Stracherte, BaCa$_6$(SiO$_4$)$_2$[(PO$_4$)(CO$_3$)]F, the first CO$_3$-bearing intercalated hexagonal antiperovskite from Negev Desert, Israel

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Abstract

The new mineral stracherte, BaCa$_6$(SiO$_4$)$_2$[(PO$_4$)(CO$_3$)]F [R$ar{3}$m, $a = 7.0877(5)$ Å, $c = 25.201(2)$ Å, $V = 1096.4(1)$ Å$^3$, $Z = 3$], belongs to the zadovite group, which also includes zadovite, BaCa$_6$(SiO$_4$)(PO$_4$)$_2$F; aradite, BaCa$_6$(SiO$_4$)(VO$_4$)(PO$_4$)$_2$F; and gazeevite, BaCa$_6$(SiO$_4$)(SO$_4$)$_2$O. All minerals of this group exhibit single-layer antiperovskite modules, which are intercalated with tetrahedral layers. In stracherte, the first CO$_3$-bearing intercalated hexagonal antiperovskite, about 38% of the (PO$_4$)$^{3-}$ tetrahedra are randomly substituted by planar (CO$_3$)$^{3-}$ groups. The mineral was discovered in spurrite rocks of the Hatrurim Complex in the Negev Desert near Arad, Israel. Associated minerals are spurrite, calcite, brownmillerite, shulamitite, CO$_3$-bearing fluorapatite, fluoraygmenite-fluorkylygenite, and ariegilatite. The empirical formula of stracherte is: (Ba$_{0.96}$K$_{0.02}$Na$_{0.01}$)$_6$(SiO$_4$)$_2$(PO$_4$)$_3$–$e^\text{–}$ alternate with [FCa$_6$(SiO$_4$)$_3$]$^{3+}$ antiperovskite modules.

Keywords: Stracherte, zadovite group, new mineral, intercalated hexagonal antiperovskites, CO$_3$, Raman, pyrometamorphic rocks, Hatrurim Complex

Introduction

Stracherte, BaCa$_6$(SiO$_4$)$_2$[(PO$_4$)(CO$_3$)]F [R$ar{3}$m, $a = 7.0877(5)$ Å, $c = 25.201(2)$ Å, $V = 1096.4(1)$ Å$^3$, $Z = 3$], was discovered in spurrite rocks of the Hatrurim Complex in the Negev Desert near Arad, Israel. It is the fourth mineral isotopic with zadovite (see Table 1 in Galuskin et al. 2018). Minerals with zadovite-type structure can be considered as intercalated hexagonal antiperovskites with a general formula of $AB_2$(TO$_4$)$_4$(TO$_4$)$_2$$W^\text{e}$, where $A$ = Ba, K...; $B$ = Ca, Na; $T$ = Si, P, V$^{4+}$, S$^{6+}$, Al...; $W$ = O$^2$–, F$^–$, and antiperovskite layers [(WF$_6$)(TO$_4$)]$^{2+}$ and $(TO_4)^{2–}$ layers occur in a ratio of 1:1. There are three zadovite-group minerals: zadovite, BaCa$_6$(SiO$_4$)$_2$(PO$_4$)$_2$F; aradite BaCa$_6$(SiO$_4$)(VO$_4$)$_2$F; gazeevite BaCa$_6$(SiO$_4$)(SO$_4$)$_2$O (Galuskin et al. 2015a, 2017). Stracherte is the first mineral of this group to exhibit a substitution of (PO$_4$)$^{3–}$ tetrahedra by planar (CO$_3$)$^{3–}$ groups. Consequently, tetrahedral modules Ba$_6$[(PO$_4$)(CO$_3$)]$^{3+}$ alternate with [FCa$_6$(SiO$_4$)$_3$]$^{3+}$ antiperovskite modules.

Minerals of the nabimusaite group can also be considered as intercalated hexagonal antiperovskites but with a general formula of the form $AB_2$(TO$_4$)$_4$(TO$_4$)$_2$$W$(A, B, T, and $W$ are as indicated above). However, in this structure type, single tetrahedral layers $(TO_4)^{2–}$ are intercalated with triple antiperovskite layers [(WF$_6$)(TO$_4$)]$^{2+}$ resulting in a 3:1 ratio of the structural modules. The mineral nabimusaite, KCa$_6$(SiO$_4$)(SO$_4$)$_2$O$_2$F [R$ar{3}$m, $a = 7.1905(4)$, $c = 41.251(3)$ Å, $V = 1847.1(2)$ Å$^3$, $Z = 3$], was the first intercalated hexagonal antiperovskite detected in pyrometamorphic rocks of the Hatrurim Complex (Galuskin et al. 2015b). Nabimusaite is an isotype of arctite, Ba(Ca$_7$Na$_5$)(PO$_4$)$_2$(PO$_4$)$_2$F; (R$ar{3}$m, $a = 7.094$ Å, $c = 41.320$ Å; Sokolova et al. 1984). Later, dargaite, BaCa$_{12}$(SiO$_4$)$_2$(SO$_4$)$_2$O$_3$, and ariegilatite, BaCa$_{12}$(SiO$_4$)$_2$(PO$_4$)$_2$F$_2$, were found and confirmed to be members of the nabimusaite group (Krüger et al. 2017; Galuskin et al. 2018; Galuskina et al. 2018). Triple antiperovskite layers in minerals of this group resemble triple antiperovskite layers in the structure of hatrurite-framework hexagonal antiperovskite (Jeffery 1952; Krivovich 2008; Galuskin et al. 2015b).

The name stracherte is given in honor of the well-known American geologist, Glenn Blair Stracher (aka “The Firewalker,” born March 31, 1949, in Albany, New York), Professor Emeritus of Geology at East Georgia State College in Swainsboro, Georgia, U.S.A. Stracher is the author and editor of numerous scientific works on coal combustion and chemical thermodynamics. He also authored books, including the GSA Engineering Geology Book and the five volumes of Coal and Peat Fire Elsevier books. Stracher edited and supported the publication of our earliest works related to the study of the Hatrurim Complex in Israel (Vapnik et al. 2007). He is the co-author of our recent study related to the fascinating discovery of stone tool workshops utilizing pyrometamorphic rocks of the Hatrurim Basin (Vapnik et al. 2015).

The mineral and name (IMA2016-098) were approved by the Commission on New Minerals, Nomenclature and Classification (CNMNC) of the International Mineralogical Association (IMA).