THE ILMENITE ASSOCIATION FROM THE FRANK SMITH KIMBERLITE, SOUTH AFRICA

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The relationship between common ilmenite discrete nodules in kimberlites and less-common intergrowths of ilmenite with silicates has been a subject of both interest and controversy (e.g. Mitchell, 1977, Haggerty et al., this volume). The abundance of ilmenite nodules and ilmenite-silicate intergrowths at Frank Smith encouraged a detailed study in which over sixty mineral analyses of ilmenites and coexisting silicates have been obtained. Ilmenite nodules in coarse concentrate from Frank Smith range up to 4-5 cm; also studied were two enstatite megacrysts with intergrown ilmenite and other phases that have maximum dimensions of 15-20 cm.

Virtually all the ilmenite discrete nodules from Frank Smith are polygranular with a grain size that ranges widely from 0.2-25 mm. Pitting on polished surfaces is the most distinctive optical feature of the ilmenite discrete nodules; similar pitting has been observed in kimberlitic ilmenites from other pipes (e.g. Dawson, 1962). Some pits are round, others triangular or elongate. SEM pictures of the pits show them to be internally irregular. Individual nodules often contain both pitted and non-pitted grains. Pits may cover an entire grain, but coarser pits often delineate grain boundaries. Pitted boundaries usually define an optically continuous grain; more rarely the region delineated by pits consists of two grains with an interface recognizable only by differences in pleochroism and/or anisotropism. Pitted grain boundaries show neither greater nor lesser degrees of textural equilibrium than do non-pitted boundaries. Detailed electron microprobe study of a nodule containing both pitted and non-pitted grains showed no significant chemical differences or inhomogeneities associated with pitting. Vickers' hardness tests on adjacent pitted and smooth grains gave variable, overlapping values, suggesting the absence of physical inhomogeneities. The pitting is possibly an alteration feature because it is enhanced at grain boundaries and shows crystallographic control.

Most of the ilmenites contain fine ($\sim 1\mu$ wide), rod-like, black spinels, often appearing as a freckling within the ilmenite grains. These spinels are too fine-grained for microprobe analysis. Spinel lamellae within a single ilmenite grain have a common orientation. Sometimes the rods of spinel are concentrated along continuous, curved trends which simulate grain boundaries. Configurations of these trends define domains that are as variable in shape as are true grains. A few specimens contain two kinds of spinel with the same orientation. Grayish tan spinel (probably ulvöspinel solid-solution) forms long lamellae with more abundant, black spinel (possibly pleonaste) forming short colinear rods that are sometimes included in the ulvöspinel lamellae. There is no relationship between pitting and spinel exsolution. Black spinels are most abundant in those ilmenite nodules which are richest in the geikielite component. Exsolution of spinel probably results from subsolidus reduction of ilmenite. Alignment of rods of exsolved spinel in curved trends may result from concentration of exsolution along dislocations in ilmenite, similar to hematite lamellae in ilmenite (S. E. Haggerty, personal communication).

Grain boundary textures and their degree of definition vary widely, even within one ilmenite nodule (e.g. Mitchell, 1973). Kimberlitic ilmenites have few deformation lamellae, in contrast to other igneous ilmenites. There are various features, however, that indicate partial or total recrystallization: (1) twin lamellae are occasionally present near the edges of a nodule; (2) equilibrium grain boundary intersections are common; (3) bands of fine mosaic ilmenite sometimes traverse coarse grains; (4) there are occasionally bands or long, tapering wedges within grains that have a slightly different extinction position from the host; (5) spinel lamellae appear to lie along dislocations; (6) a few specimens show a foliation due to alignment of elongated, highly sutured grains.

Twenty nodules in which ilmenite is intergrown with silicates include nine lamellar intergrowths, four ilmenite discrete nodules with garnet or pyroxene inclusions, five enstatite discrete nodules with inclusions of ilmenite and two polygranular nodules in which the ilmenite has an interstitial texture that may be metasomatic. A number of the lamellar intergrowths and enstatite nodules are deformed, as noted by Frick (1973). Severe deformation destroys the lamellar texture, causing recrystallization of the ilmenite as irregular blebs. It is impossible to judge whether the primary textures in some sheared enstatite-ilmenite nodules were lamellar or host-inclusion configurations.

The ilmenite discrete nodules show a substantial range in Mg/(Mg + Fe) (Figs. 1A and B; see also Mitchell, 1977). There is a tendency for Fe_2O_3 to increase with $FeTiO_3$ in the ilmenites (Fig. 1A). Cr_2O_3 in the ilmenite discrete nodules varies erratically with (Mg/(Mg + Fe) in the range < 0.05-1.00 wt % Cr_2O_3 (Fig. 1B). The two ilmenites with highest Cr_2O_3 (~3 wt %, Fig. 1B) come from nodules with textures suggesting the possibility of metasomatic introduction of ilmenite. Ilmenites from the lamellar intergrowths show a very restricted range in Mg/(Mg + Fe) (Figs. 1A and B), that is overlapped by the more magnesian discrete ilmenites.

Host-inclusion relations appear to establish a consanguinity between the discrete ilmenites and discrete garnets and pyroxenes (e.g. Boyd and Nixon, 1973). Mg/(Mg + Fe) shows the range 0.750-0.838 for twelve garnet discrete nodules from Frank Smith and the range 0.876-0.921 for twenty-five enstatite discrete nodules. These ranges in Mg/(Mg + Fe) for the discrete ilmenites, garnets, and pyroxenes are most reasonably interpreted as due to igneous fractionation prior to kimberlite eruption.

Ilmenites from the lamellar intergrowths cannot be distinguished on the basis of chemical parameters from ilmenites forming discrete nodules. Moreover, applications of pyroxene thermometry and barometry suggest that the discrete nodules and lamellar intergrowths have come from overlapping depth ranges (Boyd and Nixon, 1975). A related origin therefore seems probable. Equilibration temperatures for enstatites and diopsides from the Frank Smith lamellar intergrowths fall in the range 1175°-1275°C. This restricted range together with the restricted range in Mg/(Mg + Fe) for ilmenites from the lamellar intergrowths suggest that the chemical and possibly the physical conditions under which these intergrowths nucleated and crystallized were more constrained than for the ilmenite discrete nodules as a whole.

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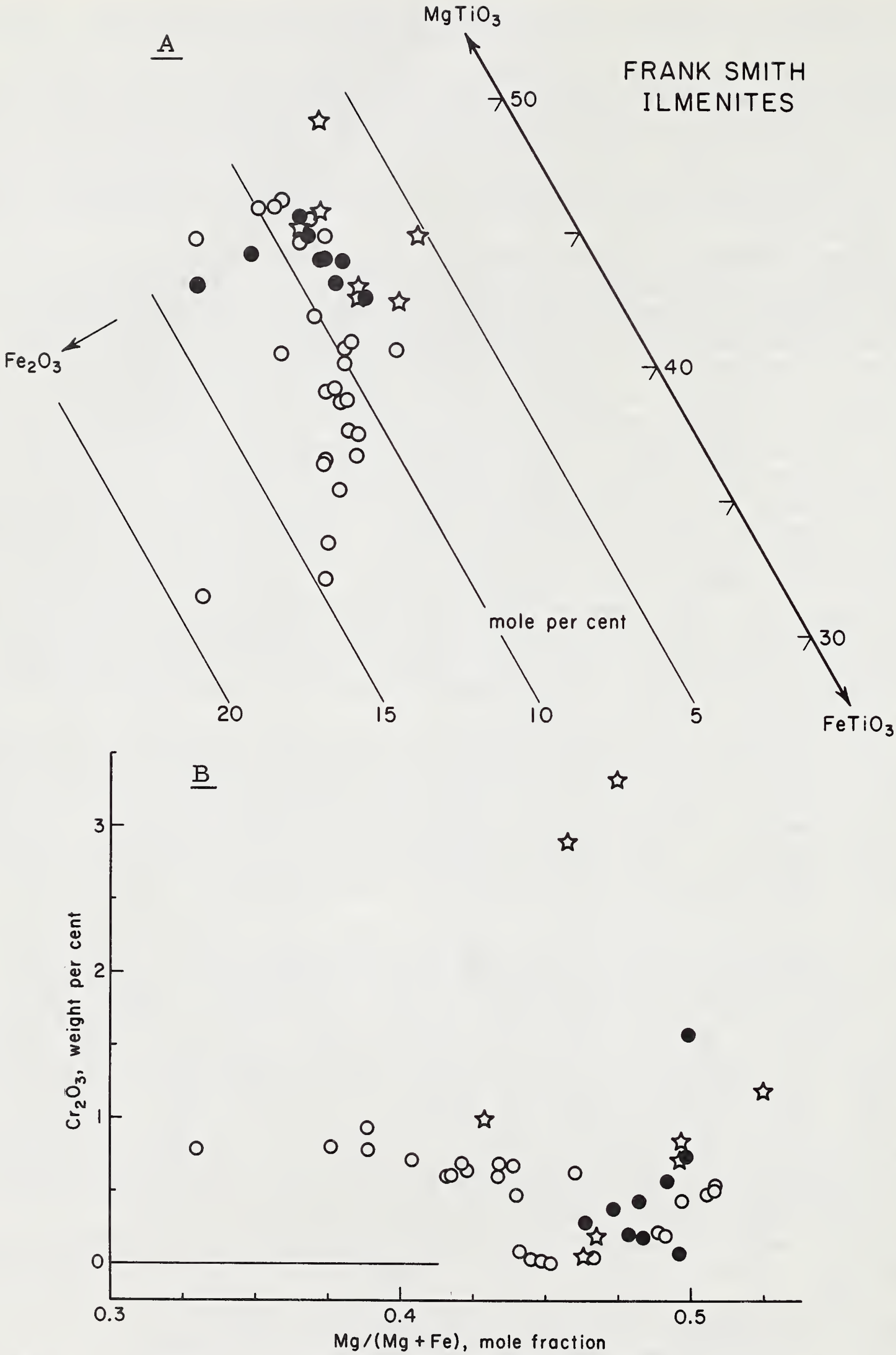

Fig. 1: Chemical variations in ilmenite discrete nodules and intergrowths from the Frank Smith mine. Open circles: discrete nodules; solid points: lamellar intergrowths; stars: other ilmenite-silicate intergrowths.