DISCRETE NODULE ASSEMBLAGES IN KIMBERLITES FROM NORTHERN COLORADO AND SOUTHERN WYOMING: EVIDENCE FOR A DIAPIRIC ORIGIN OF KIMBERLITE

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Two compositionally distinct groups of discrete nodules (megacrysts) from kimberlites of the Colorado-Wyoming State Line and Iron Mountain districts are described elsewhere in this volume (McCallum, Eggler, and Smith). Both groups have orthopyroxene, clinopyroxene, olivine, garnet, and ilmenite megacrysts. Unaltered orthopyroxenes are found, however, only in one pipe, Sloan 2 from the State Line District. From those megacrysts, a paleogeotherm has been obtained that bears on the problem of kimberlite emplacement.

The ranges of chemical parameters of the Cr-rich and Cr-poor megacrysts in Sloan 2 in general adjoin but do not overlap (Fig. 1). The compositions of the Cr-rich megacrysts are similar to those of minerals of lherzolites and harzburgites believed to be residual (depleted) and are particularly distinctive in their high Cr_2O_3 content and tightly grouped, relatively high Mg/(Mg +Fe). The Cr-poor group shows a broader range in iron content and is less refractory in all elements; minerals of the Cr-poor suite have general similarities to discrete nodules from Lesotho (Boyd and Nixon, 1973).

Pressures and temperatures of equilibration of the enstatite megacrysts have been calculated on the assumption that every enstatite coexisted with clinopyroxene and garnet (re Boyd and Nixon, 1973). Methods have been described (Eggler and McCallum, 1976). Pyroxenes are indeed found in a few cases as inclusions within each other or within other phases.

Five garnet lherzolite nodules and ten garnet websterite nodules from the Sloan pipes that were equilibrated at depths of 50-180 km fall along a shield geotherm (McCallum and Eggler, 1976). The calculated equilibration conditions of the megacrysts, together with this geotherm, are plotted in Fig. 2. The majority of the megacryst points lie near the shield geotherm, but some lie about 100°C above the geotherm. This variability is far greater than can be accounted for by analytical error. Nor are the high-temperature megacrysts significantly different in composition from megacrysts on or near the geotherm. The array of points is interpreted as a partially disturbed geotherm. In contrast, the megacryst geotherms presented by Boyd and Nixon (1973) for the Lesotho pipes and by Boyd (1974) for the Frank Smith Mine, South Africa, are distinctly inflected to the high-temperature side at depths below about 150 km, while a geotherm from the Udachnaya pipe, USSR, is noninflected (Boyd et al., 1976).

Nixon and Boyd (1973) suggested that the inflected limb of the Lesotho geotherm was caused by stress-heating in the low-velocity zone. This type of heating has been discounted by Green and Gueguen (1974) and Goetze (1975), and alternative models have been presented for heating by an upwelling diapir (Green and Gueguen, 1974) and by a mantle plume (Parmentier and Turcotte, 1974). Boyd (1976) now considers that a diapir associated with convective overturn is a possible explanation of the inflected limb.

In the model of Green and Gueguen (1974) it is assumed that peridotite of the diapir was less depleted than the mantle through which it flowed, that the top of the diapir was at the same temperature as the undisturbed mantle, that the diapir partially melted, and that there was no low-velocity zone

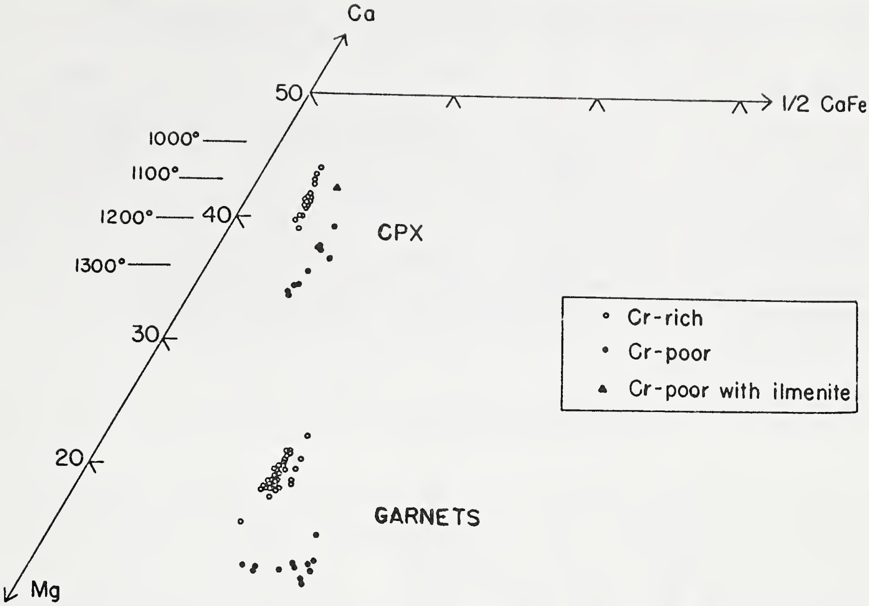

Fig. 1. Compositions of clinopyroxene and garnet megacrysts from the Sloan 2 kimberlite pipe,Colorado, plotted in mole % on a Ca-Mg-Fe projection. Temperatures are for points on the diopside solvus after Davis and Boyd(1966)

in that mantle region. This model adequately explains features of the Colorado megacryst-lherzolite suites if it is assumed that the diapir rose to a depth of about 160 km. Lherzolites at depths to 180 km would be above or very near the top of the diapir, and therefore equilibration temperatures could very well be undisturbed. Megacrysts, on the other hand, especially if they were part of the diapir, might be expected to show disturbed temperatures.

Megacrysts are here assumed to indeed have been part of the diapir and to have crystallized in a kimberlite magma. They are, in that sense, cognate. These observations support that interpretation: (1) The ultracoarse grain size and relative scarcity of mineral intergrowths suggest the megacrysts grew in a liquid, and the compositional trends of Cr-poor megacrysts can be most easily explained by liquid fractionation. Eggler and Wendlandt (this volume) show that the liquid produced by partial melting of peridotite can be kimberlitic. (2) The perturbed temperatures of megacrysts can be explained by association with a diapir. (3) Distinct groups of Cr-poor megacrysts are associated with particular pipes or groups of pipes, suggesting that the megacrysts are cognate (accidental inclusions should be found in more than one group) and that their chemical characteristics originated at the depth of kimberlite formation. (5) A few megacrysts contain carbonate inclusions.

The key to kimberlite formation is thought to be the coincidence of diapirs, rising through the asthenosphere, with a fracture system in the lithosphere. Kimberlite evolves by a combination of partial melting, liquid fractionation, and contamination. Little evidence is left of the original liquids save for the discrete nodules that grew in them. There is no need in this model for a low-velocity zone.

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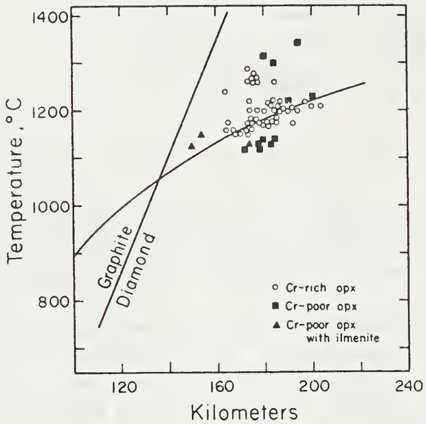

Fig. 2. Estimates of equilibration temperatures and depths for orthopyroxene megacrysts from the Sloan 2 kimberlite pipe, Colorado. The geotherm drawn is the shield geotherm of Clark and Ringwood (1964).

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