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# VIITANIEMIITE FROM THE FRANCON QUARRY, MONTREAL, QUEBEC

ROBERT A. RAMIK AND B. DARKO STURMAN

*Department of Mineralogy and Geology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6*

ANDREW C. ROBERTS

*Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8*

PETE J. DUNN

*Department of Mineral Sciences, Smithsonian Institution, Washington, D.C. 20560, U.S.A.*

## Abstract

The rare mineral viitaniemiite, $NaCaAl(PO_4)(F,OH)_3$, occurs at the Francon quarry, St-Michel district, Montreal, Quebec, within cavities of a silicocarbonatite sill. The mineral is monoclinic, $P2_1$ or $P2_1/m$, $a$ 6.865(2), $b$ 7.225(2), $c$ 5.522(1) Å, $\beta$ 109°00(2)′. Electron-microprobe analyses gave: $Na_2O$ 11.4, $Al_2O_3$ 23.4, CaO 22.3, MgO 0.1, $P_2O_5$ 28.1, F 14.5%. Unlike type viitaniemiite from the Viitaniemi pegmatite in Finland, this material is Mn-free. Crystals are elongated [010] and flattened (100), and show pervasive twinning on (100). The optical properties are: $\alpha$ 1.532(2), $\beta$ 1.544(2), $\gamma$ 1.551(2), $2V_x$ 75(2)°, with $b \parallel Y$ and $c \Lambda X$ = 24(1)° in the obtuse angle between $a$ and $c$. The density was determined to be 3.06(1) g/cm³.

*Keywords:* viitaniemiite, phosphate, Francon quarry, Quebec, mineral data.

## Sommaire

On a trouvé la viitaniémiite, espèce minérale rare, de composition $NaCaAl(PO_4)(F,OH)_3$, dans les cavités d'un sill de silicocarbonatite de la carrière Francon, au quartier St-Michel, à Montréal (Québec). Monoclinique, $P2_1$ ou $P2_1/m$, $a$ 6.865(2), $b$ 7.225(2), $c$ 5.522(1) Å, $\beta$ 109°00(2)′. Les analyses à la microsonde électronique ont donné $Na_2O$ 11.4, $Al_2O_3$ 23.4, CaO 22.3, MgO 0.1, $P_2O_5$ 28.1, F 14.5%. Contrairement à la viitaniémiite qu'on trouve dans la pegmatite de Viitaniemi (à la localité type, en Finlande), notre échantillon ne contient pas de manganèse. Les cristaux, qui sont allongés suivant [010] et aplatis sur (100), montrent généralement une macle sur (100). Propriétés optiques: $\alpha$ 1.532(2), $\beta$ 1.544(2), $\gamma$ 1.551(2), $2V_x$ 75(2)°, $b \parallel Y$, $c \Lambda X$ = 24(1)° dans l'angle obtus entre $a$ et $c$. La densité mesurée est de 3.06(1) g/cm³.

(Traduit par la Rédaction)

*Mots-clés:* viitaniémiite, phosphate, carrière Francon, Québec, données minéralogiques.

## Introduction

The Francon quarry in the St-Michel district of Montreal, Quebec, has gained prominence for its unusual mineralogy. Sabina (1979) provided brief descriptions of the numerous minerals found at the quarry and compiled a comprehensive bibliography. Recently, sabinaite, a Na–Zr–Ti oxycarbonate, was characterized by Jambor *et al.* (1980). Several other species are unique to the locality: weloganite, dresserite, hydrodresserite and strontiodresserite. This paper reports the first Canadian occurrence of viitaniemiite, and compares it to the type material from the Viitaniemi pegmatite in the Eräjärvi area, Finland.

An examination of two specimens, collected at the Francon quarry in 1976, revealed microscopic crystals of a habit atypical of any mineral then known from the quarry. During initial study of the mineral, we found similarities in the X-ray powder pattern and chemical data with those for viitaniemiite $Na(Ca,Mn)Al(PO_4)(F,OH)_3$. Dr. Seppo Lahti provided fragments of the type viitaniemiite, and its description (Lahti 1981) prior to publication. This enabled us to determine that the Francon mineral is a manganese-free viitaniemiite.

The specimens and crystals of viitaniemiite from the Francon quarry used in this study (M38127, M38128 and M38129) are preserved in the collections of the Royal Ontario Museum.

## Crystallography

Viitaniemiite from the Francon quarry has developed as small monoclinic crystals elongated [010] and flattened (100) . The crystals taper slightly toward their termination. As a result, the tips of the blades are extremely thin; no terminating faces are discernable by optical goniometer or petrographic microscope.

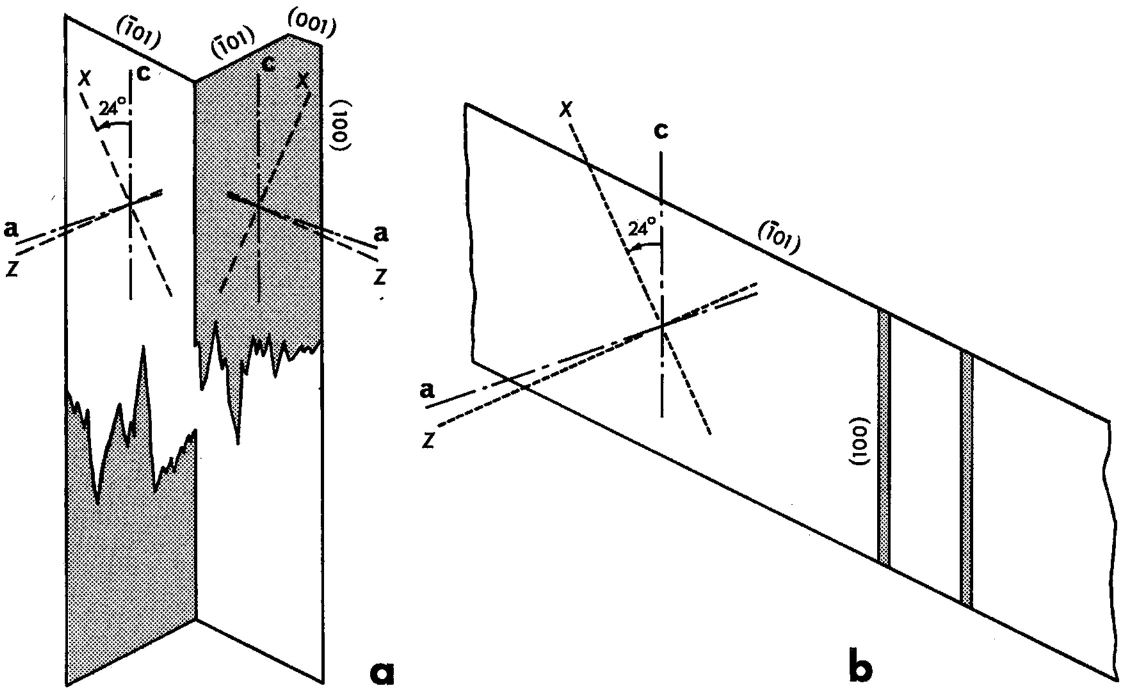


FIG. 1. Twinned viitaniemiite crystals, cross-sectioned perpendicular to the *b* axis: (a) Francon quarry, Quebec; (b) Viitaniemi pegmatite, Finland.

Only faces in the [010] zone could be measured on the optical goniometer. The faces of {100} gave good signals, but the faces of other forms, {̄100} and {001}, gave very poor signals. All crystals examined are polysynthetically twinned, with adjacent lamellae showing thin, alternately oriented {̄101} and {001} faces. Even with the microscope, on sections perpendicular to [010], it was impossible to measure accurately the angles between the faces in the [010] zone, because of the small size and curved nature of the faces. However, the known orientation of the indicatrix allows easy differentiation of the two forms. Examination of several crystal fragments on the spindle stage showed that {̄101} faces are dominant, whereas {001} faces are minor, if developed at all.

A twinned fragment composed of two individuals of different volumes was used in the single-crystal X-ray-diffraction study, as a suitable untwinned fragment was unavailable. This allowed identification of the reciprocal cell of each twin on the precession films; that, in turn, allowed us to determine the relationship between the optical and crystallographic elements.

The twin law in viitaniemiite can be expressed in several ways, as the presence or absence of a centre of symmetry was not confirmed. We prefer to describe the twin law as twinning by reflection on the (100) plane, since it is also the well-defined composition plane in polysynthetically twinned crystals.

A section through the base of one crystal shows butterfly-type twinning (Fig. 1a), the two individuals being of approximately the same volume. The contact along the (100) twin plane is very sharp, because this plane is common to both individuals, whereas the other contact surfaces are irregular. The remainder of this crystal shows the characteristic polysynthetic twinning.

Lahti (1981) did not report twinning in viitaniemiite. However, in this study we observed a few, very thin twin-lamellae in fragments of the type material from Finland (Fig. 1b). The crystals from the Viitaniemi pegmatite are developed as plates parallel to (̄101), and the composition plane occurs at an angle of 64° to the plate. The thin twin-lamellae in the Finnish material cannot be observed if the plate is lying parallel to the microscope stage. On the fragment shown in Figure 1b, we were able to see the lamellae only after the grain was mounted on the spindle stage and the {100} plane was set vertically. Study of this fragment using the precession method confirmed that the twin law is the same as that determined on the Francon crystals. Results of the single-crystal X-ray study are compared to the data of Lahti (1981) in Table 1.

The X-ray powder-diffraction data of viitaniemiite from the Francon quarry (Table 2) are similar to those given by Lahti (1981) for the Viitaniemi material, except that we observed additional diffraction-lines. The minor differences between these data sets are due principally to differences in crystal chemistry. A comparison of the diffractometer data of Lahti with our film data of the type viitaniemiite showed that, in this case, differences in powder data by these two methods are practically negligible. The least-squares refinement of unit-cell parameters was based on 17 unambiguously indexed lines of the powder pattern. The intensities of reflections on precession films aided in the indexing of the pattern.

## Physical and Optical Properties

Viitaniemiite from both localities is colorless and vitreous in fragments. The Francon viitaniemiite, however, is transparent, whereas the type material is largely clouded by alteration products (Lahti 1981). Physical and optical properties of the mineral from both localities are compared in Table 1. In order to determine the density of the Francon viitaniemiite, two crystal fragments were suspended in a methylene iodide – acetone solution. The density of the liquid was then determined with a pycnometer of known volume. The fragments showed no measurable differences in density.

The orientation of the cleavage and parting of several crystal fragments was determined on the universal stage. The parting on (100) follows composition surfaces of the twins. No sign of cleavage in this plane was observed within twinned individuals. The optical axial angle, orientation of the indicatrix and principal indices of refraction were determined using the spindle stage on a crystal previously oriented by precession methods.

TABLE 1. PHYSICAL PROPERTIES OF VIITANIEMIITE

| | Francon quarry (this study) | Viitaniemi pegmatite (Lahti 1981) |
|---|---|---|
| System | monoclinic | monoclinic |
| Space group | $P2_1$ or $P2_1/m$ | $P2_1$ or $P2_1/m$ |
| Unit cell parameters | | |
| $a$(Å) | 6.865(2) | 6.832(3) |
| $b$(Å) | 7.225(2) | 7.143(3) |
| $c$(Å) | 5.522(1) | 5.447(3) |
| β | 109°00(2)' | 109°22(5)' |
| V(Å$^3$) | 258.96(9)* | 250.795 |
| Density (g/cm$^3$) | 3.06(1) | |
| Specific gravity | | 3.245 |
| Optical properties | | |
| α | 1.532(2) | 1.557(1) |
| β | 1.544(2) | 1.565(1) |
| γ | 1.551(2) | 1.571(1)** |
| $2V_x$ meas. | 75(2)° | 81(1)° |
| $2V_x$ calc. | 74° | 81° |
| Optical orientation | $b \parallel Y$<br>$c \wedge X$ = 24(1)°† | $b \parallel Y$<br>$c \wedge X$ = 24(1)°†Ψ |
| Cleavage | ($\bar{1}01$) | ($\bar{1}01$) |
| Parting | (100) | |
| Twin plane | (100) | (100)Ψ |
| Composition plane | (100) | (100)Ψ |

* Calculated using unit-cell parameters and *esds* expressed to more significant digits than presented in this table.
** Personal communication from Dr. S. Lahti, 1981.
† Measured in the obtuse angle between $a$ and $c$.
Ψ Determined in this study on the type material from Finland.

## Chemistry

The Francon viitaniemiite was chemically analyzed, together with the type material from

TABLE 2. X-RAY POWDER-DIFFRACTION DATA FOR VIITANIEMIITE FROM QUEBEC

| I | $d_{obs}$ | $d_{calc}$ | hkl | I | $d_{obs}$ |
|---|---|---|---|---|---|
| * <2 | 6.48 | 6.49 | 100 | 2 | 1.722 |
| 15 | 5.21 | 5.22 | 001 | <2 | 1.709 |
| 22 | 4.93 | 4.926 | $\bar{1}01$ | <2 | 1.695 |
| 15 | 4.83 | 4.829 | 110 | <2 | 1.656 |
| † 3 | 4.25 | 4.232 | 011 | 10 | 1.638 |
| 8 | 4.071 | 4.070 | $\bar{1}11$ | <2 | 1.625 |
| 2 | 3.609 | 3.613 | 020 | <2 | 1.614 |
| 5 | 3.543 | 3.544 | 101 | 5 | 1.592 |
| † 5 | 3.350 | | | 6 | 1.580 |
| 41 | 3.246 | 3.246 | 200 | 2 | 1.560 |
| 9 | 3.183 | 3.182 | 111 | 2 | 1.551 |
| 7 | 3.157 | 3.157 | 120 | <2 | 1.523 |
| 16 | 2.981 | 2.983 | $\bar{2}11$ | 8 | 1.494 |
| 24 | 2.966 | 2.971 | 021 | 3 | 1.483 |
| | | 2.961 | 210 | 2 | 1.458 |
| 100 | 2.913 | 2.913 | $\bar{1}21$ | | |
| * 4 | 2.752 | 2.752 | $\bar{1}02$ | 2 | 1.444 |
| 21 | 2.611 | 2.611 | 002 | 3 | 1.431 |
| 8 | 2.529 | 2.530 | 121 | 2 | 1.416 |
| * 3 | 2.454 | 2.455 | 012 | <2 | 1.394 |
| 11 | 2.426 | 2.425 | 201 | 5 | 1.376 |
| 8 | 2.333 | 2.331 | $\bar{2}12$ | | |
| 10 | 2.279 | 2.278 | $\bar{3}01$ | | |
| 2 | 2.261 | 2.258 | 130 | | |
| 28 | 2.190 | 2.189 | $\bar{1}22$ | | |
| | | 2.188 | 102 | | |
| 5 | 2.163 | 2.164 | 300 | | |
| * 2 | 2.118 | 2.116 | 022 | | |
| <2 | 2.096 | 2.094 | 112 | | |
| * <2 | 2.072 | 2.073 | 310 | | |
| * 4 | 2.019 | 2.020 | $\bar{3}02$ | | |
| 16 | 1.929 | 1.927 | $\bar{3}21$ | | |
| <2 | 1.873 | 1.871 | 122 | | |
| * 3 | 1.856 | 1.856 | 320 | | |
| * <2 | 1.838 | 1.837 | $\bar{1}03$ | | |
| 15 | 1.806 | 1.806 | 040 | | |
| 2 | 1.772 | 1.772 | 202 | | |
| 3 | 1.763 | 1.763 | $\bar{3}22$ | | |
| * 3 | 1.743 | 1.743 | $\bar{2}13$ | | |

CuKα radiation; 114.6 mm Debye-Scherrer camera; film corrected for shrinkage; photometric intensity measurements; $d$ values in Å, calculated for a monoclinic unit-cell, $a$ = 6.865, $b$ = 7.225, $c$ = 5.522 Å and β = 109°00'.
* Similarly indexed lines observed on Debye-Scherrer films of type material from Viitaniemi in this study, but not reported by Lahti (1981).
† Lines probably due to quartz impurity: in part (4.25 Å), in total (3.350 Å).

TABLE 3. CHEMICAL DATA FOR VIITANIEMIITE

| | 1. Francon quarry (M38127) | 2. Viitaniemi (M37618) | 3. Viitaniemi (Lahti 1981) | 4. $NaCaAl(PO_4)F_3$ (theoretical) |
|---|---|---|---|---|
| $Na_2O$ | 11.4% | 12.2% | 11.6% | 12.80% |
| $Al_2O_3$ | 23.4 | 22.8 | 22.4 | 21.06 |
| $P_2O_5$ | 28.1 | 28.0 | 28.3 | 29.33 |
| CaO | 22.3 | 12.4 | 14.7 | 23.17 |
| MgO | 0.1 | 0.3 | 0.38 | |
| MnO | 0.0 | 12.3 | 10.5 | |
| FeO | 0.0 | 0.8 | 0.70 | |
| $K_2O$ | 0.0 | 0.0 | 0.27 | |
| F | 14.5 | 11.7 | 12.3 | 23.55 |
| $H_2O$ | n.d. | 4.93* | 4.93 | |
| Sum | 99.8 | 105.43 | 105.98** | 109.91 |
| less O ≡ F | 6.1 | 4.9 | 5.14** | 9.92 |
| Total | 93.7 | 100.53 | 100.84** | 99.99 |

*Total water taken from Lahti (1981); analyzed crystal is part of holotype material.
**Sum of analysis as given is 106.08; recalculation gives O ≡ F 5.2, Total 100.88.
Accuracy of analyses 1. and 2.: ± 15% for F, ± 5% for other elements.

Finland, using electron-microprobe techniques. Analyses 1 and 2 (results in Table 3) were obtained using an ARL–SEMQ electron microprobe utilizing an operating voltage of 15 kV, sample current of 0.025 $\mu$A standardized on brass, and a beam diameter of 40 $\mu$m. The standards used were marićite (Na,P), fluorite (F), manganite (Mn) and hornblende (Ca, Fe, Mg, Al and K). The data were corrected using standard Bence–Albee factors.

Our analysis of the type viitaniemiite (#2, Table 3) is in agreement with the data of Lahti (1981) (#3, Table 3) except for the CaO and MnO values. The Francon viitaniemiite differs from the type material in that no Mn was detected. The mineral is therefore the calcium end-member in terms of Ca–Mn diadochy. It is also richer in fluorine than the type material, and thus more closely approximates the end-member composition in that respect as well. The paucity of Francon viitaniemiite precluded a water analysis. We have chosen not to calculate water by difference because of the high estimated error we assign to our fluorine determination.

Normalization of data-set 1 for the Francon mineral, on the basis of 4 cations, yields: $Na_{0.91}(Ca_{0.98}Mg_{0.01})_{\Sigma=0.99}Al_{1.13}P_{0.98}$. We note with interest that the original analysis of Lahti and our analyses of the type material and of the Francon mineral all show a deficiency of Na and a surfeit of Al relative to the formula $NaCaAl(PO_4)(F,OH)_3$. Although we cannot offer an explanation for this nonstoichiometry, we call attention to it inasmuch as it may reflect complex structural features.

## Occurrence at the Francon Quarry

Viitaniemiite crystallized in the surfaces of vesicles in an alkalic silicocarbonatite, as delicate sprays and as solitary crystals reaching a maximum size of 2 × 0.5 × 0.2 mm. The vesicles are lined with crystals of colorless cryolite, calcite and yellow weloganite, and lesser amounts of viitaniemiite, pyrite, quartz, fluorite, dresserite, dawsonite, galena and sphalerite. Minute cubes of pyrite and fluorite have commonly grown on the viitaniemiite. In addition, cryolite has overgrown some viitaniemiite crystals near their points of attachment. Thus, the viitaniemiite appears to have formed at an early to intermediate stage in the sequence of cavity mineralization.

Although apatite has been observed as an accessory mineral of the intrusive rocks at the Francon quarry (Sabina 1979), viitaniemiite is the first phosphate to be recognized in the cavities of these rocks. In contrast to the Canadian mode of occurrence, the type viitaniemiite from the Viitaniemi pegmatite crystallized as fan-shaped aggregates in eosphorite (Lahti 1981).

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