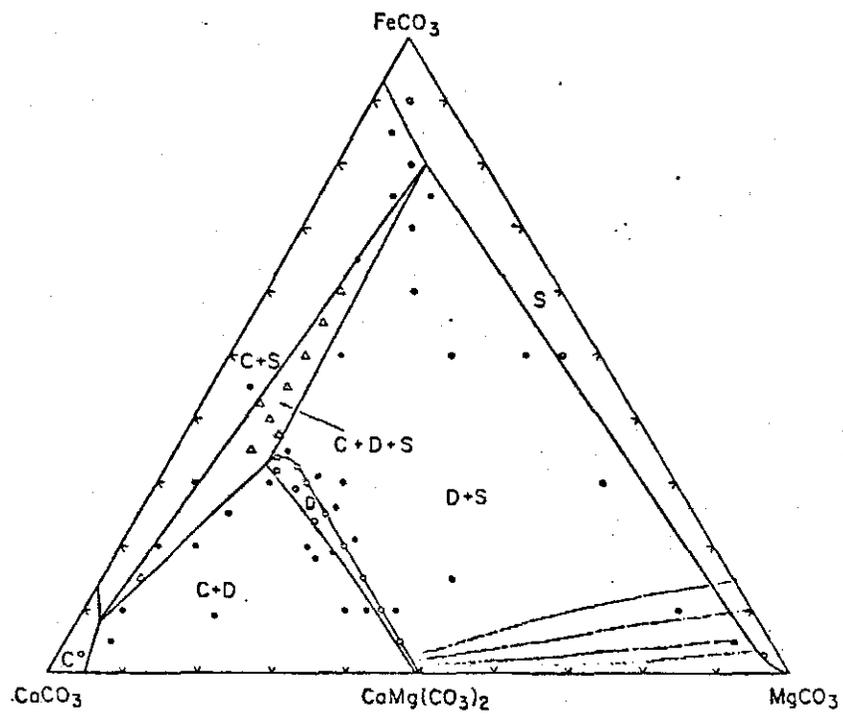


Fig. 45. The phase diagram $\text{CaCO}_3\text{-MgCO}_3\text{-FeCO}_3$ as published by Rosenberg (1967). No details of the coexisting dolomites and magnesites are given.

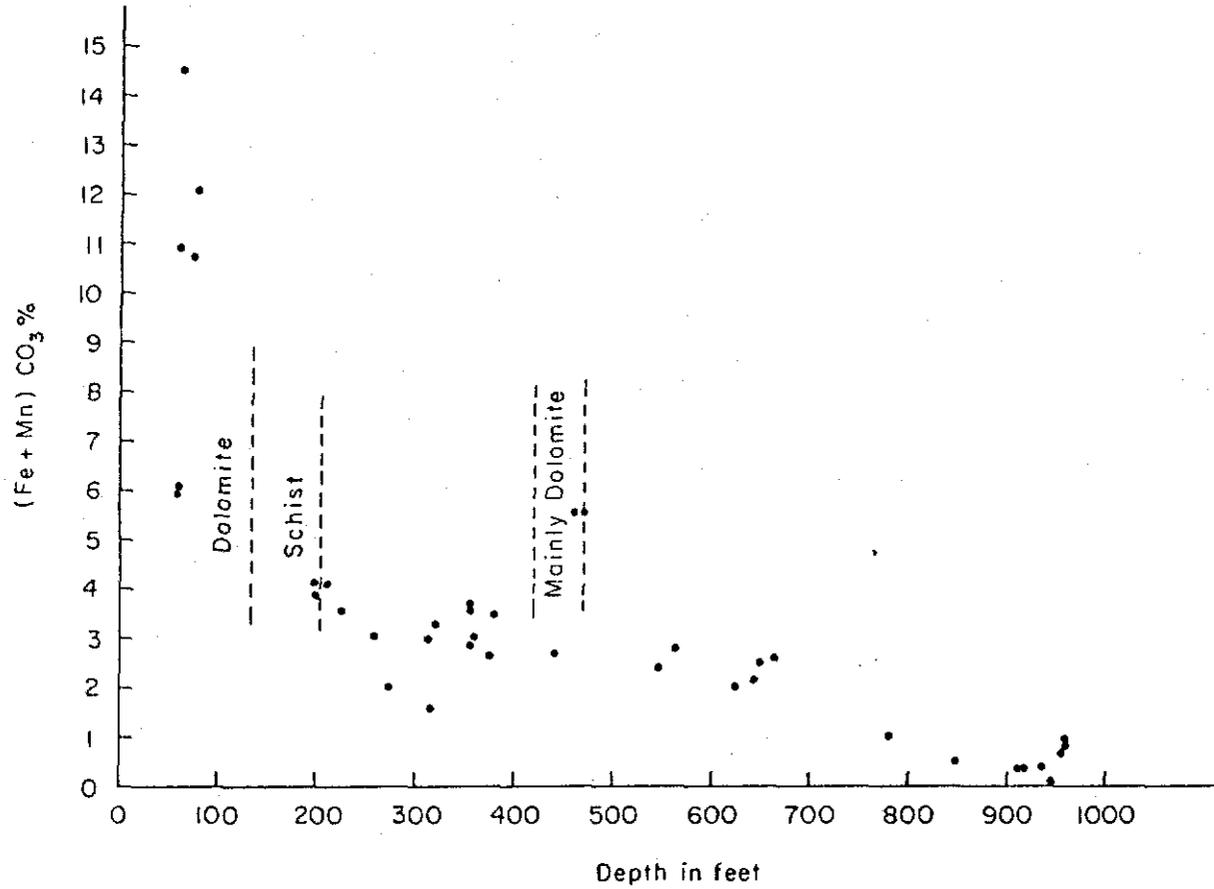


Fig. 46. The variation of magnesite composition with depth in D.D.H. M.C.1. The amount of Fe + Mn falls steadily with depth.

APPENDIX 1

DETAILS OF BULK ANALYSES FROM D.D.H.'s
IN THE SAVAGE RIVER AREA

1.1. D.D.H. R.T.A.E. No. 1

Bulk analysis of samples of magnesite.

	606 to 620'	624 to 639'
Mgo	32.16	27.79
CaO	9.79	14.35
SiO ₂	7.45	7.26
Fe ₂ O ₃	4.86	4.00

1.2. D.D.H. 46

	550-560	560-567	570-580	580-590	590-600	600-610	656-664
MgO	40.2	36.9	35.0	39.7	33.6	38.6	42.3
CaO	4.86	7.77	7.28	5.10	2.18	4.13	3.89
SiO ₂	4.30	3.95	8.75	2.65	18.2	7.35	1.20
Fe ₂ O ₃	2.66	2.33	2.43	2.33	4.16	2.62	2.09
Al ₂ O ₃	nil	nil	nil	nil	2.80	nil	nil
MnO	0.08	0.08	0.08	0.09	0.10	0.08	0.08
P ₂ O ₅	0.02	0.03	0.01	0.01	0.04	0.01	nil
S	1.04	0.06	0.07	0.48	0.24	0.06	0.05
loss on ignition	47.9	47.1	44.6	48.7	39.4	45.8	49.6

No TiO₂ detected in any sample.

1.3. D.D.H. 28

Carbonate was found from 499' to 505' and from 521' to 530'.

Mainly dolomite.

110
1.4. D.D.H. 29

Carbonate was found from 481' to 488', 503' to 510' and 540' to 600' (end of bore hole).

APPENDIX 2

SUMMARY OF D.D.H. M.C.1 AND M.C.2

Rock type details as supplied by Industrial and Mining Investigations.

Both D.D.H.'s were inclined at about 46° and their locations are shown in Fig. 2. Classification of rock types was as follows:

1. Magnesium rich dolomite
2. Calcium rich magnesite
3. Low calcium magnesite
4. Green schist
5. Carbonaceous schist.

feet from surface	M.C.1	M.C.2
0	4	4
10	4	4
20	4	1
30	4	1
40	4	1
50	4	4
60	4	3
70	4	3
80	4	3
90	4	3
100	4	3
110	4	3
120	4	3
130	4	3
140	1	3
150	1	3
160	3	3
170	3	3
180	3	3
190	3	3
200	3	3
210	3	3
220	3	3

	M.C.1	M.C.2
230	4	3
240	4	3
250	4	3
260	4	3
270	3	3
280	3	2
290	3	2
300	3	2
310	3	2
320	3	2
330	3	2
340	3	2
350	3	2
360	3	2
370	3	2
380	3	2
390	3	2
400	3	4
410	4	4
420	3	4
430	1	3
440	1	3
450	1	3
460	1	3
470	1	3
480	1	3
490	3	4
500	3	4
510	3	3
520	3	3
530	3	4
540	3	3
550	3	3
560	3	3

	M.C.1	M.C.2
570	3	3
580	3	3
590	3	3
600	2	2
610	2	2
620	3	2
630	3	2
640	3	3
650	3	3
660	5	3
670	5	3
680	3	3
690	3	3
700	3	3
710	3	3
720	2	3
730	3	3
740	3	3
750	3	3
760	3	3
770	3	3
780	3	3
790	3	4
800	3	3
810	3	3
820	3	3
830	3	3
840	3	3
850	3	4
860	3	4
870	3	4
880	3	4
890	3	3
900	3	4

	M.C.1	M.C.2
910	3	3
920	3	3
930	3	3
940	2	3
950	2	3
960	2	3
970	3	3
980	3	4
990	3	3
1000	4	3
1010	4	3
1020	4	
1030	3	

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117

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REF. No.				

INDUSTRIAL & MINING INVESTIGATIONS PTY. LTD.

Cost Estimates

for the

MAGNESITE PROJECT, TASMANIA

(APPENDIX 3 to report on
SAVAGE RIVER MAGNESITE DEPOSIT)

(APPENDIX 3)

81-1638.

WRIGHT ENGINEERS PTY. LIMITED

Project 7062

January, 1980



18
WRIGHT ENGINEERS PTY. LIMITED



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Telephone: 92 1721, 92 7485

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14th January, 1980.

D.E.J. Salier Esq.,
Managing Director,
Industrial & Mining Investigation Pty. Limited,
Suite 3709,
Australia Square,
SYDNEY. N.S.W. 2000.

Dear Mr. Salier,

SAVAGE RIVER MAGNESITE PROJECT

In accordance with your request we submit herewith our order of magnitude estimate of the capital cost for a treatment plant to produce 100 000 long tons per year of magnesia at your Savage River Project.

It is important to note that the figures are based on the parameters and metallurgical flow sheet provided by your company.

Because of the unknown crushing characteristics of the ore, we have allowed for three stage crushing to reduce the plant feed to the required 100% - $\frac{1}{4}$ " mesh. If the ore is friable (as magnesite sometimes is) it may be possible to use an impact breaker instead of three stage crushing and this would result in a significant capital saving.

In addition, our cost estimate for tailings disposal could be materially reduced if the environmental controls are not too strict.

Thank you for the opportunity of working on this estimate and we hope to be able to assist you with a feasibility study when you decide to go ahead with the project.

Yours truly,

J.B. WALLACE,
Managing Director.

MAGNESITE PROJECT, TASMANIA

The following capital cost estimates have been developed using the Wright Engineers Limited Quick Capital Cost Computer Programme.

The accuracy of the estimates is expected to be within the range of $\pm 30\%$.

Specific technical information supplied by the client is attached in an Appendix.

All costs are in January 1980 Australian dollars.



MINE LOCATION Savage River, Tasmania

TYPE OF MINING Open Pit

PLANT SIZE - Throughput of 350,000 long tons of ore per year.

Mining and crushing operates 1 shift/day,
5 days/week.

Treatment plant operates 3 shifts/day,
7 days/week on a 95% availability.

<u>CAPITAL COST</u> (Millions \$)	\$
Mining Development	6.44
Crushing & Screening	7.36
<u>Metallurgical Operation</u>	
Magnesite Burning	6.24
Slaking and Leaching	6.71
Pressure Filtration	7.78
Precipitation and Recovery	4.75
Product Calcination	11.05
CO ₂ Recovery	4.40
Water Supply	0.57
Tailings Disposal	1.10
Sub-Station & Distribution (Power Supply by State Government)	0.60
Surface Vehicles & Fuel Storage (Main Access Road by State Government)	0.09
Ancillary Buildings	1.62
Employee Housing (by State Government)	—
SUB-TOTAL	58.71



	\$
Working Capital & Inventory	1.17
Engineering & Construction Management	4.11
Administration Costs	3.12
Interest Charges	<u>4.46</u>
<u>CAPITAL COST</u> (Millions of January 1980 Australian \$)	71.56 =====



A P P E N D I X

TECHNICAL INFORMATION SUPPLIED

1. Mill Feed

Grade of ore (% Mg) to be as regular as possible.
Dolomite content not to exceed 10% and preferably below 5%.

2. Ore Crushing

100% - 1/4" mesh.

3. Ore Calcining

Temperature	700°C.
Time	1 hour
Fuel	Oil
Fuel Consumption	Approximately 0.75 long tons per ton of MgO produced. (Approximately 0.25 tons per ton of ore)
Loss in weight (approximately)	40%

4. Calcine Grinding

Sizing	100% - 35 mesh B.S.S.
Ball mill discharge to a classifier in open circuit. O/flow to leaching, U/flow to dump.	

5. Leaching

CO ₂ Pressure	25 lb. sq. in.
Time	45 minutes
Pulp Density	3% solids
Temperature	25°C.
Mg Recovery	85%

6. MgO Calcining

Dead Burning Temperature	1800°C.
Fuel	Oil
Fuel Consumption	Approximately 0.25 long tons per ton MgO

7. Water

In Circuit	60 long tons per ton MgO produced
Make-up	6 long tons per ton MgO produced

8. Operation

Continuous Process Operating Time	95% =	345 days per year
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9. Product

Premium Grade Magnesia	+ 97% MgO
	- 0.5% Fe
Quantity	100,000 long tpy

In addition to the foregoing data, other parameters are needed and, after discussion with the client, these have been set as follows:-

1. Capital

Proportion to be borrowed	60%
Interest Rate	11%
Operating Capital	3 months

2. Start of Production

Not known

3. Location

Mine)	Savage River, Tasmania.
Treatment Plant)	Approximately 70 miles south-west of the port of Burnie. Access by railway and sealed road to township of Savage River then 6 miles by road to be constructed by State Government.

4. Climate

Av. max. Winter Day Temperature	45°F.
Av. max. Summer Day Temperature	75°F.
Av. Annual Rainfall	80 inches

5. Exploration Costs

Average

6. Mining

Type	Open cut
Ore	Magnesite
Ore Grade	23.8% Mg
Ore/Waste Ratio	1:1
Pre-production Stripping	Moderate
Ore Output	350,000 long tpy
Schedule	5 shifts per week

7. Treatment Plant

Site Slope	5%
Overburden Depth	5 ft.

Crushing

Coarse Ore Storage	Nil
Primary Screening	Nil
Product Sizing	- ¼ inch
Schedule	5 shifts per week

Concentrator

Fine Ore Storage	4 days
Grindability	easy
Process	CO ₂ leaching
Schedule	Continuous Process (95%)
Make-up Water	1750 long tpd
Fuel Oil for Calcining (feed & product)	290 long tpd
Fuel Storage	Provided by supplier
Fuel Supply to Site	Provided by supplier

Tailings Disposal

Distance from plant
Quantity
Site

Approximately $\frac{1}{2}$ mile
Approximately 350 long tpd
5% slope

8. ServicesWater Supply

Source
Quantity (including Services)
Distance, Plant to Source
Height, Plant above Source

Savage River
1800 long tpd
1 mile
50 ft.

Power Supply

Source
Transmission Line Extension

State grid
Provided by State Government

Employee Housing

Provided by State Government

Access Road

Provided by State Government