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A new occurrence of yimengite-hawthorneite and crichtonite-group minerals in an orthopyroxenite from kimberlite: Implications for mantle metasomatism

Dmitriy I. Rezvukhin[1,*], Taisia A. Alifirova[1], Andrey V. Korsakov[1], and Alexander V. Golovin[1]

[1]Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, 3 Koptyuga Avenue, Novosibirsk 630090, Russia

Abstract

Large-ion lithophile elements (LILE)-enriched chromium titanates of the magnetoplumbite ($AM_{12}O_{19}$) and crichtonite ($ABC_{18}T_2O_{38}$) groups have been recognized as abundant inclusions in orthopyroxene grains in a mantle-derived xenolith from the Udachnaya-East kimberlite pipe, Daldyn field, Siberian craton. The studied xenolith consists of three parts: an orthopyroxenite, a garnet clinopyroxenite, and a garnet-orthopyroxene intermediate domain between the two. Within the host enstatite (Mg# 92.6) in the orthopyroxenitic part of the sample titanate inclusions are associated with Cr-spinel, diopside, rutile, Mg-Cr-ilmenite, and pentlandite. Crichtonite-group minerals also occur as acicular inclusions in pyrope grains of the intermediate domain adjacent to the orthopyroxenite, as well as in interstitial to enstatite oxide intergrowths together with Cr-spinel, rutile, and ilmenite.

Yimengite-hawthorneite inclusions in enstatite contain (wt%) 3.72–8.04 BaO, 2.05–3.43 K_2O, and 0.06–0.48 CaO. Their composition is transitional between yimengite and hawthorneite end-members with most grains exhibiting K-dominant chemistry. A distinct feature of the studied yimengite-hawthorneite minerals is a high content of Al_2O_3 (5.74–7.69 wt%). Crichtonite-group minerals vary in compositions depending on the occurrence in the xenolith: inclusions in enstatite are moderate-high in TiO_2 (62.9–67.1 wt%), moderately Cr-rich (12.6–14.0 wt% Cr_2O_3), Ba- or K-specific in the A site, and contain low ZrO_2 (0.05–1.72 wt%), whereas inclusions in pyrope are moderate in TiO_2 (61.7–63.3 wt% TiO_2), relatively low in Cr (8.98–9.62 wt% Cr_2O_3), K-dominant in the A site, and are Zr-enriched (4.64–4.71 wt% ZrO_2). Crichtonite-group minerals in polymineralic oxide intergrowths show highly diverse compositions even within individual aggregates, where they are chemically dominated by Ba, Ca, and Sr.

P-T estimates indicate the orthopyroxenite to have equilibrated at ~800 °C and 35 kbar. Preferentially oriented lamellae of enstatite-hosted Cr-spinel and diopside, as well as pyrope, diopside, and Cr-spinel grains developed around enstatite crystals, are interpreted to have been exsolved from the high-*T* Ca-Al-Cr-enriched orthopyroxene precursor. The exotic titanate compositions and observed textural relationships between inclusions in enstatite imply that the studied orthopyroxenite has undergone metasomatic processing by a mobile percolating agent afterward; this highly evolved melt/fluid was enriched in Ba, K, HFSE, and other incompatible elements. The infiltration of the metasomatizing liquid occurred through interstices and vulnerable zones of enstatite grains and manifested in the crystallization of titanate inclusions. It is assumed that Cr-spinel lamellae served as seeds for their nucleation and growth. The prominent textural and chemical inhomogeneity of the interstitial oxide intergrowths is either a consequence of the metasomatic oxide crystallization shortly prior to the kimberlite magma eruption or arose from the intensive modification of preexisting oxide clusters by the kimberlite melt during the Udachnaya emplacement. Our new data provide implications for the metasomatic treatment of orthopyroxenites in the subcontinental lithospheric mantle from the view of exotic titanate occurrences.

Keywords: Yimengite, hawthorneite, magnetoplumbite-group minerals, crichtonite-group minerals, Ti-oxide, xenolith, mantle metasomatism, Udachnaya kimberlite pipe