MEGACRYSTS FROM THE MONASTERY MINE

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Megacryst minerals ($>$ 2cm) are particularly common at the Monastery Kimberlite Pipe, O.F.S. They can exceed 20cm in longest dimension and garnet, clinopyroxene and orthopyroxene all occur both as large mono-mineralic single crystals and in association with ilmenite which is also a megacryst phase. The graphic intergrowths of ilmenite with clinopyroxene, and less commonly with orthopyroxene, are well known (e.g. Boyd & Nixon, 1973). Garnet when associated with ilmenite is found as small rounded grains in an ilmenite megacryst host. Olivine is a common megacryst but we can report only a single example of olivine/ilmenite. Large phlogopites are usually vermiculitised when exposed in the kimberlite. None of these minerals, not even the olivines nor the phlogopites, commonly show signs of deformation or recrystallisation.

The major element compositions of the megacryst phases (except for phlogopite) have been determined ($\sim$ 300 determinations). The variation in Ca, Mg and Fe (atomic proportions) of the clinopyroxenes, garnets, orthopyroxenes and olivines are shown in Fig.1.

The clinopyroxenes define a trend from high Mg, low Ca, low Fe (clinopyroxene megacrysts) to low Mg, high Ca and slightly increased Fe (clinopyroxene/ilmenite megacrysts). The garnets define a trend of changing Mg/Fe ratio from high magnesian megacrysts to iron rich garnet inclusions in ilmenite. The orthopyroxenes fall into two groups:-

(A) Brown glassy homogeneous orthopyroxene megacrysts which can be associated with ilmenite and define a trend of increasing calcium with increasing magnesium and decreasing iron.

(B) Opaque orthopyroxene megacrysts showing well developed cleavage and with small bright green chrome diopsides and sometimes chrome pyrope exsolution in the cleavage planes. These orthopyroxenes show constant and low calcium contents with changing Mg/Fe ratio and are all more magnesian than group (a).

The olivines fall into two groupings: Fo_{84-88} NiO $>$ 0.3%; Fo_{78-82} NiO $<$ 0.12%. The ilmenites show a wide range in compositions, particularly in iron and magnesium, but the ilmenites co-existing with clinopyroxene, orthopyroxene and garnet are all similar to each other and within the range for discrete ilmenite megacrysts.

Inclusions have been found in the megacrysts and two types are of particular interest:

(1) Megacrysts occasionally contain small inclusions of another mineral in the megacryst suite. Tie-lines between such co-existing garnet and clinopyroxene are in excellent accord with theoretical tie-lines calculated on the basis of the results of experimental systems. (e.g. Davis & Boyd 1966, Akella & Boyd 1974).

Tie-lines between these phases above, and between garnet and orthopyroxene and garnet and olivine, suggest that the most sub-calcic clinopyroxenes, the most magnesian garnets, the most magnesian orthopyroxenes of group (A) and the most magnesian olivines have formed in equilibrium with each other, and that gently rotating concordant tie-lines may be drawn for successively more iron rich compositions, finally linking the most iron rich garnets, clinopyroxenes and orthopyroxenes to the most iron rich high nickel olivines.

(2) Tubular inclusions of kimberlite occur in some olivine crystals. They have only been found in the more magnesian high nickel olivines and are quite common. The first reported example was that described by Haggerty & Boyd, (1975). A small amount of material from one of these inclusions has a bulk composition very similar to that of the Monastery Mine kimberlite type called the "Quarry Kimberlite" (Gurney & Davids, 1973). Invasions of other megacryst phases by kimberlitic fluids has been found but is not as common as for olivine.

In broad agreement with the study of Boyd & Nixon (1973), it is suggested that all the megacrysts in Fig.1 represent a single differentiation sequence and are cumulate minerals which precipitated from a magma which formed in a mantle melting event. The earliest highest temperature (> 1350°C) cumulus phase was orthopyroxene now represented by the group (B) orthopyroxenes which crystallised from a magma relatively poor in water content and containing CO_2 to account for the absence of olivine. The glassy homogeneous orthopyroxenes (group A), the magnesian olivines, the garnets and the clinopyroxenes then precipitated whilst the water content of the magma continuously increased. Ilmenite also became a liquidus phase at about 1230°C. Crystallisation of these co-existing phases was complete at $\sim$1130°C. Some fluid remained, however, and during subsequent cooling, ilmenite may have continued to crystallise, together with phlogopite. Possibly the iron rich low nickel olivines are formed as the temperature drops towards 950°C, in a CO_2 and water rich melt. The extremely wide range in temperature of crystallisation may be due to the increasing water content of the melt in an essentially closed system.

The highest temperature orthopyroxenes (group B) re-equilibrated at sub-solidus temperatures of 950°C or less by exsolution of diopside and garnet. The final very evolved liquid which had the composition of the Monastery Quarry Kimberlite, transported the megacrysts to the surface on emplacement.

The undeformed coarse garnet lherzolite which is the most common and widely distributed mantle xenolith in kimberlite, probably does not have a suitable composition to be parental material from which the postulated igneous event originated by partial melting. Such rocks do not have sufficient potassium, titanium, water or CO_2. However, metasomatised peridotites, with amphibole, mica, ilmenite and sulphides are present at Monastery and metasomatised rocks have been widely reported from elsewhere (e.g. Harte & Gurney 1975, Lloyd & Bailey 1975, Erlank & Rickard 1977), thus providing strong evidence for the local concentration of potassium, titanium and hydrous phases in some mantle rocks.

The outlined model is applicable in detail only to the Monastery Pipe. The unusually high titanium and total iron contents of the Monastery Kimberlite and the extraordinary abundance of megacrysts with wide ranges in composition in it argue against the universal applicability of the proposed differentiation sequence to all kimberlites.

The temperatures given in the model are approximations only, based on various geothermometers and the assumption that these are applicable to the megacrysts.

References

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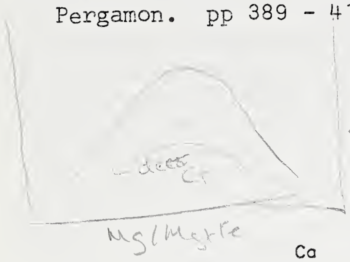
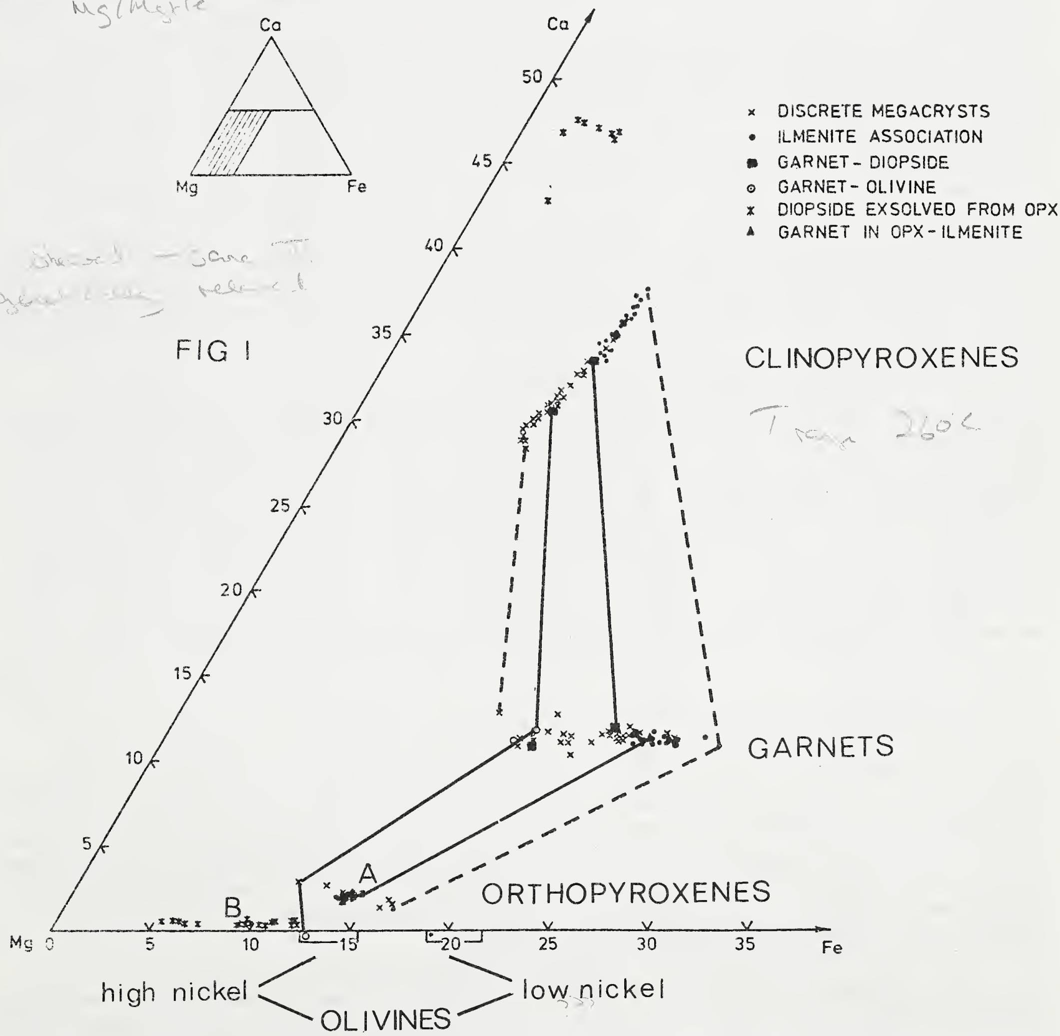


Cr ↑ decr.
Ti ↑ dec
st in ilmenite



T range 260°C

Solid tie lines : coexisting phases Dashed tie lines: inferred coexisting phases

1025 31
1050 27
1000 22