COMPOSITIONAL ZONING OF OLIVINES IN KIMBERLITE FROM THE DE BEERS MINE, KIMBERLEY, SOUTH AFRICA

F. R. Boyd (Geophysical Laboratory, Washington, D. C., U.S.A.)
C. R. Clement (De Beers Consolidated Mines, Kimberley, South Africa)

Olivine, the most abundant mineral in the modes of most kimberlites, has long been recognized to be of more than one generation or origin (e.g., Wagner, 1914, p. 54). Coarse (>1 mm), rounded grains are commonly strained and may be xenocrysts derived from disaggregated wall rocks. Smaller (0.1-1 mm) olivines tend be be euhedral or subhedral and are commonly believed to be phenocrysts (e.g., Mitchell, 1973). Both types of olivine are present as remarkably fresh, unserpentinized crystals in the De Beers "Peripheral" kimberlite.

The "Peripheral" kimberlite, one of three major phases of kimberlite intrusion within the southeastern part of the De Beers pipe, is a dark gray rock containing abundant, commonly rounded and unaltered, yellowish green olivine megacrysts set in an aphanitic matrix. Scattered megacrysts of ilmenite, garnet, chrome diopside and rare flakes of phlogopite are also present. Near-vertical flow structures formed during emplacement are locally prominent. There are abundant subhedral to euhedral phenocrysts and microphenocrysts of olivine. The fine-grained groundmass is mainly monticellite and serpentine. Monticellite occurs as a closely packed granular aggregate of subhedral crystals ranging in size from about 0.008 to 0.04 mm. Much of the monticellite is unaltered, but deuteric replacement by calcite and serpentine is evident in places. Serpentine occurs as interstitial material between earlier crystallized components, as a deuteric mineral replacing other components, and as massive serpophite in irregular segregations where it is associated with much of the limited groundmass calcite and rare apatite.

The "Peripheral" kimberlite is diamondiferous but the grade is low--approximately 5 carats per 100 tons.

Idiomorphic olivines in the De Beers "Peripheral" kimberlite range in size mainly from 0.2 to 1 mm, but in the slide on which the electron microprobe analyses were made, there are two idiomorphic crystals that are 4-5 mm in maximum dimension. Most of the small (<1 mm) olivines in this specimen show the development of some crystal faces, although many are subhedral rather than euhedral. A few are near-perfect, doubly terminated crystals.

The ten idiomorphic olivines that were studied in detail have core compositions ranging from Fo_{93} to Fo_{87}. There is no compositional distribution maximum in this range. Compositional scans made mainly across the short dimension of the euhedral olivines show complex zoning patterns that involve both normal and reverse trends (Fig. 1). The cores are usually homogeneous, and the zoning is confined to the outer 100-150 μm. A number of the scans (Fig. 1) show Fe enrichment proceeding outward from the core, followed by a reversal of trend with Mg enrichment at the outermost margins. Although the zoning patterns are complex, the edges of these crystals tend to have Mg/(Mg + Fe) in the range 0.89-0.90. Crystals with cores more Mg-rich than this range (e.g., E2 and E9, Fig. 1) have predominantly normal zoning, whereas those with cores more Fe-rich than this range (e.g., E10 and E5, Fig. 1) have predominantly reverse zoning.

The large, rounded olivines vary in size up to a maximum dimension of 6 mm. Their shapes range from lobate to subangular. Seven of the ten rounded olivines that have been studied in detail are deformed with undulate extinction; some also have internal or adhering zones of mosaic-textured, recrystallized olivine. Values of Mg/(Mg + Fe) for the homogeneous cores of these crystals are 0.840-0.934. This range is somewhat larger than that found for the euhedral olivines, although there is much overlap.

Electron microprobe scans across the margins of large, rounded olivines show that they are complexly zoned in patterns similar to those found for the small, euhedral olivines. Some crystals show restricted zoning, one has strong normal zoning and one has strong reverse zoning. The edges of these crystals tend to have Mg/(Mg + Fe) of the order of 0.89-0.90 regardless of the core composition. This same tendency was noted above for the small, euhedral crystals, and it is concordant with the observations of Emeleus and Andrews (1975), who stated that "Zoning converges on a compositional band around Mg_{87-91}...."

Electron microprobe scans across shear zones of recrystallized, mosaic-textured olivine that adhere to the margins of some of the large, rounded crystals show that these zones have also been affected by the process that caused the zoning. Figure 2 shows four scans across the edges of a large, deformed olivine (R1). Scans A-A', B-B', and C-C' across edges where the olivine has not been recrystallized show a familiar (e.g., Fig. 1) zoning pattern in which an Mg-rich core is zoned normally in the outer 150 μm, but with a reversal in trend, toward more Mg-rich olivine, in the outermost 25 μm. Scan D-D' across the shear zone (Fig. 2) shows irregular zoning toward more Fe-rich compositions, but the zoning extends 350 μm in from the edge, almost the full width of the shear zone.

The compositional range for the euhedral olivine phenocrysts suggest that they crystallized from heterogeneous batches of magma of differing Mg/(Mg + Fe) or differing temperature, or both, and were mixed during eruption. The more magnesian large, rounded xenocrysts are probably derived from peridotites, whereas the less abundant, more Fe-rich xenocrysts may have come from disaggregated dunites. The marginal zoning is believed to be metasomatic in origin rather than growth zoning because it affects patches of sheared and recrystallized olivine adhering to the edges of xenocrysts. Most of the xenocrysts have been rounded by abrasion or corrosion during eruption, and the marginal zoning has developed after the rounding. Whether the fluid that caused the metasomatism was a gas phase, residual magma, or a mixture of immiscible silicate and carbonate liquids (Clement, 1975) remains to be ascertained.

Clement, C. R., Phys. Chem. Earth, 9, 51-59, 1975.
Emeleus, C. H., and J. R. Andrews, Phys. Chem. Earth, 9, 179-197, 1975.
Mitchell, R. H., Lithos, 6, 65-81, 1973.
Wagner, P. A., The Transvaal Leader, Johannesburg, 1914 (2nd impression C. Struik (PTY) Ltd., Cape Town, 1971).

Fig. 1. Compositional scans of euhedral olivines, mostly perpendicular to long axis. E1, 2 × 4 mm; E2, 5.5 mm, broken; E9, 790 mm; E10, 795 μm. Reference values of Mg/(Mg + Fe) are given for each scan. Crystal edges are indicated by short, vertical lines at one or both ends of each scan.

Fig. 2. Variation of Mg/(Mg + Fe) across the margins of a deformed olivine crystal (R1) with an adhering, mosaic-textured, recrystallized zone. It has not been possible to show all the grain boundaries within the shear zone.

Margins Mg 891

FIG. 1

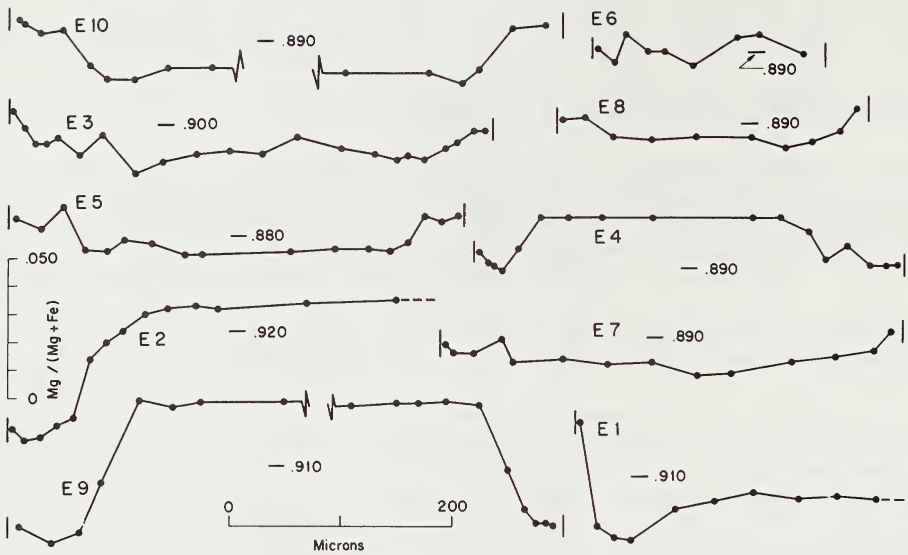

FIG. 2