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Cr-rich Megacrysts in Kimberlite

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Introduction

Large, single crystals (> 1 cm) termed megacrysts are a feature of the mantle xenolith suite in many kimberlites. Most megacrysts can be classified in one of three suites: Cr-poor, Cr-rich and Granny Smith. Confusion between different megacryst suites exists in the literature, however, which affects petrogenetic models, and some clarification is warranted.

Most common are those of the Cr-poor megacryst suite (garnet, clinopyroxene, orthopyroxene, olivine, ilmenite and, locally, zircon and phlogopite), known from kimberlites worldwide and exemplified by occurrences in northern Lesotho and the Monastery Mine (Nixon and Boyd, 1973; Gurney et al., 1979). In their coarse grain size and composition they are clearly distinct from most minerals in mantle peridotites (e.g., megacryst silicates are more Fe- and Ti-rich than peridotite equivalents). In many occurrences, clear geochemical trends are an indication that the megacrysts have formed by fractional crystallization of deep-seated magmas, possibly the host kimberlite itself.

In addition to Cr-poor megacrysts, Eggler et al. (1979) described a Cr-rich megacryst suite from the Sloan and Nix kimberlites in the Colorado-Wyoming district. This suite consists of garnet, clinopyroxene, orthopyroxene and olivine (but not ilmenite) that are compositionally distinct from Cr-poor megacrysts and have higher (and restricted) values of molar Mg/(Mg+Fe) and wt% Cr_2O_3. A reinvestigation of Cr-rich and Cr-poor megacrysts from Sloan (>400 new samples) in the present study provides a robust data set that corroborates the findings of Eggler et al. (1979) and provides new insights into the origin of these suites.

The Granny Smith megacryst suite, initially described by Boyd et al. (1984) from Kimberley and Jagersfontein, is dominated by apple green chromian diopside. Some samples contain phlogopite and/or ilmenite but garnet and orthopyroxene are absent. Modal variants include samples dominated by phlogopite (PIC "glimmerites") and certain ilmenite megacrysts.

Other "Cr-rich megacrysts"

Following the pioneering study of Eggler et al. (1979), many other researchers have purported to have identified megacrysts that belong to the Cr-rich suite at other locations, including Pennsylvania (Hunter and Taylor, 1984), Jericho (Kopylova et al., 2009), Democratic Republic of Congo (Pivin et al., 2009), Lac de Gras (Bussweiler et al., 2018) and Orapa and Bobbejaan (e.g., Nkere et al., 2021). Hunter and Taylor (1984), however, referred to mineral grains as small as 0.5 cm as megacrysts and others have followed suit and also used lower size cutoff limits for "megacrysts" (e.g., >7 mm in Nkere et al. (2021), > 6 mm in Bussweiler et al. (2018), >2 mm in Pivin et al. (2009). By not adhering to the original lower size limit of 1 cm for megacrysts (e.g., Nixon and Boyd, 1973; Eggler et al., 1979), however, the chances are increased that xenocrystal material from mantle lithologies such as peridotites and eclogites may be mistaken for members of actual megacryst suites.

In none of these other suites of so-called Cr-rich megacrysts do their garnets meet important mineral chemical criteria established for Sloan Cr-rich megacrysts. For example, although Sloan Cr-rich suite megacryst garnets range in Cr_2O_3 from 6.0 to 13.8 wt % (Fig. 1a), few garnets in these "other" suites are in this range (Fig. 1b), with some having values as low a 0.1 wt % Cr_2O_3! Overall, these "others" have greater scatter in Mg/(Mg+Fe) (Fig. 1b) and TiO_2. Sloan Cr-rich garnet megacrysts have significant titanium contents, in the restricted range 0.6–1.0 wt% TiO_2. In contrast, the "other" garnet megacrysts have TiO_2 values in the wide range 0.1 to 2.7 wt % TiO_2, and 80% are below 0.6 wt %, similar to garnets from coarse peridotite xenoliths. Such other "Cr-rich garnet megacrysts" are likely xenocrysts from peridotite.

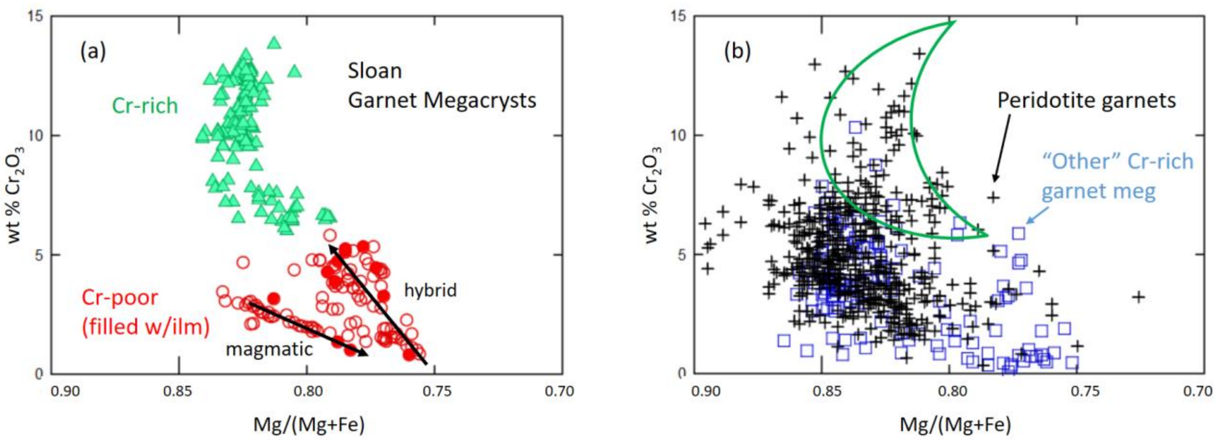

Figure 1: Garnet. (a) Compositions of Cr-rich and Cr-poor garnet megacrysts from Sloan. (b) Compositions of garnets termed "Cr-rich megacrysts" in the literature (see text for sources) compared to garnets in peridotites (compiled from literature sources) and the field for Sloan Cr-rich garnet megacrysts (approximated by green outline).

Some of the clinopyroxenes in the "other" megacryst populations may also be peridotite xenocrysts but, in the absence of garnet, many are probably variations on the "Granny Smith suite". Boyd et al. (1984) recognized that chromian diopside megacrysts from Orapa had differences from those from the Sloan Cr-rich suite but were similar to Granny Smith clinopyroxenes they described. Compositional ranges differ between Granny Smith populations from different kimberlites (Fig. 2a), as do associated minerals (e.g., ilmenite commonly occurs in Granny Smith diopsides from Kimberley and Balmoral but is rare in those from Jagersfontein). There is no one compositional range, or paragenesis (other than absence of garnet and orthopyroxene), that applies to all occurrences of Granny Smith megacrysts.

In Fig. 2a the compositions of "Cr-rich clinopyroxene megacrysts" from Orapa and Lac de Gras are compared to those from Granny Smith diopside from Kimberley, Jagersfontein and Balmoral. The Orapa and Lac de Gras populations consist of relatively dense concentrations of data in a "cloud" of data with wide ranging compositions (e.g., Orapa chromian diopsides are in the range Mg/(Mg+Fe) = 0.820 to 0.943, Ca/(Ca+Mg) = 0.356 to 0.488, extending beyond the limits of the Figure). The Orapa and Lac de Gras data distributions are interpreted as representing suites of Granny Smith diopside megacrysts (the dense clusters) mixed with cpx xenocrysts derived from peridotites (the scattered "cloud").

Megacrysts and pyroxenites described as belonging to the Cr-poor and Cr-rich suites have been reported from Jericho and Muskox kimberlites on the Slave Craton (e.g., Kopylova et al., 1999, 2009). Although their garnet and clinopyroxene compositions match neither the Sloan Cr-rich suite nor the magmatic portion of the Cr-poor suite, they do correspond to the "hybrid" portion of the Sloan Cr-poor suite (Fig. 2b). Both the Jericho megacrystalline pyroxenites and the "hybrid" Sloan megacrysts are the products of interaction of the parent magma with depleted lithospheric peridotite in the mantle prior to kimberlite eruption. The largely single crystal nature of the Sloan samples suggests a higher melt/wall rock ratio than for Jericho.

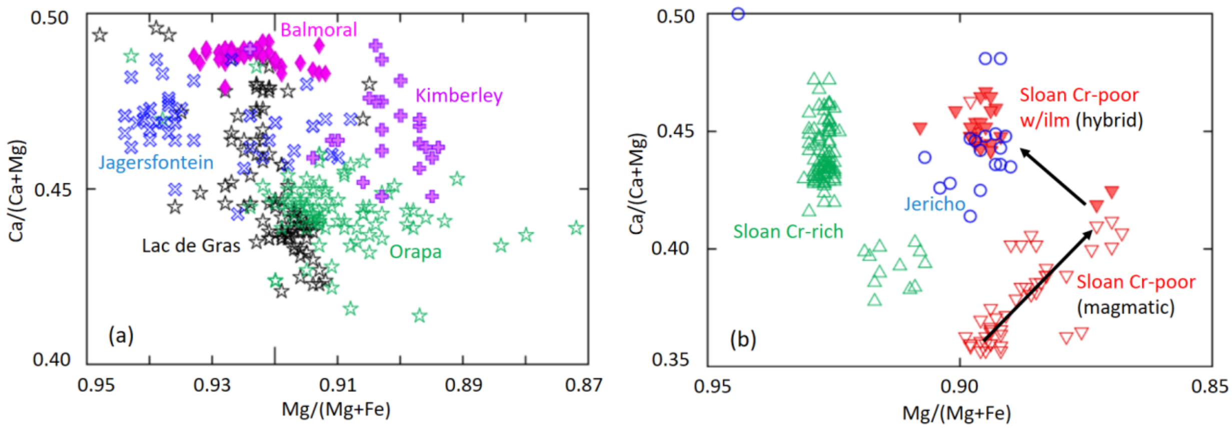

Figure 2: Clinopyroxene. (a) Compositions of Granny Smith megacrysts of chromian diopside from Kimberley (Boyd et al., 1984), Jagersfontein (Hops, 1989) and Balmoral (this study) compared with "Cr-rich clinopyroxene megacrysts" from Orapa (data summarized in Nkere et al., 2021) and Lac de Gras (Bussweiler et al., 2018). (b) Compositions of clinopyroxenes from Jericho megacrysts and pyroxenites (Kopylova et al., 1999, 2009) compared with Sloan Cr-rich and Cr-poor clinopyroxene megacrysts.

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