Burbankite, a (Sr,REE,Na,Ca)-carbonate in fluid inclusions from carbonatite-derived fluids: Identification and characterization using Laser Raman spectroscopy, SEM-EDX, and synchrotron micro-XRF analysis

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ABSTRACT

Burbankite, ideally (Na,Ca)₃(Sr,REE,Ba)₃(CO₃)₅, is a rare REE carbonate mineral that until now had been encountered only at a few localities including highly alkaline silicate rocks, carbonatites, and lacustrine sediments. It was identified as an abundant solid phase in fluid inclusions that represent fluids derived from the Kalkfeld carbonatite complex (Namibia). Burbankite occurs in association with other solids including nahcolite, halite, sylvite, rouvilleite (?), fluorite, calcite, cryolite, base metal sulfides, and phosphates. The carbonatite-derived fluids were trapped in quartzite country rocks close to the carbonatite contact. The optical and geochemical identification of burbankite has been confirmed by confocal Laser Raman spectrometry. The burbankite crystals show a Raman shift at 1078 cm⁻¹, which is significantly displaced relative to peaks for other common carbonates and is much broader. The elemental composition of burbankite was determined by a combination of SEM-EDX on opened inclusions and synchrotron-XRF analysis on unopened wafers. The SEM-EDX analyses of the burbankite crystals yielded a compositional range (in wt%) of Na₂O 10.6–17.5, CaO 3.6–17.4, SrO 12.0–26.7, BaO 2.5–5.5, La₂O₃ 3.5–7.0, Ce₂O₃ 4.7–9.0, Nd₂O₃ 0.9–2.1, and CO₂ (calc.) 29.8–35.2. The Na/Ca ratios are between 1.0 and 4.3, which is high in comparison with rock-forming burbankite occurrences, and clearly distinguishes the burbankite crystals from carbocernaite. Synchrotron micro-XRF spectra yielded REE patterns decreasing from La to Yb over 2.5 orders of magnitude with small negative Eu anomaly \([\text{Eu}/\text{Eu}^*]_{\text{calc}} = 0.5–1.0\) in some cases. The Y/Ho ratios range from 1 to 5, and Th/U ratios are between 1 and 10. The fluids trapped are interpreted to represent a highly evolved but pristine, alkali-rich, hydrous, carbonate melt, which had not lost alkalis to the country rocks by fenitization processes. The common occurrence of burbankite crystals in the fluid inclusions shows the high capability of carbonate melts and fluids to transport high-field-strength and large-ion-lithophile elements.

INTRODUCTION

Carbonatite melts derived from a partially molten metasomatized mantle source have a high potential to transport alkalis, large-ion-lithophile and high-field-strength elements. Their relatively high overall content of fluid and gaseous components such as CO₂, H₂O, and halogens means that they have low viscosities (e.g., Wolff 1994), and are able to flow very readily at moderate to low temperatures. Carbonatite melts, therefore, behave like highly mobile fluids, and have the ability to penetrate and mineralize crustal rocks to form economically important ores of REE, Sr, Th, U, F, or Fe, among others. Crystallized carbonatite melts, however, generally have lost their alkali and volatile components to associated metamorphic fluids. Therefore, whole-rock analyses of carbonatite rocks may not be representative of the compositions of the initial carbonatite magma. Only when both alkali-rich fluids and carbonatite melts are trapped (e.g., in fluid inclusions), do they together represent the pristine carbonatite melt compositions.

We report here on the identification and comprehensive geochemical characterization of the mineral burbankite, ideally (Na,Ca)₃(Sr,REE,Ba)₃(CO₃)₅, which occurs as a solid phase in multicomponent carbonatite-derived fluid inclusions. The investigated fluids were trapped in quartzites in the immediate vicinity of the Kalkfeld carbonatite complex (Namibia) and are interpreted to represent a carbonatite melt with all volatile components preserved. Burbankite is a rare mineral confined mainly to highly alkaline igneous rocks (e.g., Verwoerd 1963; Chen and Chao 1974), but it also has been reported from the alkaline lacustrine environment of the Eocene Green River Formation, U.S.A. (Milton and Fahey 1960; Fitzpatrick and...