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SODIUM-RICH DACHIARDITE FROM THE FRANCON QUARRY, MONTREAL ISLAND, QUEBEC

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ABSTRACT

Sodium-rich dachiardite was found in a silicocarbonatite sill exposed in the lower level of the Francon quarry, St-Michel, Montreal Island, Quebec. It occurs as white acicular crystals, monoclinic, elongated [010], forming parallel and divergent aggregates 1 to 2 mm in length. It has a white streak, silky lustre along the cleavage, hardness 4½ and perfect cleavage in two directions parallel to the length of the fibres. Optically transparent, it is biaxial negative, length-fast, with indices of refraction 1.471(1) || *b*, 1.475(1) ~ || *a* and 1.476(1) and a measured $2V$ of 52°. The dispersion is $r < v$ moderate, $Z \wedge c \simeq \beta - 90° \simeq 18°$. The measured specific gravity is 2.14(1). The cell parameters are *a* 18.67(1), *b* 7.488(4), *c* 10.282(6) Å, β 108.74(8)°, V 1361.2 Å^3, and the space group is $C2/m$ (No. 12). Electron-microprobe analyses show that, as to sodium content, the Francon dachiardite compares with that from Tsugawa, Japan. The chemical formula calculated on the basis of 48 oxygen atoms is $(Na_{2.93}K_{0.36}Sr_{0.01}Ca_{0.01})_{\Sigma 3.31}(Si_{20.47}Al_{3.59})_{\Sigma 24.06}O_{48}\cdot 12.43\ H_2O$. With $Z = 1$, the calculated density based on the analytical formula is 2.140 g/cm^3.

Keywords: sodium-rich dachiardite, Francon quarry, Montreal Island, Quebec, zeolite, mineralogical description, electron-microprobe analysis, X-ray diffraction, optical properties.

SOMMAIRE

On a trouvé une dachiardite riche en sodium dans un sill de silicocarbonatite qui affleure au niveau inférieur de la carrière Francon à St-Michel (île de Montréal, Québec). Ses cristaux blancs, aciculaires monocliniques allongés selon [010], forment des agrégats parallèles ou divergents de 1 à 2 mm de longueur. Elle a une rayure blanche, un éclat soyeux sur le clivage, qui est parfait en deux directions parallèles à l'axe de la fibre, et une dureté de 4½. Optiquement transparente, elle est biaxe négative, à allongement négatif, indices de réfraction 1.471(1) || *b*, 1.475(1) ~ || *a*, 1.476(1); $2V = 52°$; dispersion modérée $r < v$. La densité mesurée est de 2.14(1). Les paramètres reticulaires sont: *a* 18.67(1), *b* 7.488(4), *c* 10.282(6) Å, β 108.74(8)°, $V = 1361.2$ Å^3 et le groupe spatial est $C2/m$. D'après les analyses à la microsonde électronique, cette dachiardite ressemble, dans sa teneur en sodium, à celle de Tsugawa (Japon). La formule chimique empirique, $(Na_{2.93}K_{0.36}Sr_{0.01}Ca_{0.01})_{\Sigma 3.31}(Si_{20.47}Al_{3.59})_{\Sigma 24.06}O_{48}\cdot 12.43\ H_2O$ (O = 48), donne 2.140 pour la densité calculée (à une molécule par maille).

(Traduit par la Rédaction)

Mots-clés: dachiardite sodique, carrière Francon, île de Montréal, Québec, zéolite, description minéralogique, analyse à la microsonde électronique, diffraction X, propriétés optiques.

INTRODUCTION

Dachiardite is a rare silica-rich zeolite of the mordenite group. It was first described by D'Achiardi (1906) from a pegmatite dyke (Filone della Speranza) at San Piero in Campo, Elba, Italy, where it occurs in a hydrothermally altered zone with pink elbaite, pollucite, petalite and mordenite. A sodium-rich dachiardite was first reported by Alberti (1975) in a porphyry from Alpe di Siusi, Italy. Wise & Tschernich (1978) reported occurrences of dachiardite at Altoona, Washington, and at Cape Lookout and Agate Beach, Oregon, U.S.A. The dachiardite from the Altoona locality is characterized by a composition that is alkali-rich at the base of the crystal cluster, becoming increasingly Ca-rich towards the ends of the blades. Subsequently, Yoshimura & Wakabayashi (1977) found a "Na-dachiardite" from Tsugawa district, Niigata prefecture, Japan. More recently, Nishido *et al.* (1979) reported a new occurrence of a sodium-rich dachiardite in amygdules in andesite pillow lava from Chichijima, the Ogasawara Islands, Japan.

This paper describes the first documented occurrence of sodium-rich dachiardite in Canada, at the Francon quarry, St-Michel, Montreal Island, Quebec, where it occurs in a dawsonite-bearing silicocarbonatite sill. The mineralogy of the sill is varied, with more than 60 mineral

species reported to date, several of which are unique to the locality (Sabina 1979). The original specimen is preserved in the National Mineral Collection of the Geological Survey of Canada, Ottawa, under catalogue number 14771.

Occurrence

Specimens of Francon dachiardite were collected in 1974 by Dr. Donald Doell, from a pocket of friable sill rock measuring about 23

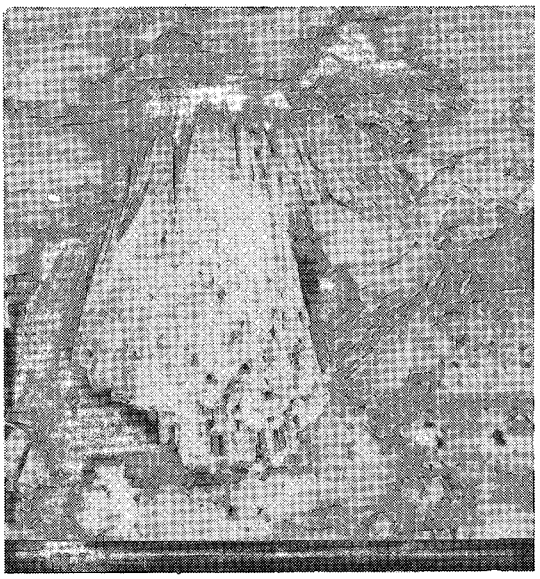

FIG. 1. Scanning-electron microscope (SEM) photomicrograph of a divergent bundle of sodium-rich dachiardite crystals.

FIG. 3. SEM photomicrograph showing slightly divergent growth of crystals of sodium-rich dachiardite and crystalline aggregates of ankerite.

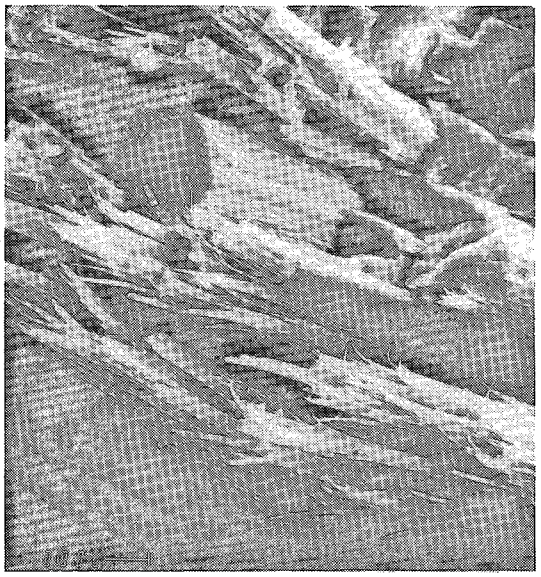

FIG. 2. SEM photomicrograph illustrating terminations of sodium-rich dachiardite blades and fibres.

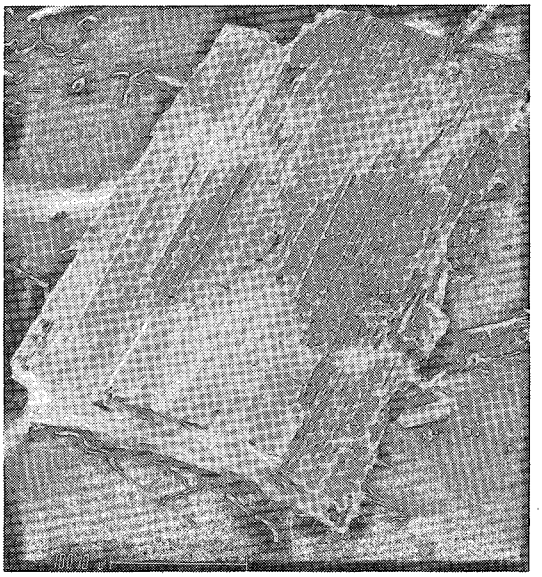

FIG. 4. SEM photomicrograph of hourglass structure of sodium-rich dachiardite.

cm in diameter, exposed along the north wall in the lower level of the quarry. Dr. Doell observed that the dachiardite-bearing rock separated into platy fragments that were lined with sodium-rich dachiardite and its associated minerals. The dachiardite was localized in one pocket and has not been recognized in subsequent quarry operations. It is associated with yellowish white crystalline aggregates of ankerite, light yellow, cone-shaped and ellipsoidal calcite, white transparent, sheaf-like and leaf-shaped quartz, yellow weloganite and white matted fibres of mordenite. These minerals occur on finely crystalline, colorless to slightly brownish analcime that forms a lining on the rock. Mordenite occupies spaces between the dachiardite tufts and occurs as isolated mounds on the analcime lining. Colorless transparent plates of albite protrude from the analcime but are relatively rare. The analcime also contains inclusions of acicular acmite.

Physical and Optical Properties

The mineral occurs as silky white acicular crystals, forming parallel and divergent fibrous bundles of tiny brittle blades, 1 to 2 mm in length (Figs. 1, 2 and 3). Less commonly, it exhibits an hourglass structure (Fig. 4). The measured specific gravity, determined in heavy liquids, is 2.14(1). Individual crystals are colorless and the aggregates are white. Crystals are elongated [010]. Cleavage is perfect in two directions parallel to the length of the fibres. The mineral has a white streak, a silky lustre along the cleavage and a vitreous to greasy lustre in cross-section, an uneven fracture and a Mohs hardness of about 4½. The sodium-rich dachiardite from the Francon quarry does not fluoresce in either long- or short-wave ultraviolet radiation. It is optically biaxial negative, length-fast, with a measured $2V$ of 52° and $r < v$ moderate. The measured indices of refraction

TABLE 1. CHEMICAL COMPOSITION OF SODIUM-RICH DACHIARDITE AND DACHIARDITE

	Francon quarry Average of 6 selected electron microprobe analyses (EDA) wt.%	Altoona Wise & Tschernich (1978)+ wt.%	Tsugawa Yoshimura & Wakabayashi (1977) wt.%	Alpe di Siusi Alberti (1975) wt.%	Elba Bonardi (1979) wt.%
SiO_2	70.10	72.57	67.38	65.72	63.20
Al_2O_3	10.44	10.12	12.65	12.15	14.31
Fe_2O_3	-	0.08	0.27	0.50	-
MgO	-	-	0.03	0.08	-
CaO	0.02	0.29	0.51	1.65	5.49
SrO	0.07*	-	-	0.01	0.13
BaO	-	-	0.13	0.06	-
Cs_2O	-	-	-	-	0.96
Na_2O	5.18	4.99	5.15	4.47	1.20
K_2O	0.98	1.66	0.97	1.87	1.92
H_2O (110°C)			1.58		
H_2O (400°C)	12.76**		9.85	12.91	13.50
H_2O (1000°C)			1.48		
Total	99.55***	89.71++	100.00	100.01	87.21++
	Cell content based on 48 oxygens				
Si	20.47	20.57	19.76	19.61	18.93
Al	3.59	3.38	4.37	4.27	5.05
Fe	-	0.02	0.06	0.11	-
Mg	-	-	0.01	0.04	-
Ca	0.01	0.09	0.16	0.53	1.76
Sr	0.01	-	-	-	0.02
Ba	-	-	-	-	-
Cs	-	-	-	-	0.12
Na	2.93	2.74	2.93	2.59	0.70
K	0.36	0.60	0.36	0.71	0.73
Si+Al	24.06	23.95	24.13	23.88	23.98
Error[x]	7.8	-3.4	20.7	1.8	-3.4
Si/Al	5.70	6.09	4.52	4.59	3.75

* From wavelength-dispersive analysis
** Determined by DTA/TGA
*** Mg, Ti, Cr, Mn, Fe and Ba were searched for but not detected

x Error = Balance Error $E = \dfrac{Al(+Fe^{3+}) - Al_{theor.}}{Al_{theor.}} \times 100$ (Passaglia 1970)

\+ Analysis of the base of the crystal cluster.
++ Remainder is H_2O

are α 1.471(1), β 1.475(1), γ 1.476(1). The orientation of the indicatrix with respect to the crystallographic axes is $X = b$, $Y \simeq a$, $Z \wedge c \simeq \beta - 90°$ or 18°. The optical properties were obtained from crystal fragments that were previously oriented on a precession single-crystal camera using a spindle stage and sodium light. All index-of-refraction liquids were checked using an Abbé refractometer. The twinning, as evidenced in X-ray single-crystal precession photographs, may be explained by proposing (001) as the twin plane or (100) as the twin axis of 180° rotation. Because crystallographic a is parallel to optical Y within the error of measurement, the twinning is not observable under the polarizing microscope but can only be shown by single-crystal X-ray examination. The Gladstone–Dale constant K_C (Mandarino 1976), calculated from the chemical composition given in Table 1, is 0.2227. This compares very favorably with $K_P = 0.2215$, calculated from the measured density and indices of refraction. The relationship $1-K_P/K_C$ (Mandarino 1979) indicates superior compatibility of the data.

Chemical Composition

Several hand-picked acicular crystals of sodium-rich dachiardite were mounted in cold-setting Epoxy (Buehler Epo-Kwick) and polished to yield a smooth surface. The samples were vacuum-coated with a layer of carbon a few hundred Ångstrom units thick in order to make them conductive. The chemical composition of Francon dachiardite was determined by energy-dispersion analysis (EDA) and wavelength-dispersion analysis (WDA), using a Material Analysis Company (MAC) electron microprobe, operated at 20 kV accelerating voltage and a counting time of 100 seconds. To minimize the effects of compositional changes due to electron bombardment and high vacuum, a defocused beam was utilized. Specimen current was 10 nA (40 nA for WDA) measured on a kaersutite standard.

Specimens were analyzed by EDA for the elements Si, Al, Ca, Mg, Na and K using the following standards: albite (Na, Al, Si), kaersutite (Mg, Ca) and orthoclase (K). For these analyses, a computer program developed by Plant & Lachance (1973) was used to convert energy-dispersion spectra into weight percentages of oxide. In addition, Sr was determined by WDA using a synthetic plagioclase standard containing 1.60% Sr. The raw data were processed using a modified version of the EMPADR computer program of Rucklidge & Gasparrini (1969). DTA/TGA analysis, performed with a Mettler thermoanalyzer on 11.844 mg of material, gave a total H_2O loss of 12.76%.

The electron-microprobe study of several crystals indicates that (1) the Francon sodium-rich dachiardite is compositionally homogeneous, and (2) it shows very little variability from the base to the tip and from the core to the edge of the crystals. The average of 6 selected EDA analyses of the Francon dachiardite is compared in Table 1 with analyses of this species from other localities. An electron-microprobe analysis of the type dachiardite from Elba by Bonardi (1979) essentially confirmed the composition determined by Gottardi (1960) except for the presence of Cs_2O. The Francon sodium-rich dachiardite is characterized by a higher Si/Al ratio (5.70) and a higher Na content (5.18% Na_2O) than the type material from Elba. It is very similar in chemical composition to the Tsugawa material. The chemical formula, calculated on the basis of 48 oxygen atoms, is $(Na_{2.93}K_{0.36}Sr_{0.01}Ca_{0.01})_{\Sigma 3.31}(Si_{20.47}Al_{3.59})_{\Sigma 24.06}O_{48}$ • 12.43 H_2O.

X-Ray-Diffraction Investigation

The X-ray powder pattern of Francon dachiardite, presented in Table 2, shows very similar d values to the pattern of Tsugawa (Yoshimura & Wakabayashi 1977) and Elba

TABLE 2. X-RAY POWDER DATA FOR SODIUM-RICH DACHIARDITE, FRANCON

$I_{est.}$	dÅmeas.	dÅcalc.	hkl	$I_{est.}$	dÅmeas.	dÅcalc.	hkl
40	9.75	9.74	001	3	2.599	2.599	421
80	8.88	8.84	200			2.598	601
3	7.91	7.93	201	5	2.568	2.568	204
80	6.92	6.90	110	20	2.528	2.526	223
30	5.96	5.99	111	10	2.499	2.498	404
3	5.28	5.32	111	10	2.468	2.471	130
5	4.99	5.00	202			2.465	712
60	4.86	4.87	002	5	2.445	2.452	023
5	4.60	4.62	401	3	2.434	2.434	004
5	4.42	4.42	400	5	2.385	2.389	313
50	3.94	3.97	402	3b	2.325	2.332	622
3	3.85	3.88	312			2.322	801
		3.82	311	5b	2.271	2.268	604
70	3.75	3.74	020	3	2.250	2.245	132
10	3.60	3.61	401	10b	2.095		
20	3.50	3.50	021	3	2.047		
100	3.45	3.45	220	5	2.031		
60	3.38	3.39	221	3	2.016		
30	3.34	3.34	511	20b	2.010		
10	3.24	3.24	003	3	1.990		
60	3.20	3.20	510	10b	1.977		
3	3.13	3.14	403	10b	1.961		
		3.13	221	3	1.933		
5	3.10	3.11	601	3	1.921		
		3.09	113	3	1.912		
10	3.05	3.04	313	5	1.904		
3	3.01	3.00	312	3	1.895		
30	2.978	2.980	602	60	1.871		
40	2.964	2.968	022	40	1.864		
3	2.944	2.946	600	20	1.844		
50	2.859	2.857	420	10b	1.831		
3	2.769	2.772	203	20	1.814		
10	2.723	2.723	422	3	1.786		
20	2.711	2.704	513	10	1.770		
20	2.658	2.661	222	20	1.762		
30	2.644	2.645	603				

Guinier-Hägg camera, Cu$K\alpha_1$ radiation, b=broad line, intensities estimated visually
Indexed with a=18.67, b=7.488, c=10.282Å, β=108.74°

(Galli 1965) dachiardites, differing only in relative intensities of some reflections. The intensity variations may be due to the different methods of recording, to preferred orientation or to differences in chemical composition.

Numerous extremely small acicular fibres of Francon sodium-rich dachiardite were examined on the precession camera, but none proved suitable for detailed single-crystal examination. The crystals are invariably twinned, and many proved to be multiples in parallel orientation. Thus the X-ray powder pattern was indexed by comparison with the data reported by Galli (1965). Eighteen lines between 5.96 and 2.499 Å, for which unambiguous indexing was possible, were used in the unit-cell refinement. The calculated cell parameters are a 18.67(1), b 7.488(4), c 10.282(6) Å, β 108.74(8)° and V 1361.2 Å^3. The space group is $C2/m$ (12) by analogy with dachiardite from Elba (Galli 1965). With $Z = 1$, the calculated density is 2.140 g/cm^3, which is identical with the measured specific gravity.

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