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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 $(Na,Ca)_3(Sr,REE,Ba)_3(CO_3)_5$, 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 Na_2O 10.6–17.5, CaO 3.6–17.4, SrO 12.0–26.7, BaO 2.5–5.5, La_2O_3 3.5–7.0, Ce_2O_3 4.7–9.0, Nd_2O_3 0.9–2.1, and CO_2 (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 $[(Eu/Eu^*)_{cn} = 0.5–1.0]$ 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.