

**GERENITE-(Y), (Ca,Na)<sub>2</sub>(Y,REE)<sub>3</sub>Si<sub>6</sub>O<sub>18</sub>·2H<sub>2</sub>O, A NEW MINERAL SPECIES, AND AN ASSOCIATED Y-BEARING GADOLINITE-GROUP MINERAL, FROM THE STRANGE LAKE PERALKALINE COMPLEX, QUEBEC-LABRADOR**

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ABSTRACT

Gerenite-(Y), ideally (Ca,Na)<sub>2</sub>(Y,REE)<sub>3</sub>Si<sub>6</sub>O<sub>18</sub>·2H<sub>2</sub>O, is a new mineral from the Strange Lake peralkaline complex, Quebec-Labrador boundary. The mineral is white to creamy in color, translucent, brittle, and has a vitreous luster, white streak, hardness of 5, uneven fracture, and is nonfluorescent in ultraviolet light;  $D_{\text{calc.}}$  is 3.46 g/cm<sup>3</sup> for the ideal formula and  $Z = 1$ . The mineral is biaxial negative,  $a$  1.602(1),  $b$  1.607(2),  $g$  1.611(1),  $2V_{\text{meas.}}$  73(3)°,  $2V_{\text{calc.}}$  83°,  $X \wedge b = 7^\circ$ . A single-crystal X-ray study indicates triclinic symmetry, space group  $P1$  or  $P\bar{1}$ ,  $a$  9.245(5),  $b$  9.684(6),  $c$  5.510(3) Å,  $\alpha$  97.44(6),  $\beta$  100.40(6),  $\gamma$  116.70(6)°. The strongest six lines of the X-ray powder-diffraction pattern [ $d$  in Å( $hkl$ )] are: 8.44(80)(010), 8.01(50)( $\bar{1}10,100$ ), 4.51(50)( $\bar{2}10,\bar{1}11$ ), 3.76(70)( $\bar{1}2\bar{1},02\bar{1}$ ), 2.973(100)( $\bar{3}20,\bar{3}10,021$ ) and 2.930(60)( $\bar{1}3\bar{1}$ ). Most Gerenite-(Y) occurs in magmatic aplite-pegmatite as anhedral masses, 1–2 cm across, that consist of eutectoid-like intergrowths of sheaves of Gerenite-(Y) and interstitial quartz. Also present within the aplite-pegmatite are kainosite-(Y) and a gadolinite-group mineral, the latter considered to be the principal source of Be in the deposit. Electron-microprobe compositions of the gadolinite-group mineral indicate that its formula is of the type (X)<sub>2</sub>Si<sub>2</sub>Be<sub>2</sub>(O,OH)<sub>10</sub>, where X is either predominantly Ca or Y. The results suggest that the mineral is a new member of the gadolinite group.

**Keywords:** Gerenite-(Y), kainosite-(Y), gadolinite-group mineral, new mineral species, Ca–Y silicates, Strange Lake deposit, Quebec–Labrador boundary.

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## SOMMAIRE

Nous décrivons ici la gérénite-(Y), de formule idéale  $(Ca,Na)_2(Y,REE)_3Si_6O_{18} \cdot 2H_2O$ , nouvelle espèce minérale provenant du complexe peralcalin de Strange Lake, sur la frontière Québec-Labrador. Il s'agit d'un minéral blanc à crèmeux, translucide, cassant, à l'éclat vitreux, la rayure blanche, dureté de 5, et cassure inégale. La gérénite est non fluorescente en lumière ultraviolette. Sa densité calculée selon la formule idéale est 3.46 ( $Z = 1$ ). Le minéral est biaxe négatif,  $a$  1.602(1),  $b$  1.607(2),  $g$  1.611(1),  $2V_{mes}$  73(3)°,  $2V_{calc}$  83°,  $X^\wedge b = 7^\circ$ . Un étude par diffraction X sur cristal unique indique une symétrie triclinique, groupe spatial  $P1$  ou  $P1$ ,  $a$  9.245(5),  $b$  9.684(6),  $c$  5.510(3) Å,  $\alpha$  97.44(6),  $\beta$  100.40(6),  $\gamma$  116.70(6)°. Les six raies les plus intenses du spectre de diffraction X (méthode des poudres) [ $d$  en Å( $hkl$ )] sont: 8.44(80)(010), 8.01(50)( $\bar{1}10,100$ ), 4.51(50)( $\bar{2}10,111$ ), 3.76(70)( $\bar{1}2\bar{1},02\bar{1}$ ), 2.973(100)( $\bar{3}20,310,021$ ) et 2.930(60)( $\bar{1}31$ ). Dans la plupart des cas, la gérénite-(Y) se présente dans l'aplite et la pegmatite litées en amas xénomorphes de 1 à 2 cm de diamètre. Ceux-ci contiennent en fait une intercroissance eutectoïde d'essaims de gérénite-(Y) et de quartz interstitiel. Sont aussi présents dans l'aplite et la pegmatite litées kainosite-(Y) et un minéral du groupe de la gadolinite. Nous considérons ce dernier comme la source principale de Be dans ce gisement. Les données obtenues sur sa composition par microsonde électronique démontrent une formule de type  $(X)_2Si_2Be_2(O,OH)_{10}$ , avec soit Ca, soit Y prédominant dans la position X. Cette phase serait un nouveau membre du groupe de la gadolinite.

(Traduit par la Rédaction)

**Mots-clés:** gérénite-(Y), kainosite-(Y), minéral du groupe de la gadolinite, nouvelle espèce minérale, silicates de Ca-Y, gisement de Strange Lake, frontière Québec-Labrador.

## INTRODUCTION

The Strange Lake peralkaline complex is on the Quebec-Labrador boundary at latitude 56°20'N, longitude 64°10'W, about 250 km northeast of Schefferville, Quebec. The complex is of Middle Proterozoic age and has a Y-REE-Nb-Zr-Be deposit contained within a lens of pegmatite and aplite, up to 20 m thick, near the central part of the granitic complex. The principal source of Nb in the deposit is pyrochlore, and gittinsite and zircon account for most of the Zr. The bulk of the rare-earth elements (REE), including Y, in the mineralized zone is contained, in order of decreasing importance, in kainosite-(Y), the new mineral described here as gerenite-(Y), and a gadolinite-like mineral of the datolite-gadolinite group. The gadolinite-like mineral is the principal host of the Be within the mineralized zone.

Gerenite-(Y) is named in honor of Richard Geren (b. 1917), of Oromocto, New Brunswick. As the former executive vice-president of the Iron Ore Company of Canada, he was instrumental in initiating and supporting the exploration program that led to the discovery and subsequent delineation of the Strange Lake deposit. The new mineral and name have been approved by the Commission on New Minerals and Mineral Names, IMA (No. 93-034). Type specimens, including the holotype (NMCC 67354), are in the Systematic Reference Series housed at the Geological Survey of Canada, Ottawa, as part of the National Mineral Collection of Canada. The single-crystal fragment used

for the X-ray structure determination (Groat 1998) is in the M.Y. Williams Museum at the University of British Columbia, Vancouver.

## OCCURRENCE

Descriptions of the nature and distribution of the magmatic pegmatite-aplite lens that hosts the principal REE mineralization within the complex are given by Miller (1996). The pegmatite-aplite, for the most part, has been delineated by diamond drilling, but the unit is also locally exposed at the surface and was trenched to obtain a bulk sample for metallurgical tests. The principal minerals in the bulk sample are quartz, albite, K-feldspar, aegirine, riebeckite, gittinsite, zircon, gerenite-(Y), and kainosite-(Y), with small amounts ( $\leq 1\%$ ) of pyrochlore, thorite, the gadolinite-group mineral, titanite, fluorite, REE-bearing epidote, hematite (which imparts a reddish color to the pegmatite-aplite lens), monazite-(Ce), sphalerite, and trace amounts of several other minerals. The geology of the bulk-sample trench is illustrated by Miller (1996), who also gives modes for the several mineralogically variable units that make up the aplite-pegmatite lens.

Intergrowths containing gerenite-(Y) are megascopically recognizable as sparsely disseminated, anhedral masses that are typically 1–2 cm across and commonly have a distinctive slightly purplish or mauve tint. All of the masses are heterogeneous. One such mass, about 3 cm across, in a pegmatite host was found to be hexagonal in outline and in internal zoning, and is much less altered by kainosite-(Y)

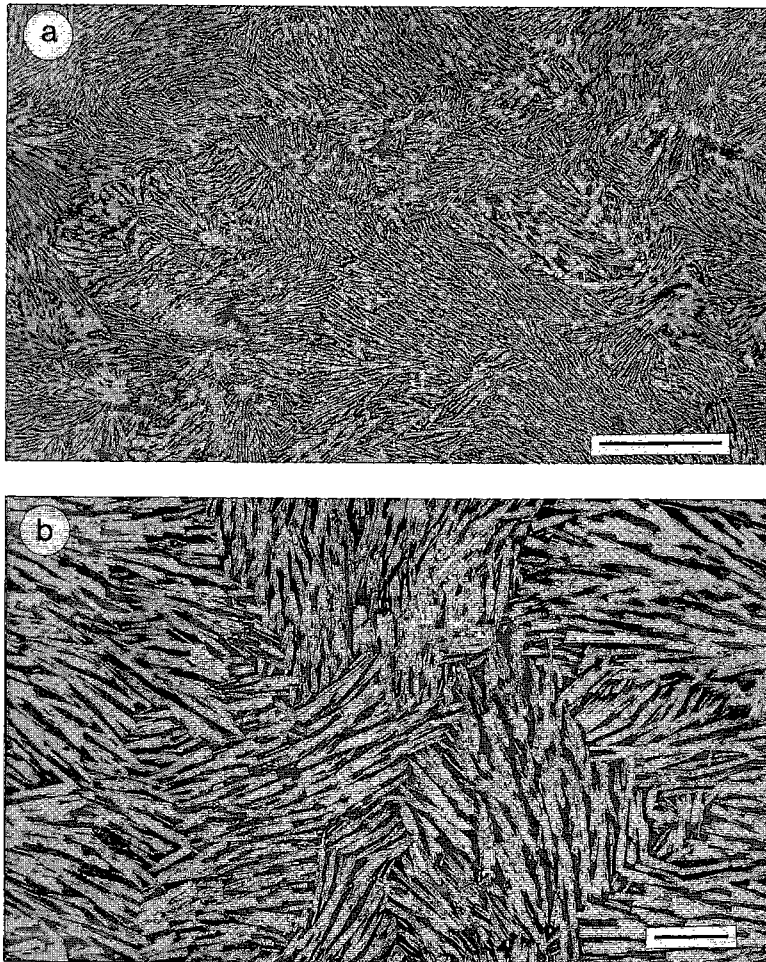


FIG. 1. Back-scattered-electron images of eutectoid intergrowth of quartz (black) and gerenite-(Y). Bar scales in (a) and (b) are 500  $\mu\text{m}$  and 100  $\mu\text{m}$ , respectively. In (b), note the bundle-like habit and, especially at top and bottom right, the flat termination.

than are most masses. This “crystal”, and the anhedral masses, consist of microscopically sheaf-like intergrowths of gerenite-(Y) and interstitial quartz (Fig. 1) that are pseudomorphous after a roughly equant, and presumably hexagonal, precursor. Miller (1996) reported that the mineral now named gerenite-(Y) occurs in the aplite–pegmatite lens as elongate, prismatic grains of primary origin, and as radiating aggregates that have replaced equant grains of leifite,  $\text{Na}_6[\text{Si}_{16}\text{Al}_2(\text{BeOH})_2\text{O}_{39}]\cdot 1.5\text{H}_2\text{O}$  (Coda *et al.* 1974). Possibly, therefore, the intergrowth of quartz and gerenite-(Y) is a pseudomorph after leifite. The single crystal of gerenite-(Y) used in the mineralogical study was taken from a pseudomorph, whereas the crystal used for the X-ray structure determination by Groat (1998) is of the primary type, from unit 6 of the aplite–pegmatite lens

(Miller 1996). Both crystals gave X-ray precession results that are identical within experimental error.

#### PHYSICAL AND OPTICAL PROPERTIES

Pseudomorphs containing gerenite-(Y) are recognizable in hand specimens mainly because of their large size and characteristic color, the latter imparted by a fine-grained dusting of inclusions of hematite  $\pm$  purple fluorite. Gerenite-(Y) is white to creamy, translucent, and has a vitreous luster. The mineral is brittle, has a hardness of 5, a white streak, an uneven fracture, and is not fluorescent in ultraviolet light. An apparent indistinct cleavage roughly parallel to the elongation [010] was observed, but the results of the crystal-structure

study (Groat 1998) indicate that a cleavage, if present, would likely be {101}. Microscopically, gerenite-(Y) typically forms bundles of slightly divergent elongate grains, most commonly with the bundles ~100 µm long and ~20 µm wide. The bundles always have interstitial quartz or are in a quartz matrix, and commonly the bundles are heterogeneous intergrowths with kainosite-(Y).

The single crystal used for X-ray precession studies was lost during an attempt to determine its density in heavy liquids, and no suitable replacement was found until a decade later. However, four bulk samples of pseudomorphic intergrowths of quartz and gerenite-(Y) gave densities ranging from 2.95 to 2.99 g/cm<sup>3</sup>. These samples consisted of thin wafers cut from the aforementioned 3-cm pseudomorph, one portion of which was a relatively pure intergrowth of quartz and gerenite-(Y). This portion was pared from the wafers after comparison with a companion thin section. Because gerenite-(Y) is slowly soluble in HCl and HNO<sub>3</sub> at room temperature, differential dissolution was used for quantitative determination of the amount of quartz in the intergrowths. Accordingly, two of the bulk samples were pulverized, boiled briefly in 30% HCl, filtered, washed, dried, and weighed. The residues indicated 39.2 and 43.2 wt.% quartz in the mixtures, respectively. Using the starting density of 2.95 g/cm<sup>3</sup> for the bulk samples, and the non-additive relationship for the densities of mixtures (Mandarino 1985), the respective calculated densities of the two samples are 3.578 and 3.466 g/cm<sup>3</sup>, and the average is 3.52 g/cm<sup>3</sup>. With the ideal formula and cell volume obtained by Groat (1998), the calculated density of gerenite-(Y) is 3.46 g/cm<sup>3</sup> for Z = 1.

In transmitted light, gerenite-(Y) can be clear, but is typically somewhat turbid. The mineral is length fast, and shows no pleochroism or dispersion. Indices of refraction measured in Na light (λ 589.9 nm) are α 1.602(1), β 1.607(2), γ 1.611(1), 2V<sub>meas.</sub> = 73(3)°, 2V<sub>calc.</sub> = 83°, X ∧ b = 7°.

#### CHEMICAL COMPOSITION

Numerous electron-microprobe analyses of gerenite-(Y) were done in various laboratories using different instruments and standards, and different specimens. Sodium in gerenite-(Y) is susceptible to migration under the electron beam, and T.S. Ercit (Canadian Museum of Nature) has shown that Na counts for gerenite-(Y) decay rapidly if a focused beam of electrons is used; with a defocused beam 6 µm in diameter, the decay rate is about eight times less than that obtained with the focused beam. Despite the analytical difficulties related to quantitative determination of Na concentration, all results calculated on an anhydrous basis for O = 18 (Table 1) are consistent in indicating that gerenite-(Y) intergrown with quartz is characterized by a predominance of Ca over Na (atomic and wt.%), a preponderance of Y<sub>2</sub>O<sub>3</sub> (27–29 wt.%), and moderate amounts (11–14

TABLE 1. ELECTRON-MICROPROBE COMPOSITIONS OF PSEUDOMORPHIC GERENITE-(Y)

wt%	1	2	3	4	5	6
Na <sub>2</sub> O	3.1	2.8	3.2	1.32	3.3	1.7(1.0-2.8)
CaO	7.6	8.4	7.8	9.79	7.3	7.6(7.1-7.9)
MnO	1.0	0.9	0.4	nd	0.4	0.6(5-0.6)
Y <sub>2</sub> O <sub>3</sub>	27.4	27.1	28.0	29.18	26.3	28.2(27.0-29.2)
La <sub>2</sub> O <sub>3</sub>	-	-	-	-	-	-
Ce <sub>2</sub> O <sub>3</sub>	nd	nd	nd	-	-	0.1(0.1-0.2)
Pr <sub>2</sub> O <sub>3</sub>	-	-	-	-	-	-
Nd <sub>2</sub> O <sub>3</sub>	0.2	0.3	0.3	0.36	0.3	0.2(0.2-0.3)
Sm <sub>2</sub> O <sub>3</sub>	0.2	0.3	0.3	0.41	0.2	0.3(0.3-0.4)
Eu <sub>2</sub> O <sub>3</sub>	-	-	-	0.10	-	-
Gd <sub>2</sub> O <sub>3</sub>	0.9	1.2	1.0	1.20	1.3	1.1(1.0-1.3)
Tb <sub>2</sub> O <sub>3</sub>	0.32	0.38	0.33	0.37	0.38	0.34
Dy <sub>2</sub> O <sub>3</sub>	4.4	4.6	4.1	4.38	4.2	4.0(3.7-4.3)
Ho <sub>2</sub> O <sub>3</sub>	1.15	1.17	1.12	1.09	1.14	1.05
Er <sub>2</sub> O <sub>3</sub>	3.9	3.9	4.0	3.56	4.0	3.6(3.4-3.9)
Tm <sub>2</sub> O <sub>3</sub>	0.51	0.52	0.52	0.47	0.53	0.51
Yb <sub>2</sub> O <sub>3</sub>	2.7	2.8	2.7	2.46	2.8	2.9(2.5-3.2)
Lu <sub>2</sub> O <sub>3</sub>	0.35	0.37	0.35	0.32	0.37	0.41
SiO <sub>2</sub>	40.0	38.9	40.9	41.14	39.8	40.5(38.9-41.7)
SUM	94.13	94.54	95.02	96.15	92.32	93.11(88.8-93.7)
[H <sub>2</sub> O]	5.87	5.46	4.98	3.85	7.68	6.89
	<i>formula ratios</i>					
Na	0.89	0.81	0.91	0.37	0.97	0.49
Ca	1.21	1.32	1.22	1.52	1.18	1.21
Mn	0.13	0.11	0.05	-	0.05	0.08
ΣA	2.22	2.26	2.18	1.89	2.20	1.78
Y	2.16	2.14	2.18	2.25	2.11	2.24
La	-	-	-	-	-	-
Ce	-	-	-	-	-	0.01
Pr	-	-	-	-	-	-
Nd	0.01	0.02	0.02	0.02	0.02	0.01
Sm	0.01	0.02	0.02	0.02	0.01	0.02
Eu	-	-	-	0.00	-	-
Gd	0.04	0.06	0.05	0.06	0.07	0.05
Tb	0.02	0.02	0.02	0.02	0.02	0.02
Dy	0.21	0.22	0.19	0.20	0.20	0.19
Ho	0.05	0.06	0.05	0.05	0.05	0.05
Er	0.18	0.18	0.18	0.16	0.19	0.17
Tm	0.02	0.02	0.02	0.02	0.03	0.02
Yb	0.12	0.13	0.12	0.11	0.13	0.13
Lu	0.02	0.02	0.02	0.01	0.02	0.02
ΣB	2.84	2.88	2.86	2.93	2.84	2.92
ΣA+B	5.06	5.13	5.05	4.81	5.04	4.71
Si	5.98	5.92	5.99	5.95	6.01	6.04
O	18	18	18	18	18	18
[H <sub>2</sub> O]	2.90	2.71	2.43	1.86	3.87	3.43

1-3: D.R. Owens, analyst; MAC 500 microprobe, CANMET, 1984.

Standards: rhodochrosite (Mn), NaNb<sub>3</sub> (Na), REE 4 (Ca, Er, Dy), YFeO<sub>3</sub> (Y) REE 3 (Ce, Yb), kaersutite and albite (Si).

4: Average of 7 analyses, M. Bonardi analyst, Geological Survey of Canada, Cameca CAMEBAX microprobe, 1986. Beam diameter 5 µm. Standards REE 1, 2, 3, 4, kaersutite (Si), and phlogopite (F).

5: T.S. Ercit, analyst, Canadian Museum of Nature, JEOL 733 microprobe, beam diameter 10 µm. Nd, Sm, and Eu fixed at values supplied by CANMET. Standards NaInSi<sub>2</sub>O<sub>6</sub> (Na, Si), synth. fersmite (Ca), YAG (Y), tephroite (Mn), GdDy(MoO<sub>4</sub>)<sub>2</sub> (Gd, Dy), REE aluminosilicate glass (Yb, Er).

6: Average and range of 3 analyses, D.R. Owens, analyst, CANMET, JEOL 733 microprobe, 1988. Standards as in columns 1-3.

*italics*: values estimated from chondrite-normalized REE spectra; nd: not detected; -: not reported; [H<sub>2</sub>O] by difference from 100%.

wt.%) of all other REE combined, with Dy, Er, and Yb predominating. Electron-microprobe analyses of the non-intergrowth gerenite-(Y) have indicated that proportions of the REE are similar to those of the mineral in the intergrowths, but in some analyses the Na:Ca ratios are

close to 1:1. A slightly Na-dominant analogue of gerenite-(Y) may exist, but this aspect requires additional study and is not dealt with here.

Chemical analysis of a bulk sample of the intergrowths of quartz and gerenite-(Y) gave 40 ppm Li, as determined by atomic absorption spectroscopy, <250 ppm Be by inductively coupled plasma (ICP) spectrometry, and 3.9 wt.% H<sub>2</sub>O by the Penfield method, thus indicating that Li and Be are not significant constituents of gerenite-(Y). The substantial variation in H<sub>2</sub>O contents in the analytical results in Table 1 is considered to arise mainly because the values were derived by difference from 100 wt.%. Chondrite-normalized plots of the REE in gerenite-(Y) suggest that, in addition to the microprobe-analyzed elements, ranges for Tb, Ho, Tm, and Lu are 0.32–0.38, 1.09–1.17, 0.47–0.53, and 0.32–0.37 wt.%, respectively, in terms of their oxides (Fig. 2). These increase the analytical sums, and therefore decrease the [H<sub>2</sub>O] content, by about 2.3 wt.%, but the formula ratios are little affected because of the high atomic weights of the REE. The ideal formula of gerenite-(Y) is (Ca,Na)<sub>2</sub>(Y,REE)<sub>3</sub>Si<sub>6</sub>O<sub>18</sub>·2H<sub>2</sub>O (Groat 1998), which requires about 4.1 wt.% H<sub>2</sub>O. If the calculated density of 3.46 g/cm<sup>3</sup> and a H<sub>2</sub>O content of 4.1 wt.% are used, the Gladstone–Dale relationship yields superior to excellent compatibility (Mandarino 1979).

Portions of the bulk sample of intergrown quartz and gerenite-(Y) used for the density determinations also were used for static heating experiments conducted at intervals of 50°C over the range 250–600°C, and at

if 40% quartz is assumed. Although X-ray powder patterns show small changes in *d* values and intensities, particularly between 300 and 350°C, and cell size seems to decrease slightly at high temperature, the basic structure is retained to 700°C. This behavior suggests a channel-type structure in which H<sub>2</sub>O is tightly bonded, but can be purged without destroying the basic structure.

Curves derived from differential thermal analysis (DTA) and thermogravimetric analysis (TGA) of a bulk intergrowth sample heated to 1000°C are rather featureless. The TGA profile shows a gradual weight-loss, without any clear-cut steps, totalling 5.0%. In the DTA curve, the only inflection is an extremely weak one at ~900°C, considered to be related to sintering of the sample and possible reaction with the alumina container. Simultaneous FTIR monitoring of gas evolution indicated that losses of H<sub>2</sub>O occur initially at <100°C, presumably a fraction of adsorbed water, and the main, continuous evolution from ~375°C. A peak for CO<sub>2</sub>, smaller than that for H<sub>2</sub>O, also appears at ~375°C, but disappears before 500°C, whereas H<sub>2</sub>O continues to evolve. The CO<sub>2</sub> peak is possibly an indication of a small amount of admixed kainosite-(Y), but the exact source is unknown. The heated end-product consists mainly of quartz and cristobalite; numerous additional weaker diffraction-lines appear on the X-ray powder pattern, but matches with known phases, such as britholite-(Y), are not precise.

A powder infrared pattern obtained from a bulk sample of gerenite-(Y) and quartz intergrowths is dominated by the spectrum of quartz. Broad, weak bands centered at 3480 and 1655 cm<sup>-1</sup> are assignable to H<sub>2</sub>O in gerenite-(Y). Other bands attributable to gerenite-(Y) are one of medium intensity at 943 cm<sup>-1</sup>, and weak bands at 668, 430, 340, 328, and 302 cm<sup>-1</sup>.

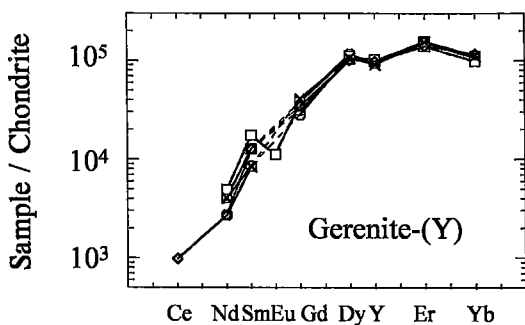


FIG. 2. Chondrite-normalized plot of concentrations of the rare-earth elements and yttrium in gerenite-(Y), with Y inserted after Dy.

700°C. Slightly less than 1 wt.% loss was recorded at 250°C, and similarly small losses gradually occurred as temperature was raised. At 700°C, the total loss was 3.5 wt.%, which corresponds to approximately 6 wt.% H<sub>2</sub>O

#### X-RAY DATA

An X-ray precession study of a grain of gerenite-(Y) extracted from a polished thin section indicates triclinic symmetry, space group *P* $\bar{1}$  or *P*1; cell dimensions, refined from the powder data (Table 2), are *a* 9.245(5), *b* 9.684(6), *c* 5.510(3) Å,  $\alpha$  97.44(6),  $\beta$  100.40(6),  $\gamma$  116.70(6)°, *V* 420.8(1) Å<sup>3</sup>, *a*:*b*:*c* = 0.9547:1:0.5690. Similar parameters from another grain were obtained by Groat (1998), who showed that the space group of gerenite-(Y) is *P* $\bar{1}$ .

#### ASSOCIATED MINERALS

On a microscopic scale, gerenite-(Y) is typically accompanied by small to large amounts of quartz and kainosite-(Y); in some occurrences, kainosite-(Y) is intergrown on an almost submicrometer scale. Both silicate minerals have compositional similarities in that they are dominated by Y, are poor in the light rare-earth elements (*LREE*) (La, Ce, Nd, Sm), and both contain percentage quantities of the heavy rare-earth elements

TABLE 2. X-RAY POWDER DATA FOR GERENITE-(Y)

<i>l</i>	<i>d</i> <sub>meas</sub>	<i>d</i> <sub>calc</sub>	<i>hkl</i>	<i>l</i>	<i>d</i> <sub>meas</sub>	<i>d</i> <sub>calc</sub>	<i>hkl</i>
80	8.44	8.40	010	10	2.700	2.702	01 $\bar{2}$
				5	2.625	2.631	002
50	8.01	8.04	$\bar{1}10$	30	2.532	2.530	202
		7.95	100				$\bar{1}\bar{1}\bar{2}$
10	5.29	5.26	001	20	2.470	2.469	$\bar{3}2\bar{1}$
							$\bar{3}2\bar{1}$
30	5.04	5.06	$\bar{1}01$				$\bar{3}31$
				10	2.422	2.423	$\bar{1}2\bar{2}$
10	4.74	4.74	110	5	2.370	2.370	220
							102
50	4.51	4.55	$\bar{2}10$				311
				20	2.318	2.315	130
			$\bar{1}\bar{1}\bar{1}$				031
5	4.33	4.32	$\bar{1}\bar{1}\bar{1}$	5	2.257	2.257	411
30	4.21	4.19	$\bar{1}\bar{1}\bar{1}$				$\bar{1}2\bar{2}$
35	4.06	4.05	011	40	2.203	2.205	$\bar{0}3\bar{2}$
20	3.98	3.98	200				$\bar{4}31$
			$\bar{1}2\bar{1}$	3	2.113	2.113	400
70	3.76	3.75	021	5	2.052	numerous	311
10	3.68	3.69	$\bar{2}01$	3	1.989	1.988	441
40	3.36	3.36	$\bar{1}21$	20	1.872	1.871	$\bar{1}50$
20	3.27	3.26	$\bar{2}21$	15	1.852	1.851	013
30	3.075	3.072	211	15	1.833	1.833	322
		2.989	$\bar{3}20$				
100	2.973	2.976	310	5	1.807	1.797	
		2.955	021	3	1.774		
60	2.930	2.932	$\bar{1}31$	5	1.755		
5	2.868	2.872	$\bar{3}11$				
10	2.763	2.762	$\bar{3}21$				

114.6-mm Gandolfi camera, Fe-filtered CoK $\alpha$  radiation ( $\lambda$  1.79021 Å). Indexed with *a* 9.245(5), *b* 9.684(6), *c* 5.510(3) Å,  $\alpha$  97.44(6),  $\beta$  100.40(6),  $\gamma$  116.70(6)°. Intensities estimated visually, and no shrinkage correction applied.

(HREE) such as Dy, Er, and Yb. In terms of an electron-microprobe analysis, kainosite-(Y) is distinguishable in that it has higher Ca and lower Na than gerenite-(Y).

The bulk of the Be in the Strange Lake potential ore zone is present in a mineral (or minerals) of the datolite-gadolinite group. In transmitted light, this mineral is colorless or, more typically, has a characteristic slightly yellowish brown color. Habit is highly variable; the most readily recognized forms are spheres and radial aggregates, which have low birefringence and generally show an extinction cross under crossed nicols. The mineral also occurs as polycrystalline aggregates, and as slightly divergent sprays to partly rosette-like heterogeneous aggregates. Maximum sizes are commonly in the range 150–300  $\mu$ m, but uneven extinction is the rule, and optical uniformity is limited to areas 10–15  $\mu$ m across. Rarely, groups of prismatic to spear-shaped crystals up to 500  $\mu$ m long and 40  $\mu$ m wide are present. Some of the crystals are terminated

TABLE 3. ELECTRON-MICROPROBE COMPOSITIONS OF KAINOSITE-(Y) AND GADOLINITE-GROUP MINERAL

	kainosite-(Y)			gadolinite-group mineral					
	1	2	3	1	2	3	4	5	6
wt. %	1	2	3	1	2	3	4	5	6
Na <sub>2</sub> O	0.4	0.4	0.3	0.1	0.1	0.1	0.4	0.1	0.2
CaO	17.6	14.0	16.2	12.5	10.1	10.5	5.5	7.8	13.5
FeO	-	0.7	nd	1.0	1.8	2.4	0.6	1.2	4.1
MnO	0.1	nd	nd	0.5	0.5	0.5	0.4	0.3	0.4
Y <sub>2</sub> O <sub>3</sub>	26.3	21.8	22.6	18.7	18.8	16.9	10.5	19.8	14.4
La <sub>2</sub> O <sub>3</sub>	-	0.1	tr	0.7	1.2	1.5	2.7	1.3	1.5
Ce <sub>2</sub> O <sub>3</sub>	nd	0.4	0.2	1.6	3.0	3.7	11.1	3.1	3.9
Pr <sub>2</sub> O <sub>3</sub>	nd	-	-	0.20	0.39	0.47	1.68	0.45	0.49
Nd <sub>2</sub> O <sub>3</sub>	nd	nd	nd	0.8	1.6	1.9	8.2	2.1	2.0
Sm <sub>2</sub> O <sub>3</sub>	nd	0.1	0.1	0.3	0.7	1.0	3.6	1.8	0.6
Gd <sub>2</sub> O <sub>3</sub>	0.1	0.8	1.0	1.3	2.5	2.4	4.7	3.4	1.4
Tb <sub>2</sub> O <sub>3</sub>	0.07	0.29	0.32	0.35	0.56	0.51	0.61	0.70	0.30
Dy <sub>2</sub> O <sub>3</sub>	2.0	4.0	3.9	3.6	4.8	4.2	3.0	5.5	2.5
Ho <sub>2</sub> O <sub>3</sub>	0.71	1.45	1.38	1.12	1.27	1.11	0.64	1.45	0.78
Er <sub>2</sub> O <sub>3</sub>	3.3	7.0	6.4	4.5	4.4	3.8	1.8	5.0	3.2
Tm <sub>2</sub> O <sub>3</sub>	0.56	0.88	0.73	0.42	0.42	0.38	0.12	0.42	0.35
Yb <sub>2</sub> O <sub>3</sub>	3.8	4.4	3.3	1.6	1.6	1.5	0.3	1.4	1.5
Lu <sub>2</sub> O <sub>3</sub>	0.64	0.54	0.37	0.15	0.15	0.15	0.02	0.12	0.16
SiO <sub>2</sub>	35.1	33.8	34.4	30.6	29.4	30.8	27.8	29.6	32.3
BeO	-	-	-	12.73	12.24	12.83	11.58	12.33	13.46
SUM	90.68	90.66	91.20	92.77	95.43	96.65	95.25	97.87	97.04
[H <sub>2</sub> O]	-	-	-	7.23	4.57	3.35	4.75	2.13	2.96
				formula ratios					
Na	0.09	0.09	0.07	0.01	0.01	0.01	0.06	0.01	0.02
Ca	2.15	1.77	2.02	0.88	0.73	0.73	0.42	0.56	0.90
Fe	0.01	0.07	-	0.05	0.10	0.13	0.04	0.07	0.21
Mn	0.01	-	-	0.03	0.03	0.03	0.02	0.02	0.02
$\Sigma A$	2.25	1.94	2.08	0.97	0.87	0.90	0.54	0.66	1.15
Y	1.60	1.37	1.40	0.65	0.68	0.58	0.40	0.71	0.48
La	-	0.00	-	0.02	0.03	0.04	0.07	0.03	0.03
Ce	-	0.02	0.01	0.04	0.07	0.09	0.29	0.08	0.09
Pr	-	-	-	0.00	0.01	0.01	0.04	0.01	0.01
Nd	-	-	-	0.02	0.04	0.04	0.21	0.05	0.04
Sm	-	0.00	0.00	0.01	0.02	0.02	0.09	0.04	0.01
Gd	0.00	0.03	0.04	0.03	0.06	0.05	0.11	0.08	0.03
Tb	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Dy	0.07	0.15	0.15	0.08	0.11	0.09	0.07	0.12	0.05
Ho	0.03	0.05	0.05	0.02	0.03	0.02	0.01	0.03	0.02
Er	0.12	0.26	0.23	0.09	0.09	0.08	0.04	0.11	0.06
Tm	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01
Yb	0.13	0.16	0.12	0.03	0.03	0.03	0.01	0.03	0.03
Lu	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
$\Sigma B$	1.99	2.12	2.05	1.01	1.19	1.07	1.37	1.31	0.87
$\Sigma A+B$	4.24	4.03	4.13	1.98	2.06	1.97	1.91	1.97	2.02
Si	4.0	4.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0
Be <sub>2</sub> Be <sub>2</sub>	-	-	-	2.0	2.0	2.0	2.0	2.0	2.0
[H <sub>2</sub> O]	-	-	-	1.58	1.04	0.72	1.14	0.48	0.61

Kainosite-(Y): 1: coexisting with gerenite-(Y) of column 2, Table 1. Remainant is CO<sub>2</sub> and H<sub>2</sub>O. Ideal formula is Ca<sub>2</sub>(Y,REE)<sub>2</sub>Si<sub>2</sub>O<sub>8</sub>(CO<sub>3</sub>)<sub>2</sub>H<sub>2</sub>O.

Gadolinite-group mineral analyses: 1, fibrous host in Figure 3a; analyses 2 and 3, larger and smaller spheres, respectively in Figure 3a; analysis 4, average of two similar areas in Figure 3b; analyses 5 and 6 from areas in Figure 3c.

[H<sub>2</sub>O] by difference from 100%; BeO<sub>2</sub> by weight ratio with SiO<sub>2</sub>; italics: values estimated from chondrite-normalized REE spectra; nd: not detected; -: not reported.

sharply by a dome. Typically, however, the crystals lack uniformity and have an irregularly altered core as well as undulose extinction.

Electron-microprobe compositions of kainosite-(Y) and some of the gadolinite-like mineral illustrated in Figure 3 are given in Table 3. Although results on Ca and Y + REE in the gadolinite-like mineral are grouped separately, this partitioning results in low totals in the A site (e.g., columns 4 and 5) and high totals in the B site, suggesting that Ca, Y, and the REE are not exclusively in separate structural positions. The formula, therefore, is of the type (X)<sub>2</sub>Si<sub>2</sub>Be<sub>2</sub>(O,OH)<sub>10</sub>, where X is either Ca-dominant or Y-dominant; however, other analyses (Jambor 1990) have shown that compositions with a predominance of Ce + Nd and relatively low Ca + Y also occur. Within the gadolinite group, the Ce-dominant species lacking Fe is hingganite-(Ce), ideally Ce<sub>2</sub>Be<sub>2</sub>Si<sub>2</sub>O<sub>8</sub>(OH)<sub>2</sub>, and the Y-dominant species is hingganite-(Y), ideally Y<sub>2</sub>Be<sub>2</sub>Si<sub>2</sub>O<sub>8</sub>(OH)<sub>2</sub>. The Ca-dominant species at Strange Lake (Table 3) differs from

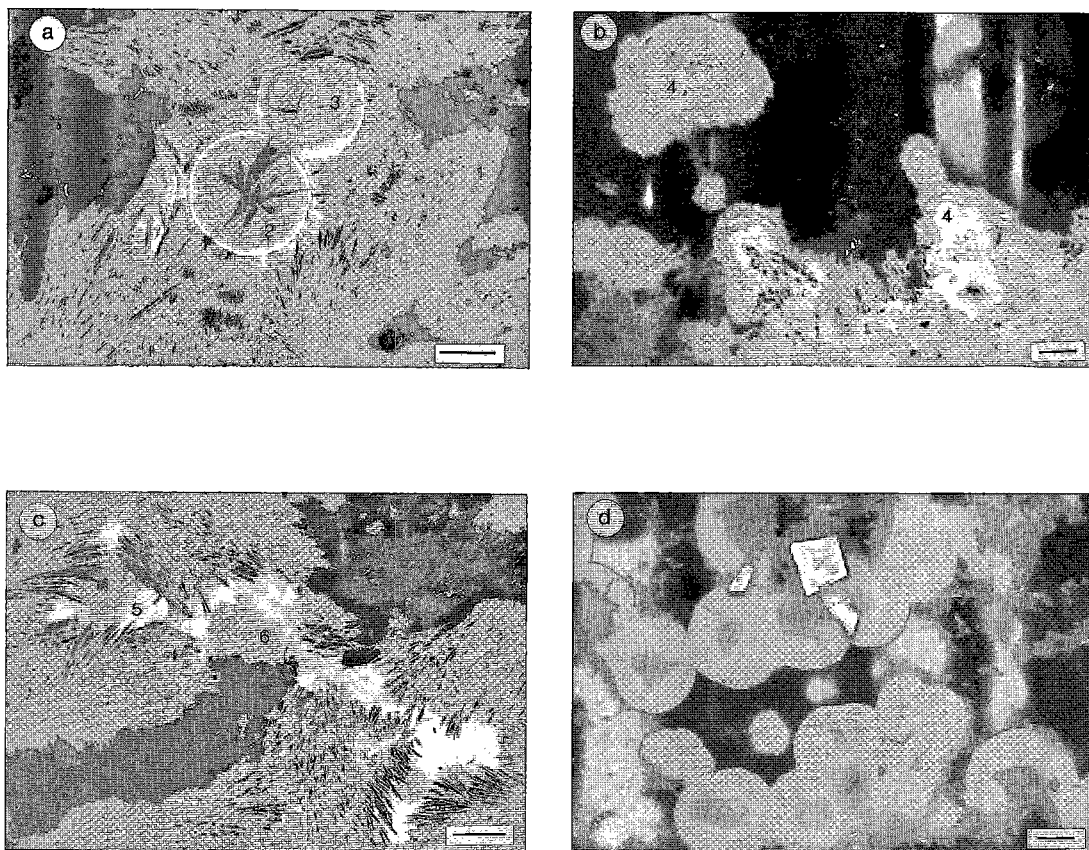


FIG. 3. Back-scattered-electron images of the gadolinite-type mineral from the Strange Lake complex. Numbers refer to analytical data reported in Table 3. (a) Fibrous (anal. 1) and zoned spheroidal (anal. 2, 3) habits, with anhedral fluorite (dark grey, almost black) to the left and right, and at the core of the larger sphere. (b) Well-zoned habit (anal. 4) in a matrix of quartz (black) and bulbous fluorite (far right, almost black). (c) Interstitial (anal. 5, 6) and fibrous habits; black fibers are Ca(Fe,Mn) silicate, dark grey anhedral mass extending from center to lower left is fluorite, and black mineral at top right is quartz. (d) Spherical habit, with composition similar to that of anal. 4, but with darker grey rims (bottom right) and centripetally replaced cores representing relative enrichment in Ca. White grains are pyrochlore, and black matrix is K-feldspar. Respective bar scales are 50, 10, 50, and 10  $\mu\text{m}$ .

minasgeraisite-(Y), the latter having  $(\text{Ca} + \text{Y}):\text{Si} = 3:2$ . The unapproved mineral "calcybeborosilite" (Rastsvetayeva *et al.* 1996, E.S. Grew in Jambor *et al.* 1996) corresponds to  $(\text{Ca}, \text{REE})_2(\text{Fe}, \text{Mn})_{0.30}(\text{B}_{0.5}\text{Be}_{0.5})\text{Si}_2\text{O}_8(\text{OH}, \text{O})_2$ , but B is an element not known to occur in significant amounts at Strange Lake. Gadolinite-group mineral UK48 from Mont Saint-Hilaire, Quebec (Chao *et al.* 1990) has the formula  $\text{CaY}_{2-x}(\text{Si}, \text{Be}, \text{B})_4(\text{O}, \text{OH})_{10} \cdot 2\text{H}_2\text{O}$ , which is closer to that of minasgeraisite-(Y) than that of the Strange Lake mineral. The Ca-dominant gadolinite-group mineral thus seems to be a new species, but complete structural characterization will be necessary

to demonstrate the mineral's uniqueness within the chemically complex gadolinite group.

Chondrite-normalized plots for the REE and Y in kainosite-(Y) and the gadolinite-group mineral are shown in Figure 4, and calculated values for non-determined REE are given in Tables 1 and 3. The apparent Y-anomaly increases in the order gerenite-(Y)  $\rightarrow$  kainosite-(Y)  $\rightarrow$  gadolinite-group mineral. Thus, Y behaves more like the HREE in gerenite-(Y), wherein the ratio of  $\text{HREE}/\text{REE}_{\text{total}}$  is highest; conversely, Y behaves more like the LREE in the gadolinite-group mineral, in which the relative proportion of LREE is highest.

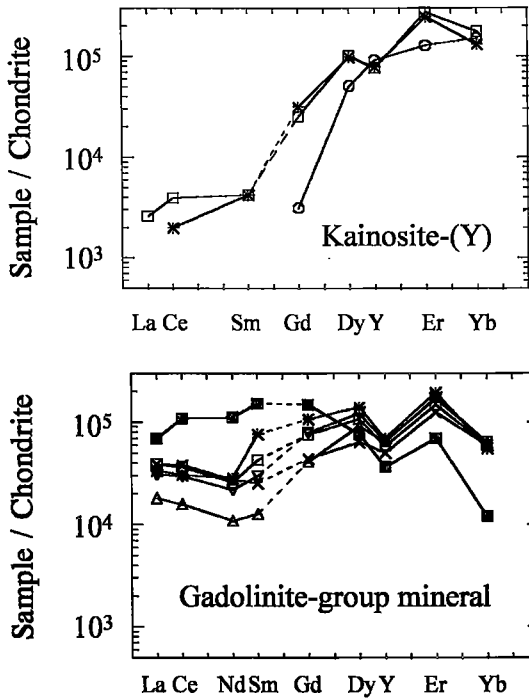


FIG. 4. Chondrite-normalized plots of concentrations of the rare-earth elements and yttrium in kainosite-(Y) and the gadolinite-group mineral, with Y inserted after Dy.

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