THE DISTRIBUTION OF Fe^{2+} AND Mg BETWEEN PYROXENE AND ILMENITE IN INTERGROWTHS FROM KIMBERLITES

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The effects of temperature, pressure and bulk composition on the iron-magnesium distribution coefficient, $K_D = (MgO/FeO)^{px}/(MgO/FeO)^{il}$, in the systems orthopyroxene-ilmenite and clinopyroxene-ilmenite have been experimentally calibrated with a piston-cylinder apparatus. Results in the orthopyroxene-ilmenite system are consistent with an ideal solution model for orthopyroxene and a regular solution model for ilmenite solid solutions near the ilmenite-geikielite join. At temperatures greater than 800°C, W_G is approximately 1.60 kcal for ilmenite. In the experiments in the clinopyroxene-ilmenite system, clinopyroxene compositions were restricted to the diopside-hedenbergite join. The regular solution model for ilmenite previously described and a regular solution model for clinopyroxene with $W_G = 2.5$ kcal are needed to account for the effect of bulk composition on the distribution coefficient in this system. There is a small pressure effect in both systems which increases the magnesium content of the silicates as the pressure is increased.

These results can help determine the physical parameters prevailing at the time of formation of the graphic and lamellar pyroxene-ilmenite intergrowths in kimberlites. A survey of the reported occurrences of these intergrowths reveals that they form a common paragenesis in kimberlite. They have been described from five kimberlites in South Africa, four in Lesotho, three in the U. S. A., three in the U. S. S. R., two in Namibia, two in Rhodesia and one in Angola. A similar clinopyroxene-ilmenite graphic intergrowth has also been found in alnöite from Malaita in the Solomon Islands.

Of five orthopyroxene-ilmenite nodules with published analyses of the coexisting phases, four have equilibration temperatures in the range 1130° - 1180°C (Fig. 1). K_D varies from 9.0 to 10.4 and $(Fe^{2+}/Fe^{2+}+Mg)^{il}$ from 0.56 to 0.65. In these calculations, pressure was assumed to be 50 kb, consistent with the estimate of Boyd and Nixon (1973). The calculated temperatures rise 5°C for every additional kilobar of pressure. The fifth orthopyroxene-ilmenite intergrowth, from Kharakhtakh, Yakutia, is unique since it also contains clinopyroxene lamellae. The calculated temperature of equilibration for this specimen is 1080°C.

Interpretation of K_D in clinopyroxene-ilmenite nodules is complicated by the presence of ferric iron in clinopyroxene. Four analyses of ferric iron in clinopyroxenes from intergrowths indicate that an average of 70% of the total iron present is in the ferrous state. When this correction is applied, a bimodal distribution in equilibration temperatures for clinopyroxene-ilmenite intergrowths is revealed (Fig. 1). Both groups indicate higher temperatures than the orthopyroxene-ilmenite intergrowths.

The low temperature group includes all but one of the Yakutian specimens and most of the Monastery specimens. The average temperature (1210°C) agrees well with the average temperature of 1190°C obtained on the same samples from the orthopyroxene-clinopyroxene miscibility gap determined by Davis and Boyd (1966) assuming that clinopyroxene has crystallized in equilibrium with orthopyroxene and garnet. The high temperature group contains all of the American and African specimens except for those from Manastery previously mentioned. The average temperature of this group, 1330°C, is significantly higher than the average temperature calculated from the orthopyroxene-clinopyroxene miscibility gap.

Possible explanations of the bimodal temperature distribution include a difference in oxidation state of the clinopyroxene (although the specimens in which ferric iron has been determined fall into both groups), a difference in quench history resulting in subsolidus reequilibration for one group, or an actual difference in the temperature-pressure regime during the formation of each group. If the latter hypothesis is true, then the high temperature group apparently did not crystallize in equilibrium with orthopyroxene and garnet.

References

Boyd and Nixon (1973), Carnegie Inst. Wash. Yearbk. 72, 431.
Davis and Boyd (1966), JGR 71, 3567.

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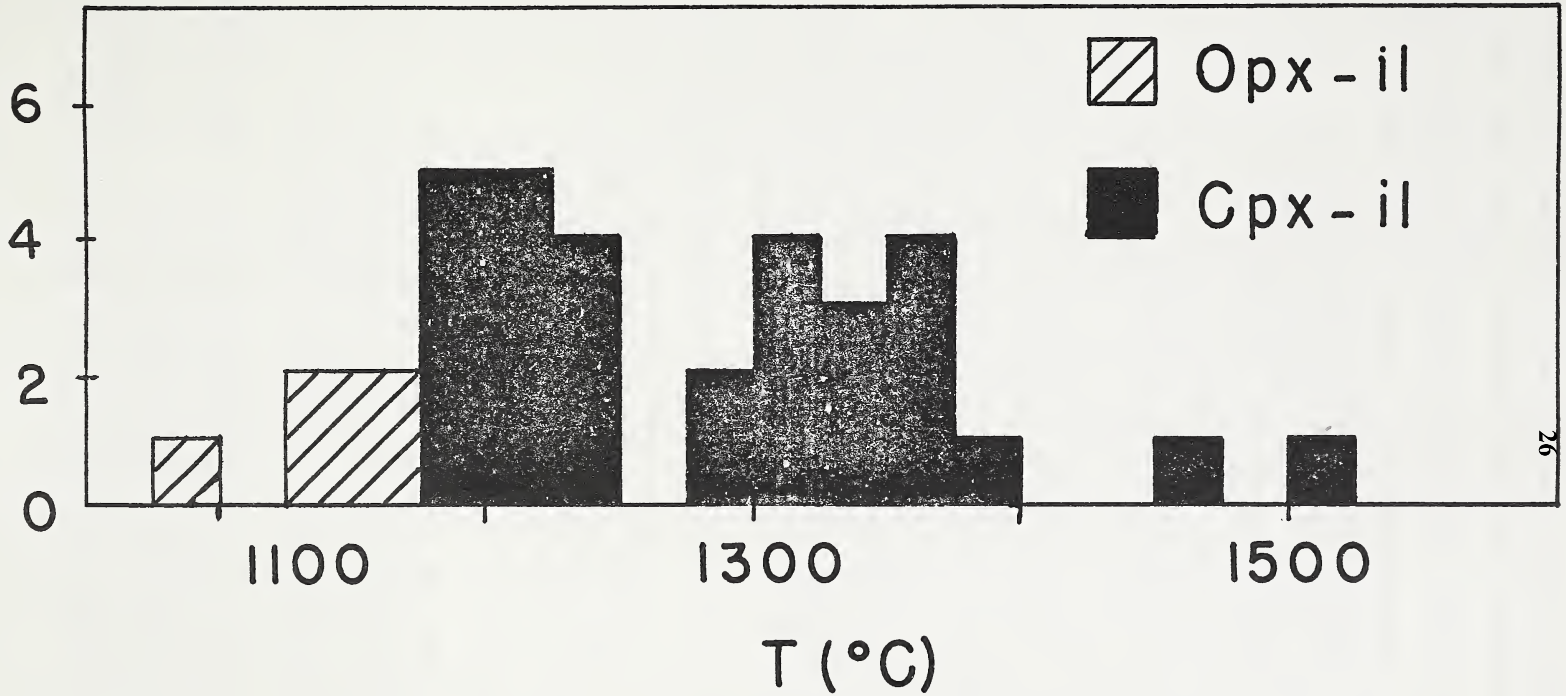

Figure 1. Number of specimens vs. calculated temperature for clinopyroxene-ilmenite and orthopyroxene-ilmenite intergrowths from kimberlites.