

## LATE-STAGE DIOPSIDES IN KIMBERLITE GROUNDMASS

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Late-stage clinopyroxene, formerly regarded as a rare phase in kimberlite groundmass, has been identified in the groundmass of five micaceous kimberlites [Roberts Victor, New Elands, Zout en Zuur, Helam (Main and "Male" dykes)], in kimberlite stringers veining two MARID-suite nodules from the Wesselton and Bultfontein Mines, (Dawson and Smith, 1977), and in late-stage crystallizing patches (the overall mineralogy of which resembles that of kimberlite groundmass) in a pyroxene-ilmenite xenolith from the kimberlite of the Weltvreden Mine. These diopsidic pyroxenes are up to 1.5mm long (generally <0.5mm), are euhedral to subhedral, and vary morphologically from equant to acicular; they are usually optically zoned and larger crystals may be twinned. Together with titanian phlogopite (a ubiquitous, abundant, associated phase), the diopsides are randomly oriented in a matrix of various combinations of calcite, "serpentine" and calcite, the matrix varying from locality to locality. [The "serpentine" has been analysed chemically and smectite (var. saponite) has been identified in one specimen, but the others (often much richer in iron than published analyses of antigorite or chrysotile) await a detailed crystallographic study]. Microcrystalline opaque grains (chromite) occur as inclusions in all phases, except in the clear rims of diopside crystals, the cores of which often contain inclusions of phlogopite and opaques.

Chemically, the diopsides plot close to the diopside-hedenbergite join in the pyroxene quadrilateral; most are quite pure diopside but one is iron-rich (Fig. 1). They show very limited solid solution towards enstatite and most have insufficient Al to make up Si deficiency in tetrahedral sites, suggesting some of the iron is  $\text{Fe}^{3+}$ , implying the presence of acmite component. In analyzed zoned crystals the rims tend to be higher in  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$  and CaO (higher  $\text{Ca}/(\text{Ca}+\text{Mg})$  ratios), but lower in  $\text{Na}_2\text{O}$  and  $\text{Cr}_2\text{O}_3$  than the cores. Core and rim analyses (in wt.%) for a zoned Roberts Victor kimberlite diopside are (rim analyses in brackets):  $\text{SiO}_2$  54.6(54.2),  $\text{TiO}_2$  0.44(0.70),  $\text{Al}_2\text{O}_3$  0.19(0.36),  $\text{Cr}_2\text{O}_3$  0.68(0.12), total iron as FeO 3.45(3.45), MgO 17.4(17.0), CaO 22.6(23.9),  $\text{Na}_2\text{O}$  0.61(0.32),  $\text{Ca}/(\text{Ca}+\text{Mg})$  0.483(0.501).

Bulk analyses of host rocks show high  $\text{K}_2\text{O}$  (indicative of the high phlogopite) content and high CaO relative to  $\text{CO}_2$  and  $\text{P}_2\text{O}_5$ , indicating high diopside, e.g. BD 1089B, (New Elands Mine):  $\text{SiO}_2$  36.12,  $\text{TiO}_2$  1.46,  $\text{Al}_2\text{O}_3$  4.38,  $\text{Fe}_2\text{O}_3$  6.80, FeO 2.68, MnO 0.22, MgO 22.82, CaO 8.33,  $\text{Na}_2\text{O}$  0.29,  $\text{K}_2\text{O}$  5.04,  $\text{H}_2\text{O}^+$  4.89,  $\text{H}_2\text{O}^-$  1.28,  $\text{CO}_2$  3.80,  $\text{P}_2\text{O}_5$  1.46,  $\Sigma$  99.73, analyst - Joy R. Baldwin.

In simple synthetic systems, serpentine occurs only when the mole fraction of  $\text{CO}_2$  in  $\text{H}_2\text{O}-\text{CO}_2$  mixtures is less than ~0.05 (Kerrick, 1974, Fig. 13a), and serpentine + diopside is the low-T assemblage with respect to tremolite + forsterite +  $\text{H}_2\text{O}$  and ~400°C for 1 kbar pressure of  $\text{H}_2\text{O}$  (Winkler, 1974, Fig. 11-7). In the absence of direct phase equilibria relevant to the system diopside-phlogopite - "serpentine" - calcite, we tentatively suggest that the diopside-bearing late-stage assemblages may have crystallized at perhaps ~400-500°C with  $X(\text{CO}_2) < \sim 0.05$ , and at low pressures (the last parameter based on estimate of overburden at the time of kimberlite emplacement). Even though the diopside-bearing assemblages are hydrous, there is no reason to expect crystallization of tremolite or richterite under these low P-T conditions.

## References

Dawson and Smith (1977), *GCA* 41, 309.

Kerrick (1974), *Am. Mineral.* 59, 729.

Winkler (1974), *Petrogenesis of Metamorphic Rocks*, 3rd ed.

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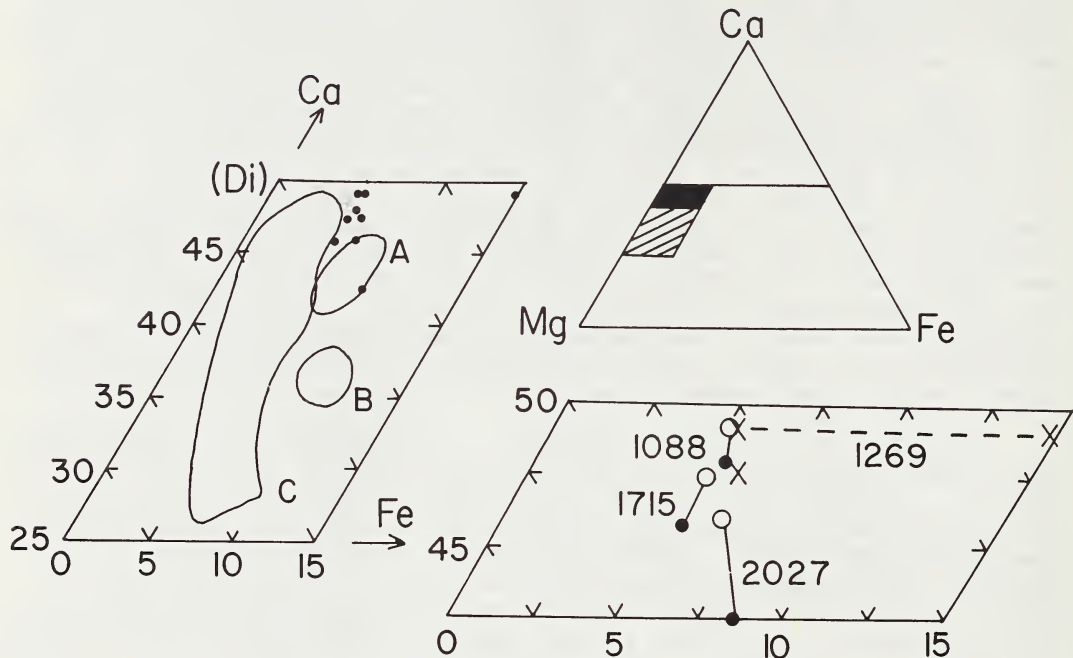


Fig. 1. Chemical composition of groundmass diopside. The left-hand and lower-right diagrams, respectively, are enlargements of the marked areas in the upper-right diagram. In the left-hand diagram, dots show the analyses listed in Table 2; in the lower-right diagram the analyses are distinguished by the following symbols: filled circle, core; open circle, rim; cross, other analyses. At the left, A shows the composition range for the MARID suite, B for clinopyroxene-ilmenite intergrowths, and C for lherzolite and websterite xenoliths.