

NOTES ON THE MINERALOGY AND COEXISTING PYROXENES FROM THE GRANULITES OF MONT TREMBLANT PARK, QUEBEC

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ABSTRACT

The minerals of the granulites are distinctive of the granulite facies. Two analyses of coexisting pyroxene pairs from rocks associated with the granulites are presented from an interlayered pyroclastic and an intrusive quartz mangerite. The analyses of the pyroclastic indicate that the granulites formed under conditions of approximately 600–700°C and up to 10 kbs in pressure and that of the mineralogy of the quartz mangerite confirms its magmatic origin.

INTRODUCTION

The granulites of Mont Tremblant Park are located in the southwest portion of the Grenville province of Quebec (Katz 1969). These rocks are fine-grained and display a characteristic foliation and/or lineation marked by elongated plates of quartz. The microstructure of these rocks suggest a history of intense deformation and recrystallization (Katz 1968a). The granulites consist of two main groups; quartzofeldspathic granulites which are pink, quartz-micropertthite rocks, and hypersthene granulites which are grey-green, quartz-micropertthite and/or antiperthite-hypersthene rocks. Retrograde diopside, biotite and hornblende granulites are mainly confined to the contacts of the late stage charnockitic and syenitic intrusions of the anorthosite suite of the Morin Series (Katz 1968b).

The minerals of the granulites are essentially anhydrous and characteristic of the granulite facies. The alkali feldspars are primarily microcline micropertthites or mesopertthites (Michot 1957) ($2V$ ranges from 70° to 80° in the porphyroclasts and 80° to 87° in the recrystallized matrix). The plagioclase feldspars are antiperthitic and range in composition from An_{22} in the quartzofeldspathic granulites to An_{40} in the hypersthene granulites. The peculiar greenish-brown colour imparted to the hypersthene granulites by the quartz and feldspars has been confirmed as a yellow-green alteration material as suggested by Howie (1967). Hypersthene is pleochroic from green to pink to yellow, and one x -ray determination indicates that it contains about 2% Al_2O_3 . The hypersthene appears to be altered to a chlorite (x -ray powder photos show moderate reflections at 14.16 Å and 7.12 Å). One determination on a garnet indicates a pyrope-almandine

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with about 10% grossularite ($n = 1.795$, $a = 11.557 \text{ \AA}$) (Sastri 1962). When present, diopside is pale green, hornblende is a deep green to almost brown colour and biotite is deep brown to red-brown. Coexisting titaniferous magnetite or ilmenite-magnetite and ilmenite are persistent accessories, especially in the recrystallized granulites. Hematite-ilmenite is more common in the unrecrystallized rocks retaining perthitic feldspars. Rutile is common and sphene is invariably absent from the granulites. Green spinel and scarce corundum, usually intergrown with the iron-titanium oxide minerals occasionally appear in rocks containing free quartz. Apatite and zircon do not appear to be enriched in the quartzofeldspathic granulites and do not display forms typical of magmatic origin.

ANALYSES OF COEXISTING PYROXENES

Much has been written recently on the composition of coexisting pyroxene pairs in igneous and metamorphic rocks (Howie 1965). Based on thermodynamic theory, the distribution of major ions in the coexisting pyroxenes has been given by Mueller (1960). Assuming equilibrium conditions and ideal solutions, the distribution coefficient $K(p)$ is as follows

$$\frac{(\text{Fe}^{+2}/\text{Mg})_{\text{orthopyroxene}}}{(\text{Fe}^{+2}/\text{Mg})_{\text{clinopyroxene}}} = K(p)$$

Similar distribution coefficients have been derived by Kretz (1961, 1963) and Binns (1962). Kretz (1963) demonstrated that K appears to be constant for a given set of conditions, but changes as a function of temperature while pressure and other factors, including composition, have little effect. This latter point was disputed by Binns (1962).

The values of K confirmed from a great variety of analyses published in the literature (Kretz 1963) seem to be specific for igneous rocks ($K \approx 1.4$) and metamorphic rocks ($K \approx 1.8$). As Kretz (1961) points out. "*Unfortunately distribution coefficients have not yet been determined experimentally and all the information available comes to us from studies of naturally occurring crystalline rocks.*"

Because the granulites in this study do not contain substantial amounts of clinopyroxene the two coexisting pyroxene pairs were analyzed from an intrusive quartz mangerite (K16—5) (16% quartz, 58% feldspar as equal amounts of microperthite and antiperthite, 11% orthopyroxene, 5% clinopyroxene, 9% iron titanium oxides and 1% accessories) and a pyriclasite (F18—13) interbanded with the granulites (2% quartz, 35% antiperthite, 30% orthopyroxene, 13% clinopyroxene, 15% iron-titanium oxides, 3% hornblende, 1% garnet and 1% accessories). (Table 1). From

TABLE 1. ANALYSES¹ OF CO-EXISTING PYROXENES²

	Specimens ³			
	1	2	3	4
SiO ₂	49.61	51.21	48.19	50.27
TiO ₂	1.80	0.80	0.42	1.06
Al ₂ O ₃	2.43	2.80	2.14	2.39
Fe ₂ O ₃	0.80	1.14	1.86	2.05
FeO	21.81	9.49	27.45	10.24
MnO	0.42	0.56	0.42	0.58
MgO	21.16	12.44	17.26	12.68
CaO	1.29	21.46	1.67	20.54
Na ₂ O	0.47	0.13	0.13	0.46
K ₂ O	0.45	0.23	0.18	0.17
Total	100.24	100.26	99.72	100.44
Si } ₄	1.867	1.919	1.877	1.896
Al } ₄	0.108	0.081	0.098	0.104
Al } ₅		0.045		
Ti } ₅	0.052	0.022	0.012	0.029
Fe ⁺³ } ₅	0.023	0.032	0.056	0.059
Fe ⁺² } ₅	0.687	0.297	0.894	0.324
Mn } ₅	0.014	0.018	0.014	0.018
Mg } ₅	1.186	0.695	1.002	0.713
Ca } ₅	0.052	0.862	0.070	0.829
Na } ₅	0.018	0.005	0.005	0.016
K } ₅	0.011	0.005	0.005	0.005
W } ₆	0.081	0.872	0.080	0.854
X } ₆	1.887	1.010	1.910	1.055
Y } ₆	0.075	0.099	0.068	0.088
Z } ₆	1.975	2.000	1.975	2.000
Ca } ₇	2.7	45.3	3.4	42.7
Mg } ₇	60.4	36.5	49.2	36.7
Fe } ₇	36.9	18.2	47.4	20.6
n _z	1.715	1.720	1.728	1.725
2V°	57.5	60.0	57.0	56.0
a(Å)	18.3092		18.2783	
b(Å)	8.9100		8.8954	

¹Analyst: M. B. Katz.²Locations: K16—5: Lat. 46°20', Long. 74°15';
F18—13: Lat. 46°24', Long. 74°13'.³1. Orthopyroxene, sample K16—5

2. Clinopyroxene, sample K16—5

3. Orthopyroxene, sample F18—13

4. Clinopyroxene, sample F18—13

⁴Relative numbers of atoms in tetrahedral sites.⁵Relative numbers of atoms in octahedral sites.⁶Standardized formula of the pyroxenes as $W_{1-p}(X, Y)_{1+p}Z_2O_6$.⁷Relative numbers of cations Ca, Mg and Fe (=Fe⁺² + Fe⁺³ + Mn) in the pyroxenes.

this data estimates can be made on the temperature of formation. The quartz mangerite (K16—5) has a value of $K = 1.36$ indicating a temperature of formation of 1100°C and the pyriclasite (F18—13) with a

value of $K = 1.96$ gives a temperature of formation of 600°C (Kretz 1963). These temperature values are consistent with the facts that the quartz mangerite has crystallized from a silicate melt and the pyriclasite interbanded with the granulites has formed under conditions of high grade metamorphism.

Pyroxenes formed under granulite facies conditions contain relatively large amounts of alumina (Boyd & England 1960). There is no doubt, however, that the amount of alumina in the environment plays an important role in the composition of the pyroxenes (Howie 1965). The alumina content of the orthopyroxene from the pyriclasite (F18-13) is just over 2.00% (Table 1). Cell dimensions of a hypersthene from a charnockitic granulite were determined; $a = 18.3068 \text{ \AA}$, $b = 8.8976 \text{ \AA}$, and indicate that the composition is En_{55} containing about 2% Al_2O_3 (Howie 1963). Both these values suggest that P-T conditions of approximately $600\text{--}700^{\circ}\text{C}$ at 10 kbs are possible (Boyd & McGregor 1964). The extrapolations involved are so great that the estimates cannot be made with any confidence, although the P-T conditions are reasonable for the granulite facies.

CONCLUSIONS

The compositions of coexisting pyroxene pairs from 1) a dark pyriclasite interlayered with, and assumed to have been metamorphosed at the same time as, the granulites gives an estimated temperature of formation of 600°C , and from 2) a quartz mangerite confirms its intrusive and magmatic origin. The alumina content of the orthopyroxenes give P-T conditions in the order of $600\text{--}700^{\circ}\text{C}$ at 10 kbs. Also, the presence of micropertthites, especially when composed of equal amounts of potash feldspar and plagioclase (mesopertthite) indicate that the minimum possible temperature of formation is $660^{\circ}\text{C} \pm 10^{\circ}\text{C}$ (Tuttle & Bowen 1958, p. 42). The presence of antiperthites (Sen 1959), coexisting iron and titanium oxides (Buddington & Lindsley 1964) and intergrowths of magnetite-spinel and corundum (Turnock & Eugster 1962) suggests original solid solutions which could only have been formed at relatively high temperatures. All the mineralogical data are therefore consistent with the views that these rocks were formed under high grade metamorphic conditions of the granulite facies.

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