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MONTROYALITE, A NEW HYDRATED Sr–Al HYDROXYCARBONATE FROM THE FRANCON QUARRY, MONTREAL, QUEBEC

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Abstract

Montroyalite, ideally $Sr_4Al_8(CO_3)_3[(OH),F]_{26}{\bullet}10\text{–}11\ H_2O$, occurs as translucent white 1-mm-sized hemispheres in cavities in a silicocarbonatite sill exposed at the Francon quarry, Montreal, Quebec. Major associated minerals are: albite, quartz, strontiodresserite, calcite, dawsonite, ankerite and fluorite. Montroyalite hemispheres have a dull surface and a porcelaneous interior with a waxy lustre. Indistinct fibres radiate from the core and produce rough to botryoidal exterior surfaces. Individual grains are irregular to lath-shaped, up to 0.02 mm long and 0.005 mm thick. The mineral is brittle; it has a white streak, Mohs hardness of 3½, uneven to splintery fracture, no observable cleavage; it is soluble in 1:1 HCl at room temperature (20°C), and fluoresces white under both long- and short-wave ultraviolet light. D(meas.) 2.677 g/cm³. Montroyalite is biaxial negative, α 1.515(5), β 1.530(5), γ 1.545(5), $2V$(meas.) 80(10)°, $2V$(calc.) 89°; Y is parallel or nearly parallel to the elongation of the lath, and X and Z make angles of about 45° with the plane of the lath. Microprobe analyses and TGA/EGA give Al_2O_3 28.8, SrO 27.7, CaO 1.1, CO_2 9.2, H_2O 24.6, F 11.5, total 102.9, less O=F 4.84, total 98.06 weight %. The material is not suitable for X-ray single-crystal studies. The strongest eight lines in the powder pattern [d in Å(I)] are: 6.57(100), 4.00(50). 3.283(55), 3.190(50), 2.862(40), 2.551(40b), 2.481(40) and 2.356(45b). Transmission electron-microscopy reveals twin lamellae approximately 50 Å wide parallel to a net plane with translations of 7.14 and 6.55 Å and with an inter-row angle of approximately 77.5°. The new species is named after the Monteregian hill Mont Royal, a prominent landmark in Montreal, from which the name Montreal is itself derived.

Keywords: montroyalite, new mineral species, strontium aluminum hydroxycarbonate hydrate, Francon quarry, Montreal, Quebec, X-ray data, chemical composition, transmission electron-microscopy.

Sommaire

La montroyalite $Sr_4Al_8(CO_3)_3\ [(OH),F]_{26}{\bullet}10\text{–}11\ H_2O$ se présente en petits hémisphères (*ca.* 1 mm) blancs translucides, dans les cavités d'un filon-couche de silicocarbonatite à la carrière Francon, à Montréal, Québec. Parmi les minéraux qui lui sont associés, on note albite, quartz, strontiodresserite, calcite, dawsonite, ankerite et fluorine. Les hémisphères de montroyalite, ternes en surface, simulent dans leur intérieur une porcelaine à éclat cireux; leur texture, grossièrement fibroradiée, produit une surface rugueuse et botryoïdale. Les grains sont irréguliers ou en forme de lattes qui atteignent au plus 0.02 mm de long et 0.005 mm d'épaisseur. Propriétés observées: fragilité, trait blanc, dureté Mohs 3½, fracture en esquilles, clivage non observé, solubilité dans HCl 1:1 à température ordinaire, fluorescence, en blanc dans l'ultraviolet de longue ou courte longueur d'onde, densité (mes.) 2.677, optiquement biaxe négative, α 1.515(5), β 1.530(5), γ 1.545(5), $2\ V$ (mes.) 80(10)°, $2V$ 89° (calc.), orientation, Y parallèle (ou presque) à l'allongement de la latte, X et Z tous deux à environ 45° du plan de la latte. Les analyses à la microsonde électronique avec l'appoint d'une analyse thermogravimétrique et des gaz libérés donnent Al_2O_3 28.8, SrO 27.7, CaO 1.1, CO_2 9.2, H_2O 24.6, F 11.5, total 102.9, moins O=F 4.84, total 98.06% (en poids). Ce matériau ne se prête pas à l'étude d'un monocristal par diffraction X. Les huit raies les plus intenses du cliché de poudre [d en Å(I)] sont: 6.57(100), 4.00(50), 3.283(55), 3.190(50), 2.862(40), 2.551(40b), 2.481(40) et 2.356(45b). La microscopie électronique par transmission révèle des lamelles maclées, épaisses d'environ 50 Å. Elles sont parallèles à un plan réticulaire dans lequel on a déterminé deux translations du réseau, de 7.14 et 6.55 Å de longueur, faisant entre elles un angle d'environ 77.5°. Le nom de la nouvelle espèce, tout comme celui de Montréal, est tiré de celui de la colline montérégienne, le Mont Royal, qui domine la ville.

(Traduit par la Rédaction)

Mots-clés: montroyalite, nouvelle espèce minérale, hydroxycarbonate de strontium et d'aluminium, carrière Francon, Montréal, Québec, données aux rayons X, composition chimique, microscopie électronique par transmission.

INTRODUCTION

The silicocarbonatite sills that intrude Ordovician limestone at the Francon quarry, Montreal, Quebec, have yielded several new minerals since investigation of the unique mineral assemblage began in 1966. The new species are: weloganite (Sabina *et al.* 1968, Chen & Chao 1975, Grice & Perrault 1975), dresserite (Jambor *et al.* 1969), hydrodresserite (Jambor *et al.* 1977b, Szymański 1982), strontiodresserite (Jambor *et al.* 1977a, Roberts 1978), sabinaite (Jambor *et al.* 1980, Chao & Gu 1985), franconite (Jambor *et al.* 1984), doyleite (Chao *et al.* 1985) and hochelagaite (Jambor *et al.* 1986). Rare mineral species from the quarry previously reported in the literature include sodium-rich dachiardite (Bonardi *et al.* 1981) and viitaniemiite (Ramik *et al.* 1983). While on a routine visit to the quarry in 1982, one of us (APS) found yet another new species, a hydrous strontium aluminum carbonate. We name this mineral *montroyalite,* after Mont Royal, the name given by 16th century explorer Jacques Cartier to the Monteregian hill that is a prominent landmark in Montreal, and from which this city's name was derived.

The mineral and name have been approved by the Commission on New Minerals and Mineral Names, I.M.A. Type specimens are housed in the Systematic Reference Series of the National Mineral Collection at the Geological Survey of Canada, Ottawa, under catalogue numbers 64261 to 64265. All data, except for TEM and TGA/EGA studies, were collected using material from the holotype specimen, number 64261. In addition, about 45 other montroyalite-bearing specimens, containing a total of approximately 5–10 mg of the mineral, are entered in the mineral collection at the Geological Survey of Canada.

OCCURRENCE AND ASSOCIATED MINERALS

Montroyalite is one of about 70 minerals (Sabina 1979) occurring within cavities in dawsonite-bearing zirconium- and niobium-rich (Steacy & Jambor 1969, Jambor *et al.* 1976) silicocarbonatite sills that intrude Ordovician limestone at the Francon quarry. Montroyalite is localized in a zone of the sill exposed along the west wall of the upper level of the quarry, an area commonly referred to as the 'alcove'. The cavities in which the mineral occurs are irregularly shaped, up to 10 cm long, and are lined with albite plates, and less commonly with colorless drusy quartz. On this lining, montroyalite occurs as polycrystalline hemispheres or aggregates of hemispheres in association with strontiodresserite and crystals of calcite, quartz, dawsonite, ankerite and fluorite. Barite, strontianite, smythite, marcasite and pyrite are also present. Halloysite commonly coats these minerals or forms loose to semicompact masses over them and amongst their interstices. Doyleite is associated with the halloysite.

PHYSICAL AND OPTICAL PROPERTIES

Montroyalite occurs as white translucent hemispheres up to 1 mm in diameter. It may have a bluish or greyish cast imparted by included marcasite. The hemispheres have a dull lustre and are commonly flattened, elongated or distorted. Cross-sections exhibit a compact porcelaneous interior with waxy lustre, from which a rim of indistinct fibres radiates to produce a bumpy to botryoidal surface. Most individual grains are irregular, but some are lens-shaped and up to 0.02 mm long and 0.005 mm thick. The mineral is brittle, has a white streak, uneven to splintery fracture, and a Mohs hardness of 3½ as determined by abrasion against micromounts of standard minerals. The specific gravity measured in heavy liquids is 2.677(3) g/cm^3. Montroyalite is soluble in 1:1 HCl at room temperature and fluoresces white under short- and long-wave ultraviolet light. No cleavage was observed.

Optical properties were determined on grain edges of crystal aggregates set on the universal and spindle stages. Montroyalite is biaxial negative with α 1.515(5), β 1.530(5), γ 1.545(5), $2V$(meas.) 80(10)°; $2V$(calc)89° in white light. Y is parallel or nearly parallel to the elongation of lath-like grains, and X and Z are at angles of about 45° to the plane of the lath. No dispersion of the optical axis was observed.

CHEMISTRY

Montroyalite was analyzed using a Materials Analysis Company (MAC) electron-microprobe equipped with a KEVEX energy-dispersion spectrometer. Accelerating voltage was 20 kV with a sample current of 10 nA as measured on kaersutite. To minimize sample degradation and compositional change due to electron bombardment, a slightly defocused beam was used over a counting time of 100 seconds. An energy-dispersion scan on a hand-picked cluster of hemispheres indicated that Al, Sr and Ca are the only elements present with atomic number greater than 10. Subsequent energy-dispersion analyses were made using kaersutite (for Al), strontianite (for Sr) and calcite (for Ca) as standards. Analytical data were processed using a modified version of the EMPADR VII electron-microprobe data-reduction program of Rucklidge & Gasparrini (1969). Fluorine was determined quantitatively by CAMECA electron-microprobe at CANMET (Physical Metallurgy Research Laboratories) using natural fluorite as a standard. TGA/EGA (Evolved Gas Analysis) determinations for H_2O and CO_2 were made on 5.1 mg of sample using the Mettler thermal analyzer and integrated mass-spectrometer at the

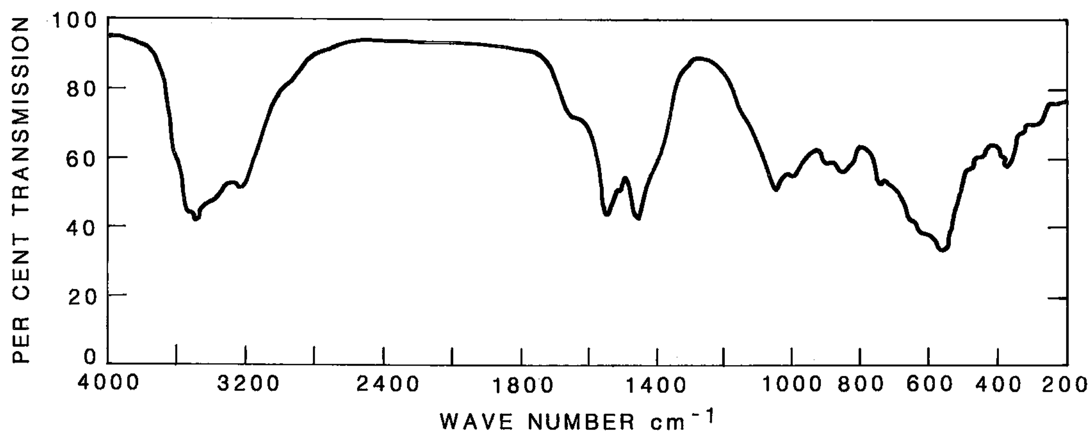

FIG. 1. Infrared-absorption spectrum for montroyalite.

Royal Ontario Museum. Two major H_2O peaks occur at 205° and 300°C followed by a CO_2 peak at 505°C. The end product of the TGA/EGA run (to 1540°C) was found by X-ray powder-diffraction to consist principally of $SrAl_2O_4$ (PDF 9–39). Nine additional powder-diffraction lines, grading from medium to very weak intensity, remain unindexed following a search of the PDF inorganic file. An infrared-absorption analysis (Fig. 1) shows the presence of H_2O, OH and CO_2 vibration bands.

Combined analytical results gave Al_2O_3 28.8, SrO 27.7, CaO 1.1, CO_2 9.2, H_2O 24.6, F 11.5, total 102.9, less O = F 4.84, total 98.06 weight %. Assuming 8 Al atoms, the empirical formula for montroyalite is $(Sr_{3.78}Ca_{0.28})_{\Sigma 4.06}Al_8(CO_3)_{2.96}$ $[(OH)_{17.63}F_{8.57}]_{\Sigma 26.20}\cdot$ 10.52 H_2O. The ideal formula is considered to be $Sr_4Al_8(CO_3)_3[(OH)_{17.5}F_{8.5}]_{\Sigma 26}\cdot nH_2O$, where n = 10 or 11.

Calculations using the Gladstone–Dale relationship yield $K_P = 0.199$ and $K_C = 0.205$ for the analytical formula using constants reported by Mandarino (1981); hence $1-(K_P/K_C)$ is 0.0293, indicating excellent compatibility (Mandarino 1979).

X-RAY- AND ELECTRON-DIFFRACTION RESULTS

Repeated attempts to obtain single-crystal X-ray precession photographs showed that even extremely small fragments of montroyalite are complexly twinned and are composed of multiple crystallites. Specimens for examination by transmission electron-microscopy (TEM) were prepared by crushing montroyalite hemispheres with a few drops of n-butanol in an agate mortar and dispersing the fragments on a copper grid. Montroyalite fragments were located by energy-dispersion analysis obtained with a Tracor Northern energy-dispersion analyzer. Imaging and electron-diffraction studies were performed with a JEOL 200CX transmission electron-microscope operated at 200 kV. Montroyalite was stable in the beam for up to 1 hour. Individual crystallites measuring up to 0.5 μm were found to be common. They are invariably polysynthetically twinned; TEM photomicrographs show fine lamellae that are approximately 50 Å thick. A thorough TEM electron-diffraction study resulted in the location of one zone that has axial translations of 7.14 and 6.55 Å and an interaxial angle of approximately 77.5°. This net will satisfactorily index 14 of the 58 X-ray powder-diffraction lines presented in Table 1. Additional electron-diffraction photographs support our contention that montroyalite is probably triclinic, but a third axis was not located.

Unit-cell calculations based on the powder-diffraction data were not successful, but according to R.L. Snyder (written comm. 1984), computational tests for symmetry higher than triclinic proved totally negative. The powder pattern superficially resembles that of triclinic alumohydrocalcite (Roberts & Bonardi 1983), especially for some of the higher and stronger *d*-values, but the overall powder-pattern, measured specific gravity and chemical formula are completely unlike those for alumohydrocalcite or any other known mineral. This is the second recognized strontium - aluminum - carbonate - hydroxyl - hydrate mineral, the first being strontiodresserite (Jambor *et al.* 1977a, Roberts 1978).

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TABLE 1. X-RAY POWDER DATA FOR MONTROYALITE

I est.	dÅ meas.	*I* est.	dÅ meas.
10	7.16	15	2.850
100	6.57	3	2.792
25	6.39	20	2.751
5	5.70	3	2.654
25	5.52	15	2.629
20	4.37	40b	2.551
5	4.22	40	2.481
3	4.13	35b	2.429
15	4.04	10	2.382
50	4.00	45b	2.356
35	3.82	15b	2.298
35	3.58	5	2.284
3	3.53	5	2.278
15	3.49	10	2.253
3	3.43	15b	2.238
3	3.37	5b	2.209
3	3.33	35	2.185
55	3.283	25	2.174
3	3.258	5	2.159
20	3.216	3	2.131
50	3.190	3b	2.120
3	3.100	20b	2.107
5	3.067	3	2.099
3	3.032	3	2.092
5	3.013	35	2.067
3	2.943	5	2.059
3	2.908	5	2.041
40	2.862	3	2.034
		3	2.028
		10	1.999

- Guinier-DeWolff camera employing Co radiation and Fe filter (λ CoK α_1 = 1.78892Å)
- b = broad line
- NBS spinel used as internal standard

Snyder, Alfred University, for computational unit-cell determinations. Collection of material from the Francon quarry was made possible by the generous co-operation of Francon, Division of Canfarge Ltd. We thank Robert F. Martin, George Y. Chao and an anonymous referee for critical readings of the manuscript.

References

Bonardi, M., Roberts, A.C., Sabina, A.P. & Chao, G.Y. (1981): Sodium-rich dachiardite from the Francon quarry, Montreal Island, Quebec. *Can. Mineral.* **19**, 285-289.

Chao, G.Y., Baker, J., Sabina, A.P. & Roberts, A.C. (1985): Doyleite, a new polymorph of $Al(OH)_3$, and its relationship to bayerite, gibbsite and nordstrandite. *Can. Mineral.* **23**, 21-28.

______ & Gu, Jiexiang (1985): Sabinaite: a new occurrence and new data. *Can. Mineral.* **23**, 17-19.

Chen, T.T. & Chao, G.Y. (1975): X-ray crystallography of weloganite. *Can. Mineral.* **13**, 22-26.

Grice, J.D. & Perrault, G. (1975): The crystal structure of triclinic weloganite. *Can. Mineral.* **13**, 209-216.

Jambor, J.L., Fong, D.G. & Sabina, A.P. (1969): Dresserite, the new barium analogue of dundasite. *Can. Mineral.* **10**, 84-89.

______, Plant, A.G. & Steacy, H.R. (1976): A dawsonite-bearing silicocarbonatite sill from Montreal Island, Quebec. *Geol. Surv. Can. Pap.* **76-1B**, 357-362.

______, Sabina, A.P., Roberts, A.C., Bonardi, M., Owens, D.R. & Sturman, B.D. (1986): Hochelagaite, a new calcium-niobium oxide mineral from Montreal, Quebec. *Can. Mineral.* **24**, 449-453.

______, ______, ______, ______, Ramik, R.A. & Sturman, B.D. (1984): Franconite, a new hydrated Na-Nb oxide mineral from Montreal Island, Quebec. *Can. Mineral.* **22**, 239-243.

______, ______, ______ & Sturman, B.D. (1977a): Strontiodresserite, a new Sr-Al carbonate from Montreal Island, Quebec. *Can. Mineral.* **15**, 405-407.

______, ______ & Sturman, B.D. (1977b): Hydrodresserite, a new Ba-Al carbonate from a silicocarbonatite sill, Montreal Island, Quebec. *Can. Mineral.* **15**, 399-404.

______, Sturman, B.D. & Weatherly, G.C. (1980): Sabinaite, a new anhydrous zirconium-bearing carbonate mineral from Montreal Island, Quebec. *Can. Mineral.* **18**, 25-29.

Mandarino, J.A. (1979): The Gladstone-Dale relationship. III. Some general applications. *Can. Mineral.* **17**, 71-76.

______ (1981): The Gladstone-Dale relationship. IV. The compatibility concept and its application. *Can. Mineral.* **19**, 441-450.

Ramik, R.A., Sturman, B.D., Roberts, A.C. & Dunn, P.J. (1983): Viitaniemiite from the Francon quarry, Montreal, Quebec. *Can. Mineral.* **21**, 499-502.

Roberts, A.C. (1978): The space group of strontiodresserite. *Geol. Surv. Can. Paper* **78-1B**, 180.

______ & Bonardi, M. (1983): The X-ray crystallography of a chromian alumohydrocalcite from the Akenobe mine, Hyogo Prefecture, Japan. *Geol. Surv. Can. Pap.* **83-1A**, 477-479.

RUCKLIDGE, J. & GASPARRINI, E.L. (1969): EMPADR VII: Specifications of a computer program for processing electron microprobe analytical data. *Dep. Geol., Univ. Toronto, Toronto, Ont.*

SABINA, A.P. (1979): Minerals of the Francon quarry, (Montreal Island): a progress report. *Geol. Surv. Can. Pap.* **79-1A**, 115-120.

———, JAMBOR, J.L. & PLANT, A.G. (1968): Weloganite, a new strontium–zirconium carbonate from Montreal Island, Canada. *Can. Mineral.* **9**, 468-477.

STEACY, H.R. & JAMBOR, J.L. (1969): Nature, distribution and content of zirconium and niobium in a silico-carbonatite sill at St-Michel, Montreal Island, Quebec. *Geol. Surv. Can. Pap.* **69-20**.

SZYMAŃSKI, J.T. (1982): The crystal structure of hydrodresserite, $BaAl_2(CO_3)_2(OH)_4 \cdot 3H_2O$. *Can. Mineral.* **20**, 253-262.

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