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THE HARP LAKE COMPLEX, LABRADOR ; AND THE MORIN COMPLEX, QUEBEC : EXAMPLES OF IGNEOUS AND META-IGNEOUS ANORTHOSITIC COMPLEXES IN THE EASTERN CANADIAN SHIELD (*)

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(7 fig. dans le texte)

ABSTRACT

The Harp Lake complex underlies about 10,000 km² in central Labrador. Approximately 75 percent of the complex comprises leucotroctolites, leucogabbros, leuconorites and anorthosite. Layered structures are widespread in these rocks but do not define a simple structural entity. Younger pyroxene- and olivine-bearing adamellites make up most of the remainder of the complex. Olivine gabbros, gabbros and diorites are present at the margins of the anorthositic rocks and occur as dikes and small intrusive masses within the complex. Analyzed pyroxenes and feldspars show continuous compositional ranges from the anorthositic rocks through rocks of intermediate composition to the adamellites. Orthopyroxenes extend from Mg_{73} to Mg_{21} and plagioclases from An_{72} to An_{6}.

The Morin meta-igneous complex in Quebec comprises an anorthositic massif (chiefly anorthosite and leucogabbro) that underlies about 2,500 km² together with a similar area of closely spatially associated pyroxene quartz monzonites with lesser proportions of gabbro, pyroxene diorite and monzodiorite. Dikes of pyroxene monzodiorite cut only anorthositic rocks and dikes of pyroxene quartz monzonite cut both anorthositic rocks and pyroxene monzodiorites. Analyzed pyroxene and feldspar compositions form continuous ranges from the anorthositic rocks through pyroxene monzodiorites to pyroxene quartz monzonites. Orthopyroxenes extend from Mg_{70} to Mg_{36}, plagioclases from An_{53} to An_{24} and alkali feldspars from Or_{95} to Or_{80}. The lower degree of iron enrichment in the pyroxenes by comparison with Harp Lake is in accord with a greater abundance of oxide minerals in the rocks and numerous oxide mineral deposits suggesting higher oxygen fugacities in equilibrium with the Morin magmas.

The mineral chemistry of both complexes implies that they resulted from some sort of evolving magmatic process. Periodic tapping of a magma reservoir undergoing fractional crystallization at depth is suggested as a possible mechanism to explain the observed geological relations and the patterns of mineral variation. The Harp Lake complex retains mineral equilibria resulting from subsolidus reactions during cooling from igneous temperatures. The Morin complex reflects mineral equilibria in part characteristic of lower temperature metamorphic conditions, in part a presevation of higher temperature, presumably relict igneous, equilibria.

INTRODUCTION

The common spatial association of anorthositic rocks with pyroxene quartz

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monzonites or adamellites (farsundites, quartz mangerites, charnockites of some authors) has been recognized for many years. It has remained controversial whether this is also a genetic association and if so the nature of the relationship (Emslie, 1973). The excellent layered sequence of Bjerkrem-Sogndal, southern Norway (Michot, 1970; Duchesne, 1972) containing a stratigraphic succession from anorthositic through intermediate rocks to pyroxene quartz monzonites seems to be a rare, if not unique, occurrence. In North American anorthosite suites the evidence for a genetic relation ship of these rocks has been far less clear and there has been much discussion of possible models to explain the association.

Wide ranging speculation has been fostered because of a severe shortage of chemical and mineralogical information on the various members of anorthositic complexes. In recent years, new tools are being applied that should be capable of supplying important constaints to various models attempting to explain the genesis of anorthositic and related rocks (minor element distributions, concentrations of stable and radioactive isotopes, rare earth element patterns). All of these are limited in their usefulness, however, if the basic geology and rock and mineral chemistry of anorthositic complexes is poorly understood.

This contribution presents preliminary results of electron microprobe analyses of the essential silicate minerals in the main rock units of the Harp Lake complex, Labrador and the Morin complex, southwestern Quebec. The analyses were carried out using recognized techniques and appropriate standards for the compositions analyzed. In the graphical presentation of the data each plotted point is the average of 3 to 8 spot analyses from two or more grains. The detailed analytical results will be presented elsewhere. In this paper the broad aspects of the mineral chemistry in each complex are given and the implications with respect to the genesis of the complexes are considered.

In the eastern Canadian Shield a natural primary subdivision may be made between anorthositic complexes that lie within the Grenville Province and those that lie north of the Grenville Front in central and northern Labrador (Fig. 1). The Morin complex (Martignole and Schrijver, 1970; Emslie, 1974) is a representative of the former group and the Harp Lake complex (Emslie *et al*, 1972) of the latter. This does not mean that either may be regarded as necessarily typical of the group to which it belongs. On the other hand, it can be argued with equal conviction that there is no reason to believe they are atypical.

Both the Harp Lake and Morin complexes contain grossly similar major rock units — relatively large areas of anorthositic rocks, small areas of intermediate rocks and substantial areas of quartz-bearing rocks. Crude estimates of the relative areas of these rocks in each complex are :

	Harp Lake	Morin
Anorthositic rocks	75 %	50 %
Intermediate rocks	2 %	10 %
Silicic rocks	23 %	40 %

At Harp Lake substantial amounts of leucotroctolite and minor amounts of troctolite occur in the anorthositic rock group. The Morin complex contains no leucotroctolite but a small amount metatroctolite is present at one locality adjacent to anorthosite. Its relationship to the complex is uncertain.

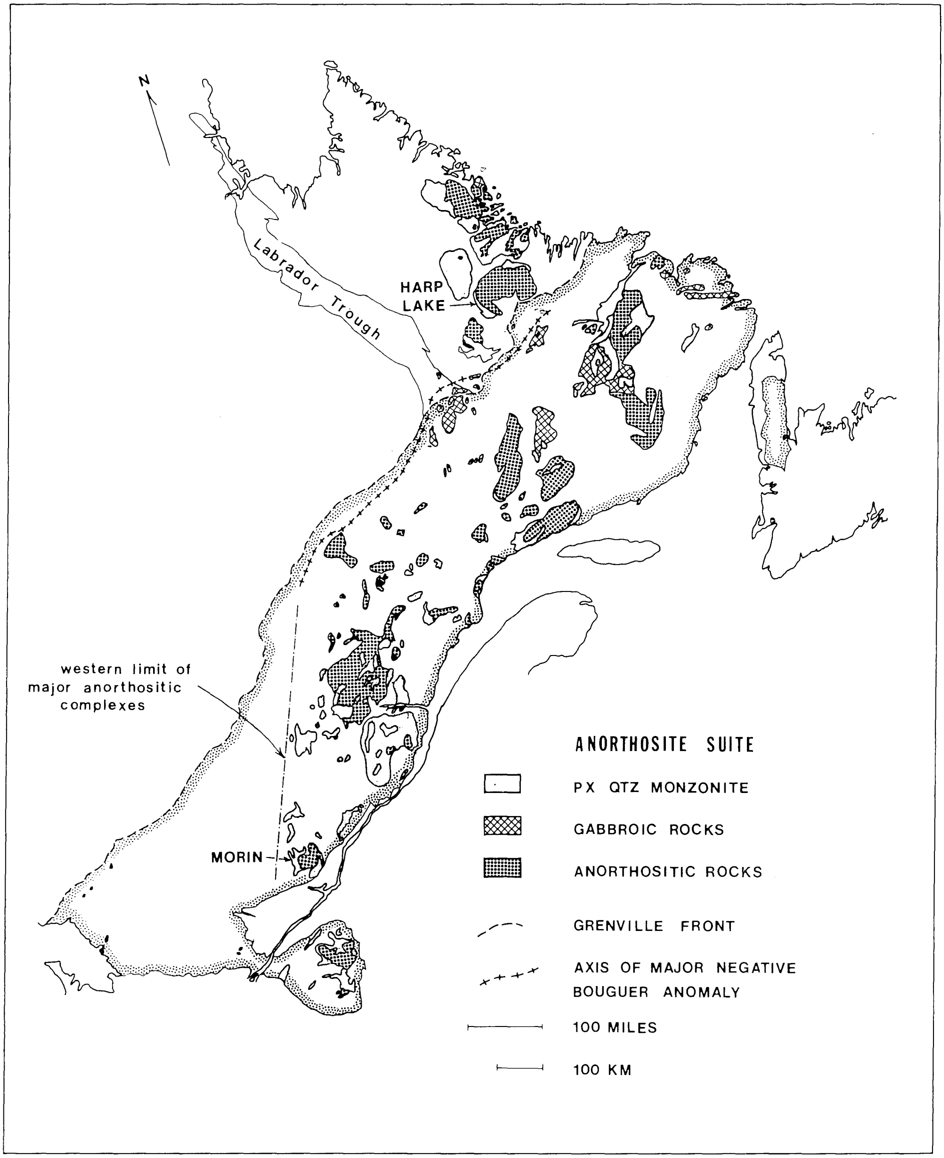

Fig. 1. — Distribution of anorthositic and related rocks in the eastern Canadian Shield. The Grenville structural province is outlined with a stippled pattern. Locations of Harp Lake and Morin complexes are indicated.

THE HARP LAKE COMPLEX

The Harp Lake complex (Emslie *et al*, 1972) underlies about 10,000 km^2 in central Labrador (Fig. 1). It lies within the Western Nain Province as defined by

Stockwell (1964). Zircons from adamellite of the complex have yielded a nearly concordant U-Pb age of about 1450 m.y. (Krogh and Davis, 1973).

Most of the county rocks surrounding the Harp Lake complex are amphibolite facies granitoid gneisses with sparse layers and lenses of metasedimentary rocks and amphibolite. Adjacent to the complex these rocks are upgraded to granulite facies mineral assemblages, presumably due to contact metamorphism. The metamorphic terrain east of the Harp Lake complex has yielded K-Ar metamorphic mineral ages indicative of the Archean. The terrain north and west of the complex is believed to have been regionally metamorphosed during the Hudsonian Orogeny ($\sim$ 1700 m.y. ago) but has yielded post-Hudsonian K-Ar mineral ages presumably due to later uplift.

In area, the largest unit of the Harp Lake complex comprises anorthositic rocks including anorthosite, leucotroctolite, leucogabbro and leuconorite. These rocks contain common and widely destributed layered structures, chiefly with low to moderate dips. Partly because of outcrop limitations, but perhaps even more due to the inherent nature of the processes that produced the layering, individual layers or sections of layered rocks cannot be traced or correlated over large horizontal distances. Consequently, although attitudes of layering are regular over substantial areas it has not been possible to define a simple overall structure. Marginal to the anorthositic rocks, fine — to medium — grained gabbro, norite and olivine gabbro occur at contacts with older county rocks only, not at contacts with other members of the complex.

Dikes and small intrusive bodies of pyroxene diorite and monzodiorite occur within the anorthositic rocks in many places. Pyroxene diorite and monzodiorite are also commonly present at the margins of large adamellite masses.

The adamellite group is the second largest unit of the complex and makes up about one-quarter of the total area. As dikes and apophyses, rocks of the adamellite group intrude both the previous groups. On the basis of field relations the rock units of the complex progress from basic to silicic with decreasing intrusive ages.

There is no recognizable regional metamorphic overprint on the rocks of the complex. A swarm of large olivine diabase dikes trends east-northeast and postdates the complex.

Compositions of pyroxenes and Fe-rich olivines of the main rock units of the Harp Lake complex are shown in Fig. 2b. Tie lines join coexisting minerals. Nearly all pyroxenes are exsolved to some degree and the compositions plotted are those of the host phase only. All of the low Ca pyroxenes except those from anorthositic rocks have textures characteristic of inverted pigeonites. The assemblage of Fe-rich coexisting clinopyroxene, orthopyroxene and olivine (plus quartz) is similar to those described by Smith (1974) from the Nain area to the north. At Harp Lake the assemblage occurs in a monzodiorite at the margin of a large adamellite mass.

Feldspars from the complex are plotted in Fig. 2a. Plagioclase compositions in anorthositic rocks cluster around An_{54} but range from An_{47} to An_{72}. In the pyroxene diorites the range is An_{31} to An_{45} and these are commonly antiperthitic. Plagioclases in the adamellites range from An_{6} to An_{33} and coexist with alkali feldspars. Mesoperthites occur in the pyroxene diorites and adamellites but these have not yet been analyzed.

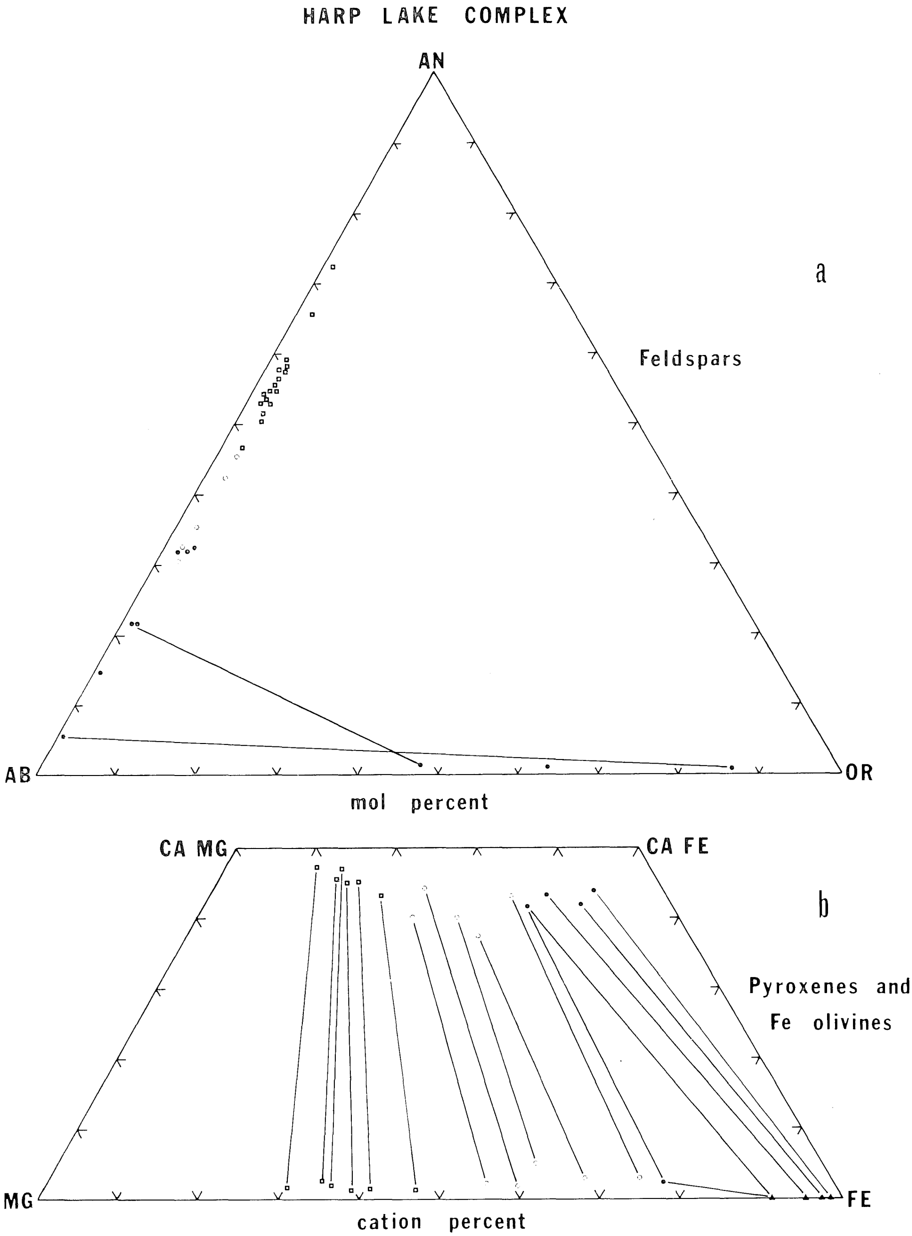

Fig. 2. — a) Analyzed feldspars of the Harp Lake complex. b) Analyzed pyroxenes and Fe-rich olivines from the Harp Lake complex. Fe is total iron. Tie lines join coexisting minerals. Open squares indicate minerals from anorthositic rocks, open circles from intermediate rocks, solid circles from silicic rocks, solid triangles are olivines. Additional analyses indicate that the range of low Ca pyroxene is at least Mg_{73} to Mg_{21} and plagioclase is An_{72} to An_6.

THE MORIN COMPLEX

The anorthositic rocks of the Morin complex underlie about 2,500 km^2. Quartz-bearing rocks of the complex underlie a similar but less well defined area because it is uncertain to what extent satellitic intrusions should be included as part of the complex. The metamorphic age of the complex is probably about 1124 $\pm$ 27 m.y. according to a Rb-Sr isochron by Barton and Doig (1972) on similar rocks of the nearby Lac Croche complex. These authors suggest that the low initial ratio of $Sr^{87}/Sr^{86} = 0.7042$ indicates a short interval between igneous crystallization and subsequent regional metamorphism.

The descriptive rock names used for the Morin complex should all be prefixed by meta-. In the interests of simplicity, however, an igneous terminology will be used.

The country rocks into which the Morin complex was intruded consist dominantly of quartzofeldspathic granulites, granitic gneisses and metasedimentary rocks. These are probably of more than one age on the basis of Rb-Sr dating (Barton and Doig, 1973).

Structures formed by mineral layering occur in the anorthositic rocks of the complex. Due in part to the poorer rock exposure, such layering is much less common than at Harp Lake and consequently it is of little help in defining the original structure of the anorthositic rocks. Anorthosite and leucogabbro are the dominant rock types.

The intermediate rocks are chiefly pyroxene diorites and monzodiorites (jotunites of some authors). These occur principally around the margins of the pyroxene quartz monzonites and separate them from the anorthositic rocks. They occur as dikes and as large, apparently isolated, patches within the anorthositic rocks. Small scale layering involving concentration of opaque oxides and pyroxenes is present in many exposures excepting the dikes.

Large areas of pyroxene quartz monzonite (quartz mangerite, farsundite, of some authors) are present on the north, west, and south sides of the complex. Mineral layering is very rare to absent in most of these rocks. Dykes of pyroxene quartz monzonite cut both the intermediate and anorthositic rocks of the complex.

The regional metamorphism impressed upon the Morin complex is essentially the same grade as the surrounding country rocks, that is upper amphibolite to granulite facies. The Morin metamorphism has been interpreted by Martignole and Schrijver (1970) as a « retrograde » metamorphism that took place during cooling of the complex as a consequence of its having been emplaced in county rocks at high grade ambient conditions. This interpretation is in accord with that of Barton and Doig (1972) based on Rb-Sr isotopic data. Objections, however, can be raised against the interpretation (Emslie, 1974). For example, angular inclusions of metasedimentary rocks and of anorthositic rocks occur in younger rocks of the complex; sharp-walled dikes and intrusive contacts are common among members of the complex. These are phenomena usually associated with shallow to moderate depths of emplacement into rocks capable of failure by brittle fracture.

Coexisting pyroxenes in the Morin complex have a continuous range of compositions from relatively magnesian in the anorthositic rocks to moderately Fe-rich in the pyroxene quartz monzonites (Fig. 3b). Fine exsolution lamellae are visible in many pyroxenes but they are much less well developed than at Harp Lake. As in Fig. 2 the pyroxene compositions plotted are those of the host pyroxene only. A few low Ca pyroxenes from pyroxene monzodiorite and pyroxene quartz monzonite have textures and proportions of high Ca pyroxene blebs suggestive of original pigeonite

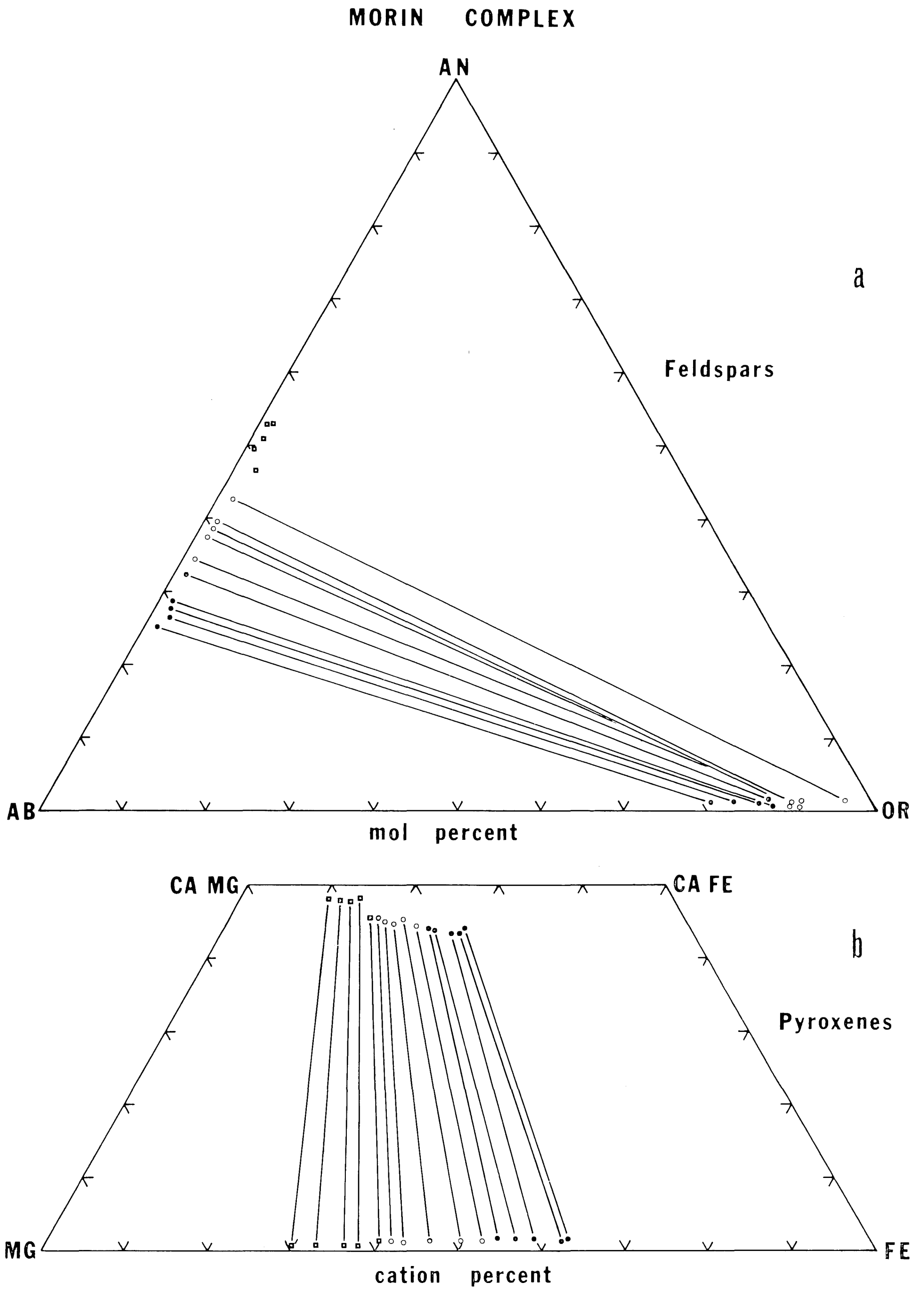

Fig. 3. — a) Analyzed feldspars of the Morin complex. b) Analyzed pyroxenes of the Morin complex. Fe is total iron. Tie lines join coexisting minerals. Open squares indicate minerals from anorthositic rocks, open circles from intermediate rocks, solid circles from silicic rocks. Additional analyses indicate that the range of low Ca pyroxene is at least Mg_{70} to Mg_{36}, plagioclase An_{53} to An_{24} and alkali feldspars Or_{95} to Or_{80}.

but these are rare. Pyroxene grain outlines range from primary subophitic through partly recrystallized to completely recrystallized. In most samples so far analyzed the pyroxenes are remarkably homogeneous. Even rocks that are partly recrystallized and clearly in textural disequilibrium have homogeneous pyroxenes. Inhomogeneities and zoning do occur however and seem to be more common in pyroxenes of the intermediate group.

Analyzed plagioclases from anorthositic rocks fall in the range An_{43} to An_{53} (Fig. 3a). Plagioclase compositions in pyroxene diorite and monzodiorite extend from about An_{45} to An_{33} and coexist with alkali feldspars Or_{95} to Or_{89}. The pyroxene quartz monzonites have plagioclases An_{32} to An_{24} coexisting with alkali feldspars Or_{88} to Or_{82}.

SOME COMPARISONS AND CONTRASTS

The Harp Lake complex and the Morin complex both contain rock successions of decreasing intrusive age which indicate that the basic (anorthositic) group is older, intermediate (pyroxene diorite, monzodiorite) rocks are younger and silicic (pyroxene quartz monzonite, adamellite) rocks are youngest. Within each complex, although the ranges in composition of pyroxenes and feldspars differ, there are no significant compositional gaps.

The range of Fe/Mg ratios in Morin pyroxenes is truncated at the Fe-rich end by comparison with Harp Lake pyroxenes. Fe-rich olivines are not known to occur in the Morin complex. A question of some interest is whether the lack of extremely Fe-rich pyroxene and olivine compositions is related to the stage of magmatic crystallization or to subsequent metamorphism. Several Fe-Ti oxide deposits of moderate size and many smaller concentrations are known in the Morin complex (Rose, 1969) whereas oxide mineral concentrations are small and rare at Harp Lake. Considering the rocks themselves, Fig. 4 shows the modal distribution of opaque Fe-Ti oxides in the main rock groups at Morin and at Harp Lake. Although they are grossly similar, all of the Morin rock units have higher concentrations of Fe-Ti oxide minerals than comparable units at Harp Lake. There is no apparent significant increase in abundance of opaque oxide minerals in the recrystallized rocks of the Morin complex. The available data suggest that the ranges of Fe/Mg ratios in pyroxenes at Harp Lake and Morin are inversely related to the amounts of primary (igneous) Fe-Ti oxide minerals in the complexes. This in turn implies that oxygen fugacities prevailing during magmatic crystallization exerted the major control on Fe-enrichment shown by the silicates.

The distribution of Fe and Mg between coexisting pyroxenes is known to be a function of temperature (Kretz, 1961; Davidson, 1968). It is commonly expressed in the form of a distribution coefficient (K_D) such as :

$$K_D = \frac{\text{Fe/Mg opx}}{\text{Fe/Mg cpx}}.$$

A plot of Fe/Mg opx vs. Fe/Mg cpx is shown for Harp Lake and Morin pyroxenes in Fig. 5. For comparison, an average K_D of 1.66 is shown for Davidson's Quairading pyroxene pairs from pyroxene granulites (the value 1.66 was recalculated from Davidson's analyses using total Fe instead of Fe^{2+} to facilitate comparison with the present data). Davidson showed that there is a small but significant and regular decrease in K_D with increasing Fe/Mg in pyroxene pairs equilibrated under isothermal conditions. For the present discussion this need not concern us.

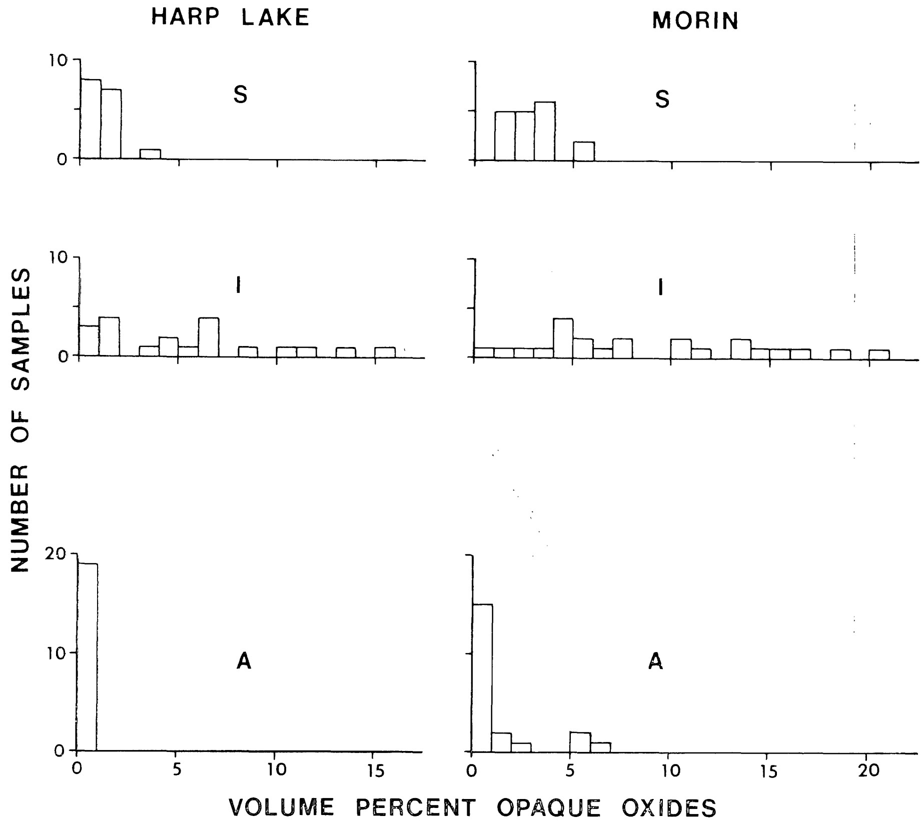

Fig. 4. — Distribution of opaque oxide minerals in the main rock units of the Harp Lake and Morin complexes. S — silicic rocks, I — intermediate rocks, A — anorthositic rocks.

It may first be noted from Fig. 5 that most of the data points lie to the right i.e. have lower K_D's than the Quairading pyroxenes. This suggests that their equilibration temperatures were somewhat higher. Secondly, there is considerable overlap of the Harp Lake and Morin data suggesting overlap in their temperatures of equilibration. In view of the severe metamorphic overprint on the Morin complex one might have anticipated that the pyroxenes would reflect somewhat lower temperatures than at Harp Lake.

The Ca content of clinopyroxene in equilibrium with orthopyroxene is also known to be a function of temperature (Boyd and Schairer, 1964). In Fig. 6 the mol percent $CaSiO_3$ in clinopyroxenes is plotted against K_D (Fe-Mg) of the pyroxene pairs. As a first approximation, increasing Ca in clinopyroxene and increasing K_D (Fe-Mg) are expected to be related inversely to temperature. Therefore, in Fig. 6 pyroxenes with lower equilibration temperatures should tend to plot toward the upper right of the diagram and pyroxenes recording higher temperatures of equilibration should tend to plot toward the lower left. Although there is still some overlap in the distributions, many of the Harp Lake pyroxenes have apparently equilibrated at higher temperatures than Morin pyroxenes. This observation is in accord with the geological evidence that Morin pyroxenes have at least partly equilibrated to lower metamorphic temperatures.

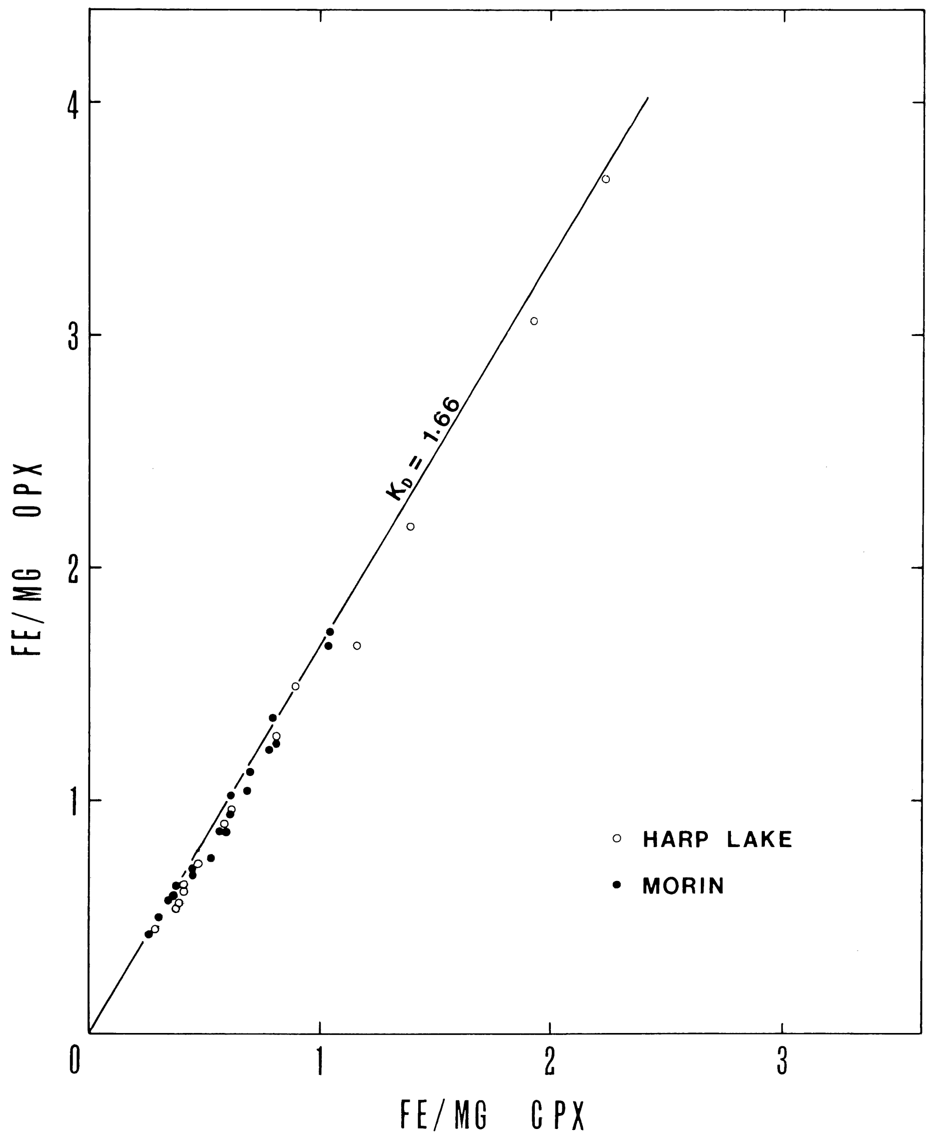

Fig. 5. — Distribution of total iron and magnesium between coexisting pyroxenes in the Harp Lake and Morin complexes. $K_D = 1.66$ is the average K_D for Quairading granulite pyroxenes with Fe as total iron.

The plagioclases from Harp Lake adamellites extend to more sodic compositions than their counterparts in the Morin pyroxene quartz monzonites. This is in agreement with the high grade metamorphism at Morin where sodic plagioclases would not be expected to be stable.

Garnet occurs sporadically in rocks of the Morin complex. It is found in the intermediate and silicic rocks but is rare or absent in anorthositic rocks. Fig. 7

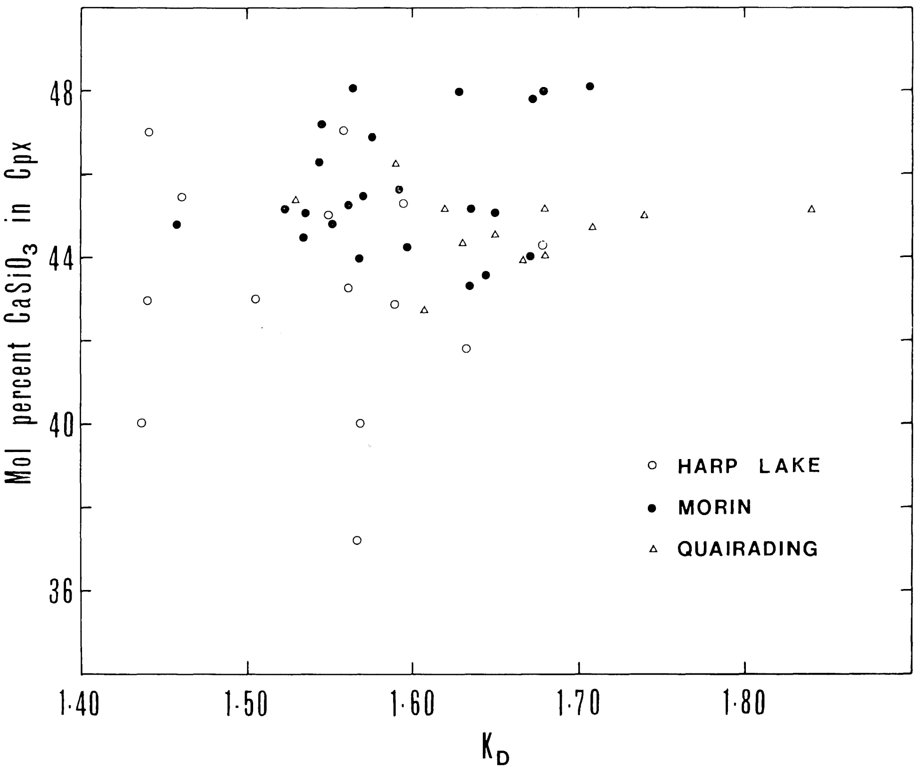

Fig. 6. — $CaSiO_3$ in clinopyroxenes vs. K_D (Fe/Mg) in pyroxene pairs. Lower temperature pyroxenes are expected to plot toward the upper right and higher temperature pyroxenes toward the lower left of the diagram. Quairading pyroxenes shown for comparison.

shows the range of garnet compositions found in the Morin complex projected on the Ca-Fe-Mg plane. The MnO contents of garnets ranges from about 1.0 to 2.8 %. The Ca content of the garnets is nearly constant but it can be seen in Fig. 7 that Fe and Mg are variable and apparently in equilibrium with coexisting pyroxenes.

Correlation of the occurrence of Fe-Ti oxide mineral concentrations with limited iron enrichment in pyroxenes of an anorthositic complex as at Morin suggests a potentially useful prospecting tool.

DISCUSSION

The major rock units in both the Harp Lake complex and the Morin complex show continuous, regular variations in their constituent pyroxenes and feldspars that correspond to the intrusive age sequence from basic through intermediate to silicic rocks. This constitutes very strong evidence for a genetic association of the rocks within each complex. The geological evidence is also strong that although we have within each complex the products of a continuous process, that process did not take place at the existing level of exposure. The successive intrusive relationships clearly indicate that each complex contains rock units derived from a process that

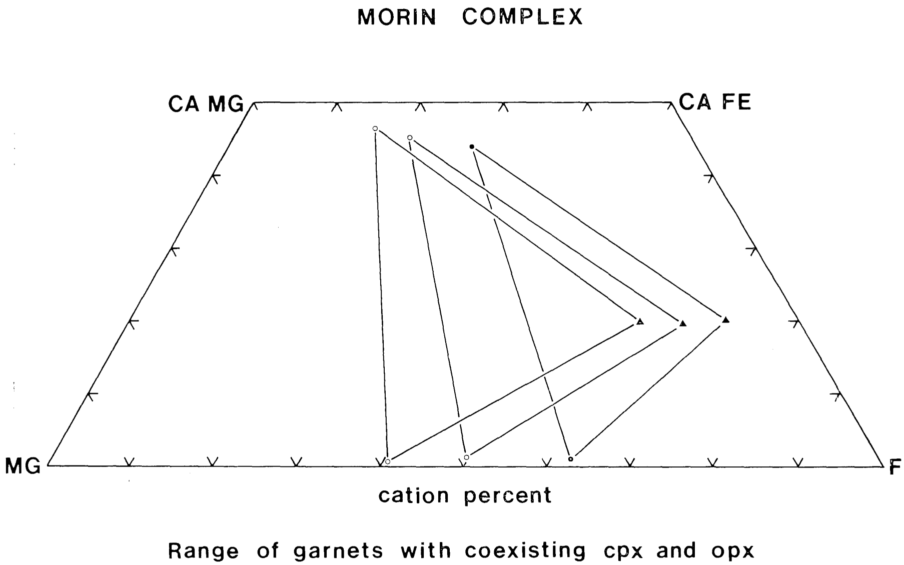

Fig. 7. — Range of garnet compositions in intermediate and silicic rocks of the Morin complex projected on the Ca-Mg-Fe plane. Fe is total iron. Ca contents are nearly constant at 20 percent. Open circles indicate pyroxenes from intermediate rocks, solid circles are pyroxenes from silicic rocks, solid triangles are garnets.

took place somewhere outside the complex, presumably at depth. This is reinforced by the fact each complex contains different proportions of each of the major rock groups. It might be argued that this evidence is invalid because we may be observing different levels of exposure. There is, however, no reason for believing this to be true and it can be seen even on the scale of Fig. 1 that the proportion of silicic rocks associated with anorthositic rocks varies greatly in different complexes.

If it is accepted that the rock sequences exposed in both the Harp Lake and Morin complexes can best be explained by some process operating at depth several possibilities may be considered : 1) partial fusion, 2) contamination of a suitable primary magma, 3) fractional crystallization.

To simplify discussion the initial assumption is made that the parent magma to the anorthositic rocks lay somewhere in the basalt-andesite range and was probably silica saturated or nearly saturated.

Different degrees of partial fusion of some suitable source rock might produce a succession of magmas ranging from silica- and Fe-enriched first, followed by intermediate and basic compositions with greater degrees of melting. Production of such a succession of magmas is in the reverse age sequence to the order of intrusive ages observed. Some sort of collection and storage facility would therefore be required so that the magmas could be intruded in the reverse order of production. This difficulty might be avoided by postulating initial large scale melting of the source rock followed, as heat is dissipated, by progressively lesser degrees of melting further out from the initial « hot spot ». This would involve having a very efficient gathering system to collect small volumes of melt from very large volumes of source rock.

Contamination of an initial andesitic or basaltic magma by sialic crustal rocks on a large scale requires that the initial magma have a substantial amount of superheat. If such contamination took place the optimum time would have been when the initial magma first reached the crust. Sr^{87}/Sr^{86} ratios in anorthositic rocks (Heath and Fairbairn, 1969) are not unduly high (0.703-0.706) so that if contamination occurred the contaminant must have had unusually low $Sr/^{87}Sr^{86}$ ratios for crustal material.

The patterns of continuous pyroxene and feldspar variations in the Harp Lake and Morin rocks are those that would be predicted to result from a fractional crystallization process. The only serious obstacle in the way of accepting this explanation is that it seems impossible to derive the various members of the complexes by *in situ* fractional crystallization of any common magma. If however, at some depth beneath the complex, fractional crystallization took place in a chamber that was tapped at intervals during crystallization it is reasonable to expect that the proportions of various rock types would be variable and that some would be rare or missing. This is not to deny that fractional crystallization also took place within the complexes because the anorthositic rocks are essentially plagioclase crystal cumulates : the suggestion is rather that the primary fractionation control for the whole rock sequence was at depth.

The data currently available do not allow choices between the above models to be made on a rigorous basis. The processes of magma contamination and of partial fusion seem to require rather specialized circumstances to be appealing as widespread recurring processes able to produce the characteristic suites of rocks associated with anorthosites. One cannot deny that these processes may have played a rôle in some complexes but it is difficult to credit them with a central rôle.

On the other hand, fractional crystallization characteristically produces similar trends and final products even from initial magmas that may show some diversity. Production of potassic, silica- and Fe-rich magmas such as appear commonly to be associated with anorthositic suites requires strong fractionation processes.

Periodic tapping of a fractionating magma at depth suggests a possible explanation of why, although anorthositic rocks are enriched in Eu the younger adamellites or pyroxene monzonites seem not to be depleted in Eu (Green *et al*, 1969; Philpotts *et al*, 1966). Fractional crystallization at depth may not involve plagioclase or at least not large amounts of plagioclase. It is known, for example, that in some simple systems plagioclase crystallization is suppressed at moderate pressures (Clarke *et al*, 1962; Emslie, 1970) and this effect is also observed in more complex natural systems (Green and Ringwood, 1967; Green, 1969).

Appeal to a source of fractionating magma at depth might be regarded as simply burying the problems deeper within the earth. However, there are some clues that offer support to this interpretation. At Harp Lake and Morin as in many of the other complexes the typical habit of pyroxenes is subophitic to poikilitic in anorthositic rocks. This provides clear evidence that these pyroxenes crystallized interstitially to the cumulus plagioclase. The Al_2O_3 content of these pyroxenes is low — orthopyroxenes rarely contain much over 2 weight percent Al_2O_3 and commonly much less. One layered section about 150 m thick of anorthosite and leuconorite at Harp Lake contains sub-spherical cumulus orthopyroxene crystals up to 1 cm in diameter. These contain 3.6 weight percent Al_2O_3 (they have Fe/Mg ratios in the range of orthopyroxenes shown in Fig. 2b). It seems probable that these pyroxenes were deposited in their present position in the complex after having initially crystallized at greater depths.

Wheeler (1965) and Smith (1974) have reported on Fe-rich pyroxenes from the Nain area of Labrador that have compositions similar to those from Harp Lake adamellites. Using arguments based on experimental data Smith concluded that the pyroxenes required a minimum pressure of 5 kb for stable crystallization. The low Ca pyroxenes have commonly broken down (apparently in the subsolidus region) to olivine + orthopyroxene + quartz. The breakdown is interpreted by Smith as indicating that the original pigeonitic pyroxenes became unstable due to decompression accompanying uplift sometime after crystallization of the rocks. It is equally possible, however, that the pyroxenes, after initially crystallizing at depth, became unstable after being brought into the complex by a magma intruded to higher levels in the crust.

Before proposing a detailed model for the evolution of anorthositic complexes based on fractionation processes at deep crustal or sub-crustal levels, further petrologic and mineralogic evidence of pre-existing higher pressure equilibria will be necessary.

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