REDEFINITION OF A MINERAL IN THE JOAQUINITE GROUP: ORTHOJOAQUINITE-(La)

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Abstract

Orthojoaquinite-(La) from Ilímaussaq, Greenland, is a new member of the joaquinite group. Its description was published by Semenov *et al.* (1967); although the chemical analytical data indicated that La is the dominant *REE* in the mineral, its true position in the group was not established for a third of a century. Orthojoaquinite-(La) is orthorhombic, probable space-group *Ccmm*, a 10.539(10), b 9.680(5), c 22.345(10) Å, V 2280 Å^3, $Z = 4$. Chemical analytical data are: Na$_2$O 2.41, K$_2$O 0.22, CaO (+SrO) 0.03, MnO 0.70, FeO 4.78, BaO 21.46, Fe$_2$O$_3$ 0.39, La$_2$O$_3$ 10.05, Ce$_2$O$_3$ 9.40, Pr$_2$O$_3$ 0.99, Nd$_2$O$_3$ 2.15, SiO$_2$ 33.82, TiO$_2$ 9.20, ThO$_2$ 0.38, Nb$_2$O$_5$ 2.31, H$_2$O 1.50, F 0.38, sum 100.17, less O = F 0.16, total 100.01 wt.%. The empirical formula (based on O + OH + F + H$_2$O = 28) is: $(Ba_{1.99}Ca_{0.01})_{\Sigma2.00}(Na_{1.11}K_{0.07})_{\Sigma1.18}(La_{0.88}Ce_{0.81}Nd_{0.18}Pr_{0.09})_{\Sigma1.96}$ $(Fe^{2+}_{0.95}Mn_{0.14})_{\Sigma1.09}$ $(Ti_{1.64}Nb_{0.25}Fe^{3+}_{0.07}Th_{0.02})_{\Sigma1.98}$ $Si_{8.01}O_{26.00}[(OH)_{0.37}O_{0.35}F_{0.28}]_{\Sigma1.00}\cdot1.00H_2O$. The simplified formula is $Ba_2Na(La,Ce)_2Fe^{2+}Ti_2Si_8O_{26}(OH,O,F)\cdot H_2O$. The mineral is brown, has a silky luster, and is transparent. The Mohs hardness is about 5 (VHN 350–430 kg/mm^2); it has a good {001} cleavage. The measured density is 4.1 g/cm^3, and the calculated density is 4.14 g/cm^3. Optical data: optically biaxial (+), α 1.754, β 1.760, γ 1.797; 2V(meas.) 40°, 2V(calc.) 45°; orientation $Z = c$; pleochroism strong in yellow-green, $Z > X$.

Keywords: new mineral species, joaquinite group, orthojoaquinite-(La), Ilímaussaq, Greenland.

Sommaire

L'orthojoaquinite-(La), provenant du complexe d'Ilímaussaq, au Groënland, est un nouveau membre du groupe de la joaquinite. Semenov *et al.* ont publié sa description en 1967; quoique les données existaient pour indiquer que le lanthane prédomine dans le site occupé par les terres rares, sa place parmi les membres du groupe n'a été établie qu'un tiers de siècle plus tard. L'orthojoaquinite-(La) est orthorhombique, groupe spatial probable *Ccmm*, a 10.539(10), b 9.680(5), c 22.345(10) Å, V 2280 Å^3, $Z = 4$. Les données analytiques sont: Na$_2$O 2.41, K$_2$O 0.22, CaO (+ SrO) 0.03, MnO 0.70, FeO 4.78, BaO 21.46, Fe$_2$O$_3$ 0.39, La$_2$O$_3$ 10.05, Ce$_2$O$_3$ 9.40, Pr$_2$O$_3$ 0.99, Nd$_2$O$_3$ 2.15, SiO$_2$ 33.82, TiO$_2$ 9.20, ThO$_2$ 0.38, Nb$_2$O$_5$ 2.31, H$_2$O 1.50, F 0.38, somme 100.17, moins O = F 0.16, pour un total de 100.01% (poids). La formule empirique (fondée sur O + OH + F + H$_2$O = 28) est: $(Ba_{1.99}Ca_{0.01})_{\Sigma2.00}(Na_{1.11}K_{0.07})_{\Sigma1.18}(La_{0.88}Ce_{0.81}Nd_{0.18}Pr_{0.09})_{\Sigma1.96}$ $(Fe^{2+}_{0.95}Mn_{0.14})_{\Sigma1.09}$ $(Ti_{1.64}Nb_{0.25}Fe^{3+}_{0.07}Th_{0.02})_{\Sigma1.98}$ $Si_{8.01}O_{26.00}[(OH)_{0.37}O_{0.35}F_{0.28}]_{\Sigma1.00}\cdot1.00H_2O$. La formule simplifiée est $Ba_2Na(La,Ce)_2Fe^{2+}Ti_2Si_8O_{26}(OH,O,F)\cdot H_2O$. Il s'agit d'un minéral brun et transparent, ayant un éclat soyeux. La dureté de Mohs est d'environ 5 (VHN 350–430 kg/mm^2). Il possède un bon clivage {001}. La densité mesurée est 4.1 g/cm^3, et la densité calculée est 4.14 g/cm^3. Le minéral est biaxe positif, α 1.754, β 1.760, γ 1.797; 2V(mes.) 40°, 2V(calc.) 45°; orientation $Z = c$; pléochroïsme intense en teintes jaune verdâtre, $Z > X$.

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Mots-clés: nouvelle espèce minérale, groupe de la joaquinite, orthojoaquinite-(La), Ilímaussaq, Groënland.

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INTRODUCTION

In the course of compiling the *International Encyclopedia of Minerals*, the first author was responsible for writing the descriptions of the six species of the joaquinite group of minerals. At that time these were: joaquinite-(Ce), orthojoaquinite-(Ce), strontiojoaquinite, strontio-orthojoaquinite, bario-orthojoaquinite and byelorussite-(Ce). When the second author edited the descriptions, he noted that two sets of chemical analytical data listed for orthojoaquinite-(Ce) actually indicated two species based on the dominant rare-earth-element (*REE*) content: orthojoaquinite-(Ce) (already known) and orthojoaquinite-(La) (a new species). A proposal was submitted to the Commission on New Minerals and Mineral Names of the International Mineralogical Association, and the latter species and name were approved.

THE JOAQUINITE GROUP

The first member of the joaquinite group was described very briefly and named by Louderback (1909) from Joaquin Ridge, San Benito County, California, U.S.A., where it was found sparingly with benitoite. Palache & Foshag (1932) obtained additional material and gave a much more complete description, including physical properties, crystallography and chemical composition. Bell (1963) reported joaquinite from Seal Lake, Labrador, Canada. The rare earths in minerals of the joaquinite group were the object of a study by Semenov *et al.* (1967) in which they described a joaquinite-group mineral with a high rare-earth content from the Ilímaussaq alkaline complex, south Greenland. A very complete study of the physical, optical and structural properties of benitoite, neptunite and joaquinite from the type locality was carried out by Laird & Albee (1972). Their analyses indicate total rare-earth contents from 17.73 to 19.16 wt.%, with Ce the dominant rare-earth element. The crystal structure of a monoclinic joaquinite was published by Cannillo *et al.* (1972). Chihara *et al.* (1974) described a joaquinite-group mineral with a very low rare-earth content (1.12 wt.%) and orthorhombic symmetry from Ohmi, Niigata Prefecture, Japan. Dowty (1975) solved the crystal structure of monoclinic joaquinite from San Benito County, California.

Two new joaquinite-group minerals from San Benito County, California (strontiojoaquinite and bario-orthojoaquinite) were described by Wise (1982). These are monoclinic and orthorhombic, respectively. Wise also gave a new nomenclature for the joaquinite group (approved by the CNMMN) with the following species (based on crystallography and the dominant ion in the "*X*" site): joaquinite (*REE*) is monoclinic, orthojoaquinite (*REE*) is orthorhombic, strontiojoaquinite (Sr) is monoclinic, strontio-orthojoaquinite (Sr) is orthorhombic, and bario-orthojoaquinite (Ba) is orthorhom-

bic. Nickel & Mandarino (1987) noted that the names joaquinite and orthojoaquinite should be changed to joaquinite-(Ce) and orthojoaquinite-(Ce), respectively, to conform with the Levinson system for rare-earth minerals.

Shpanov *et al.* (1989) described the new mineral byelorussite-(Ce) from Belarus (formerly Byelorussia, USSR). Kato & Mizota (1990) solved the crystal structure of strontio-orthojoaquinite from Ohmi, Niigata Prefecture, Japan.

At this point in the chronology of contributions about the joaquinite group, the authors of this paper looked at all the available data for the group and discovered that the mineral from the Ilímaussaq alkaline complex studied by Semenov *et al.* (1967) should be renamed orthojoaquinite-(La) in accordance with the system of nomenclature for rare-earth minerals proposed by Levinson (1966) because La is the dominant rare-earth element in the mineral.

ORTHOJOAQUINITE-(LA)

The occurrence and properties of orthojoaquinite-(La) are summarized here. Except where noted, the data are those given Semenov *et al.* (1967).

It occurs in the intermediate zone of nepheline–sodalite syenite pegmatites of the Ilímaussaq alkaline complex, on the right bank of the Narsaq River at the foot of Kvanefjeld Mountain, south Greenland, as banded gneissic and irregular masses up to $4 \times 3 \times 1$ cm, which consist of bent flakes 1 mm long. Associated minerals are: riebeckite, analcime, sodalite and steenstrupine-(Ce).

It is brown with an unknown streak, has a silky luster and is transparent. No fluorescence was reported. The Mohs hardness is about 5 (VHN 350–430 kg/mm^2), and the tenacity is not known. It has a good {001} cleavage, but the fracture was not given. The density is 4.1 g/cm^3 measured by hydrostatic weighing. The density calculated here from the unit-cell parameters and empirical formula is 4.14 g/cm^3.

It is optically biaxial (+), α 1.754, β 1.760, γ 1.797. 2V(meas.) 40°, 2V(calc.) 45°. Orientation: Z = *c*. Pleochroism: strong in yellow-green, $Z > X$. The 2*V* was calculated here. The Gladstone–Dale compatibility, $1 - (K_P/K_C)$, calculated here is 0.047 or good.

The following other properties are recorded. Thermal analysis: there is a strong endothermic reaction at 1040°C due to melting, and a small reaction at 770°C, possibly due to release of H_2O. Infrared absorption spectra: absorption bands are characteristic for chain (ribbon) silicates.

A chemical analysis carried out by M.E. Kazakova gave the following data: Na_2O 2.41, K_2O 0.22, CaO (+SrO) 0.03, MnO 0.70, FeO 4.78, BaO 21.46, Fe_2O_3 0.39, La_2O_3 10.05, Ce_2O_3 9.40, Pr_2O_3 0.99, Nd_2O_3 2.15, SiO_2 33.82, TiO_2 9.20, ThO_2 0.38, Nb_2O_5 2.31, H_2O 1.50, F 0.38, sum 100.17, less O = F 0.16, total 100.01

wt.%. The individual rare-earth oxides are calculated from total $(REE)_2O_3$ 22.59, and the ratio of the individual REE determined by Yu.A. Balashov (La 44.5, Ce 41.6, Pr 4.4, Nd 9.5). The empirical formula derived here (based on O + OH + F + H_2O = 28) is: $(Ba_{1.99}Ca_{0.01})_{\Sigma 2.00}(Na_{1.11}K_{0.07})_{\Sigma 1.18}(La_{0.88}Ce_{0.81}Nd_{0.18}Pr_{0.09})_{\Sigma 1.96}(Fe^{2+}_{0.95}Mn_{0.14})_{\Sigma 1.09}(Ti_{1.64}Nb_{0.25}Fe^{3+}_{0.07}Th_{0.02})_{\Sigma 1.98}Si_{8.01}O_{26.00}[(OH)_{0.37}O_{0.35}F_{0.28}]_{\Sigma 1.00} \cdot 1.00 H_2O$. The simplified formula is $Ba_2Na(La,Ce)_2Fe^{2+}Ti_2Si_8O_{26}(OH,O,F) \cdot H_2O$.

Single-crystal X-ray studies gave: orthorhombic, space group probably $Ccmm$, a 10.539(10), b 9.680(5), c 22.345(10) Å, V 2280 Å^3, Z = 4. Indexed X-ray powder-diffraction data are given with 47 lines from 7.09 to 1.397 Å. The unit-cell parameters given by Semenov *et al.* (1967) have been interchanged here to conform with the orientation of the other orthorhombic members of the joaquinite group [bario-orthojoaquinite, byelorussite-(Ce), orthojoaquinite-(Ce) and strontio-orthojoaquinite].

The mineral was referred to as "a member of the joaquinite group" by Semenov *et al.* (1967). Later, when orthorhombic and monoclinic members were recognized, it was designated as orthojoaquinite, and after the introduction of the Levinson system for rare-earth minerals, the name was changed to orthojoaquinite-(Ce). There are true Ce-dominant examples of this mineral from other occurrences, but apparently nobody ran the necessary calculations to show which rare-earth element is dominant in the material from Ilímaussaq. Semenov *et al.* (1967) gave the ideal formula as $NaBa_2FeCe_2Ti_2Si_8O_{26}(OH)$. It is possible that Ce in this case was used to denote total rare earths, and later mineralogists took this to mean dominance by Ce. Misnomers for the Ilímaussaq mineral have been carried over into various compendia. For example, Anthony *et al.* (1995) refer to it as orthojoaquinite-(Ce), and Gaines *et al.* (1997) call it joaquinite-(Ce).

SUMMARY

The CNMMN-approved nomenclature for the joaquinite group modified to conform with the Levinson system for rare-earth minerals and with addition of new species discovered since 1982, consists of the following species:

joaquinite-(Ce)   monoclinic
    $Ba_2NaCe_2Fe^{2+}Ti_2Si_8O_{26}(OH,F) \cdot H_2O$
orthojoaquinite-(Ce)   orthorhombic
    $Ba_2NaCe_2Fe^{2+}Ti_2Si_8O_{26}(O,OH) \cdot H_2O$
orthojoaquinite-(La)   orthorhombic
    $Ba_2NaLa_2Fe^{2+}Ti_2Si_8O_{26}(O,OH) \cdot H_2O$
strontiojoaquinite   monoclinic
    $Sr_2Ba_2(Na,Fe^{2+})_2Ti_2Si_8O_{24}(O,OH) \cdot H_2O$
strontio-orthojoaquinite   orthorhombic
    $Sr_2Ba_2(Na,Fe^{2+})_2Ti_2Si_8O_{24}(O,OH) \cdot H_2O$

bario-orthojoaquinite   orthorhombic
    $(Ba,Sr)_4Fe^{2+}_2Ti_2Si_8O_{26} \cdot H_2O$
byelorussite-(Ce)   orthorhombic
    $Ba_2NaMn^{2+}Ce_2Ti_2Si_8O_{26}(F,OH) \cdot H_2O$

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