

Perbøeite-(Ce) and alnaperbøeite-(Ce), two new members of the epidote-törnebohmite polysomatic series: Chemistry, structure, dehydrogenation, and clue for a sodian epidote end-member

PAOLA BONAZZI^{1,*}, GIOVANNI O. LEPORE¹, LUCA BINDI¹, CHRISTIAN CHOPIN², TOMAS A. HUSDAL³
AND OLAF MEDENBACH⁴

¹Dipartimento di Scienze della Terra, Università di Firenze, Via La Pira 4, I-50121 Florence, Italy

²Laboratoire de Géologie, Ecole normale supérieure, CNRS, 24 rue Lhomond, F-75005 Paris, France

³Veslefrikk 4, N-8028 Bodø, Norway

⁴Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

ABSTRACT

In yttrian fluorite from pegmatites of the Tysfjord granite, Norway, grayish-green to very pale green gatelite-like crystals occur along with millimeter-size aggregates of Y-silicates as a late primary phase; they are associated with allanite-(Ce), bastnäsite-(Ce), and intimately inter- or overgrown by törnebohmite-(Ce). Sub- to euhedral crystals, up to 400 μm in size, are chemically zoned between two near-end-member compositions that imply the existence of two new members of the polysomatic gatelite group, in which *ET* polysomes are composed of *E* modules with epidote-type structure alternating with *T* modules of törnebohmite-type structure. The two new minerals form a continuous solid-solution series, along which two crystals of intermediate compositions served for species definition. Their electron-microprobe analyses yield the empirical formulas $(\text{Ca}_{1.00}\text{Mn}_{0.03}\text{Na}_{0.08}\text{La}_{0.51}\text{Ce}_{1.30}\text{Pr}_{0.16}\text{Nd}_{0.62}\text{Sm}_{0.10}\text{Gd}_{0.06}\text{Dy}_{0.03}\text{Er}_{0.01}\text{Y}_{0.06}\text{Th}_{0.01})_{\Sigma 3.97}(\text{Al}_{3.21}\text{Fe}_{0.79}^{2+})_{\Sigma 4.00}\text{Si}_{5.01}\text{O}_{20}(\text{OH})_2$ for perbøeite-(Ce) [IMA 2011-55] and $(\text{Ca}_{1.10}\text{Mn}_{0.03}\text{Na}_{0.20}\text{La}_{0.42}\text{Ce}_{1.14}\text{Pr}_{0.16}\text{Nd}_{0.60}\text{Sm}_{0.13}\text{Gd}_{0.07}\text{Dy}_{0.03}\text{Er}_{0.01}\text{Yb}_{0.01}\text{Y}_{0.12}\text{Th}_{0.02})_{\Sigma 4.04}(\text{Al}_{3.54}\text{Fe}_{0.40}^{2+}\text{Mg}_{0.02})_{\Sigma 3.96}\text{Si}_{4.99}\text{O}_{20}(\text{OH})_2$ for alnaperbøeite-(Ce) [IMA 2012-54]. The respective end-member formulas are $^{\text{A}}(\text{Ce}_3\text{Ca})^{\text{M}}(\text{Al}_3\text{Fe}^{2+})\text{Si}_2\text{O}_7(\text{SiO}_4)_3\text{O}(\text{OH})_2$, which requires Ce_2O_3 45.10, CaO 5.14, FeO 6.58, Al_2O_3 14.01, SiO_2 27.52, H_2O 1.65, total 100.00 wt%; and $^{\text{A}}(\text{Ce}_{2.5}\text{CaNa}_{0.5})^{\text{M}}(\text{Al}_4)\text{Si}_2\text{O}_7(\text{SiO}_4)_3\text{O}(\text{OH})_2$, which requires Ce_2O_3 40.86, CaO 5.58, Na_2O 1.54, Al_2O_3 20.31, SiO_2 29.92, H_2O 1.79, total 100.00 wt%. Cell parameters of perbøeite-(Ce) and alnaperbøeite-(Ce) for these crystals are $a = 8.9277(6)$ and $8.9110(4)$, $b = 5.6548(6)$ and $5.6866(2)$, $c = 17.587(1)$ and $17.5252(7)$ Å, $\beta = 116.475(8)$ and $116.300(5)^\circ$, $V = 794.8(1)$ and $796.13(7)$ Å³, respectively. Members of the perbøeite-(Ce)–alnaperbøeite-(Ce) solid solution are topologically identical to the minerals gatelite-(Ce) and västmanlandite-(Ce). Structural data (space group $P2_1/m$) were obtained for the holotype crystals and for several crystals with intermediate composition. Structural refinements of a crystal annealed step-wise in air confirm that most of Fe in M3 is divalent before heating and show that oxidation/dehydrogenation takes place mostly in the *E* module (M3 and H1). Perbøeite-(Ce) derives from gatelite-(Ce) by the homovalent substitution [$^{\text{M3}}\text{Fe}^{2+} \rightarrow ^{\text{M3}}\text{Mg}$]. Alnaperbøeite-(Ce) derives from perbøeite-(Ce) or gatelite-(Ce) by the coupled heterovalent substitutions [$^{\text{A}}\text{Na}^+ + 2^{\text{M3}}\text{Al}^{3+} \rightarrow ^{\text{A}}\text{REE} + 2^{\text{M3}}(\text{Fe}^{2+} \text{ or } \text{Mg})$].

Törnebohmite-(Ce) associated with alnaperbøeite-(Ce) is Na-free, whereas coexisting allanite is Na-bearing and shows the same coupled substitution between A and M sites as the one relating perbøeite-(Ce) and alnaperbøeite-(Ce) ($\text{Na}_{0.5}\text{Al} \leftrightarrow \text{REE}_{0.5}\text{Fe}^{2+}$). This could suggest, although crystallographic evidence is inconclusive, that Na incorporation in the *ET* polysome occurs in the *E* module alone (A2 or A1 sites), leading to the sodian *E* end-member $^{\text{A}}(\text{CaREE}_{0.5}\text{Na}_{0.5})^{\text{M}}(\text{Al}_3)\text{Si}_2\text{O}_7(\text{SiO}_4)_3\text{O}(\text{OH})$. In any event, this new epidote end-member is needed to account for up to ca. 10 mol% of the composition of allanite-group minerals, in which Na_2O contents may reach 0.3 wt%. Sodium must be analyzed in epidote-super group and gatelite-group minerals.

Keywords: New mineral, perbøeite-(Ce), alnaperbøeite-(Ce), Tysfjord granite (Norway), polysomatic series, epidote supergroup, crystal structure, chemical composition, gatelite group