Ferrous freudenbergite in ilmenite megacrysts: A unique paragenesis from the Dalnaya kimberlite, Yakutia

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ABSTRACT

A suite of picroilmenite megacrysts from the Dalnaya kimberlite, Siberia, was found to fall into one of two groups, the most abundant having 11–12 wt% MgO and 650–1500 ppm Nb, and the others having lower MgO (8.8–10.2 wt%) and higher Nb (1700–2700 ppm). Ferrous freudenbergite (Na2 FeTi7 O16) crystals were found included in many of the megacrysts from the first group. The freudenbergite-bearing ilmenite megacrysts are also pervaded by micrometer-size spots that have elevated Al2 O3 (0.2 wt%), SiO2 (0.04 wt%), and Na2 O (0.15 wt%) contents. The low Cr2 O3 vs. Nb content of the second group may reflect clinopyroxene crystallization. This may be a factor influencing the lack of freudenbergite in these megacrysts.

All ferrous freudenbergite samples studied previously are manifested as metasomatic reaction mantles replacing rutile. The freudenbergite from the Dalnaya kimberlite described in this paper occurs as small (max. 150 x 40 μm), euhedral, prismatic inclusions in picroilmenite (11–12 wt% MgO) megacrysts, with no associated rutile. Minor-element (Cr, Al, and Mg) substitutions for Fe are more extensive than in previously studied freudenbergite, with up to 1.4 wt% Cr2O3, 1.9 wt% Al2O3, and 3.1 wt% MgO. Nb is relatively low, typically less than 0.3 wt% Nb2O5 with a maximum of 1.1 wt%. Reaction of some of the freudenbergite with an alkali fluid has resulted in thin, discontinuous rims and embayments of perovskite and an unidentified hydrous calcium titanate, around most crystals. Rapid ascent from depth and shielding by ilmenite may have been contributing factors to the preservation of freudenbergite in these samples.

The significance of the euhedral nature of freudenbergite and the lack of any genetic relationship with rutile suggest that it crystallized by a process other than simple metasomatic replacement of rutile. Indeed, the freudenbergite probably crystallized directly from a Na + Ti-rich fluid infiltrating the ilmenite megacrysts. The several occurrences (Liberia, Bultfontein, and Dalnaya) of ferrous freudenbergite suggest that it may be more common in kimberlites than previously recognized.

INTRODUCTION

The type locality for the rare mineral freudenbergite is the apatite-rich Katzenbuckel (Odenwald, Germany) alkali-syenite complex, where it occurs as a xenomorphic accessory mineral associated with hematite (Frenzel 1961; Frenzel et al. 1971). Freudenbergite, sensu stricto Na2Fe2+Ti7 O15, has only been observed in this complex. Ferrous analogs of freudenbergite (Na2FeTiO15) have been reported from xenoliths entrained in kimberlites. These were in lower crustal granulate xenoliths from Liberia (Haggerty 1983) and upper mantle zircon-bearing xenoliths with lindsleyite-mathiasite from Bultfontein, South Africa (Haggerty and Gurney 1984; Haggerty 1991). In the Liberian samples, ferrous freudenbergite occurs as the inner-most phase of reaction mantles on rutile, followed concentrically by ilmenite, perovskite, and sphene. This assemblage suggests that rutile reacted with an alkali-rich fluid, metasomatically precipitating freudenbergite first (Haggerty 1983). A sodium titanate, similar to freudenbergite in composition, was also observed mantling rutile in a kimberlite dike in the west Ukikit field, Yakutia (Oleinikov 1995). In the present study, the observed mineral occurs as small euhedral crystals embedded in picroilmenite megacrysts and, importantly, with no associated rutile or hematite.

Frenzel (1961) originally reported freudenbergite as hexagonal Na2FeTiO15, but McKie (1963) and McKie and Long (1970) corrected this to monoclinic NaFeTiO15 on the the basis of observations of Wadsley (1964) that the X-ray data are similar to synthetic Na3TiO5 “bronze.” Bayer and Hoffman (1965) demonstrated extensive solid solution of the synthetic Na3TiO5 “bronze,” resulting in a general formula of A,B,Ti1−x−yO15, where A = Na, Rb, and K; B = Fe, Mg, Al, Cr, Mn, Zn, Ni, Co,