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NIOBOAESCHYNITE-(Y), A NEW MEMBER OF THE AESCHYNITE GROUP FROM THE BEAR LAKE DIGGINGS, HALIBURTON COUNTY, ONTARIO, CANADA

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ABSTRACT

Nioboaeschynite-(Y), with ideal chemical formula $[(Y,Ln),Ca,Th](Nb,Ta,Ti,Fe)_2(O,OH)_6$, is a new member of the aeschynite group. It was discovered at the Bear Lake Diggings, Lot 9, concession X, Monmouth Township, Haliburton County, near Gooderham, Ontario, Canada. It occurs as subhedral crystals up to 1 cm in size, in association with apatite, amphibole, feldspar, biotite, calcite, quartz, monazite, pyrite, and uranian thorite. The mineral is translucent, deep brownish red with a grayish brown streak, with a vitreous luster. It is brittle, with a Mohs hardness of 5–6, and its measured microhardness VHN_{100} is 922. It shows no discernable cleavage and has a conchoidal fracture. The reflectance values for the COM wavelengths [%, R_{oil}, R_{air}] are 3.4, 14.6 (470 nm), 3.3, 14.1 (546 nm), 3.2, 13.8 (589 nm), and 3.2, 13.7 (650 nm). It is dark brown in plane-polarized light. Pleochroism, bireflectance and anisotropy are absent. It is naturally metamict; after heating at 1000°C, it recrystallizes to an orthorhombic structure, space group *Pbnm*, with a 5.279(3), b 10.966 (5), c 7.443(3) Å, V 430.9(3) Å^3, $Z = 4$. The strongest eight X-ray powder-diffraction lines [d in Å(I)(hkl)] are: 3.009(100)(130), 2.931(69)(112), 3.079(20)(022), 1.580(16)(134), 1.863(14)(004), 2.783(12)(131), 2.636(12)(200) and 2.006(11)(222). An electron-microprobe analysis gave CaO 4.34, MnO 0.11, Fe_2O_3 2.16, Y_2O_3 5.34, La_2O_3 0.84, Ce_2O_3 4.50, Pr_2O_3 0.65, Nd_2O_3 4.47, Sm_2O_3 1.21, Eu_2O_3 0.10, Gd_2O_3 0.91, Dy_2O_3 0.60, Er_2O_3 0.42, Tm_2O_3 0.05, Yb_2O_3 0.57, ThO_2 12.10, UO_2 0.59, TiO_2 18.41, Nb_2O_5 31.46, Ta_2O_5 3.97, H_2O 2.61, total 95.41 wt%. The H_2O content was determined by TGA. The empirical formula of nioboaeschynite-(Y), based on six atoms of oxygen (without H_2O) is $[(Y_{0.19}Ln_{0.34})Ca_{0.31}Th_{0.18}U_{0.009}Mn_{0.006}]_{\Sigma 1.04}(Nb_{0.94}Ti_{0.92}Ta_{0.07}Fe^{3+}{}_{0.11})_{\Sigma 2.04}O_6$. $D_{meas.} = 5.34$ g/cm^3, $D_{calc.} = 5.33$ g/cm^3. The crystal structure was not refined, but it is of the same type as for the other minerals of this group. The name of the new mineral species (IMA 2003–038a) recalls the dominant *B*-site cation present in this aeschynite-group mineral.

Keywords: nioboaeschynite-(Y), aeschynite group, new mineral species, Bear Lake diggings, Ontario, Canada.

SOMMAIRE

La nioboaeschynite-(Y), de formule chimique idéale $[(Y,Ln),Ca,Th](Nb,Ta,Ti,Fe)_2(O,OH)_6$, est un nouveau membre du groupe de l'aeschynite. Nous l'avons découvert à l'indice dit Bear Lake Diggings, Lot 9, concession X, canton de Monmouth, comté de Haliburton, près de Gooderham, Ontario, Canada. Les cristaux subidiomorphes atteignent 1 cm. Lui sont associés apatite, amphibole, feldspar, biotite, calcite, quartz, monazite, pyrite, et thorite uranifère. Le minéral est translucide, brun rougeâtre foncé, avec une rayure brun grisâtre, et un éclat vitreux. Il est cassant, avec une dureté de Mohs de 5–6, et sa microdureté mesurée VHN_{100} est 922 kg/cm^2. Il ne semble pas y avoir de clivage, et la fracture est conchoïdale. Les valeurs de réflectance aux longueurs d'onde COM [%, R_{oil}, R_{air}] sont 3.4, 14.6 (470 nm), 3.3, 14.1 (546 nm), 3.2, 13.8 (589 nm), et 3.2, 13.7 (650 nm). La nioboaeschynite-(Y) est brun foncé en lumière polarisée. Il n'y a ni pléochroïsme, ni biréflectance, ni anisotropie.

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Il s'agit d'un minéral métamicte; après chauffage à 1000°C, il recrystallise à une structure orthorhombique, groupe spatial *Pbnm*, *a* 5.279(3), *b* 10.966 (5), *c* 7.443(3) Å, *V* 430.9(3) Å^3, $Z = 4$. Les huit raies les plus intenses du spectre de diffraction, méthode des poudres [*d* en Å(I)(*hkl*)] sont: 3.009(100)(130), 2.931(69)(112), 3.079(20)(022), 1.580(16)(134), 1.863(14)(004), 2.783(12)(131), 2.636(12)(200) et 2.006(11)(222). Une analyse avec une microsonde électronique a donné CaO 4.34, MnO 0.11, Fe_2O_3 2.16, Y_2O_3 5.34, La_2O_3 0.84, Ce_2O_3 4.50, Pr_2O_3 0.65, Nd_2O_3 4.47, Sm_2O_3 1.21, Eu_2O_3 0.10, Gd_2O_3 0.91, Dy_2O_3 0.60, Er_2O_3 0.42, Tm_2O_3 0.05, Yb_2O_3 0.57, ThO_2 12.10, UO_2 0.59, TiO_2 18.41, Nb_2O_5 31.46, Ta_2O_5 3.97, H_2O 2.61, pour un total de 95.41% (poids). La teneur en H_2O a été établie par thermogravimétrie. La formule empirique de la nioboaeschynite- (Y), exprimée sur une base de six atomes d'oxygène (sans H_2O) est $[(Y_{0.19}Ln_{0.34})Ca_{0.31}Th_{0.18}U_{0.009}Mn_{0.006}]_{\Sigma1.04}(Nb_{0.94}Ti_{0.92}Ta_{0.07}Fe^{3+}_{0.11})_{\Sigma2.04}O_6$. La densité mesurée est 5.34 g/cm^3, et la densité calculée est 5.33 g/cm^3. Nous n'en avons pas affiné la structure, mais elle semble typique des autres membres du groupe. Le nom de la nouvelle espèce minérale (IMA 2003–038a) rappelle le cation dominant au site *B* dans ce membre du groupe de l'aeschynite.

(Traduit par la Rédaction)

Mots-clés: nioboaeschynite-(Y), groupe de l'aeschynite, nouvelle espèce minérale, indice Bear Lake diggings, Ontario, Canada.

INTRODUCTION

Minerals of the aeschynite group are orthorhombic (space group *Pbnm*) and have the general formula AB_2O_6. The large-cation *A* site is mainly occupied by REE, Ca, Th and U, whereas Ti, Nb and Ta occupy the *B* site. The substitution of Ca +(Nb,Ta) for REE + Ti (Y included with the REE) is mainly responsible for distinguishing the different members of the mineral group.

The name nioboaeschynite-(Y) has been used twice for a mineral. Deliens (1991) renamed the discredited "lyndochite" (Ellsworth 1927) as nioboaeschynite-(Y). An electron-microprobe analysis of a zoned aeschynite grain from miarolitic pegmatites of the Baveno pink granite in northwestern Italy was found to correspond to nioboaeschynite-(Y) (Aurisicchio *et al.* 2001), although the rest of the grain was generally aeschynite-(Y). In both cases, the mineral name had not been approved by CNMMN, and there are no other data about these minerals.

The new mineral species, found in the Bear Lake diggings in central-eastern Ontario, and its name have been approved by the Commission on New Minerals and Mineral Names (CNMMN) of International Mineralogical Association (IMA) (#2003–38a). The holotype specimen of nioboaeschynite-(Y) is entered in the Croatian Natural History Museum collection (catalogue #600:ZAG; 9613MP1).

BACKGROUND INFORMATION

Aeschynite is now considered to be aeschynite-(Ce), after applying Levinson's nomenclature (1966). "Blomstrandine", "sinicite" and "priorite" are synonymous with aeschynite, and "priorite" is now aeschynite-(Y) (Černý & Ercit 1989). Tantal-aeschynite [(REE,Ca)(Ta,Ti,Nb)$_2$O$_6$] (Adusumilli *et al.* 1974) and nioboaeschynite-(Ce) [(Ce,Ca)(Nb,Ti)$_2$O$_6$] (Rosenblum & Mosier 1975) are the established members not having Ti as the dominant *B*-site cation. Similarly, there are two Ca-dominant members: vigezzite [(Ca,Ce)(Nb,Ta,Ti)$_2$O$_6$] (Graeser *et al.* 1979) and rynersonite $CaTa_2O_6$ (Foord & Mrose 1978). The minerals of the aeschynite group are summarized and classified in Table 1. On the basis of the dominant *B*-cation, aeschynite-group minerals may be divided into three subgroups: aeschynite, nioboaeschynite and tantalaeschynite. The minerals are further distinguished by the dominant *A*-cation. Aeschynite is commonly found to be metamict, although there are some occurrences of non-metamict aeschynite, for example, that described by Bonazzi & Magnanelli (1994).

It is interesting to mention the resemblance of nioboaeschynite-(Y) in appearance and chemical composition to the mineral sample previously identified as "lyndochite" (Butler 1957). "Lyndochite" was originally discovered by Ellsworth (1927) in Lyndoch Township, Ontario, Canada. The mineral was also found in China (Gorzhevskaya & Sidorenko 1962) and in Kenya (Horne & Butler 1965). "Lyndochite" was first considered to be a variety of euxenite, unusually high in Nb, Th and Ca (Ellsworth 1927), but poor in U. Butler (1957) found it to be more similar to aeschynite after he had determined the concentrations of the individual rare-earth elements in the mineral. Fleischer (1966) confirmed the strong similarity of

TABLE 1. MINERALS OF THE AESCHYNITE GROUP

Mineral	Dominant cations		Mineral formula
	A site	*B* site	
aeschynite-(Ce)	Ce	Ti	(Ce,Ca,Fe,Th) (Ti,Nb)$_2$ O$_6$
aeschynite-(Y)	Y	Ti	(Y,Ca,Fe,Th) (Ti,Nb)$_2$ O$_6$
aeschynite-(Nd)	Nd	Ti	(Nd,Ce,Ca,Th) (Ti,Nb)$_2$ O$_6$
tantal-aeschynite-(Y)	Y	Ta	(Y,Ce,Ca) (Ta,Ti,Nb)$_2$ O$_6$
nioboaeschynite-(Ce)	Ce	Nb	(Ce,Ca,Th) (Nb,Ti)$_2$ O$_6$
"nioboaeschynite-(Nd)"*	Nd	Nb	(Nd,Ce) (Nb,Ti)$_2$ O$_6$
nioboaeschynite-(Y)	Y	Nb	(Y,Ln,Ca,Th) (Nb,Ti)$_2$ O$_6$
vigezzite	Ca	Nb	(Ca,Ce) (Nb,Ta,Ti)$_2$ O$_6$
rynersonite	Ca	Nb	Ca Nb$_2$ O$_6$

* Not approved by IMA CNMNC.

"lyndochite" to aeschynite by summarizing the data on the compositions of 24 members of the aeschynite group and three known samples of "lyndochite". On that basis, he concluded that "lyndochite" was not a mineral of euxenite group. Černý & Ercit (1989) considered "lyndochite" to be synonymous with aeschynite. Recently, Ercit (2002) re-established "lyndochite" as a thorian variety of euxenite on the basis of chemical data. The "lyndochite" sample described by Butler (1957) and later by Fleischer (1966), although originating from the "type" locality in Lyndoch Township, was not the one resembling euxenite originally described by Ellsworth (1927).

OCCURRENCE

Nioboaeschynite-(Y) was found at the Bear Lake Diggings, Lot 9, concession X, Monmouth Township, Haliburton County, near Gooderham, Ontario, Canada (Fig 1). The locality is situated in the mineralogically famous Bancroft area, structurally belonging to the Central Metasedimentary Belt of the western Grenville Province, a part of the Canadian Shield (Wynne-Edwards 1972). The Bear Lake Diggings are characterized by narrow discontinuous, subparallel vein-dykes of calcite up to 2 m in width and 60 cm to 7 m in depth. These are part of a broad zone of dykes (Lumbers *et al.* 1990), up to 20 km in width, running parallel to the boundary between the Central Metasedimentary belt and the Central Gneiss belt (Wynne-Edwards 1972). The Bear Lake vein-dykes occur within a zone of highly syenitized rocks, developed in metasediments and meta-alaskite, with increasing alteration closer to the vein-dykes. This alteration is characterized by the introduction of Na, K, Ca, Fe, Ti , P, F, Cl, U, Th, REE, Zr, Ba and Mo, interpreted by Lumbers *et al.* (1990) as fenitization, and the vein dykes as carbonatites. Mills *et al.* (2003) suggested that the geochemistry and ^{39}Ar/^{40}Ar dates provide evidence for a 930 Ma carbonatitic intrusive event. Lentz (1998, 1999) suggested that these vein-dykes may be the result of volatile fluxing and metasediment syntexis, a view supported by Berry & Mills (2001). Mitchell (2005), on the other hand, stated that these rocks should not be considered as *bona fide* carbonatites, as they are clearly anatectic melts of crustal rocks, totally unrelated to mantle-derived alkaline magmas.

The calcite vein-dikes at Bear Lake host the minerals apatite-(CaF), amphibole, titanite, and feldspar group (anorthite and microcline), annite (*biotite*), calcite, quartz, monazite, pyrite and U-rich thorite.

The mineral grain investigated is about 10 mm in length and 6 mm thick, showing only poorly crystal faces.

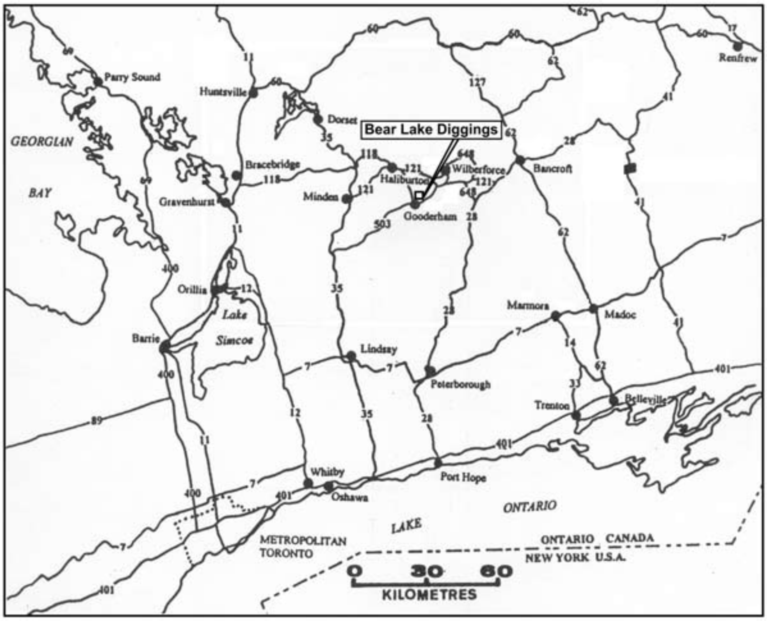

FIG. 1. Location of the mineral sampling area investigated; the map is from Vertolli *et al.* (1998).

PHYSICAL PROPERTIES

Nioboaeschynite-(Y), if broken, shatters. It is translucent and deep brownish red; otherwise it is dark, almost black, with a vitreous luster and a conchoidal fracture. No cleavage is observed. The streak is grayish brown. Reflectance measurements are consistent with its isotropy, with the following values for oil and air, respectively: 3.4 and 14.6 (470 nm), 3.3 and 14.1 (546 nm), 3.2 and 13.8 (589 nm), and 3.2 and 13.7 (650 nm). The estimated Mohs hardness is about 5½, and the average Vickers hardness is 922(10) kg/mm^2. The density measured by pycnometer is 5.34 g/cm^3, and the calculated density is 5.33 g/cm^3.

CHEMICAL COMPOSITION

The chemical analyses were performed on a JEOL 733 electron microprobe in wavelength-dispersion (WD) mode, using Tracor Northern 5500 and 5600 automation. Data reduction was done with a PAP routine in XMAQNT (C. Davidson, CSIRO, pers. commun.). The operating voltage was 15 kV, and the beam current was 20 nA. The beam diameter was 20 μm. The following standards were used: synthetic $NiTa_2O_6$ (Ta), synthetic UO_2 (U), synthetic ThO_2 (Th), tantalite-(Mn) (Mn), rutile (Ti), columbite-(Mn) (Nb), synthetic YAG (Y), almandine (Fe), and a set of REE phosphates (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). Several 100 s energy-dispersion (ED) scans indicated no elements with Z > 8 other than those reported here. The chemical composition and cation assignment (six-oxygen basis) are presented in Table 2. The back-scattered electron images and element-distribution maps were produced with a Tescan TS 5136MM scanning electron microscope and an Inca (Oxford Instruments) energy-dispersive system.

The empirical formula calculated on the basis of six atoms of oxygen is: $[(Y_{0.19}Ln_{0.34})Ca_{0.31}Th_{0.18}U_{0.009}Mn_{0.006}]_{\Sigma 1.04}(Nb_{0.94}Ti_{0.92}Ta_{0.07}Fe^{3+}_{0.11})_{\Sigma 2.04}O_6$. This corresponds quite well to the general AB_2O_6 stoichiometry of the aeschynite group.

Because of the low analytical totals, cation ratios were also checked by additional analyses (55 point analyses) performed on two different microprobes. The analyses yielded the same cationic ratios as the original dataset presented in Table 2. The back-scattered electron image shows that the mineral is homogeneous, as well as the distribution of Nb and Ti (Fig. 2). The amount of H_2O was determined by thermogravimetric analysis in a nitrogen atmosphere. The mass loss of 2.61%, which is attributed to H_2O, occurs up to 600°C.

The distribution of the major cations in both the *A* and *B* sites is presented in triangular diagrams (Fig. 3). The diagrams also include the data for 23 samples of aeschynite-group minerals available from literature. The diagram for the *A* site shows that nioboaeschynite-(Y) from Bear Lake is grouped together with the samples previously identified as "lyndochite". The *B*-site diagram clearly separates the aeschynite-group minerals into three fields (aeschynite, nioboaeschynite and tantal-aeschynite). Again, nioboaeschynite-(Y) is grouped together with the samples of "lyndochite", but also with other samples of nioboaeschynite.

TABLE 2. NIOBOAESCHYNITE-(Y): CHEMICAL COMPOSITION AND CATION PROPORTIONS

	wt.%	range	*apfu*		wt.%	range	*apfu*
CaO	4.34	4.24-4.48	0.313	TiO_2	18.41	17.94-18.73	0.915
MnO	0.11	0.00-0.19	0.006	Nb_2O_5	31.46	30.40-31.99	0.940
Y_2O_3	5.34	5.11-5.50	0.188	Ta_2O_5	3.97	3.83-4.09	0.071
La_2O_3	0.84	0.77-0.91	0.020	Fe_2O_3	2.16	1.57-2.51	0.107
Ce_2O_3	4.50	4.47-4.55	0.109				
Pr_2O_3	0.65	0.56-0.71	0.016	Sum *B*			2.033
Nd_2O_3	4.47	4.34-4.57	0.106				
Sm_2O_3	1.21	1.10-1.27	0.028	H_2O	2.61		
Eu_2O_3	0.10	0.00-0.29	0.002				
Gd_2O_3	0.91	0.85-1.02	0.020	Total	95.41		
Dy_2O_3	0.60	0.00-1.04	0.013				
Er_2O_3	0.42	0.38-0.44	0.009				
Tm_2O_3	0.05	0.00-0.16	0.001				
Yb_2O_3	0.57	0.56-0.60	0.011				
ThO_2	12.10	11.88-12.29	0.182				
UO_2	0.59	0.50-0.63	0.009				
Sum *A*			1.033				

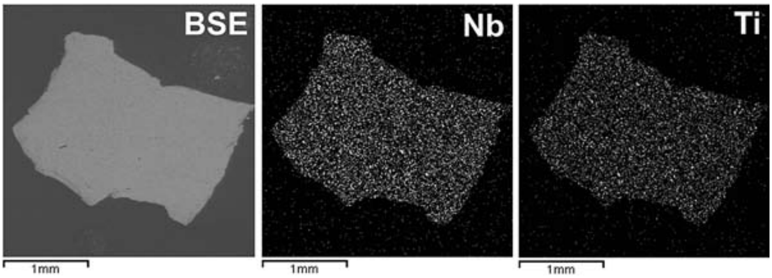

FIG. 2. Back-scattered electron image (BSE); map of Nb and Ti distribution in nioboaeschynite-(Y).

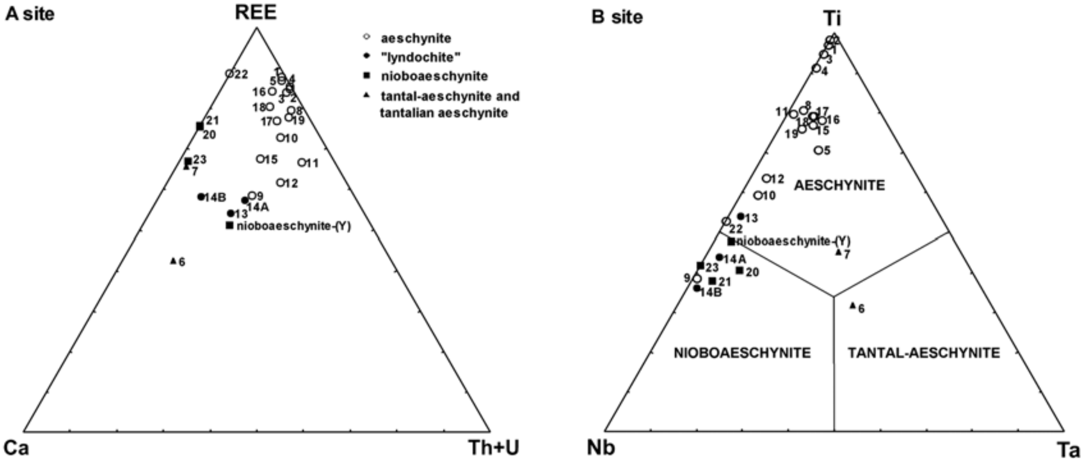

FIG. 3. *A*- and *B*-site occupancy of aeschynite-group minerals. Samples plotted: 1 aeschynite-(Y), Triolet Valley, Aosta, Italy; 2 aeschynite-(Y), Miage moraine, Aosta, Italy; 3 aeschynite-(Y), Triolet Valley, Aosta, Italy; 4 aeschynite-(Y), Pizzo Cervandone, Novara, Italy; 5 aeschynite-(Y), Vigezzo Valley, Novara, Italy; 6 tantal-aeschynite, Raposa pegmatite, São Jose do Sabugi, Paraiba State, Brazil; 7 tantalian aeschynite, Siberia; 8 aeschynite, Hiterö, Norway; 9 aeschynite, Miask, Urals; 10 aeschynite, Hiterö, Norway; 11 "blomstrandine", Hiterö, Norway; 12 aeschynite, Morefjaer, Norway; 13 "lyndochite", Kenya; 14A and 14B "lyndochite", Lyndoch Township, Ontario, Canada; 15, 16, 17, 18 aeschynite-(Y), Trout Creek Pass District, Chaffee County, Colorado; 19 aeschynite-(Y), Tuftane, Norway; 20 nioboaeschynite-(Ce), Thor Lake, N. W.T., Canada; 21 "nioboaeschynite-(Nd)", Thor Lake, N.W.T, Canada; 22 aeschynite-(Nd), Thor Lake, N.W.T., Canada; 23 nioboaeschynite-(Ce), Hot Springs district, central Alaska. Sources: Bonazzi & Menchetti (1999): 1, 2, 3, 4, 5; Adusumilli *et al.* (1974): 6, 7; Ewing (1975): 8, 9, 10, 11, 12; Fleischer (1966): 13, 14A; Ercit (2002): 14B, Hanson *et al.* (1992): 15, 16, 17, 18; Tomašić *et al.* (2004): 19; Pinckston & Smith (1995): 20, 21, 22; Rosenblum & Mosier (1975): 23.

Also, what appears to be evident for different aeschynite samples is a positive correlation of Nb with the LREE (Fig. 4a) and negative correlation with the HREE in aeschynite-group minerals, whereas Ti shows completely opposite behavior, *i.e.*, a positive correlation with the HREE (Fig. 4b) and negative correlation to LREE. This could explain the more frequent occurrence of aeschynite-(Y) in comparison to nioboaeschynite-(Y), and also the slight prevalence of Nb over Ti in nioboaeschynite-(Y).

X-RAY-DIFFRACTION STUDY

X-ray powder-diffraction patterns were obtained using a Philips PW 1050/70 X-ray powder diffractometer. We used a graphite monochromator, Cu$K\alpha_1$ radiation (λ = 1.54178 Å), fixed divergence slit of 1°, and a scan speed of 1° 2θ/min. As the mineral sample was found to be naturally metamict, showing no diffraction lines, it was heated in order to obtain its diffraction pattern. The heating was done in air in a muffle furnace at 1000°C with heating time of 21 hours. Unit-cell parameters were calculated using UNIT CELL (Holland & Redfern 1997).

TABLE 3. POWDER-DIFFRACTION DATA OF NIOBOAESCHYNITE-(Y)

I	d_{meas} (Å)	d_{calc} (Å)	*hkl*	*I*	d_{meas} (Å)	d_{calc} (Å)	*hkl*
9	5.469	5.483	020	4	2.259	2.260	023
8	4.422	4.414	021	5	2.208	2.207	042
8	3.711	3.721	002	11	2.006	2.004	222
5	3.391	3.386	121	8	1.954	1.954	151
20	3.079	3.079	022	10	1.915	1.913	133
100	3.009	3.005	130	14	1.863	1.861	004
69	2.931	2.931	112	9	1.842	1.842	241
12	2.783	2.787	131	7	1.818	1.828	060
7	2.738	2.742	040	9	1.784	1.784	213
12	2.636	2.640	200	11	1.692	1.692	311
8	2.566	2.566	210	16	1.580	1.582	134
5	2.438	2.433	140	3	1.546	1.540	044
				9	1.501	1.502	170

The diffraction data of the investigated sample are presented in Table 3. Along with the diffraction data presented, three diffraction maxima that do not belong to nioboaeschynite-(Y) were observed [*d* in Å(*I*)]: 3.281(7), 2.970(36) and 2.822(7). Heat treatments of aeschynite commonly fail to recrystallize the material to a single phase, *i.e.,* along with aeschynite, other phases appear (Ewing & Ehlmann 1975, Bonazzi *et al.* 2002). The calculated unit-cell parameters are consistent with an orthorhombic symmetry: *Pbnm, a* 5.279(3), *b* 10.966 (5), *c* 7.443(3) Å, *V* 430.9(3) Å^3.

The crystal structure was not refined, as no single crystal is available. However, the diffraction pattern is of the same type as for the other minerals of the aeschynite group, so that the structure is inferred to be the same as for the other members of the group (Aleksandrov 1960).

DISCUSSION

The physical properties, diffraction pattern and chemical data for nioboaeschynite-(Y) from Bear Lake are consistent with those of an aeschynite-group mineral. The powder-diffraction data correspond to an aeschynite-(Y) diffraction pattern, shifted to higher *d*-values. This is reflected in the unit-cell parameters, which are also greater than the corresponding parameters of aeschynite-(Y) (Table 4), owing to prevalence of Nb over Ti at the *B* site. The chemical analyses and formula calculation on the basis of six atoms of oxygen show Y to be the most abundant cation of the REE group, which as a group dominate the *A* site. At the *B* site, Nb is the most abundant cation, which differentiates nioboaeschynite-(Y) from aeschynite-(Y). As shown in Figure 3, the nioboaeschynite-(Y) is grouped together with the samples previously described as "lyndochite". Note that the type sample of "lyndochite" originally described by Ellsworth (1927) is not grouped with other samples of "lyndochite". As shown by Ercit (2002), the type sample of "lyndochite" is a thorium-rich variety of euxenite, but other samples of "lyndochite" described by Gorzhevskaya & Sidorenko (1962) and Horne & Butler (1965) apparently belong to the aeschynite group.

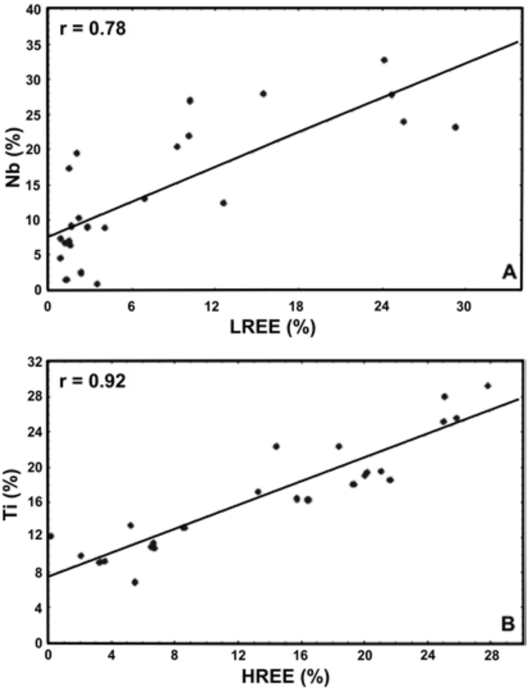

FIG. 4. a) LREE–Nb and b) HREE–Ti correlations for aeschynite-group minerals (compositional data for the mineral samples cited in Fig. 3).

"Lyndochite" also seems to have caused a little confusion in powder-diffraction files. The X-ray data in PDF file 18–765 (ICDD, 2004), evidently referring to the Horne & Butler (1965) "lyndochite" and otherwise very close to the diffraction data of nioboaeschynite-(Y), are said to belong to yttropyrochlore-(Y). It is certain that this is not a pyrochlore-group mineral.

To develop a consistent nomenclature that would help to differentiate aeschynite- and euxenite-group minerals, Ewing (1976) performed stepwise discriminant analysis on a large set of analytical data for these minerals available in literature. This multivariant analysis yielded a classification on the basis of the three extracted variables (ΣCe_2O_3, TiO_2, Nb_2O_5) that differentiates euxenite, polycrase and aeschynite. Taking ΣCe_2O_3 (=LREE) as the most significant variable, "lyndochite" of Ellsworth (1927) is euxenite, and "lyndochite" of Butler (1957) is aeschynite-(Y) (Ercit 2002). However, the other two variables are not so discriminating in these two cases. Following the same criterion, nioboaeschynite-(Y) from Bear Lake belongs to the aeschynite group.

Recently, Ercit (2005) described an improved discriminant canonical analysis, showing how the minerals of the aeschynite + euxenite, fergusonite and samarskite groups could be distinguished using 11 principal chemical constituents as variables. He extracted canonical variables (functions), which could be applied to the composition of any complex Nb–Ta–Ti–REE oxide mineral in order to classify the mineral correctly. This method seems to be advantageous since many of these minerals cannot be structurally characterized without previous heating experiments owing to their metamict state which, on the other hand, commonly does not lead to straightforward identification based on the XRD data (for instance, multiphase systems or phase transitions during recrystallization experiments). Following Ercit's statistical approach, nioboaeschynite-(Y) from Bear Lake belongs to the aeschynite + euxenite mineral group, and using a working differentiation founded on preliminary calculations done by Ewing (1976), nioboaeschynite is an aeschynite-group

TABLE 4. UNIT-CELL PARAMETERS OF AESCHYNITE-(Y), NIOBOAESCHYNITE-(Ce) AND NIOBOAESCHYNITE-(Y)

	a (Å)	*b* (Å)	*c* (Å)	*V* (Å^3)
aeschynite-(Y) [1]	5.194(2)	10.930(3)	7.386(2)	419.3(2)
nioboaeschynite-(Ce) [2]	5.396(1)	11.085(2)	7.585(3)	453.7(1)
nioboaeschynite-(Y) [3]	5.279(3)	10.966(5)	7.443(3)	430.9(3)

Data from [1] Tomašić *et al.* (2004), [2] Rosenblum & Mosier (1975), [3] this study.

mineral, since LREE > 0.326Ti – 0.060Nb + 3.1 (oxide wt%) (Ercit 2005).

The occurrence of a variety of aeschynite-group minerals demonstrates a great tolerance of the aeschynite structure to a large number of substitutions. In this case, along with Ti-rich members like aeschynite-(Ce), aeschynite-(Nd) and aeschynite-(Y), nioboaeschynite-(Y) also demonstrates the variability in the *A*-site of Nb-rich members along with nioboaeschynite-(Ce) (Rosenblum & Mosier 1975) and "nioboaeschynite-(Nd)" (Pinckston & Smith 1995, Yang *et al*. 2001).

Nioboaeschynite-(Y) from Bear Lake shows both crystallographically and chemically the features of an aeschynite-group mineral. The unit-cell parameters are between those for aeschynite-(Y) and nioboaeschynite-(Ce) (Table 4). Complying with the general formula of the group, AB_2O_6, the *A* site is dominantly occupied by REE, with Y being the most abundant. At the *B* site, Nb prevails, although the Ti occupancy is significant and very close to that of Nb. Following the occurrences of previously investigated aeschynite-group minerals being named according to the dominant cations, the Bear Lake mineral is here named nioboaeschynite-(Y), an aeschynite-group mineral species previously described with only its chemical composition (Aurisicchio *et al*. 2001).

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