CARBONATITES AND ASSOCIATED ALKALIC ROCKS PERRY RIVER AND MOUNT GRACE AREAS SHUSWAP COMPLEX SOUTHEASTERN BRITISH COLUMBIA (82M/7, 10)

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INTRODUCTION

Carbonatites are carbonate-dominated igneous rocks that occur most commonly as intrusive bodies, generally associated with alkaline igneous rocks (Pecora, 1956; Heinrich, 1980). Extrusive carbonatites are less common but have been described in western Uganda (von Knorring and du Bois, 1961), northern Tanzania (Dawson, 1962, 1964; Hay, 1983), central Kenya (Le Bas and Dixon, 1965), western Kenya (Le Bas, 1977; Deans and Roberts, 1984), and Germany (Keller, 1981).

Many carbonatite bodies are valuable sources of a number of commodities. Nb has been produced at Oka and St. Honoré, Quebec and Araxa, Brazil; the Mountain Pass carbonatite in California is the largest producer of rare earth elements in the western world; and copper and by-product apatite, magnetite, vermiculite, and ZrO_2 are produced in Palabora, South Africa (Currie, 1976; Heinrich, 1980). Carbonatite deposits in the eastern Canadian Cordillera (Pell, 1985; White, 1985) have recently received some interest due to their enriched pyrochlore and rare earth element content, but none have yet had any production.

Carbonatites in the Perry River area along the northwestern margin of Frenchman Cap dome on the eastern edge of the Shuswap Metamorphic Complex (Fig. 8-1) were originally described by McMillan (1970) and McMillan and Moore (1974). Two varieties were recognized: type I intrusive sills and dykes, and a type II extrusive layer. Detailed mapping in the Mount Grace area north of the Perry River (Höy, 1979) led to the discovery of new occurrences of the type II carbonatite layer, referred to as the Mount Grace carbonatite (Höy and Kwong, in press) and confirmed the suggestion (McMillan and Moore, 1974) that it is an extrusive layer.

Work during the 1985 field season included eight days of sampling, detailed mapping, and section measuring. Sampling of both the intrusive carbonatites in the Perry River area and of the Mount Grace carbonatite provided additional data on their geochemistry and petrography. Detailed mapping and section measurements resulted in a better understanding of the relationship between intrusive carbonatites and associated syenites, a knowledge of the internal stratigraphy of the Mount Grace carbonatite, and the discovery of thin carbonatite tuff layers adjacent to the main Mount Grace carbonatite layer. Observations of clast size distributions in the Mount Grace carbonatite allow speculation regarding source areas. Continued research includes oxygen and carbon isotope studies in progress at the University of Alberta, U/Pb dating of zircons collected from both the carbonatites and nepheline syenites, and field mapping tracing the Mount Grace carbonatite northward.

Initial exploration in the Mount Grace area was centred around the Cottonbelt deposit, a massive sulphide Pb-Zn layer discovered in 1905. Carbonatites in the area have been periodically sampled for their rare earth element content, most recently by Duval International Corporation (Pilcher, 1983). Work by Duval was restricted to carbonatites south of Ratchford Creek; it included prospecting, geochemical sampling, and mapping. Claims in this area have been acquired recently by Active Mineral Explorations Ltd. of Vancouver.

GEOLOGICAL SETTING

INTRODUCTION

The Mount Grace carbonatite, intrusive carbonatites, and syenite gneiss bodies occur within a mixed paragneiss succession along the northwestern margin of Frenchman Cap gneiss dome (Fig. 8-1), one of several late domal structures near the eastern margin of the Shuswap Metamorphic Complex in southeastern British Columbia (Wheeler, 1965). The dome is exposed as a window between the Columbia River fault to the east and the Monashee décollement to the west (Read and Brown, 1981).

The core of Frenchman Cap dome comprises a mixed paragneiss and orthogneiss succession of probable Aphebian age (R. L. Armstrong, pers. comm., 1980). It is basement to an unconformably overlying 'mantling gneiss' or autochthonous cover succession, comprising a basal quartzite and overlying pelitic and calcareous rocks. The autochthonous cover succession hosts the carbonatites and syenite gneisses, as well as the Cottonbelt Pb-Zn layer.

The ages of the mantling paragneiss succession and carbonatites are not known. Based on regional correlations with platformal rocks to the east, a number of authors (Wheeler, 1965; Fyles, 1970; Höy and McMillan, 1979) tentatively assigned Eocambrian to Early Paleozoic ages to these rocks. A preliminary U/Pb date of 773 Ma was obtained from zircon of a syenite gneiss at the southern margin of Frenchman Cap dome (Okulitch, *et al.*, 1981) which is presumably of similar age to the carbonatites (McMillan and Moore, 1974; Currie, 1976; Höy and McMillan, 1979). Zircons from carbonatites and syenites from this area are being analysed and will provide a better age for these alkalic rocks and the host succession.

STRUCTURE AND METAMORPHISM

The structure of the northwestern margin of Frenchman Cap dome is dominated by the tight, early Mount Grace syncline (Fig. 8-2). The Mount Grace carbonatite occurs on both of its limbs. The fold has been traced approximately 20 kilometres from north of Ratchford Creek to south of Kirbyville Creek (where it is referred to as the Kirbyville syncline; Brown, 1980) and has been projected southward to the Perry River area where it is correlated (Journeay

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1985, Paper 1986-1.

1982) with an early 'Phase 1' isoclinal fold described by McMillan (1970, 1973). Its axial surface is defined by a mineral foliation that generally parallels layering in the attenuated limbs of the fold. Later southwest-trending 'Phase 2' folds are prominent in the Perry River area (McMillan, *op cit.*). They are superimposed on large isoclinal Phase 1 folds, accounting for the relatively complex outcrop pattern in that area (Fig. 8-2). Both phases of folding deform the Mount Grace carbonatite, the intrusive carbonatites, and the syenite gneisses.

Amphibolite facies regional metamorphism along the western and northwestern margin of Frenchman Cap dome has produced sillimanite-kyanite, sillimanite, and sillimanite-potassic feldspar-bearing assemblages in pelitic rocks. Calc-silicate assemblages contain diopside, garnet, and actinolite. Carbonates and the carbonatites are recrystallized to medium to locally coarse-grained granoblastic marbles.

STRATIGRAPHIC SUCCESSION

The stratigraphy of the 'mantling gneiss' succession that hosts the alkalic rocks is summarized from McMillan (1973) and Höy (1979). A laterally extensive quartzite (unit 3, Fig. 8-3) of variable thickness and purity forms the base of the succession. Crossbeds and graded grit beds occur locally in the quartzite and provide some of the few reliable stratigraphic top indicators. The quartzite is overlain by a sequence of interfingering, dominantly calcareous and pelitic schists (unit 4). Amphibolite layers, thin impure quartzite layers,

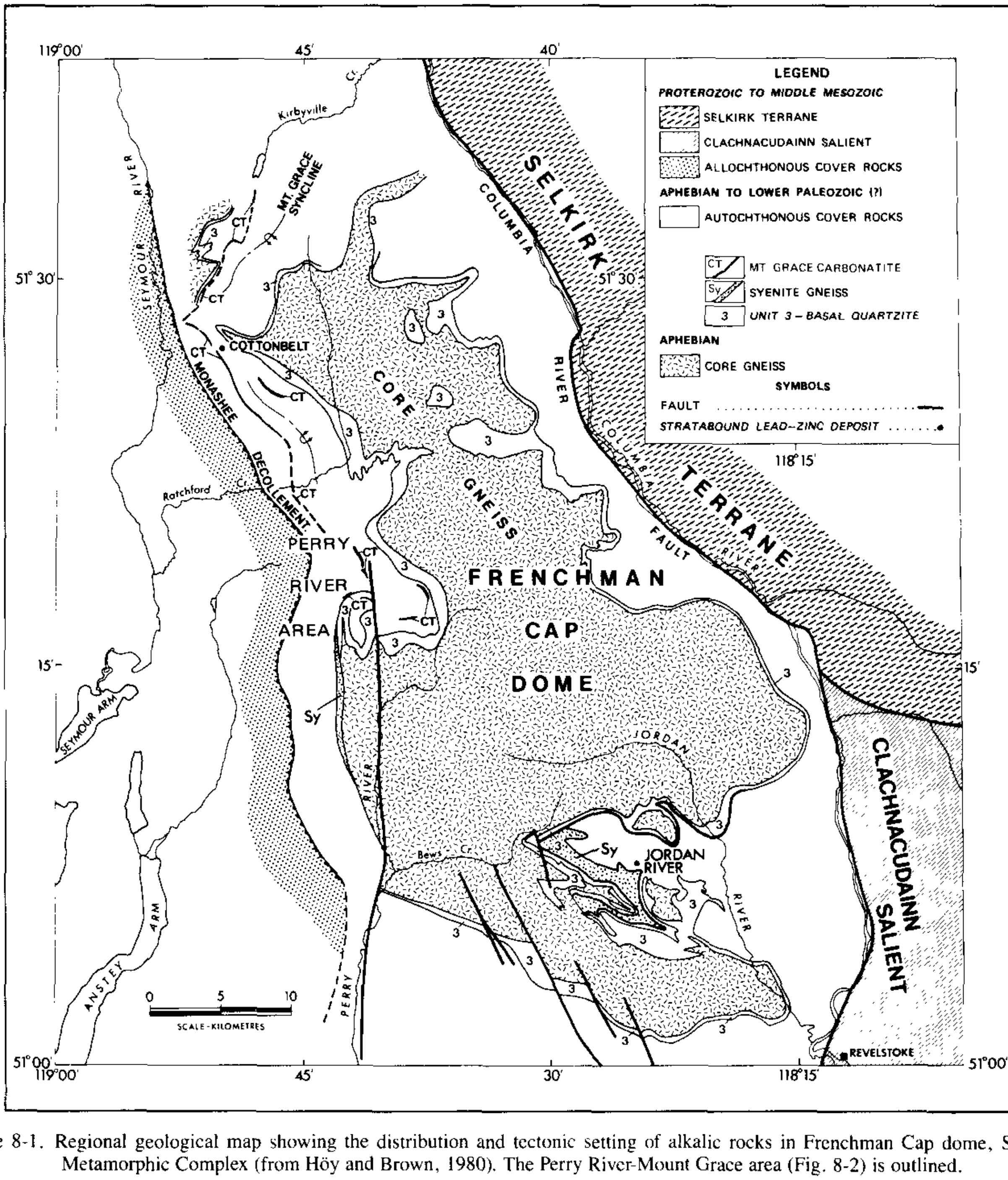


Figure 8-1. Regional geological map showing the distribution and tectonic setting of alkalic rocks in Frenchman Cap dome, Shuswap Metamorphic Complex (from Höy and Brown, 1980). The Perry River-Mount Grace area (Fig. 8-2) is outlined.

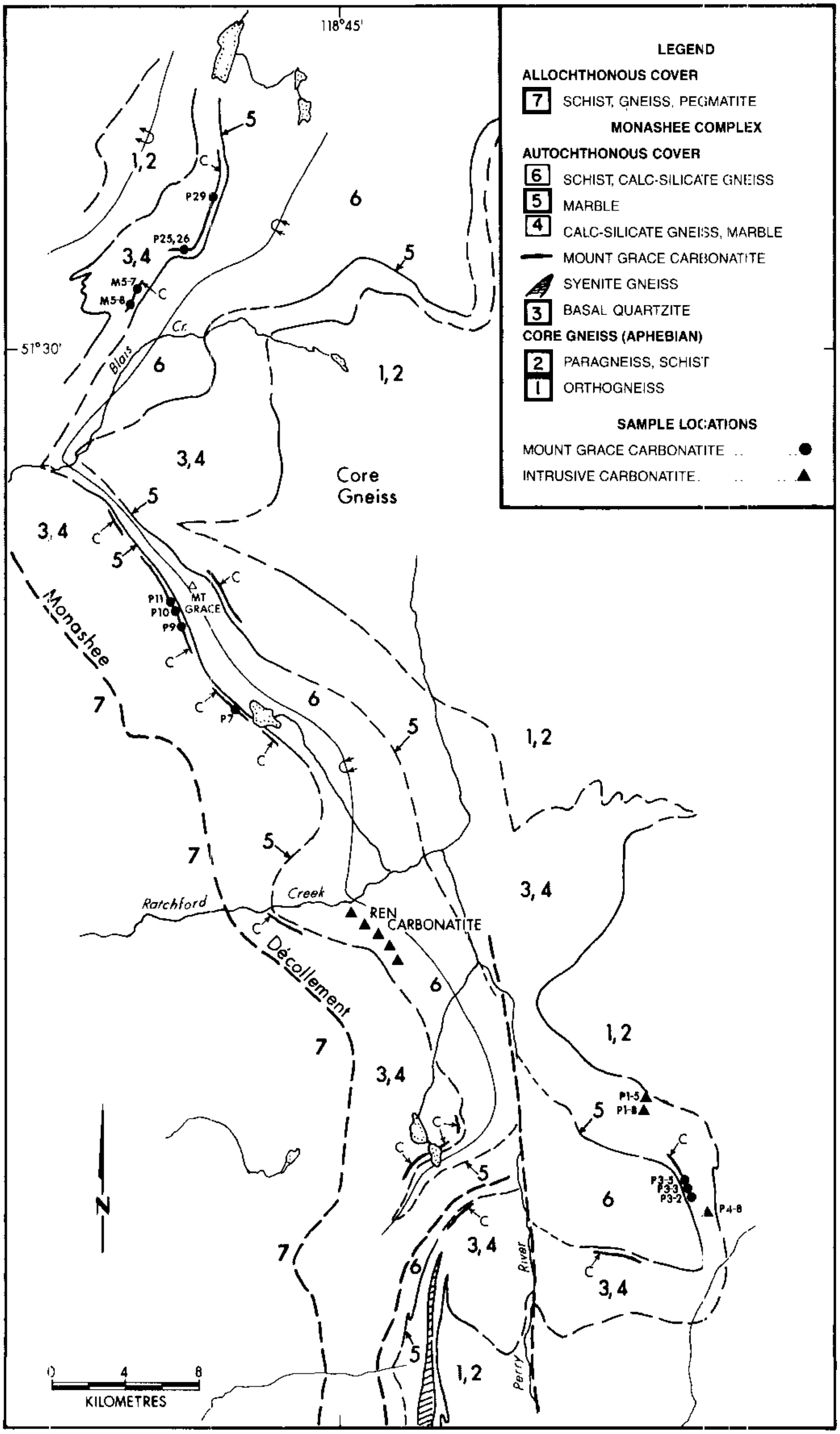


Figure 8-2. Location and structural setting of the Mount Grace carbonatite, intrusive carbonatites, and syenites in the Mount Grace-Perry River area (geology after McMillan, 1973; Höy, 1979; Journeay, 1982). Sample locations and sites referred to in text are shown.

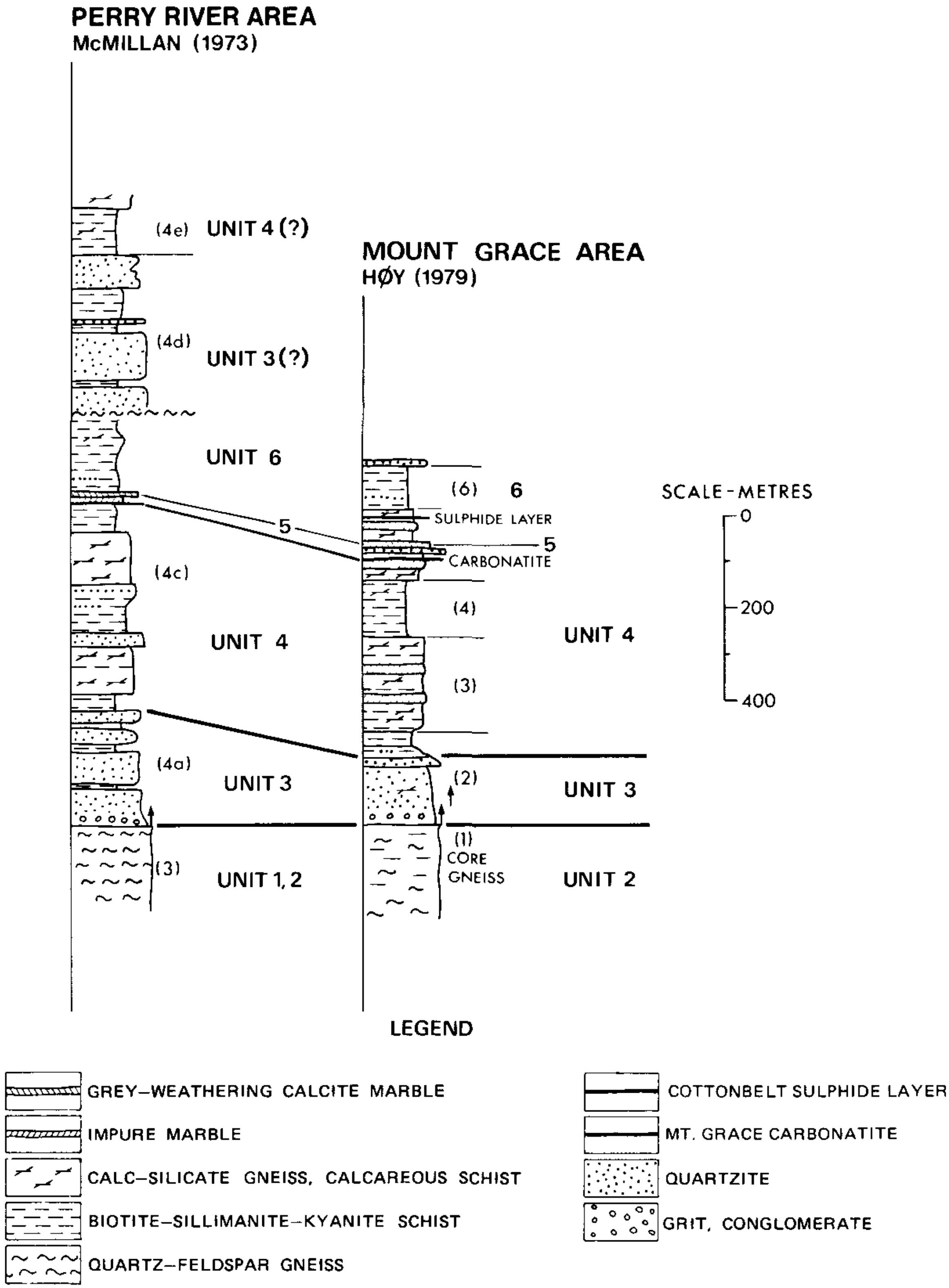


Figure 8-3. Correlations of units hosting carbonatites and syenites between the Mount Grace and Perry River areas. (Numbers in parentheses are unit designations of McMillan, 1973 and Höy, 1979).

TABLE 8-1
CHEMICAL ANALYSES OF TWO SAMPLES OF THE SYENITE GNEISS AT THE HEADWATERS OF ANSTEY RIVER (FIG. 8-2)

Sample No.	SiO_2	Al_2O_3	Fe_2O_{3T}	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	$+H_2O$	$-H_2O$	CO_2	P_2O_5	S	FeO	Fe_2O_3
H78MC-1	53.57	19.76	5.54	0.37	2.79	6.037	10.9	0.597	0.154	0.45	0.05	0.62	<0.08	<0.01	1.30	4.10
H78MC-2	51.88	22.07	4.93	0.26	2.26	5.070	10.3	0.881	0.142	1.34	0.08	0.70	<0.08	<0.02	3.29	1.27

and swirled quartz-feldspar-biotite gneiss are common throughout this unit. The upper part of the unit is dominantly calcareous, comprising an interlayered succession of thin-bedded calc-silicate gneiss, kyanite and sillimanite schist and gneiss, calcitic and dolomitic marble, amphibolite, the Mount Grace carbonatite, and thin scapolite-rich calcareous layers. Overlying unit 4 is a grey-weathering crystalline calcite-dolomite marble layer (unit 5, Fig. 8-3). This marble is a valuable marker that can be traced around the margins of Frenchman Cap dome. It is overlain by a calcareous and pelitic succession (unit 6) that includes the Cottonbelt lead-zinc deposit.

In the Perry River area nepheline syenite gneiss bodies and associated discontinuous carbonatite lenses occur near the base of unit 3. They are overlain by the Mount Grace carbonatite (Plate 8-1a) which, in the core of the Mount Grace syncline just south of Ratchford Creek, is overlain by a lens (or lenses) of intrusive carbonatite (Pilcher, 1983), referred to as the 'Ren' carbonatite.

The succession in the Mount Grace and Perry River areas has been correlated (Höy and McMillan, 1979; Brown, 1980) with a similar succession in the Jordan River area at the south end of Frenchman Cap dome (Fyles, 1970). Here, syenite gneiss bodies, originally believed to occur stratigraphically above the level of the Mount Grace carbonatite (Currie, 1976), are now recognized to occur at a deeper stratigraphic level (Höy and McMillan, 1979).

The 'mantling gneiss' or autochthonous cover succession that unconformably overlies the core gneisses has been interpreted to be a shallow marine or platformal succession (McMillan, 1973; Höy

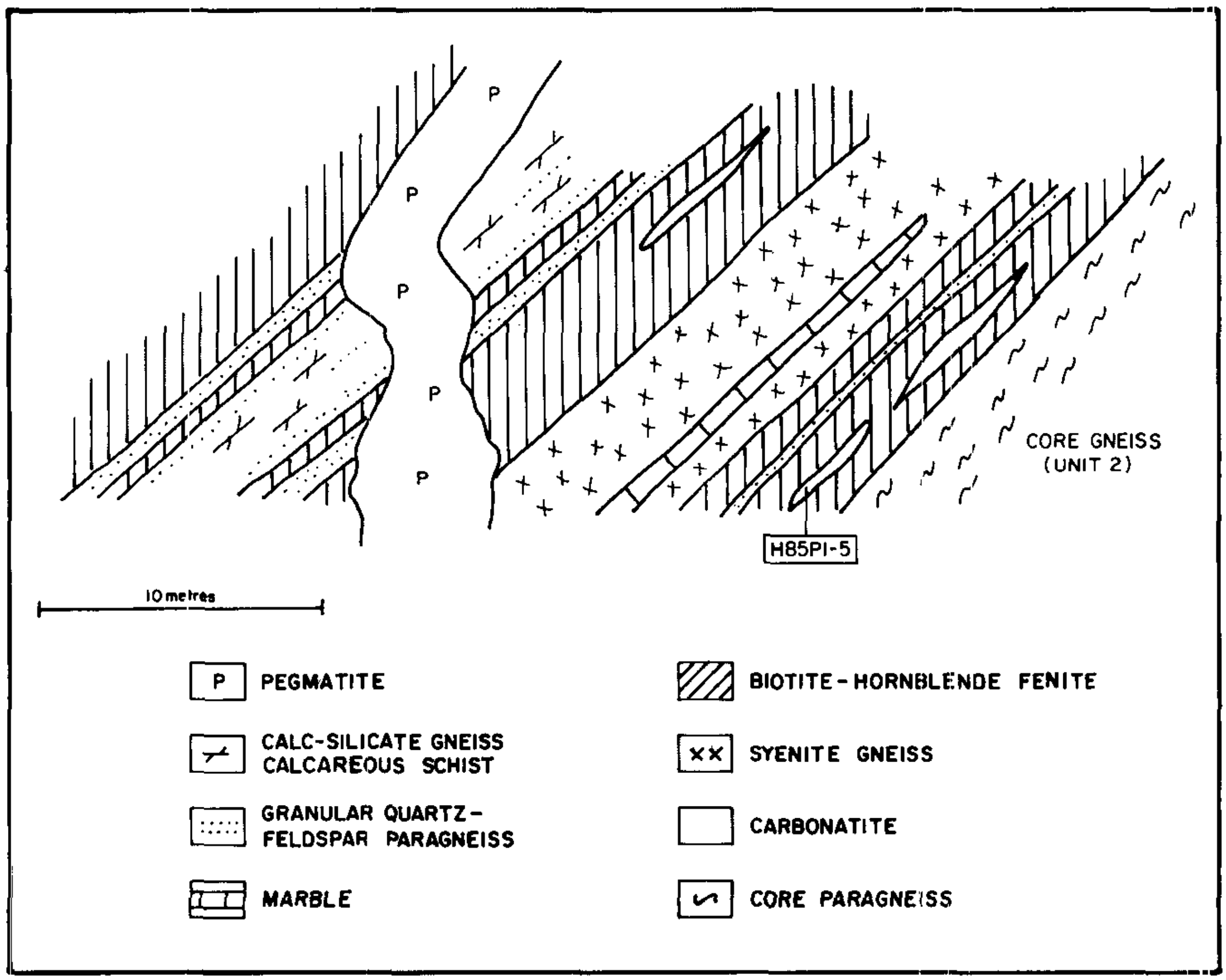


Figure 8-4. A schematic vertical section through the syenite-intrusive carbonatite-fenite zone at station H85P1 (Fig. 8-2).

and McMillan, 1979; Brown, 1980). It represents a transgressive marine sequence deposited on a low relief basement complex. Coarse fluvial sandstone, conglomerate, and perhaps a veneer of marine beach sands overlying a regional unconformity pass upward into fine-grained, calcareous muds and siltstones which probably were deposited on extensive tidal flats. The extrusive Mount Grace carbonatite was deposited near the top of this succession in a shallow marine environment.

ALKALIC ROCKS

INTRODUCTION

Alkalic rocks in the Perry River-Mount Grace area include:
(1) syenite, nepheline syenite gneiss;
(2) intrusive carbonatites, syenite;
(3) the intrusive 'Ren' carbonatite; and
(4) the extrusive Mount Grace carbonatite.

The syenites and intrusive carbonatites are restricted to the Perry River area, south of Ratchford Creek (Fig. 8-2). They are generally concordant with surrounding layering in metasedimentary rocks and are commonly intimately intermixed. Intrusive carbonatites are thin layers or lenses with well-defined metasomatic envelopes or 'fenite' margins. The Mount Grace carbonatite is essentially a thin layer that has been traced or projected at least 45 kilometres from the Perry River area to north of Blais Creek.

SYENITE, NEPHELINE SYENITE (UNIT 4b OF McMILLAN, 1973)

The largest syenite body in the Perry River area (*see* Fig. 8-2) is a concordant unit up to 300 metres thick and 12 kilometres long (McMillan, 1973). It is internally foliated and layered with alternating bands of syenitic and feldspathoidal rock. Country rocks along its margins are metasomatically altered with development of a rusty zone enriched in feldspar, pyroxene, muscovite, and/or pyrrhotite. Two analyses of the syenite are shown in Table 8-1; additional analyses are given by McMillan (*op cit.*). Semi-quantitative emission spectrographic analyses of these two samples indicate enrichment, relative to granites, of Ga, Be, Y, and Yb, as well as Nb, Zr, and sometimes Ba (McMillan, 1973).

INTRUSIVE CARBONATITES AND ASSOCIATED SYENITIC ROCKS

This unit includes a zone of intermixed syenitic rocks, fenite, carbonatite, and metasedimentary rocks near the base of the autochthonous cover succession. Two occurrences (sites H85P1, H85P4, Fig. 8-2) were studied in detail and extensively sampled for geochemistry and zircon separations. These occurrences appear to be part of a single continuous zone at least 4 kilometres in length (*see* Fig. 3 of McMillan and Moore, 1974). The zone is concordant with layering but on a regional scale may cut up section to the south.

TABLE 8-2a
MINOR AND TRACE ELEMENT DATA (SEMI-QUANTITATIVE EMISSION SPECTROSCOPY) OF CARBONATITES AND METASEDIMENTARY HOST ROCKS, PERRY RIVER AND MOUNT GRACE AREAS*

Sample No.	Rock Type	Mn	Sr	Ba	Nb
H85P1-5	intrusive carbonatite	3 000	>1 000	1 700	tr
H85P1-8	intrusive carbonatite	2 000	>2 000	1 100	tr
H85P3-2A	impure marble	100	1 500	400	—
H85P3-2B	impure marble	300	1 000	900	—
H85P3-2C	impure marble	200	700	200	—
H85P3-2E	Mt. Grace carbonatite	1 000	1 200	900	—
H85P3-3	Mt. Grace carbonatite	6 500	700	200	700
H85P3-5B	impure marble	2 500	tr	tr	tr
H85P4-3B	intrusive carbonatite	400	>2%	1 800	100
H85P4-3C	intrusive carbonatite	1 400	>1%	2 500	tr
H85P7	Mt. Grace carbonatite	2 800	400	2 200	200
H85P9	Mt. Grace carbonatite	6 000	5 000	1 800	500
H85P10	Mt. Grace carbonatite	4 000	>5 000	200	500
H85P11	Mt. Grace carbonatite	2 500	3 000	2 800	100
MG5-7	Mt. Grace carbonatite	3 000	1 500	1 600	100
MG5-8	Mt. Grace carbonatite	1 300	4 000	1 500	100
H85P25A	impure marble	1 500	600	900	—
H85P25B	carbonatite tuff	1 000	>1%	900	400
H85P25C	impure marble	1 200	600	1 200	—
H85P26A	Mt. Grace carbonatite	2 500	>1%	1 000	500
H85P26B	Mt. Grace carbonatite	2 500	>1%	3 000	1 000
H85P26Bi	mixed tuff-marble	800	700	300	—
H85P26C	mixed tuff-marble	1 500	1 000	1 000	—
H85P26D	Mt. Grace carbonatite	800	6 000	1 600	200
H85P26E	Mt. Grace carbonatite	400	4 000	900	—
H85P26F	Mt. Grace carbonatite	1 200	5 000	1 600	100
H85P26G	marble, minor tuff	1 200	1 000	3 500	100
H85P26H	impure marble	1 300	500	400	—
H85P29	Mt. Grace carbonatite	4 000	4 000	1 200	300

* All analyses in ppm.
Sample localities plotted on Figure 8-2.

Sections through the zone are illustrated on Figures 8-4 and 8-5. The syenitic rocks are most prominent near the base of the zone. In the northern section, they comprise essentially a single layer 5 to 6 metres thick, whereas at site H85P4 they form a number of layers. The syenitic rocks are foliated, compositionally banded, and contain rare thin metasedimentary layers and occasional small discontinuous carbonatite lenses. The syenitic rocks are composed primarly of 70 to 80 per cent plagioclase (andesine) and microcline in varying proportions. True syenites are less common than monzonites (microcline is generally less abundant than plagioclase). Principal mafic minerals are aegerine ± biotite. Sphene, magnetite, apatite, chalcopyrite, and allanite are common accessory minerals. A thin layer of predominantly albite within calc-silicate gneiss at site H84P1 contains abundant coarse molybdenite.

Dark grey to black, well-layered amphibole fenite occurs throughout both sections. It is comprised primarily of aegerine, sodic amphibole, biotite, and sphene. Calcite, apatite, plagioclase, magnetite, chalcopyrite, and ilmenite may also be present. In section H85P1, it forms a thin 2 to 3-metre-thick footwall contact zone between the syenitic rocks and core gneiss and a considerably thicker hangingwall zone where it is interbedded with metasedimentary layers (Fig. 8-4). It comprises greater than 50 per cent of the southern section where it contains abundant irregular zones, discontinuous lenses, and thin layers of carbonatite. The contacts between fenites and syenite gneiss, core gneiss, and thin granular quartz-feldspar layers within fenite are generally sharp, whereas contacts between fenites and calc-silicate layers are gradational. This, and the occurrence of thin remnant granular gneiss layers within fenite, suggest that calc-silicate layers are fenitized in preference to less calcareous layers.

Carbonatite lenses occur throughout the fenite and occasionally within the syenite and adjacent metasedimentary layers. Carbonate minerals comprise 70 to 80 per cent of the rock. Amphibole, apatite and phlogopite are the principal mafic components. Sphene aegerine, plagioclase, magnetite, pyrrhotite, pyrochlore, chalcopyrite, pyrite, and ilmenite may be present. Within fenite, the carbonatites may occur as relatively thick buff-weathering foliated and laminated layers (Plate 8-1); as swirled, discontinuous lenses (Plate 8-2a); or as small coarse-grained irregular pods with typically calcite centres and biotite-amphibole margins. Large subhedral to euhedral amphibole, sphene, ilmenite, and apatite crystals occur throughout these pods. Thin continuous carbonatite layers also occur in syenite and in metasedimentary layers (Plate 8-2b). They are fine grained, include thin discontinuous fenite amphibolite lenses, and have only thin fenite margins. Analyses of two samples of intrusive carbonatite are shown in Tables 8-2a and 8-2b; H85P1-5 is a coarse-grained variety within fenite and H85P1-8 is a white crystalline marble in overlying schist.

TABLE 8-2b
RARE EARTH ELEMENT DATA (NEUTRON ACTIVATION) OF CARBONATITES AND METASEDIMENTARY HOST ROCKS, PERRY RIVER AND MOUNT GRACE AREAS*

Sample No.	Ce	Dy	Er	Eu	Gd	Ho	La	Lu	Nd	Pr	Sc	Sm	Tb	Th	Tm	Yb
H85P1-5	2 010	41	<100	18	<720	9	1 470.0	1.7	654	290	8.45	73.8	5.4	35.9	3.4	17.4
H85P1-8	927	18	<100	9	<430	5	704.0	1.3	271	<99	0.12	35.6	2.4	<0.5	2.0	10.0
H85P3-2A	10	<1	<100	<1	<200	<1	6.6	<0.1	<5	<50	1.37	0.8	<0.5	1.2	<0.5	<0.5
H85P3-2B	18	1	<100	<1	<200	<1	11.1	<0.1	8	<50	2.92	1.6	<0.5	3.1	<0.5	<0.5
H85P3-2C	7	<1	<100	<1	<200	<1	4.1	<0.1	<5	<50	1.17	0.7	<0.5	2.6	<0.5	<0.5
H85P3-2E	155	4	<100	2	<240	<1	93.9	0.3	65	<64	7.42	8.2	0.8	30.6	<0.5	1.6
H85P3-3	1 430	20	<130	13	<590	5	957.0	0.7	469	<130	3.78	56.0	3.3	3.2	1.6	6.5
H85P3-5B	19	<1	<100	<1	<200	<1	10.2	<0.1	8	<50	0.63	1.9	<0.5	1.8	<0.5	<0.5
H85P4-3B	7 630	55	<100	83	<2 800	<3	>2 000.0	0.5	3 540	<550	0.58	313.0	11.0	24.8	6.7	7.4
H85P4-3C	614	13	<100	11	400	8	317.0	0.2	279	<71	0.12	41.4	1.6	5.0	1.2	2.9
H85P7	1 170	8	<100	8	<540	2	736.0	0.2	380	<120	7.19	33.2	1.4	3.7	1.0	3.4
H85P9	1 190	15	<100	12	<530	3	722.0	0.5	424	170	6.89	42.7	2.2	15.2	1.6	4.9
H85P10	875	15	<100	12	<440	4	505.0	0.5	345	100	6.70	43.6	2.3	15.0	1.9	4.9
H85P11	1 410	10	<100	9	<580	2	937.0	0.4	433	<130	8.75	38.2	1.5	5.7	1.0	3.3
MG5-7	198	12	<100	5	<260	2	94.2	0.4	91	<65	5.37	16.[illegible]	1.5	0.7	0.8	3.3
MG5-8	235	11	<100	4	<280	2	131.0	0.4	88	<68	4.42	14.6	1.4	0.6	0.7	3.3
H85P25A	126	4	<100	2	<250	<1	79.1	0.2	43	<62	9.27	5.9	<0.5	22.9	<0.5	1.4
H85P25B	598	20	<100	9	390	8	320.0	1.2	236	<80	1.89	33.9	3.0	17.9	2.0	9.0
H85P25C	47	2	<100	<1	<220	<1	28.7	<0.1	12	<56	7.56	3.1	<0.5	11.1	<0.5	1.0
H85P26A	670	17	<100	8	620	8	400.0	1.0	247	110	2.35	34.4	2.4	7.1	1.5	8.7
H85P26B	605	14	<100	7	<440	5	362.0	0.9	224	<96	2.17	28.6	1.8	6.4	1.8	6.1
H85P26Bi	152	3	<100	2	<200	<1	83.7	0.2	57	<50	2.01	9.2	0.6	<0.5	<0.5	1.2
H85P26C	176	5	<100	3	<200	<1	110.0	<0.1	64	<50	1.51	10.4	0.5	<0.5	<0.5	1.2
H85P26D	611	7	<100	4	<440	<1	479.0	0.3	149	<100	4.67	13.4	0.8	3.1	0.5	2.6
H85P26E	289	7	<100	5	<250	1	151.0	0.1	123	<60	2.14	15.1	0.8	0.6	0.7	1.6
H85P26F	512	9	<100	6	<370	2	310.0	0.3	188	<89	5.51	23.2	1.3	1.3	0.6	2.5
H85P26G	311	6	<100	4	<320	1	184.0	0.2	114	<78	6.68	15.2	1.3	4.9	0.8	2.3
H85P26H	45	4	<100	<1	<200	<1	26.5	0.2	17	<50	7.42	3.5	<0.5	6.5	<0.5	1.4
H85P29	398	11	<100	5	<400	1	242.0	0.5	139	<100	5.22	17.8	1.1	0.5	0.8	4.1

* All analyses in ppm.
Sample localities plotted on Figure 8-2.

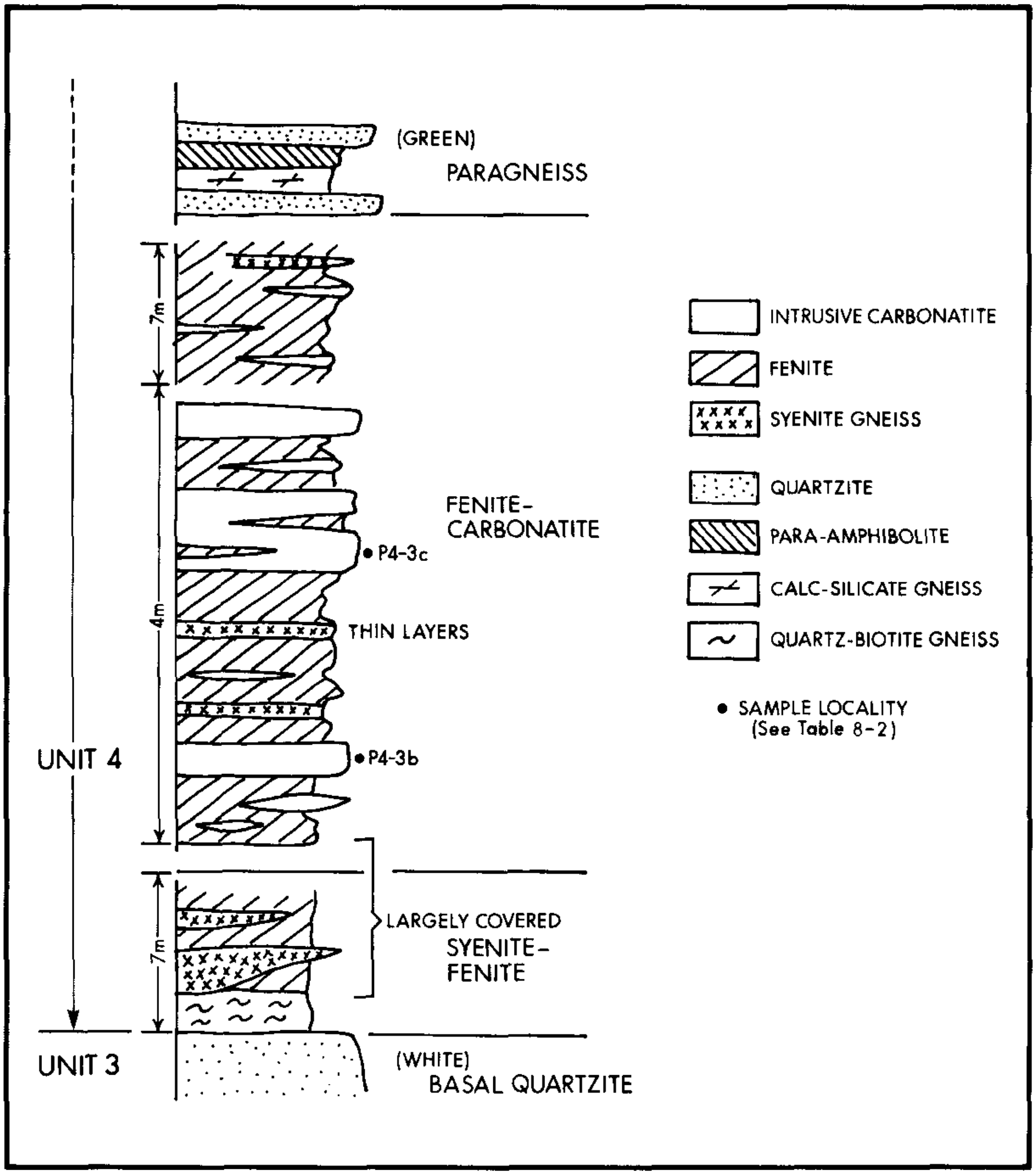
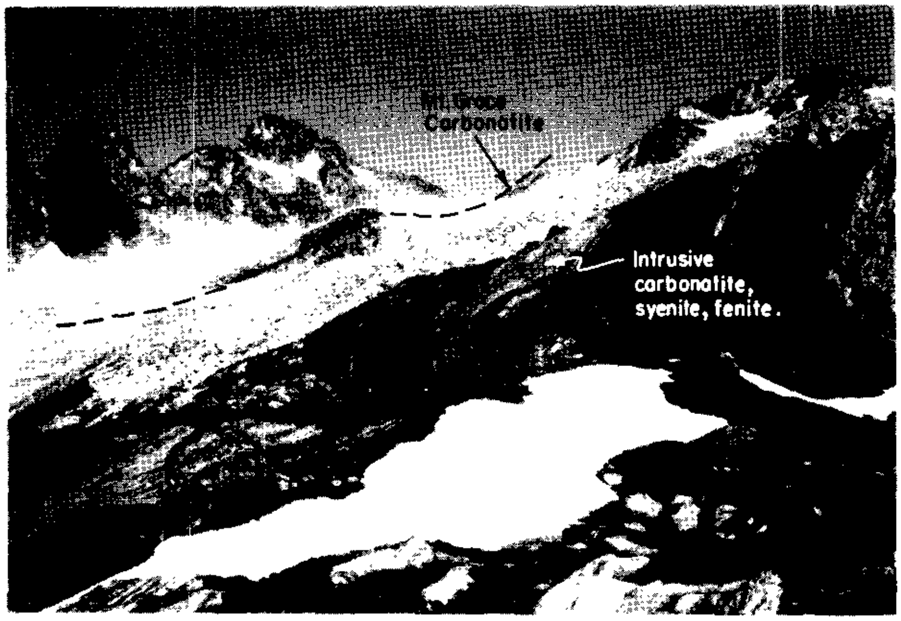
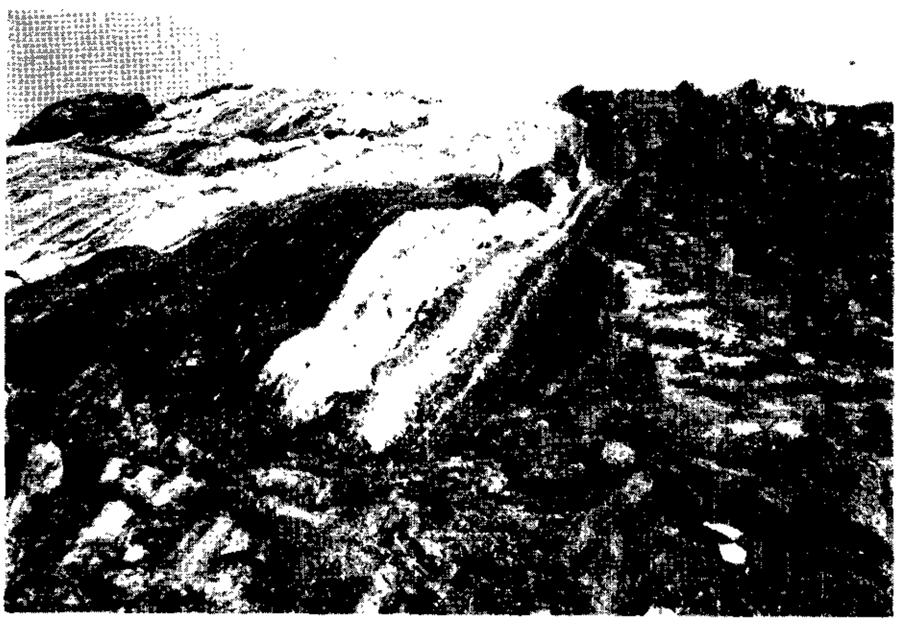


Figure 8-5. A measured section through the syenite-intrusive carbonatite-fenite zone at station H85P4 (Fig. 8-2).



(a)



(b)

Plate 8-1. Intrusive carbonatites-fenites, just south of station H85P4 (Fig. 8-2). (a) Overview showing position of carbonatite-fenit-syenite unit in foreground, and overlying Mount Grace carbonatite in distance. (b) Detail of interlayered ntrusive carbonatite and dark grey o black amphibolitic fenite.

(a)

(b)

Plate 8-2. Intrusive carbonatites at station H85P1. (a) Swirled, discontinuous carbonatite lenses in fenite (sample H85P1-5). (b) Intermixed buff-weathering carbonatite and fenite, overlain by grey-weathering carbonatite (sample H85P1-8).

REN CARBONATITE

A new occurrence of a carbonatite in unit 6 in the core of the Mount Grace syncline (Fig. 8-2) is reported by Pilcher (1983). It is a concordant unit at least 3 kilometres in length and 20 to 200 metres in width that has fenitized margins and zones of fenite within it (Pilcher, pers. comm., 1985). It weathers to 'a mottled orange-brown colour, has a well-banded to salt-and-pepper texture, and averages 60 to 80 per cent calcite, 10 to 30 per cent apatite with accessory biotite, amphibole, sphene, and minor pyrrhotite, pyrite, sphalerite, chalcopyrite, pyrochlore (?), and monazite (?)' (Pilcher, *op cit.*, p. 8). It differs from the previously described intrusive carbonate-syenite complex; it is substantially thicker, occurs higher in the succession, and does not appear to be closely associated with syenite.

MOUNT GRACE CARBONATITE

GENERAL DESCRIPTION

Field descriptions, petrography, and geochemistry of the Mount Grace carbonatite are described by Höy and Kwong (in press). This paper reviews briefly that data and presents extensive additional trace and rare earth element data and some detailed sections through the carbonatite layer.

The Mount Grace carbonatite layer averages 3 to 5 metres in thickness. Locally it narrows to less than a metre, but near (?) its northern limit (H85P29, Fig. 8-2), it is estimated to be greater than 60 metres thick. Although in most places it is a single layer, it locally comprises a main layer plus a number of thinner layers separated by paragneiss and marble. It has been traced or projected beneath overburden for a strike length of approximately 60 kilometres. The contacts of the Mount Grace carbonatite with overlying and underlying calcareous gneisses are sharp, but in places they grade through approximately 1 metre into grey-weathering, massive to thin-bedded calcite marble. In contrast with intrusive carbonatites in the Perry River area, the Mount Grace carbonatite has no fenitized margins.

In the field, the carbonatite is recognized and characterized by an unusual pale to medium brown-weathering colour. Grains of dark brown phlogopite, colourless apatite, and needles of amphibole weather in relief. Pyrrhotite, pyrochlore, and zircon are locally developed accessory minerals. The Mount Grace carbonatite is commonly internally bedded, with a layer or several layers of 'blocky' tephra interbedded with finer grained, massive or laminated carbonatite. The blocky tephra layers contain three types of matrix-supported clasts: small granular albitite clasts up to 3 centimetres in diameter, consisting of pure albite or albite with variable amounts of phlogopite; syenite clasts, 1 to 10 centimetres in diameter, consisting of K-feldspar with variable amounts of plagioclase calcite, apatite, and rare feldspathoids; and larger rounded to subrounded biotite-plagioclase gneiss, schist, and quartzite clasts that *are commonly up to 20 centimetres in diameter. The lithic clasts* may be internally folded and have a pronounced layering or foliation that is randomly oriented with respect to the regional mineral foliation. The lithic and albitite clasts are generally randomly distributed.

(a)

(b)

Plate 8-3. Mount Grace carbonatite (station H85P3). (a) Well-layered extrusive carbonatite containing small clasts of dominantly albitite (b) Large clast of mixed syenite-paragneiss (?) with relief fenite (?) along contact.

throughout a blocky tephra layer, but in some layers they are concentrated in the central portion or occasionally graded with clast size increasing up section.

The Mount Grace carbonatite was examined in detail and extensively sampled in the Perry River area (H85P3), in the Mount Grace area, and north of Blais Creek (H85P25).

PERRY RIVER AREA (H85P3)

The maximum thickness of the Mount Grace carbonatite in exposures at this site and north to the ridge (*see* Plate 8-1a) is approximately 1 metre. It consists of a single well-bedded layer that contains generally small (2 to 3-centimetre) albitite and lithic clasts (Plate 8-3a). Uncommon, larger clasts (to 15 centimetres maximum) include folded lithic fragments and a rare syenite clast with a preserved fenite margin (Plate 8-3b). The carbonatite layer is within a mixed impure marble, calc-silicate and pelitic gneiss sequence (Plate 8-4). The immediate footwall is a thin grey marble of sedimentary origin (*see* Tables 8-2a and 8-2b, sample H85P3-2C).

Rare earth element data and some trace element data for both the carbonatite and host rocks from this locality are listed in Tables 8-2a and 8-2b.

MOUNT GRACE AREA

The Mount Grace carbonatite occurs on the inverted west limb of the Mount Grace syncline. It structurally overlies the white crystalline marble of unit 5 and the Cottonbelt Pb-Zn layer near the base of unit 6. It has been traced discontinuously approximately 13 kilometres in the Mount Grace area, from limited exposures in trees near its south end to fairly continuous exposures west of Mount Grace, to two drill intersections at its north end. Its thickness varies from less than a metre at its north end to a maximum of approximately 3 metres just north of sample P11 (Fig. 8-2). It decreases in thickness southward but appears to increase again in the southern exposures. The size of included clasts appears to increase proportionately with thickness; 30 to 40-centimetre diameter clasts are common in the thicker sections, but only 5 to 10-centimetre maximum clast sizes occur in thinner sections.

Trace and rare earth element data of carbonatite samples from the Mount Grace area are given in Höy and Kwong (in press), and some additional data from this study (H85P7 to H85P11) are listed in Tables 8-2a and 8-2b.

BLAIS CREEK AREA

A measured section at site H85P25 (Fig. 8-2) illustrates the succession in the Blais Creek area and the position of the Mount Grace carbonatite near the top of unit 4 (Fig. 8-6). The carbonatite unit is 8.2 metres thick and includes a thick basal part of mixed coarse blocky tephra and fine-grained tuff and marble, overlain by interlayered impure metasedimentary marble and tuff (Fig. 8-7). Within the basal part are interbedded coarse tephra layers, fine-grained layers, and a number of coarsening upward cycles. Clasts are abundant (Plate 8-5), averaging 15 to 20 centimetres in diameter; the largest are 30 to 40 centimetres. In general, lithic clasts are larger than albitite clasts. The top of the Mount Grace carbonatite is dominated by impure siliceous marble that contains a few thin, brown-weathering, fine-grained tuff layers.

Analyses of the carbonatite layers and host rocks are listed in Tables 8-2a and 8-2b, and selected data plotted on Figure 8-7. The data confirms the existence of thin tuff layers within metasedimentary marble at the top of the carbonatite unit (sample H85P25B) and indicates that some of the fine-grained marble layers within the basal part of the carbonatite unit, those that have low REE concentrations (for example, H85P26B, H85P26D), may be largely of sedimentary origin with only a minor tuff component.

The thickness of the Mount Grace carbonatite increases dramatically northward to at least 20 metres at site H85P29 (Fig. 8-2). An associated increase in clast sizes here indicates close proximity to a source or vent area. The Mount Grace carbonatite has not been studied in detail at this locality and has only been traced a further 1 kilometre to the north.

TRACE ELEMENT AND RARE EARTH ELEMENT (REE) DATA

Analyses of selected samples of the intrusive carbonatites, the Mount Grace carbonatite, and host metasedimentary rocks are listed in Tables 8-2a and 8-2b. These samples are mainly from the Perry River and Blais creek areas as data from the Mount Grace area are given in Höy and Kwong (in press). Both types of carbonatite are characterized by relatively high Mn, Sr, and Ba values, and the extrusive Mount Grace carbonatite by Nb values that range up to 1 000 ppm (Table 8-2a).

Total REE concentrations (Table 8-2b) of both extrusive and intrusive carbonatites average between 0.1 and 0.2 per cent, with one sample of the Perry River intrusive carbonatite (H85P4-3B) containing greater than 1.5 per cent REE content. Chondrodite normalized REE plots of selected samples (Figs. 8-8, 8-9, and 8-10) illustrate the light rare earth element (La through Eu) enrichment that is typical of carbonatites worldwide. Comparison of plots for intrusive and extrusive carbonatites shows that although the slopes (enrichment) are similar, the intrusive carbonatites that are closely associated with syenite (Fig. 8-8) generally have higher absolute values of REE's than the Ren or the Mount Grace carbonatites. Overlap in REE values suggests that contamination of the Mount Grace carbonatite by simultaneous deposition of marine carbonate was minimal.

CONCLUSIONS

Initial alkalic magmatism included intrusion of syenites, nepheline syenites, and carbonatite lenses in a platformal metasedimentary succession that unconformably overlay a basement complex. Subsequent explosive volcanism from widely separated vent areas produced a number of interfingering pyroclastic ash flow or air fall layers, now preserved as the Mount Grace carbonatite. The extrusive episodes were separated by quiescent periods and locally deposition of marine carbonate. Intrusion of the Ren carbonatite in overlying metasedimentary rocks indicates that alkalic magmatism spanned a considerable time interval.

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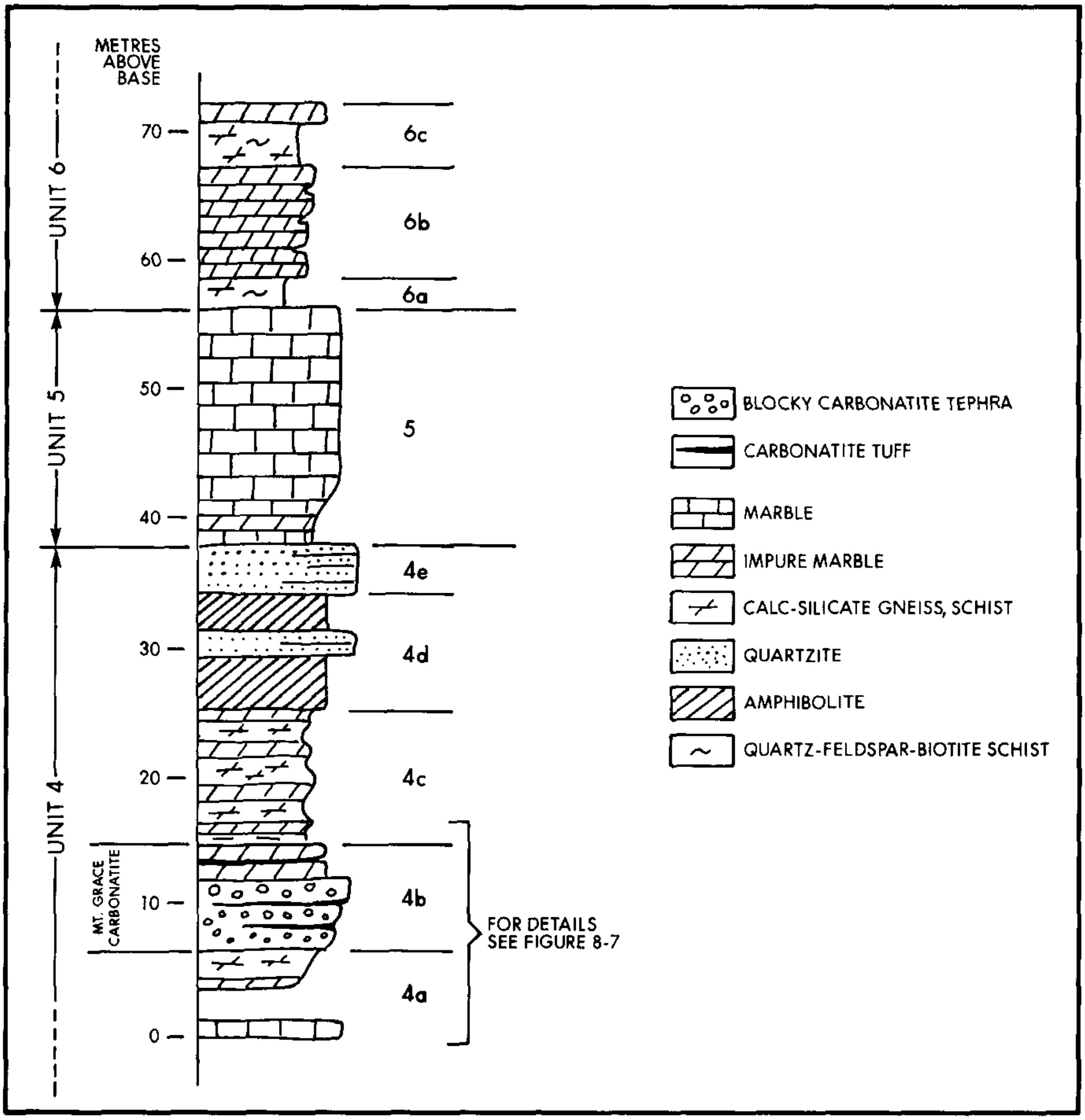


Figure 8-6. A measured section at stations H85P25, H85P26, Blais Creek area that includes the Mount Grace carbonatite and adjacent host rocks.

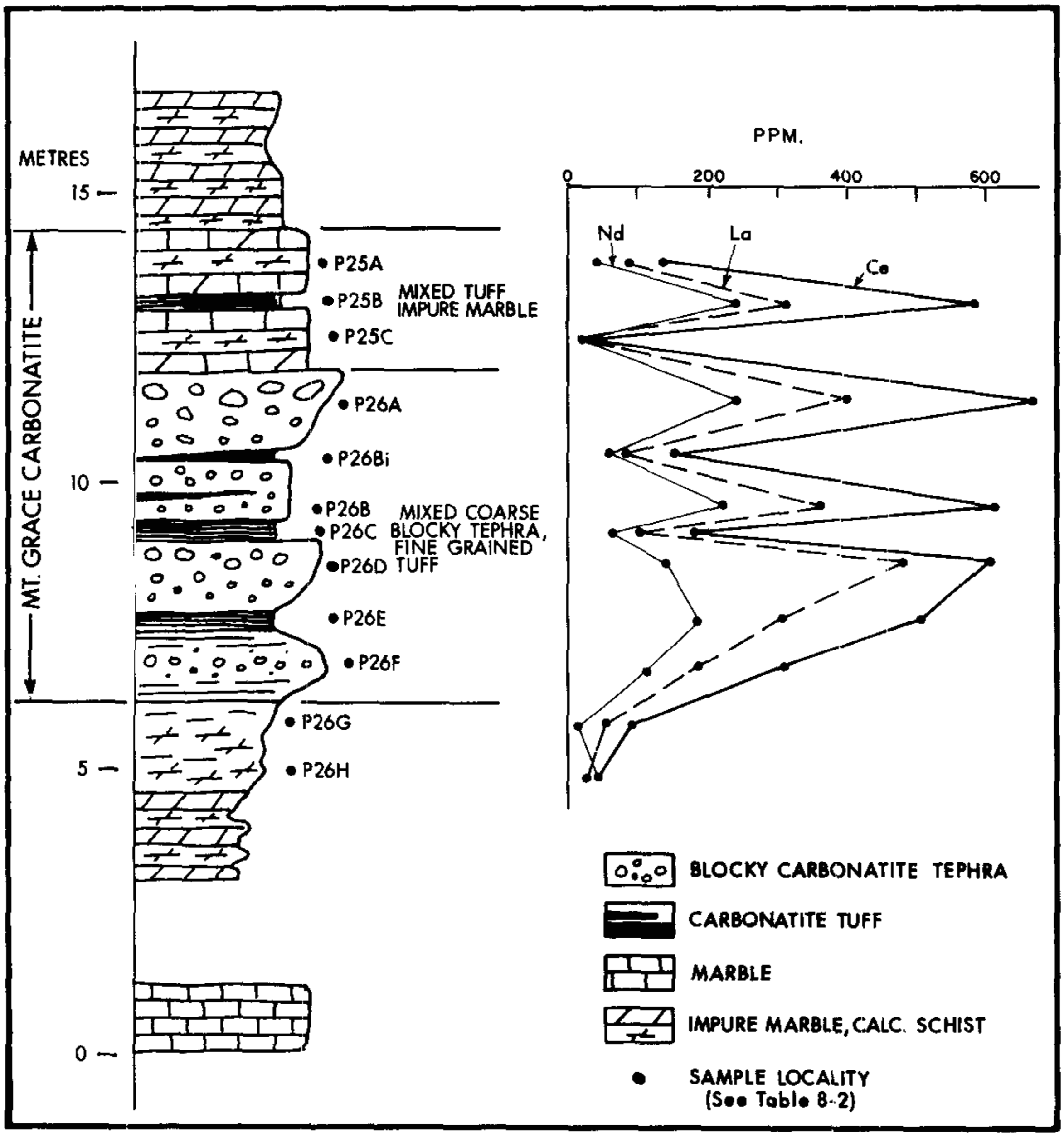


Figure 8-7. Detailed section of the Mount Grace carbonatite, Blais Creek (stations H85P25 and H85P26), showing La, Ce, and Nd values of selected samples.

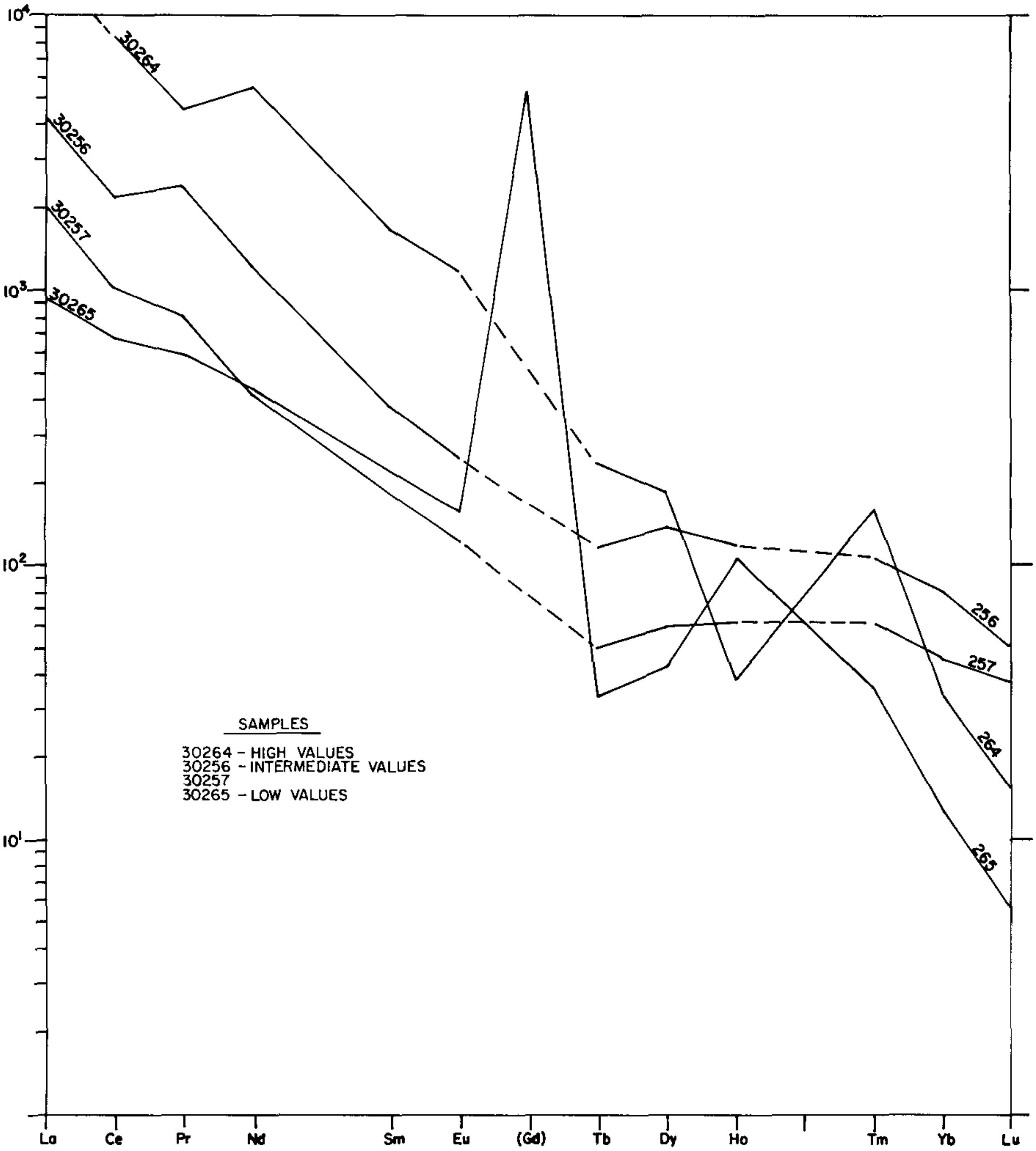


Figure 8-8. Chondrodite normalized rare earth element plots of intrusive carbonatites, Perry River area.

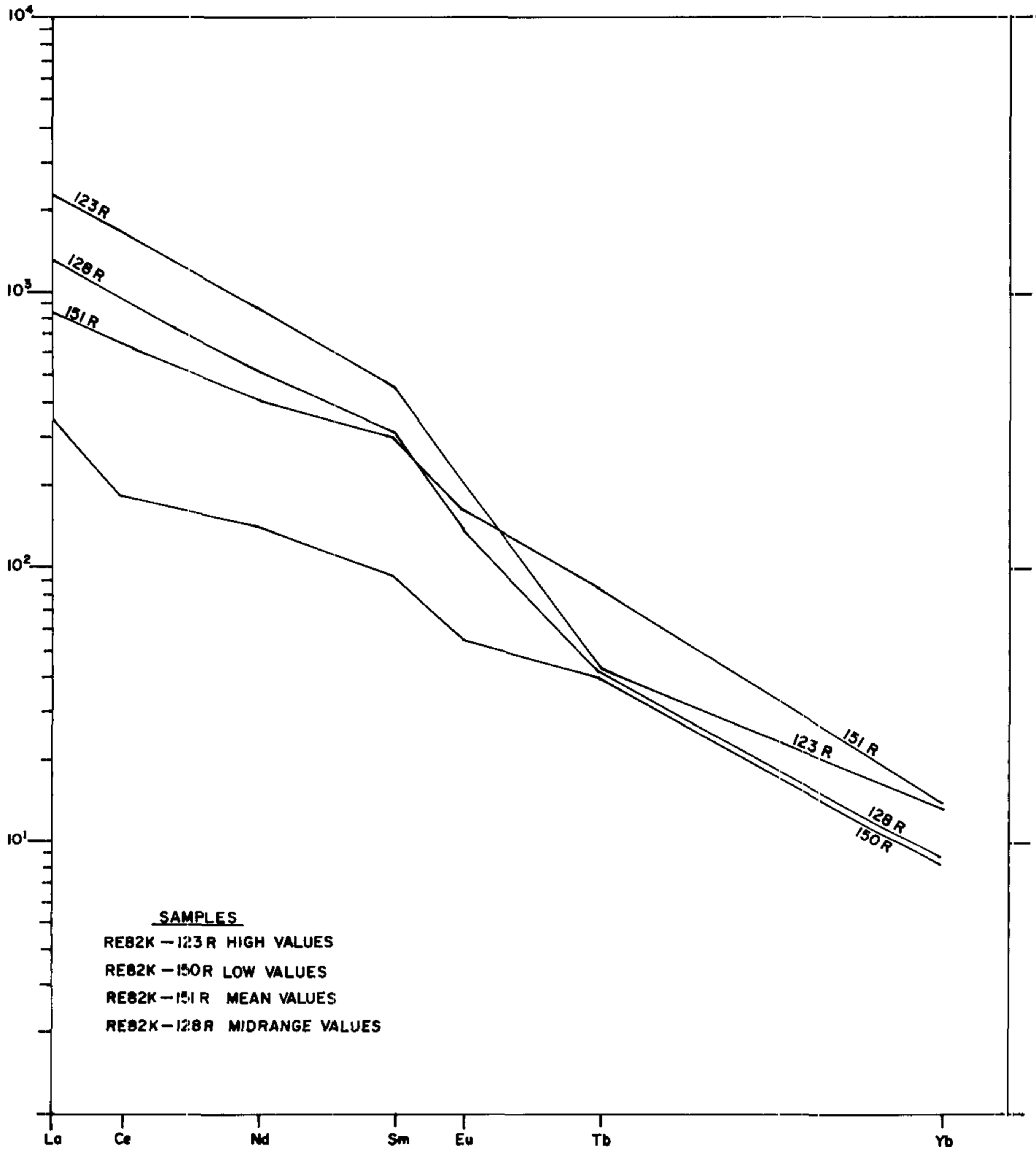


Figure 8-9. Chondrodite normalized rare earth element plots of the Ren intrusive carbonatite.

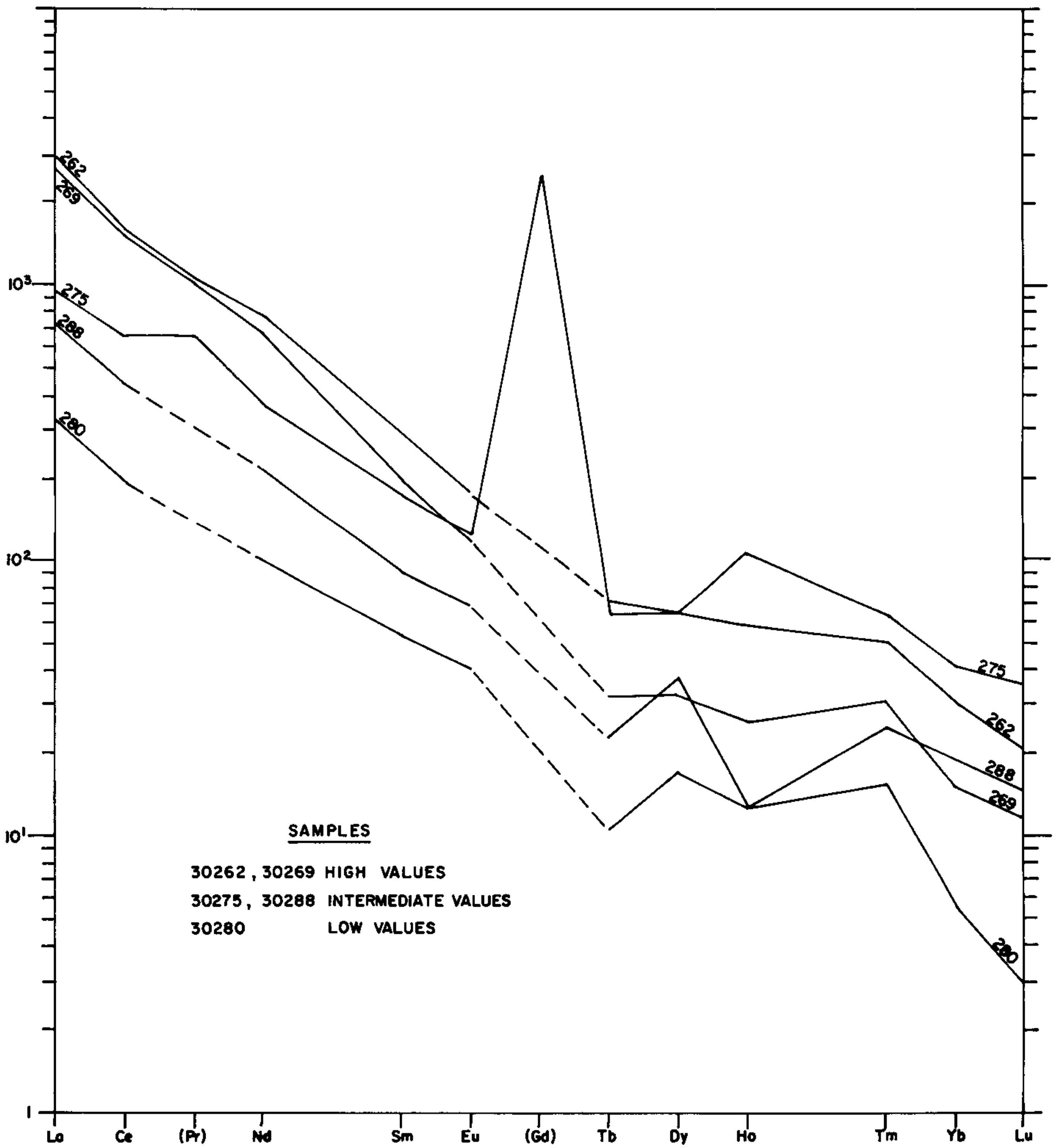
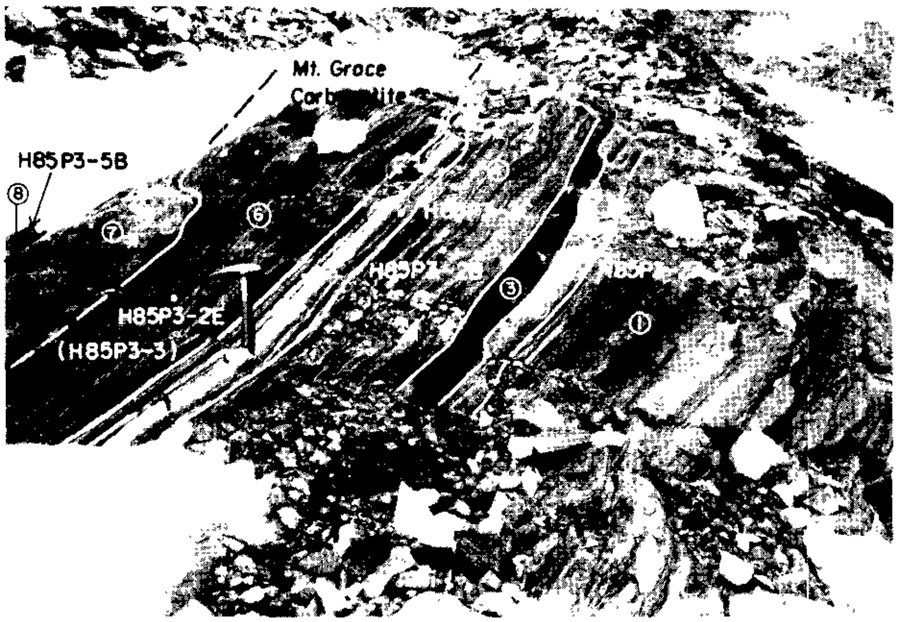


Figure 8-10. Chondrodite normalized rare earth element plots of the Mount Grace intrusive carbonatite.



LEGEND

8 IMPURE MARBLE
7 CALC-SILICATE GNEISS
6 MOUNT GRACE CARBONATITE
5 GREY MARBLE
4 IMPURE MARBLE, CALC-SILICATE GNEISS
3 RUSTY SCHIST
2 IMPURE MARBLE
1 CALC-SILICATE GNEISS, IMPURE MARBLE, PELITIC SCHIST

Plate 8-4. The Mount Grace carbonatite and host succession at site H85P3, showing locations of analysed samples (Tables 8-2a and 8-2b).

Plate 8-5. Subrounded paragneiss clasts in the Mount Grace carbonatite at the Blais Creek section (station H85P25).