ADAMSITE-(Y), A NEW SODIUM–YTTRIUM CARBONATE MINERAL SPECIES FROM MONT SAINT-HILAIRE, QUEBEC

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ABSTRACT

Adamsite-(Y), ideally NaY(CO$_3$)$_2$•6H$_2$O, is a newly identified mineral from the Poudrette quarry, Mont Saint-Hilaire, Quebec. It occurs as groups of colorless to white and pale pink, rarely pale purple, flat, acicular to fibrous crystals. These crystals are up to 2.5 cm in length and form spherical radiating aggregates. Associated minerals include aegirine, albite, analcime, ancyline-(Ce), calcite, catapleiite, dawsonite, donnayite-(Y), epiditez, epididymite, eudialyte, eudidymite, fluorite, gaidonnayite, galena, genthelvite, gmelinite, gonardite, horváthite-(Y), kuplestkit, leifite, microcline, molybdenite, narsarsukite, natrolite, nenadkevichite, petersenite-(Ce), polylithionite, pyrochlore, quartz, rhodochrosite, rutile, sabinaite, sérandite, siderite, sphalerite, thomasclarkite-(Y), zircon and an unidentified Na–REE carbonate (UK 91). The transparent to translucent mineral has a vitreous to pearly luster and a white streak. It is soft (Mohs hardness 3) and brittle with perfect {001} and {100} and {010} cleavages.

Adamsite-(Y) is biaxial positive, $\alpha = 1.480(4), \beta = 1.498(2), \gamma = 1.571(4), 2V_{\text{meas.}} = 53^\circ$, $2V_{\text{calc.}} = 55^\circ$ and is nonpleochroic. Optical orientation: $X = [001], Y = b, Z \perp a = 14^\circ$ (in $\beta$ obtuse). It is triclinic, space group $P\overline{1}$, with unit-cell parameters refined from powder data: $a = 6.262(2), b = 13.047(6), c = 13.220(5)$ Å, $\alpha = 91.17(4), \beta = 103.70(4), \gamma = 89.99(4)^\circ, V = 1049.1(5)$ Å$^3$ and $Z = 4$. The strongest six X-ray powder-diffraction lines $[d$ in $\text{Å}(I)]$ are: 12.81(100)(001), 6.45(70)(002), 4.456(60)(−1 −21, −120), 4.291(60)(003), 2.571(60)(005, 043) and 2.050(50)(125, −126).

Electron-microprobe and thermogravimetric analyses, supported by crystal-structure analysis and infrared-absorption spectroscopy, yield Na$_2$O 8.64, CaO 0.05, Y$_2$O$_3$ 22.88, Ce$_2$O$_3$ 0.37, Nd$_2$O$_3$ 1.41, Sm$_2$O$_3$ 1.02, Dy$_2$O$_3$ 0.56, Dy$_2$O$_3$ 3.28, H$_2$O 0.90, Er$_2$O$_3$ 2.83, Tb$_2$O$_3$ 0.27, Yb$_2$O$_3$ 1.04, Ce$_2$O$_3$ 25.10. H$_2$O 29.90, total 100.17 wt.%. The empirical formula, based on 12 oxygen atoms, is Na$_{1.00}$ (Y$_{0.72}$ Dy$_{0.06}$ Er$_{0.05}$ Gd$_{0.04}$ Nd$_{0.03}$ Yb$_{0.02}$ Sm$_{0.02}$ Hf$_{0.02}$ Ce$_{0.01}$ Tb$_{0.01}$ Mn$_{0.01}$)$_{0.99}$ C$_{2.04}$ H$_{11.87}$ O$_{12}$.

The calculated density from the empirical formula is 2.27 g/cm$^3$, and the measured density is 2.27(2) g/cm$^3$. The structure has been refined to $R = 0.046$. The structure is layered, with two different carbonate groups, one parallel and one perpendicular to the layering. Slabs of [Na$_2$Y(CO$_3$)$_2$] are separated by [H$_2$O] layers. Adjacent [H$_2$O] layers are only H-bonded together, which gives rise to the perfect {001} cleavage. The mineral is named after Frank Dawson Adams (1859–1942), geologist and professor at McGill University, Montreal.

Keywords: adamsite-(Y), new mineral species, sodium yttrium dicarbonate hexahydrate, crystal structure, Mont Saint-Hilaire, Quebec.

Sommaire

La nouvelle espèce minérale adamsite-(Y), de composition idéale NaY(CO$_3$)$_2$•6H$_2$O, a été découverte à la carrière Poudrette, au mont Saint-Hilaire, Québec. Elle se présente en groupes de cristaux incolores, blancs ou rose pâle, plus rarement violacés, plats et aciculaires ou fibres. Ces cristaux atteignent 2.5 cm en longueur et forment des agrégats fibroradiés. Lui sont associés aegirine, albite, analcime, ancyline-(Ce), calcite, catapleiite, dawsonite, donnayite-(Y), epiditez, epididymite, eudialyte, eudidymite, fluorite, francoonite, gaidonnayite, galène, genthelvite, gmelinite, gonardite, horváthite-(Y), kuplestkit, leifite, microcline, molybdenite, narsarsukite, natrolite, nenadkevichite, petersenite-(Ce), polylithionite, pyrochlore, quartz, rhodochrosite, rutile, sabinaite, sérandite, sphalerite, thomasclarkite-(Y), zircon et un carbonate à Na–REE non encore identifié (UK 91). Le minéral est transparent à translucide et possède un éclat vitreux à nacré et une rayure blanche. Il s’agit d’un minéral mou (dureté de Mohs de 3) et cassant, ayant un clivage {001} parfait et des clivages {100} et {010} assez bons.

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L’adamsite-(Y) est biaxe positive, \( \alpha = 1.480(4), \beta = 1.498(2), \gamma = 1.571(4) \), \( 2V_{\text{max}} = 53(3)^\circ, 2V_{\text{calcul}} = 55^\circ \), et non pleochroïque. Son orientation optique est: \( X = [001], Y = b, Z = a = 14^\circ \) (dans l’angle \( \beta \) obtus). Le minéral est triclinique, groupe spatial \( \text{P1} \), avec une maille élémentaire affinée à partir des données obtenues sur poudre: \( a = 6.262(2), b = 13.047(6), c = 13.220(5) \), \( \alpha = 91.17(4), \beta = 103.70(4), \gamma = 89.99(4) \). \( V = 1049.1(5) \) \( \AA^3 \) et \( Z = 4 \). Les six raies les plus intenses du spectre de diffraction X [d en Å(bhk)] sont: 12.81(100)(001), 6.45(70)(002), 4.45(60)(121), 4.29(160)(003), 2.57(60)(005, 043) et 2.05(50)(125,126). Les analyses obtenues par microsonde électronique et par thermogravimétrie, supplémentées par une ébauche de la structure cristalline et un spectre d’absorption dans l’infra-rouge, mène à la composition \( \text{Na}_2\text{O} 8.64, \text{CaO} 0.05, \text{Y}_2\text{O}_3 22.88, \text{Ce}_2\text{O}_3 0.37, \text{Nd}_2\text{O}_3 1.41, \text{Sm}_2\text{O}_3 1.02, \text{Gd}_2\text{O}_3 1.92, \text{Tb}_2\text{O}_3 0.56, \text{Dy}_2\text{O}_3 3.28, \text{Ho}_2\text{O}_3 0.90, \text{Er}_2\text{O}_3 2.83, \text{Tm}_2\text{O}_3 0.27, \text{Yb}_2\text{O}_3 1.04, \text{CO}_2 25.10, \text{H}_2\text{O} 29.90 \), pour un total de 100.17% (poids). La formule empirique, fondée sur une base de 12 atomes d’oxygène, est \( \text{Na}_{1.00} \text{(Y}_{0.72} \text{Dy}_{0.06} \text{Er}_{0.05} \text{Gd}_{0.04} \text{Nd}_{0.03} \text{Yb}_{0.02} \text{Sm}_{0.02} \text{Ho}_{0.02} \text{Ce}_{0.01} \text{Tb}_{0.01} \text{Tm}_{0.01}) \). La densité calculée (à partir de la formule empirique) est 2.27 g/cm\(^3\), et la densité mesurée est 2.27(2) g/cm\(^3\). La structure a été affinée jusqu’à un résidu \( R \) de 0.046. L’adamsite-(Y) est un minéral en couches ayant deux groupes de carbonate distincts, un parallèle aux couches et l’autre perpendiculaire. Les couches de carbonate sont séparées par des couches d’ motivoxyd, ce qui rend compte du clivage \{001\} parfait. Le minéral honore Frank Dawson Adams (1859–1942), géologue et professeur à l’Université McGill.

Mots-clés: adamsite-(Y), nouvelle espèce minérale, bicarbonate de sodium et yttrium hexahydraté, structure cristalline, mont Saint-Hilaire, Québec.

**INTRODUCTION**

The new mineral species described herein, adamsite-(Y), is the latest in a series of new carbonate minerals recently described from the Poudrette quarry, Mont Saint-Hilaire, Rouville County, Quebec. Fifty-seven carbonate species are known to occur at Mont Saint-Hilaire, many of them containing essential Na and rare-earth elements (REE) (Grice & Gault 1998). To date, a total of 333 mineral species have been identified from this locality, a well-known source of rare and exotic minerals (Horváth & Gault 1990).

Adamsite-(Y) was initially recognized as being a new species in 1992 by Dr. G.Y. Chao, Carleton University, on material submitted by a private collector, Gilles Haineault, and was designated as UK 96. In 1998, more material was found, but the chemical and X-ray data were not compared with those of the initial find, and the mineral from this second find was designated UK 106. It has since been determined that these two minerals are identical. Another mineral with similar chemical composition, similar appearance, and found in the same environment as adamsite-(Y), has been designated as UK 91. This material is more finely fibrous than adamsite-(Y), however, and has a significantly different X-ray powder-diffraction pattern.

Adamsite-(Y) is named in honor of Frank Dawson Adams (1859–1942), geologist and professor at McGill University. After graduating in chemistry and mineralogy from McGill University, he joined the Geological Survey of Canada in 1879 as “lithologist” and chemist. He studied the new science of petrography at Heidelberg, Germany in 1881 and went on to become one of the Survey’s leading specialists in the study of crystal-line rocks. In 1889, he was appointed Logan Professor of Geology at McGill University, where he continued his studies on Precambrian rocks, particularly those of the Laurentian and Grenville regions of Quebec and Ontario. It was during this period that he studied the Cretaceous igneous rocks of the Monteregian Hills, of which Mont Saint-Hilaire is a member, and was the first to describe this group of hills as the Monteregian Hills petrographic province (Adams 1903). As well, he served as president of the Geological Society of America and the Canadian Mining Institute.

The new mineral and mineral name were approved by the Commission on New Minerals and Mineral Names, IMA. Coty material is housed in the collection of the Canadian Museum of Nature under catalogue numbers CMNMC 82939 and CMNMC 82940.

**OCURRENCE**

Adamsite-(Y) occurs as a late-stage, low-temperature hydrothermal phase within cavities in a large alka-line pegmatite dike, informally designated the Poudrette dike, exposed in the southern corner of the Poudrette quarry. The quarry, in turn, is situated on the northeastern flank of Mont Saint-Hilaire, one of a series of plutons aligned along the St. Lawrence Valley for almost 550 km eastward from Oka to Megantic, in the province of Quebec. The pegmatite dike, which pinches and swells from 2 to 4 m across, has been exposed on levels 6, 7, 8 and 9 of the quarry. Five new Na- and REE-bearing carbonate mineral species have been described from this dike: lukechangite-(Ce), horváthite-(Y), reederite-(Y), thomasclarkite-(Y) and adamsite-(Y), the subject of this paper. Minerals found in that portion of the dike in which adamsite-(Y) was discovered include aegirine, albite, analcime, anelyite-(Ce), calcite, catapleiite, dawsonite, donnayite-(Y), elpidite, epididymite, eudialyte, eudidyinite, fluorite, franconite, gaidonnayite, galena, genthelvite, gmelinite, gonnardite, horváthite-(Y), kupletskeite, leifite, microcline, molybdenite, narsarsuk-
ADAMSITE-(Y) FROM MONT SAINT-HILAIRE, QUEBEC

Fig. 1. Photograph of adamsite-(Y). Photograph by Harry Taylor. The National History Museum, London, specimen number BM 1998, 172. Scale bar: 1 cm.
ite, natrolite, nenadkevichite, petersonite-(Ce), poly-lithionite, pyrochlore, quartz, rhodochrosite, rutile, sabinite, serandite, siderite, sphalerite, thomascloellite-(Y), zircon and an unidentified Na–REE–carbonate (UK 91). We discuss the genesis of adamsite-(Y) later in this paper.

**Physical and Optical Properties**

Adamsite-(Y) occurs as flat, acicular to fibrous crystals, up to 2.5 cm in length. They typically form spherical groups of radiating crystals, and rarely form reticulated groups (Fig. 1). The mineral is elongate on [001] and flat on [001]. Forms observed are the pinacoids [010] and [001]. It is colorless to white, occasionally pale pink, and rarely pale purple. It is transparent to translucent with a vitreous and occasionally pearly luster, and a white streak. It is brittle with perfect {001} and good {100} and {010} cleavages. Adamsite-(Y) is relatively soft (Mohs hardness 3) and does not fluoresce in either long- or short-wave ultraviolet light. The density, measured by suspension in a solution of bromoform and butyl alcohol, is 2.27(2) g/cm³, which compares very well to the density of 2.27 g/cm³ calculated for the empirical formula. Adamsite-(Y) is biaxial positive, α 1.480(4), β 1.498(2), γ 1.571(4); 2Vₘₑₙₓ = 53(3)°, 2Vₐₛₜ = 55°, (for λ = 590 nm). The optical orientation is X = [001], Y = b, Z = c (in β obtuse). It is nonpleochroic. A Gladstone–Dale calculation gives a compatibility index of ~0.009, which is regarded as superior (Mandarino 1981).

**Chemical Composition**

Chemical analyses were done in wavelength-dispersion (WD) mode on a JEOL 733 electron microprobe using Tracer Northern 5500 and 5600 automation. Data reduction was done with a PAP routine in XMAQNT (pers. commun., C. Davidson, CSIRO). The analysis of adamsite-(Y) by electron microprobe was problematic because of decrepitation of the sample and the lifting of carbon coating due to dehydration under prolonged vacuum. The decrepitation results from the weak H-bonding linking adjacent H₂O groups in the structure. To minimize this effect, calibration of the standards was performed first, and the samples were later introduced into the specimen chamber and analyzed immediately. This method, along with adoption of a rather large diameter of the beam, 50 μm, limited Na migration, volatilization and general burn-up of the sample. The beam current was 20 nA. Data for all elements in the samples were collected for 25 s or 0.50% precision, whichever was attained first. A 100 s energy-dispersion scan indicated no elements with Z > 8 other than those reported here. Seven analyses were performed on three crystals. The presence of CO₂ and H₂O was confirmed by infrared-absorption spectroscopy, and their concentrations were established by thermogravimetric analysis (TGA). As only one-half of the CO₂ was evolved during TGA, the amount given below consists of two summed portions, one measured (the gas evolved, 12.9 wt.%) and the other, the ideal amount determined by crystal-structure analysis (non-evolved during heating, 12.2 wt.%).

The following standards were used in the electron-microprobe analyses: albite (Na₄O₆), calcite (CaCO₃), synthetic yttrium iron garnet (YIG) (Y₆O₁₁), and a set of synthetic REE phosphates (Ce₆O₁₁, Nd₆O₁₁, Sm₆O₁₁, Gd₆O₁₁, Tb₆O₁₁, Dy₆O₁₁, Ho₆O₁₁, Er₆O₁₁, Tm₆O₁₁, Yb₆O₁₁). La, Pr and Eu were sought but not detected. Lu was detected in trace amounts. Data for standards were collected for 50 s or 0.25% precision, whichever was attained first. The REE raw data were corrected for overlaps. The chemical composition is Na₄O₂.84, CaO 0.05, Y₂O₃ 22.88, Ce₂O₃ 0.37, Nd₂O₃ 1.41, Sm₂O₃ 1.02, Gd₂O₃ 1.92, Tb₂O₃ 0.56, Dy₂O₃ 3.28, Ho₂O₃ 0.90, Er₂O₃ 2.83, Tm₂O₃ 0.27, Yb₂O₃ 1.04, CO₂ 25.10, H₂O 29.90, total 100.17 wt.%. The empirical formula, based on 12 atoms of oxygen, is Na₁₂O₂₄(Y₂O₃)₂(bromoform = 55 wt.%) and the other, the ideal amount determined by crystal-structure analysis (non-evolved during heating, 12.2 wt.%).

Two differential thermogravimetric analyses (DTG) of adamsite-(Y) were done using a Mettler–Toledo TA8000 system (software version 3.0), which uses a Mettler TG50 module linked to a Mettler M3 microbalance. The purge gas was dry nitrogen, with a flow rate of 200 mL/min. Two samples of pure material, weighing 10.196 and 10.847 mg, respectively, were each ground to a fine powder and heated from room temperature to 1000°C at a rate of 5°C/min. The weight losses of 4.334 mg (42.5 wt.% and 4.670 mg (43.1 wt.% occurred in two major steps (DTG, Fig. 2): between 80 and 270°C, 27.0 wt.% on average and between 380 and 590°C, 15.8 wt.% on average. The interpretation of the DTG scan is given in Table 1. The first weight-loss step is interpreted as the loss of 10 (H₂O) groups, which ideally should be 25.0 wt.% making the measured value a
little high. The second weight-loss step is interpreted as the loss of two additional (H₂O) groups plus the breakup of one of the (CO₃)²⁻ anions and its loss as CO₂ (Mochizuki et al. 1974). Ideally, this second weight-loss step should be 12.2 wt.%, making the observed value of 12.9 wt.% a little high. Mochizuki et al. (1974) discussed their DTG and differential thermal analysis (DTA) results on synthetic double carbonates similar in composition to adamsite-(Y). The TGA and DTA curves they presented are very similar to those of adamsite-(Y). They proposed that the final product after heating is a REE oxycarbonate, e.g., YNaO(CO₃). Although the final product after heating was X-rayed, we found no suitable match to any compound listed in the Powder Diffraction File (PDF), including NaYO₂ (PDF 32–1203). It is well established that the production of sodium peroxide, Na₂O₂, takes place at temperatures below 500°C (Cotton & Wilkinson 1980). Thus an alternative explanation is that Na acts as a reducing agent for the entire system and evolves CO, not CO₂, and that the final product is a peroxide, NaYO₄. Although two possible end-products of heating have been postulated, there is a preference for the REE oxycarbonate based on a chemical test with HCl that produced effervescence.

The differential thermal analysis curve (DTA, Fig. 2) reveals one smooth endothermic peak for the initial loss in H₂O, followed by a distinct shoulder that corresponds to almost 25% of the weight percent loss in H₂O. This weight loss would be the H₂O groups more strongly bonded to both Na and Y (OW13 and OW15; see below), whereas the other H₂O groups are bonded to Na only (OW17, OW18, OW19, OW20, OW21, OW22, OW23 and OW24). The second weight-loss is trimodal on the DTA curve and is due to the difference in energy required to drive off two additional H₂O groups (OW14 and OW16) and the two less strongly bonded (CO₃)²⁻ groups.

Fig. 2. Differential thermogravimetric analysis (DTG) and differential thermal analysis (DTA) of adamsite-(Y).

Fig. 3. Infrared-absorption spectrum of adamsite-(Y).
INFRARED SPECTROSCOPY

The infrared-absorption spectrum of adamsite-(Y) (Fig. 3) was obtained using a Bomem Michelson MB–120 Fourier-transform infrared spectrometer equipped with a diamond-anvil cell as a microsampling device. The dominant absorption band is that of the O–H stretching mode (3297 cm$^{-1}$). The (H$_2$O) bending band (1673 cm$^{-1}$) forms a shoulder on the large, split, asymmetric stretching band for (CO$_3$)$^{2-}$. This splitting (1513 and 1377 cm$^{-1}$) is explained by the fact that the carbonate groups are very distorted, with distinctly differing C–O bond lengths, as seen in the crystal-structure determination. For this same reason, the (CO$_3$)$^{2-}$ symmetric band is also split (1115 and 1070 cm$^{-1}$). The weak intensity of this symmetric band is due to the limited ability of the (CO$_3$)$^{2-}$ group to undergo this type of stretching mode. The 876 and 849 cm$^{-1}$ bands may be due to out-of-plane bending of (CO$_3$)$^{2-}$. The remainder of the spectra could not be unequivocally assigned. This infrared-absorption spectrum is very similar in appearance to that of thomasclarkite-(Y) (Grice & Gault 1998).

X-RAY CRYSTALLOGRAPHY AND CRYSTAL-STRUCTURE DETERMINATION

Precession single-crystal photographs initially showed adamsite-(Y) to be pseudo-orthorhombic, with diffraction symmetry mmm. These crystals are twinned by reflection on {001}; subsequent more precise work on single crystals using a four-circle diffractometer indicated triclinic symmetry, but metrically close to monoclinic. Much of the problem with the early single-crystal work was the failure to realize that this mineral reacts with the binding agent, amyl acetate, causing dehydration and subsequent almost complete decrepitation of the crystal. This decrepitation reaction was exacerbated by intense X-radiation; crystals subjected to this treatment developed a crazed appearance. The crystal used for the final data-collection was mounted on a glass fiber with non-reacting epoxy. X-ray powder-diffraction data, obtained with a Debye–Schererr camera having a diameter of 114.6 mm and using CuK$_x$ radiation, are given in Table 2. Whereas neither variation in intensity nor shifting of d-values was noted in the X-ray powder patterns during this study, other researchers have noted some variability in the patterns, possibly indicating that adamsite-(Y) may not be stable under minor fluctuations in humidity levels (pers. commun., A.M. McDonald, Laurentian Univ.). Indexing the powder data was difficult owing to the previously mentioned pseudosymmetry, but the process was successful with the aid of powder-pattern intensities calculated from the results of the crystal-structure analysis.

In the final stage of data collection, a crystal fragment of adamsite-(Y), measuring 160 $\times$ 180 $\times$ 40 $\mu$m for [100] $\times$ [010] $\times$ [001], was mounted on a CCD-equipped Bruker P4 fully automated four-circle diffractometer operated at 40 kV and 40 mA. With the CCD detector, almost a full sphere of intensity data was collected out to $\theta$ = 60$^\circ$ using a 15 s frame time and a crystal-to-detector distance of 4 cm. The lowering of the incident radiation power and the high-speed data collection were in anticipation of potential problems with crystal decrepitation. With these operating conditions,
no decrepitation was evident in the final analysis of the intensity standards. Information relevant to the data collection and structure determination is given in Table 3. The three-dimensional data were reduced for Lorentz, polarization, and background effects using the Bruker program SAINT. An empirical plate-absorption correction was done on the basis of 3998 reflections and reduced the merging $R$ of this dataset from 3.45% before the absorption correction to 3.10% after the absorption correction with a glancing angle of 7°.

Phasing of a set of normalized structure-factors gave a mean value $|E^2 - 1|$ of 0.862. A calculated sharpened Patterson function for space group $P1$ located the two Y sites, the two Na sites and six lighter-element sites. This model refined to $R = 0.22$. Additional O and C sites were added following a series of $\Delta F$ synthesis maps, which, in turn, reduced the $R$ index to 0.066. In the final least-squares refinement, all atomic positions were refined with anisotropic-displacement factors to a residual of $R = 0.046$. The addition of an isotropic-extinction factor did not improve the results. Although the $|E^2 - 1|$ statistic is low for centrosymmetric structures, lowering the symmetry to $P1$ did not improve the refinement, nor was there any indication that the lower symmetry suggested a better structural model. Use of the program MISSYM (Le Page 1987) suggests the possible presence of a two-fold axis. The Laue merging for monoclinic symmetry is 6.1%. The metric deviation from monoclinic symmetry is only 0.2°, with $a = 25.72$, $b = 6.260$, $c = 13.085$ Å, $\alpha = 90.19$, $\beta = 91.21$ and $\gamma = 89.87$. Essentially the same structure can be refined in $C2/c$ ($R = 0.06$) with four of the six H$_2$O groups coordinated to the Na site split into two half-occupied sites each. We view the 0.2° metric deviation, the 6.1% Laue merging and the site splitting in $C2/c$ as sufficient evidence to rule out monoclinic symmetry.

Table 4 contains the final positional anisotropic-displacement factors and equivalent isotropic-displacement parameters, and Table 5 contains selected interatomic distances and angles. Observed and calculated structure-factors have been submitted to the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Ontario K1A 0S2, Canada.
DESCRIPTION AND DISCUSSION OF THE STRUCTURE

The structure of adamsite-(Y) has four large-cation sites with two distinct polyhedra. The two Na sites, each with six-fold coordination, occupy [Na(H2O)6] polyhedra that may be described as a bifurcated tetragonal pyramid with the Na atom slightly above the square base. This base consists of four H2O groups, whereas the bifurcated apex has two additional H2O groups. The nine-fold coordination (seven O atoms and two H2O groups) around each Y site may be described as a monocapped square antiprism. All (CO3) polyhedra share edges with this (Y(H9278)9) polyhedron (H9278 is an unspecified ligand).

The crystal structure of adamsite-(Y) is layered on (001) (Fig. 4). The layering of REE-bearing carbonates is described in detail by Grice et al. (1994). In adamsite-(Y), there are thick slabs (Fig. 4) composed of a unit of Y atoms and parallel “flat-lying” (CO3) polyhedra sandwiched between layers of Na(H2O)6 polyhedra and perpendicular “standing-on-end” (CO3) polyhedra (Grice et al. 1994). These [Na(Y(CO3))] slabs are H-bonded together, and it is these H-bonds that give rise to the perfect (001) cleavage and the relatively unstable nature of adamsite-(Y).

Adamsite-(Y), NaY(CO3)2•6H2O, and thomascottite-(Y), NaY(HCO3)(OH)3•4H2O (Grice & Gault 1998), are found intimately associated with one another at Mont Saint-Hilaire. These two minerals share similarities in chemical composition and crystal structure. In both minerals, there is a distinctive fundamental unit that consists of a stacked, edge-sharing unit of three polyhedra centered by a C, a Y and a Na atom (Fig. 5). Although the two sets of polyhedra differ in coordination number (Y polyhedron) and ligands (OH groups versus H2O groups in both the Na and Y polyhedron), the fundamental building block is essentially the same. In adamsite-(Y), the Na–Y–C tri-polyhedra form planes and have a strong cross-linkage in the (001) plane with the (YO9) polyhedra, sharing corners and edges and being further reinforced by the “flat-lying” carbonate groups (Fig. 5a). In thomascottite-(Y), the Na–Y–C tri-polyhedra share edges, forming single chains parallel to (001) (Fig. 5b).

Genesis of adamsite-(Y)

Adamsite-(Y) occurs as a very late-stage, low temperature, hydrothermal phase within cavities in an alkali pegmatite dike in the nepheline syenite intrusion. In these cavities, adamsite-(Y) appears to crystallize after rhodochrosite and petersenite-(Ce), is contemporaneous with horváthite-(Y) and donnayite-(Y), and precedes thomascottite-(Y), which has been observed as an epitactic growth on adamsite-(Y) (pers. commun., L. Horváth). This sequence of crystallization is indicative of lowering carbonate activity and Lewis basicity. Comparing the formulae of the minerals involved shows a decrease in the ratio of carbonate groups relative to the number of cations plus the other chemical species involved [(H2O), (OH), F]. The lowering of Lewis basicity is effected by the distribution of the H atoms. As H bonds to O, the basicity decreases; for example, typical Lewis base strengths (valence units) (O’Keeffe & Navrotsky 1981) are: (CO3)2– 0.22, (HCO3)– 0.17, O2– 0.50, (OH)– 0.40, (H2O) 0.20. Thus in the transition from adamsite-(Y) to thomascottite-(Y), there is a shift from a carbonate to a bicarbonate. Grice & Gault (1998) and Grice (1991) discussed the typical formation of bicarbonate minerals at low-temperature, slightly acidic conditions. Similarly, in this transition, more of the O atoms become protonated, thus lowering the Lewis base strength of thomascottite-(Y) relative to adamsite-(Y).

### TABLE 5. ADAMSITE-(Y): SELECTED BOND LENGTHS (Å) AND ANGLES (°)

<table>
<thead>
<tr>
<th>Bond Type</th>
<th>Bond Length (Å)</th>
<th>Bond Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na–O</td>
<td>2.64 (2)</td>
<td>160</td>
</tr>
<tr>
<td>Y–O</td>
<td>2.39 (2)</td>
<td>170</td>
</tr>
<tr>
<td>C–O</td>
<td>1.20 (2)</td>
<td>120</td>
</tr>
</tbody>
</table>

### Discussion

The crystal structure of adamsite-(Y) is layered on (001) (Fig. 4). The layering of REE-bearing carbonates.
ACKNOWLEDGEMENTS

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REFERENCES


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