FAYALITIC OLIVINE IN NORTHERN NEWFOUNDLAND-LABRADOR

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ABSTRACT

The olivine facies of adamellite intruding anorthosite in northern Newfoundland-Labrador contains an ultramafic segregation high in olivine. A chemical analysis of the olivine indicates a composition close to Fa_{94}. X-ray diffraction patterns indicate some olivine in the adamellite is even higher in iron.

In marginal facies of the adamellite lamellar intergrowths of ferrohedenbergite, ferrohortonalite with granular quartz, and eulite indicate ferriferous pigeonite crystallized early, followed by ferrohedenbergite. Ferrohedenbergite exsolution plates formed in the basal plane of the pigeonite. A little eulite and an intergrowth of ferrohortonalite and quartz formed at the expense of the pigeonite. Finally thin exsolution lamellae formed in the pyroxenes. The time relation of pyroxene and olivine is the reverse of that in crystallization of gabbroic magma.

GENERAL PETROGRAPHY

Extensive intrusive masses of adamellite are associated with the Nain anorthosite mass in northern Newfoundland-Labrador near Lat. 56° 30′ N. Inclusions of anorthosite in the adamellite and dikes penetrating from the adamellite into the anorthosite indicate the adamellite is younger. Individual adamellite masses can be subdivided into a number of facies on the basis of modal composition. Adamellite is the predominant rock type, although individual specimens range through monzoite, syenodiorite, grandiorite, and granite, according to the Johannsen classification.The dark minerals vary greatly so that pyroxenes, olivine, hornblende, or biotite may predominate in individual specimens. The rocks have been described in considerable detail elsewhere (Wheeler, 1942, 1955, and 1960).

The most widespread olivine facies of the adamellite is along the west margin of the main anorthosite body. It occurs in what appears to be a continuous zone 100 miles long. The zone is at least 2½ miles wide in places, and more extensive sampling might demonstrate that it is wider. This facies has the greenish grey colour characteristic of charnockitic rocks and rusts readily so that olivine is difficult to detect in the field, even where it is a major constituent.

Rock High in Fayalite

The olivine facies is well developed at the west end of the biggest lake near the head of Puttualuk Brook, for which the name Tallifer Lake has been proposed (Lat. 57° 06′ N., Long. 62° 49′ W.). Modal analysis 1, Table 1, gives the composition of a specimen from this area 0.7 miles from the anorthosite margin. The texture of this rock is uneven-grained with raggedly irregular K-feldspar grains up to 10 mm across. Occasional quartz grains or aggregates may be almost as large, though plagioclase grains rarely exceed 4 mm across and the dark mineral grains average 2 mm. The K-feldspar contains the usual spindle-type perthitic inclusions. The optic axial angle is moderately large, negative, and *x*-ray powder patterns made and interpreted by P. M. Orville show monoclinic symmetry, so the mineral is orthoclase. Grains of plagioclase, quartz, and dark minerals are not uncommon in the orthoclase. Quartz grains have the usual rounded outlines, embaying the other minerals. The content of orthoclase is lower than usual in rocks of this facies.

TABLE 1. MODAL ANALYSES

	1	2	3	4
Plagioclase	61.0	41.5	64.9	16.0
K-feldspar	5.5	28.2	0.6	0.6
Quartz	26.1	17.9	—	
Clinopyroxene	3.3	6.3	9.8	21.9
Olivine	2.2	2.5	20.6	49.9
Hornblende	1.2	2.4	0.2	0.7
Biotite	0.3	—	—	0.1
Black ore	0.2	0.8	2.8	8.1
Apatite	0.2	—	1.1	2.0
Zircon	—	—	—	0.7
Points counted	582	719	539	707
Plagioclase An content	36	35	42	30

1. Specimen 2-1280. Granodiorite, 227′ (Johannsen). Main summit west of Tallifer Lake, Lat. 57° 06′.2 N., Long. 62° 49′.5 W.
2. Specimen 2-1278. Clinopyroxene adamellite, 227′ (Johannsen). Tallifer Lake west end massif, southeast ridge, Lat. 57° 06′ .0 N., Long. 62° 48′ .6 W.
3. Specimen 2-1281. Clinopyroxene-olivine diorite, 2212 (Johannsen). Olivine composition Fa_{76}. Tallifer Lake west end massif, east ridge: Lat. 57° 06′ .2 N., Long. 62° 48′ .7 W.
4. Specimen 2-1282. Ilmenite-plagioclase wehrlite, 4′ 24 (Johannsen). Massif west of Tallifer Lake, south flank: Lat. 57° 06′ .1 N., Long. 62° 49′ .2 W.

Nearer the anorthosite contact the rock becomes finer-grained and more variable in composition, but generally contains a few large irregular feldspars. Analyses 2 and 3, Table 1, show variations in modal composition of these marginal types.

In the marginal zone of variable rock a small outcrop high in dark minerals was encountered. Analysis 4, Table 1, shows its modal composition, and Table 2 gives the chemical analysis of olivine from this rock. Superior analyses of olivine commonly show some Fe_2O_3, but none could be found with such a high content as in this analysis. Therefore disposition of this oxide in computing the olivine molecular composition becomes a problem. The specimen was collected at the surface, and possibly some of the Fe_2O_3 represents oxidized FeO in the olivine, though low H_2O in the analysis and the appearance of the olivine under the microscope indicate that alteration is slight. If most of the Fe_2O_3 in the analysis is assumed to be derived from FeO, the slight excess of SiO_2 over the amount required for the olivine molecule disappears. The small amount of CaO can be accounted for as a replacement of iron by calcium in the fayalite molecule. If it results from contamination by clinopyroxene, the most abundant mineral in the rock except olivine, only about 1% by weight of clinopyroxene would be necessary. The relative proportion of MgO and FeO in the analysis without adjustment for oxidation of FeO to Fe_2O_3 or contamination by clinopyroxene indicates the mineral is fayalite, Fo_6Fa_{94}. Assigning TiO_2 to ilmenite, CaO to clinopyroxene, and changing Fe_2O_3 to FeO gives a formula of $2(Mg_{.057}Mn_{.013}Fe_{.930})O.SiO_2$ with a deficit of only 0.37% by weight of SiO_2. Thus the iron content of the fayalite appears to be fixed within 1%.

TABLE 2. OLIVINE ANALYSIS[1] BY S. COURVILLE AND G. BENDER, GEOLOGICAL SURVEY OF CANADA

SiO_2	29.82
Al_2O_3	0.00
Fe_2O_3	2.16
FeO	64.21
CaO	0.24
MgO	2.34
Na_2O	ND
K_2O	ND
H_2O+	0.04
H_2O-	ND
TiO_2	0.01
P_2O_5	ND
MnO	0.92
Sum	99.74

[1] Olivine from Specimen 2-1282 for which the modal analysis is given in Table 1, No. 4.

When olivine powder grains are immersed in arsenic tribromide refractive index liquids their surface has a bubbly appearance, as though the liquid were not wetting the grains properly, making the Becke line difficult to observe. α appears to be near 1.815, which corresponds to the value to be expected from the chemical analysis within the limits of observational error. Colour is not prominent in thin section, and the mineral is probably dark in the hand specimen.

Clinopyroxene $2V$ is moderately large and γ' in cleavage fragments is a little above 1.730, indicating a composition near $Ca(Mg_{.35}Fe_{.65})SiO_4$. Minute, thin, parallel-oriented, smoky-violet inclusions, the classic microplakite, and thin basal exsolution lamellae are present.

R. O. Bloomer kindly checked the optical identification of zircon by *x*-ray powder photograph.

The dark minerals of the rock form a mosaic of rounded equant, mutally indenting grains up to 2 mm across, more automorphic than plagioclase grains, which reach 2.8 mm across. Zircon grains to 0.2 mm across are subhedral.

The field relations between this rock and adamellite are concealed. The high iron content of the olivine and clinopyroxene, the moderately low calcium content of the plagioclase, and the zircon content indicate the unusual nature of the rock. The exsolution lamellae in the clinopyroxene suggest magmatic temperatures. The composition of plagioclase and clinopyroxene, as indicated by their optical properties, is similar to the composition of these minerals in the olivine adamellite. The texture and mineral compositions are compatible with an origin by segregation of early mafic minerals from the adamellite.

After completing this paper, the writer found the curve by Yoder & Sahama (1957) for determining olivine composition by *x*-ray diffraction, and C. H. Smith called attention to Simonen's (1961) paper on fayalite in Finland. There is a noteworthy similarity in composition and physical properties between the analysed fayalites from Finland and Labrador, and most of the features which Simonen gives in his brief description of the olivine rapakivis can be matched in the Labrador olivine adamellites, although the Na:K ratio in the adamellites is greater than unity whereas it is less than unity in all Simonen's rapakivi analyses. Like the fayalite from Finland, the Labrador fayalite has a $d(130)$ spacing smaller than its composition would require according to the curve of Yoder & Sahama. *X*-ray diffraction patterns of several olivines from Labrador adamellites all give a larger $d(130)$ spacing than that of the analysed olivine, indicating an even higher Fe:Mg ratio in the olivine of the adamellite. This is in keeping with the conclusion that the analysed olivine is from an early mafic segregation in the adamellite.

PYROXENE-OLIVINE INTERGROWTHS

Lamellar intergrowths are widespread in the pyroxenes of the adamellite. Orthopyroxene contains thin plates in the *c* zone and thicker, more irregular plates, some identifiable as clinopyroxene, at a large angle to *c*. Clinopyroxene contains thin plates at a large angle to the axial plane. Such lamellae are the result of subsolidus exsolution in cooling igneous rocks (Brown, 1957, p. 527-534).

Several specimens of olivine adamellite contain intergrowths of a more complex nature. At first glance they look like an improbable exsolution intergrowth of granular olivine between parallel plates of clinopyroxene, Fig. 1. Closer examination shows that most of the olivine, though granular in appearance, is optically continuous. It is studded with a nearly equal volume of sinuously irregular quartz grains that are sometimes elongate, suggesting myrmekitic intergrowth. Optically continuous clinopyroxene partly encloses these masses and penetrates them with thick lamellae like the exsolution plates found in orthopyroxene that has formed by inversion of pigeonite. The orientation of the optical ellipsoid in these plates appears to be that given by Poldervaart & Hess (1951, p. 484, Fig. 7B) for the augite exsolution lamellae that form in the (001) plane of pigeonite.

Locally small areas of orthopyroxene occur in the clinopyroxene. Generally the boundaries between the two pyroxenes are indistinct because of gradational interlamination between them. In some places plates of clinopyroxene similar to the plates in nearby olivine-quartz intergrowths, and with the same optical orientation occur in the orthopyroxene also.

In addition, very thin exsolution lamellae occur in both pyroxenes. They are parallel to the axial plane in orthopyroxene, and to (001) in clinopyroxene.

Clinopyroxene $2V$, measured on the universal stage by S. C. Clement, is 50° and β is 1.739, indicating a composition of $Ca_{36}Mg_8Fe_{56}$. There are suggestions of radial extinction in larger grains, indicating there may be slight zoning.

Orthopyroxene dispersion is strong, $r < v$, which is characteristic of the orthopyroxene formed by inversion of pigeonite in this group of rocks. Refractive index and $2V$ indicate its composition as Fs_{84}.

The olivine composition is roughly estimated at Fa_{87}, based on an *x*-ray diffraction pattern of an impure olivine sample that gives only a poor $d(130)$ reflection. The high refractive index of the mineral is in keeping with this estimate.

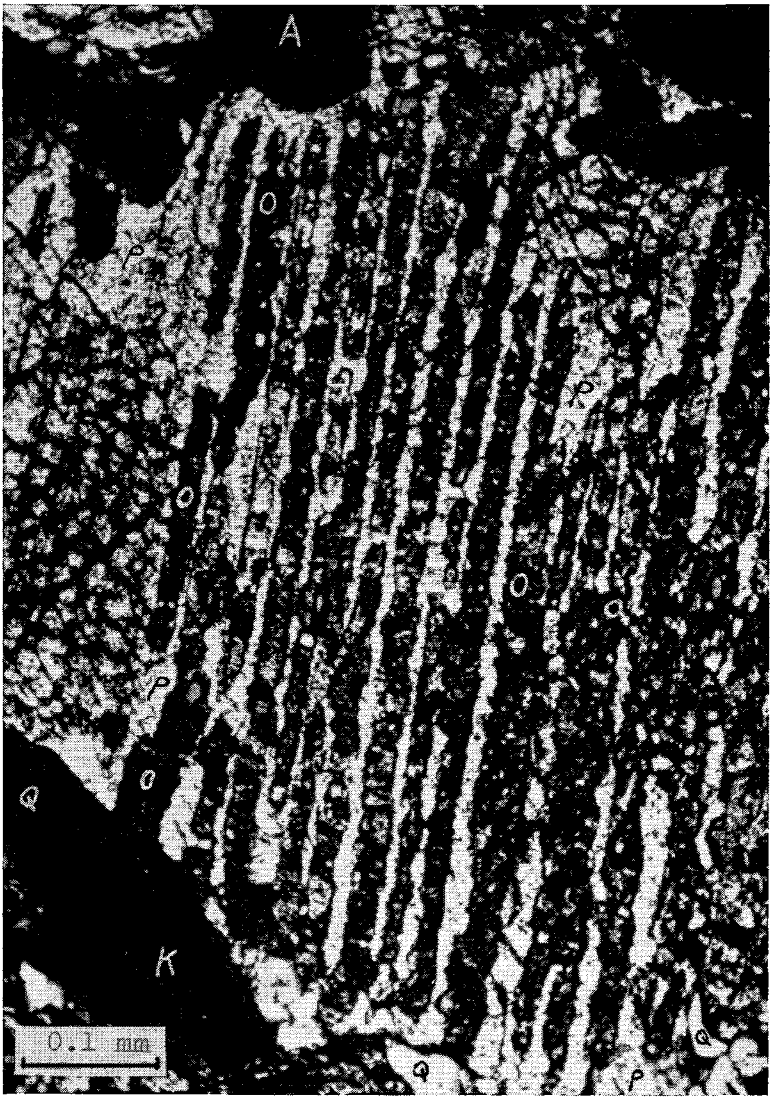

FIG. 1. Photomicrograph of lamellar hedenbergitic clinopyroxene intergrown with olivine and quartz. Crossed nicols. P = clinopyroxene, pale and showing rectangular cleavage on left side of photograph. O = olivine, dark bands. Q = quartz. Many of the light rounded spots in olivine are quartz, too small to label. A = apatite. K = orthoclase. Photograph by P. M. Orville.

The rocks in which these textures occur are finer-grained than the normal adamellite, and occur in confused areas associated with gneiss and anorthosite inclusions. They appear to be chilled marginal facies, though the anorthosite contact outcrops several miles away, suggesting that it has a low dip.

The following course of crystallization, illustrated in Fig. 2, is proposed for the mafic minerals:

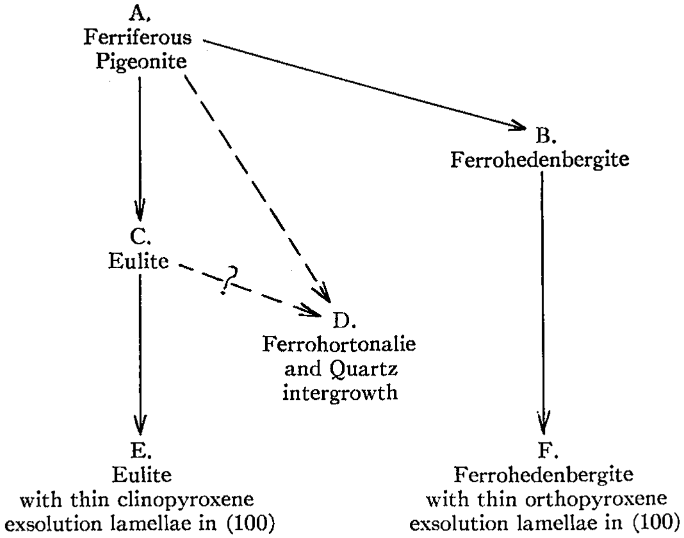

FIG. 2. Ferromagnesian mineral changes during crystallization of olivine facies adamellite in marginal zone.

A. The first mineral to crystallize was ferriferous pigeonite.

B. As the temperature fell, ferrohedenbergite began to form. On the basis of Muir's hypothetical equilibrium diagram (1954, p. 385, Fig. 4C) this would be the result of a cotectic reaction between pigeonite and melt.

C. In the subsolidus region exsolution plates of ferrohedenbergite formed in the (001) plane of the pigeonite and some of the pigeonite inverted to eulite.

D. Most of the pigeonite broke down into an intergrowth of ferrohortonalite and quartz. Alternatively, if all the pigeonite inverted to eulite, most of the eulite broke down into the olivine-quartz intergrowth.

E. Thin clinopyroxene exsolution lamellae formed in the remaining orthopyroxene with falling temperature.

F. At the same time thin orthopyroxene exsolution lamellae formed in the (100) plane of the ferrohedenbergite.

This account leaves two points unexplained. First, if the formation of ferrohedenbergite is a cotectic reaction, it should take place at a constant temperature, and the ferrohedenbergite should not be zoned.

Second, there is no obvious reason why both orthopyroxene and olivine-quartz intergrowth should have developed from pigeonite. Chilling may have prevented completion of the reaction that would have eliminated the orthopyroxene, but it did not prevent the formation of thin, late exsolution lamellae in the orthopyroxene. Orthopyroxene is restricted to the marginal rocks of the adamellite suit. Coarser-grained rocks from the interior of the intrusive with more fayalitic olivine contain some clinopyroxene but no orthopyroxene, even where olivine-quartz intergrowths occur to suggest that earlier-formed pigeonite has broken down.

The main conclusion to be drawn from the occurrence is that the course of crystallization followed by gabbroic magma of normal Mg:Fe ratio, where olivine forms first and is later resorbed with formation of pyroxene, is reversed in this adamellite magma with a low Mg:Fe ratio, and pyroxene crystallizes first, breaking down into olivine and quartz with falling temperature.

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