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Hydroxyl-bastnaesite-(Nd), a new mineral from Montenegro, Yugoslavia

ZORAN MAKSIMOVIĆ

Faculty of Mining and Geology, University of Belgrade, Djušina 7, 11000 Belgrade, Yugoslavia

AND

GYÖRGY PANTÓ

Laboratory for Geochemical Research, Hungarian Academy of Sciences, Budaörsi út, 45, H-1112 Budapest, Hungary

ABSTRACT. Hydroxyl-bastnaesite-(Nd), the Nd- and OH-dominant new member of the bastnaesite group, has been found in the red karstic bauxites near Nikšić, Montenegro. It occurs as whitish, irregular aggregates of crystals usually 100–200 μm in diameter. Hexagonal with the cell dimensions $a = 7.191$ and $c = 9.921$ Å, with $Z = 6$. The strongest lines of the X-ray powder diffraction pattern (*d*, *I*, *hkl*) are: 4.95 80(002); 3.596 79(110); 2.911 100(112); 2.077 29(300); 2.042 51(114); 1.914 30(302). The mineral is uniaxial positive, ω 1.715, ε 1.81; D_{calc} 4.89 g/cm³.

Electron probe analysis, using garnet, apatite and synthetic glass standards, combined with thermogravimetric and evolved gas analysis, gave Y_2O_3 0.2, La_2O_3 27.1, Ce_2O_3 0.3, Pr_2O_3 8.5, Nd_2O_3 31.5, Sm_2O_3 4.4, Eu_2O_3 1.3, Gd_2O_3 1.4, CaO 0.3, F 3.3, H_2O 2.26, CO_2 20.63, sum 101.19, less O = F 1.39, total 99.80%. This analysis calculates to $(Nd_{0.41}La_{0.36}Pr_{0.11}Sm_{0.06}Gd_{0.02}Eu_{0.02}Ca_{0.01})_{\Sigma 0.99}(CO_3)_{1.03}[(OH)_{0.55}F_{0.38}]_{\Sigma 0.93}$, or ideally, $(Nd,La)CO_3(OH,F)$, with Nd > La and OH > F.

KEYWORDS: hydroxyl-bastnaesite-(Nd), bastnaesite, new mineral, rare-earth elements, Montenegro, Yugoslavia.

HYDROXYL-BASTNAESITE-(Nd) was discovered recently in the Jurassic karstic bauxites near town Nikšić in Montenegro (Maksimović and Pantó, 1983). It occurs in very small quantities as a rare authigenic mineral in the red bauxites near the contact with the footwall limestone. The mineral was concentrated in whitish, irregular aggregates of crystals, usually 100–200 μm across, but a few occur as clusters 1 to 5 mm in diameter in which the bastnaesite is intergrown with bauxite.

Morphology. The crystal habit of hydroxyl-bastnaesite-(Nd) is typically platy, but the plates may have crystallized or intergrown so as to produce a variety of morphologies within a small volume. In an SEM photograph of an area approximately 30 μm by 40 μm (fig. 1), a small cavity of crystals occurs within what appears to be a more massive body. The outside, apparently massive rim is composed of plates of bastnaesite so tightly intergrown and compacted as to appear massive. The cleavage surfaces and edges of the crystal stacks show, however, that they are built of plates. Within the cavity is a more open cluster of stacks of plates present in several orientations that illustrate the crystal habit and morphology. Many of the plates tend to be elongated. Because a wavelength-dispersive microprobe scan showed all of these crystals to be bastnaesite-(Nd), it is inferred that, despite differences in physical compaction and intergrowth, these are mineralogically the same.

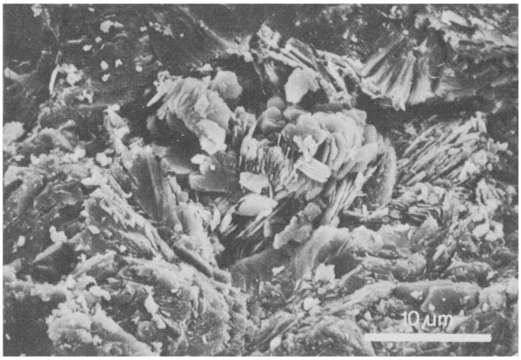

FIG. 1. SEM photograph of hydroxyl-bastnaesite-(Nd).

Chemical properties. The mineral was chemically analysed with a JEOL Superprobe JXA-733, utilizing an operating voltage of 15 kV and a beam current of 0.15 μA. The data were corrected using the ZAF method adapted to the instrument by JEOL Ltd. The standards used were Y-Al garnet for Y; apatite for Ca and F; synthetic glass standards of Drake and Weill (1972) for rare-earth elements. H_2O and CO_2 were determined by means of a Perkin Elmer TGS-2/System 4 Thermobalance, equipped with a Balzers QMG-511 mass-spectrometer. The analysis is presented in Table I.

Table I. Electron microprobe analysis of hydroxyl-bastnaesite-(Nd)

	wt.%
Y_2O_3	0.2
La_2O_3	27.1
Ce_2O_3	0.3
Pr_2O_3	8.5
Nd_2O_3	31.5
Sm_2O_3	4.4
Eu_2O_3	1.3
Gd_2O_3	1.4
CaO	0.3
F	3.3
H_2O^*	2 26
CO_2^*	20.63
Total	101.19
$-O=F_2$	1.39
Total	99.80

* CO_2 and H_2O determined by thermogravimetric and evolved gas analysis.

A 5.128 mg sample of the mineral was analysed by simultaneous TG/DTG and evolved gas analysis, using an argon atmosphere and a heating rate of 10 °K/min. The DTG curve shows a strong peak at 552 °C due to the losses of CO_2 and H_2O, and a small one at 746 °C due to loss of CO_2 (fig. 2). The thermal data indicate two possible CO_3 groups which are held differently in the structure: one group is released between 450 and 620 °C, and the other between 650 and 900 °C. This agrees well with the infra-red study of natural hydroxyl-bastnaesite by Akhmanova and Orlova (1966).

The resultant analysis yields the following empirical formula, based on 4 oxygen ions:

$$(Nd_{0.41}La_{0.36}Pr_{0.11}Sm_{0.06}Gd_{0.02}Eu_{0.02}Ca_{0.01})_{\Sigma 0.99}(CO_3)_{1.03}[(OH)_{0.55}F_{0.38}]_{\Sigma 0.93}.$$

The ideal formula is (Nd,La)CO_3(OH,F), with Nd > La and OH > F.

Physical and optical properties. Under the stereoscopic microscope hydroxyl-bastnaesite-(Nd) is whitish, with a white streak. The luster is dull. The hardness of individual grains could not be determined because of the weak cohesion of the aggregates; the apparent aggregate hardness is about 1 to 2. Parting: {001}. Density could not be measured because of the small grain size. The calculated density is 4.89 g/cm^3. The mineral does not luminesce in either ultraviolet radiation or the beam of the electron microprobe.

Optically, hydroxyl-bastnaesite-(Nd) is uniaxial positive with refractive indices $\omega = 1.715(2)$, and $\varepsilon = 1.81(1)$.

Satisfactory compatibility of the chemical and physical data is suggested by $1-K_P/K_C = 0.019$ (Mandarino, 1979).

X-ray study. An X-ray single crystal study could not be made because of the fine-grained nature of the material. The powder diffraction pattern was

Table II. X-ray powder diffraction data for hydroxyl-bastnaesite-(Nd) (Analyst Dr L.Farkas)

d_{obs}	d_{calc}	hkl	I
4.95	4.96	002	88
3.596	3.596	110	79
2.911	2.911	112	100
2.633	2.637	202	3
2.481	2.480	004	16
2.292	2.290	211	3
2.126	2.127	212	2
2.077	2.076	300	29
2.042	2.042	114	51
1.914	1.915	302	30
1.798	1.798	220	10
1.690	1.690	222	16
1.655	1.654	006	3
1.591	1.592	304	12
1.502	1.502	116	9
1.455	1.456	224	9
1.359	1.359	410	5
1.311	1.311	412	10
1.294	1.294	306	5
1.217	1.217	226	4
1.192	1.192	414	7
1.165	1.165	332	4

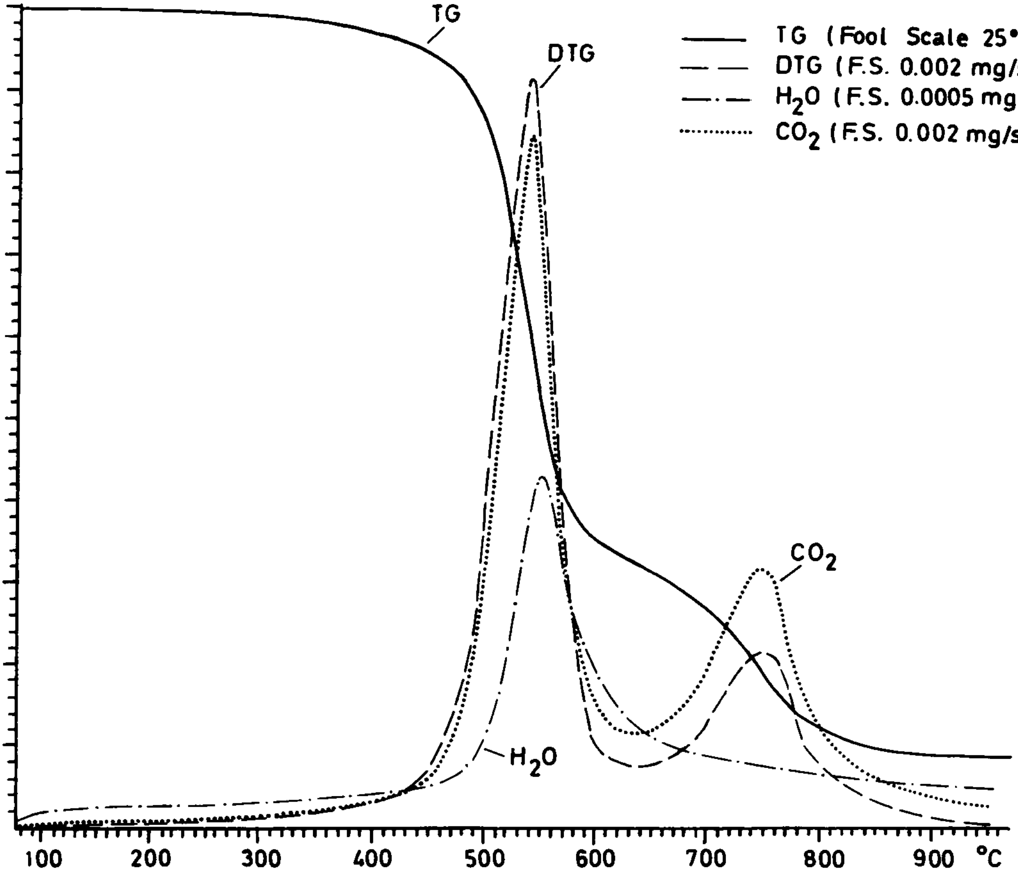

FIG. 2. TG-DTG curves of hydroxyl-bastnaesite-(Nd), combined with evolved gas analysis.

indexed by analogy with the pattern of bastnaesite (Table II). The lattice parameters were refined by least squares, utilizing the powder data. The refined unit-cell parameters of the hexagonal cell are $a = 7.191(1)$, $c = 9.921(2)$ Å, which give a cell volume of 444.3 $Å^3$.

Infra-red spectrum. The infra-red spectrum of hydroxyl-bastnaesite-(Nd) indicate the presence of OH based on vibrations in the 3400–3600 cm^{-1} region. The wave numbers of the maxima of the observed bands are very similar to those of natural hydroxyl-bastnaesite, as given by Akhmanova and Orlova (1966).

Name and type specimen. Hydroxyl-bastnaesite-(Nd), the Nd- and OH-dominant member of the bastnaesite group, was named in accordance with Levinson's rules for the naming of rare-earth analogues of known species (Levinson, 1966). The name and the species were approved by the IMA Commission on New Minerals and Mineral Names, prior to publication. The holotype material (Zagrad 10, 8397) is deposited at the Department of Mineralogy and Petrology, Faculty of Mining and Geology, University of Belgrade, Belgrade, Yugoslavia; at the Laboratory for Geochemical Research, Hungarian Academy of Sciences, Budapest, Hungary; and at the Royal Ontario Museum, Toronto, Canada.

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