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## Some FeMn phosphates from the Buranga pegmatite, Rwanda

by O. v. Knorring\* and Th. G. Sahama\*\*<sup>1</sup>

### Abstract

From a small specimen collected from the dumps of the Buranga pegmatite, Rwanda, the following iron manganese phosphate minerals are described:

Reddish violet strengite (Mn-bearing) in euhedral development.  $a = 9.873 \text{ \AA}$ ,  $b = 10.100 \text{ \AA}$ ,  $c = 8.715 \text{ \AA}$ . Space group  $Pbca$ . Calculated density 2.87. Perfect cleavage on (100). Optical orientation  $a \parallel \gamma$ ,  $b \parallel \alpha$ ,  $c \parallel \beta$ . Optically positive with very small  $2V_{\gamma}$ . Strong pleochroism:  $\gamma \sim \alpha$  pink, slightly violet;  $\beta$  almost colorless, slightly bluish. Absorption  $\gamma > \alpha > \beta$ . Strong dispersion  $v > r$ . Refractive indices  $\alpha \sim \beta = 1.730$ ,  $\gamma = 1.753$ . Composition  $(\text{Fe}, \text{Mn})^{3+} \text{PO}_4 \cdot 2\text{H}_2\text{O}$ . The mineral represents possibly an orthorhombic counterpart of vilateite.

Dark brown bermanite, euhedral in wugs.  $a = 6.19 \text{ \AA}$ ,  $b = 8.88 \text{ \AA}$ ,  $c = 19.23 \text{ \AA}$  (orthorhombic setting by LEAVENS). Space group  $C222_1$ . Perfect cleavage (001), poor (010). Optical orientation  $a \parallel \gamma$ ,  $b \parallel \beta$ ,  $c \parallel \alpha$ . Optically negative. Clear pleochroism:  $\alpha$  brownish yellow,  $\beta$  greenish yellow,  $\gamma$  brownish pink. Absorption  $\gamma > \alpha \sim \beta$ . Strong dispersion  $v > r$ . Twinning on (010) and (100). The composition corresponds to that of bermanite (LEAVENS) with  $100 \cdot \text{Fe}/(\text{Fe} + \text{Mn}) = 30$ .

Brownish, fibrous dufrénite-like mineral. Powder pattern indexed on a monoclinic cell:  $a = 6.44 \text{ \AA}$ ,  $b = 6.93 \text{ \AA}$ ,  $c = 19.43 \text{ \AA}$ ,  $\beta = 93^\circ 15'$ . Cell dimensions checked with electron diffraction photographs. Space group possibly  $P2_1$ ,  $Pm$  or  $P2/m$ . Extinction straight or nearly so with  $\alpha$  parallel to the fiber axis. Weak pleochroism with  $\gamma \sim \beta > \alpha$ . Optically positive with small axial angle.  $\alpha \sim 1.80$ ,  $\gamma \sim 1.85$ . The composition corresponds to that of dufrénite (FRONDEL), but the powder pattern and the cell data are different from those of that mineral. The powder pattern shows similarity with the phosphate mineral from Waldgirmes, Hessen (FRONDEL). The family of the hydrous iron manganese phosphates is considered too inadequately investigated to propose a new name to the mineral.

### INTRODUCTION

Granite pegmatites are widespread in the Burundian System of Rwanda, and a striking example of mineralized lithium pegmatites is found around Gatumba ( $29^\circ 39' \text{ E}$ ,  $1^\circ 55' \text{ S}$ ), some 50 km south of Ruhengeri in northern Rwanda.

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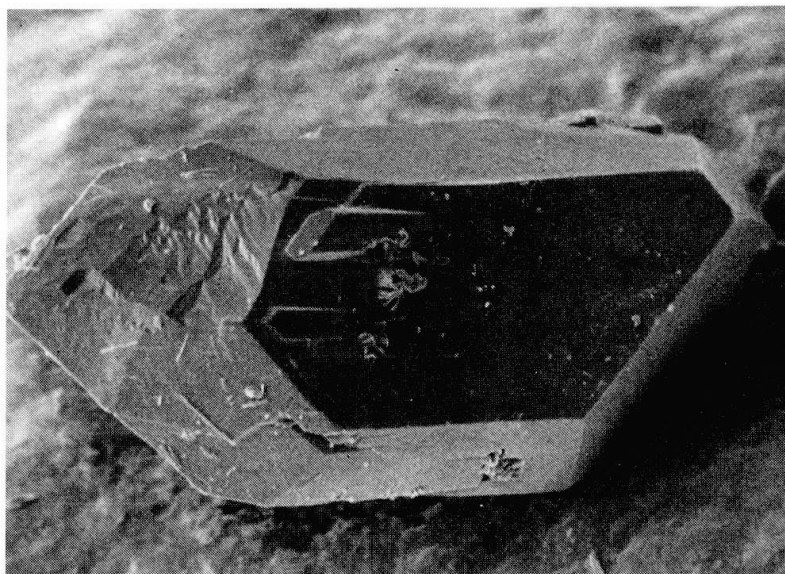
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<sup>1</sup> Annotation in press by the editor: Unfortunately, this paper is the last contribution to mineralogy by Prof. Th. G. Sahama. He died on 8 March, 1983.

Buranga mine at Gatumba, in particular, is noted for its rich variety of phosphate minerals, which have been described, among others, by THOREAU and BASTIEN (1954), ALTMANN (1961), GALLAGHER and GERARDS (1963), v. KNORRING and MROSE (1966), v. KNORRING and FRANSOLET (1975, 1977), v. KNORRING et al. (1977) and FRANSOLET (1980). Most of the secondary phosphates found, have been derived from the gradual replacement and alteration of lithiophilite-triophyllite and amblygonite-montebrazite by residual fluids during the late stages of crystallization and by subsequent weathering and leaching processes in the tropical environment.

This paper describes some additional phosphates from the Buranga mine. None of these phosphates were present in amount and quality sufficient for chemical analysis, and only microprobe analyses could be made. The only available material of the original specimen, weighing ca. 90 grams, has been deposited in the mineral collection of the Smithsonian Institution, Washington, D.C.

A.



B.

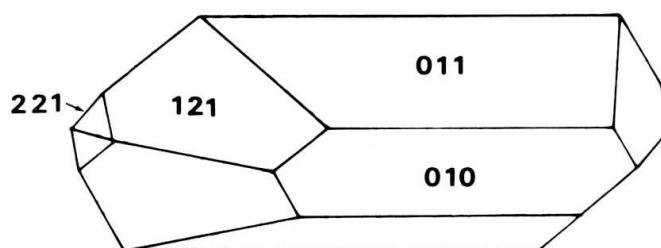


Fig. 1 Crystal habit of strengite, Buranga, Rwanda. A. Scanning electron micrograph, crystal length 0.25 mm. B. Ideal habit.

*Strengite*

The reddish violet strengite occurs in the specimen as euhedral crystals up to 0.35 mm long (Fig. 1). The form {221} is often poor or lacking. The X-ray powder pattern of the mineral is summarized in Table I. The lines listed in this table were checked on single crystal precession photographs about all three crystallographic axes. A few weak lines were omitted. The unit cell dimensions calculable from the powder pattern and measured from the single crystal photographs are:  $a = 9.873 \pm 0.008 \text{ \AA}$ ,  $b = 10.100 \pm 0.008 \text{ \AA}$ ,  $c = 8.715 \pm 0.005 \text{ \AA}$ , volume =  $869 \text{ \AA}^3$ . These cell dimensions agree reasonably well with those reported by

| I   | hkl                                        | $d_{\text{meas.}}$ | $d_{\text{calc.}}$                             |
|-----|--------------------------------------------|--------------------|------------------------------------------------|
| 70  | 111                                        | 5.49               | 5.486                                          |
| 35  | 200                                        | 4.93               | 4.937                                          |
| 100 | 021                                        | 4.368              | 4.369                                          |
| 45  | 102                                        | 3.988              | 3.987                                          |
| 20  | 112                                        | 3.709              | 3.708                                          |
| 60  | 212                                        | 3.107              | 3.108                                          |
| 30  | 131                                        | 2.993              | 2.993                                          |
| 20  | 311                                        | 2.946              | 2.945                                          |
| 35b | $\begin{Bmatrix} 312 \\ 040 \end{Bmatrix}$ | 2.533              | $\begin{Bmatrix} 2.542 \\ 2.525 \end{Bmatrix}$ |
| 35  | 313                                        | 2.129              | 2.129                                          |

Table I X-ray powder pattern of strengite, Buranga, Rwanda. Philips wide angle goniometer, filtered copper radiation, spinel standard. b = broad.

| Crystal I                                           |      |                  |       | Crystal II |                  |        |  |
|-----------------------------------------------------|------|------------------|-------|------------|------------------|--------|--|
| Wt. %                                               |      | O = 32           |       | Wt. %      |                  | O = 32 |  |
| Fe <sub>2</sub> O <sub>3</sub>                      | 38.4 | Fe               | 7.24  | 40.7       | Fe               | 7.65   |  |
| Mn <sub>2</sub> O <sub>3</sub>                      | 4.12 | Mn               | 0.79  | 1.90       | Mn               | 0.36   |  |
| P <sub>2</sub> O <sub>5</sub>                       | 37.6 | P                | 7.98  | 37.8       | P                | 7.99   |  |
| H <sub>2</sub> O                                    | 19.9 | H <sub>2</sub> O | 16.64 | 19.6       | H <sub>2</sub> O | 16.33  |  |
| $\frac{100 \cdot \text{Mn}}{\text{Fe} + \text{Mn}}$ |      | 9.8              |       | 4.5        |                  |        |  |

Table II Microprobe analyses of two strengite crystals, Buranga, Rwanda. H<sub>2</sub>O by difference. Fe and Mn considered trivalent.

McCONNELL (1940) and mentioned in the ASTM card 15-513 (a- and b-axes interchanged). The space group is *Pbca* (No. 61). Table II summarizes microprobe analyses of two strengite crystals. No other elements were detected in the energy-dispersive graph. Fillowite from Ankole, Uganda (v. KNORRING, 1963), was used as a standard. The composition ( $Z = 8$ ) corresponds to the formula  $(\text{Fe,Mn})^{3+}\text{PO}_4 \cdot 2\text{H}_2\text{O}$ . The calculated density is 2.87. The cleavage parallel to (100) is perfect. Optical orientation:  $a \parallel \gamma$ ,  $b \parallel \alpha$ ,  $c \parallel \beta$ . The mineral is optically positive. The optic axial angle was measured from the interference figure with an apertometer.  $2V_\gamma$  is virtually zero for red and ca.  $10^\circ$  for blue. Strong pleochroism  $\gamma$  and  $\alpha$  are pink, slightly violet,  $\beta$  is almost colorless, slightly bluish, absorption  $\gamma > \alpha > \beta$ . Refractive indices:  $\alpha \sim \beta = 1.730$  and  $\gamma = 1.753$ , both  $\pm 0.003$ . The mineral is possibly an orthorhombic counterpart of the Mn-bearing variety called vilateite by LACROIX (1910) of which no chemical analysis is available.

#### *Bermanite*

The dark brown bermanite forms the majority of the fine grained matrix. Euhedral crystals, grown in wugs, are usually smaller than those of strengite, but may reach the same size. The idealized habit is illustrated in Fig. 2. The faces of the form  $\{111\}$  are often stepwise, simulating steep pyramids. The face (001) shows mostly more or less strongly developed growth hillocks which, in extreme cases, form acicular extensions of the crystal (Fig. 3). The mineral was identified by the X-ray powder pattern. The unit cell dimensions were deter-

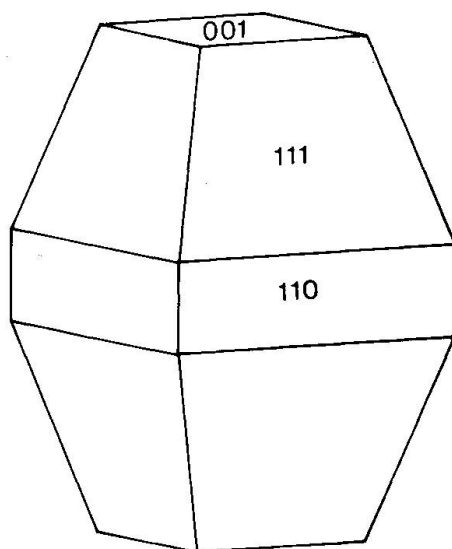


Fig. 2 Idealized crystal habit of bermanite, Buranga, Rwanda.



Fig. 3 Acicular growth on the basal plane of a bermanite crystal, Buranga, Rwanda. Visible length of the crystal 0.15 mm.

mined from single crystal X-ray precession photographs about the *a*- and *b*-axes, using the setting of LEAVENS (1967). The unit cell dimensions thus obtained are:  $a = 6.19 \pm 0.01 \text{ \AA}$ ,  $b = 8.88 \pm 0.02 \text{ \AA}$ ,  $c = 19.23 \pm 0.03 \text{ \AA}$ , volume =  $1057 \text{ \AA}^3$ . These cell dimensions agree reasonably well with those reported by HURLBUT (1936), LEAVENS (1967) and HURLBUT and ARISTARAIN (1968). The space group is  $C222_1$  (No. 20). A microprobe analysis is reproduced in Table III, and is compared with the theoretical composition of the mineral. The standard was the same as for the microprobe analysis of strengite. The unknown distribution of Fe, Mn between the divalent and trivalent positions and the obviously high water content make a calculation of the chemical formula arbitrary. No additional elements were detected in an energy-dispersive X-ray graph. The mineral is high in iron with  $100 \cdot \text{Fe}/(\text{Fe} + \text{Mn}) = 30$ , the highest known so far from bermanite. The density could not be measured and its calculation from the microprobe analysis would be meaningless. Cleavage parallel to (001) is perfect and parallel to (010) poor.

The optical properties are nearly identical with those summarized by HURLBUT and ARISTARAIN (1968). Optical orientation:  $a \parallel \gamma$ ,  $b \parallel \beta$ ,  $c \parallel \alpha$ . Optically negative. Refractive indices  $\alpha = 1.687$ ,  $\beta = 1.729$ ,  $\gamma = 1.749$  (all  $\pm 0.003$ ). Pleochroism  $\alpha$  = brownish yellow,  $\beta$  = greenish yellow,  $\gamma$  = brownish pink, absorption  $\gamma > \alpha \sim \beta$ . Strong dispersion  $v > r$ .

|                               | 1                          | 2          |                         |      |
|-------------------------------|----------------------------|------------|-------------------------|------|
|                               | Theoretical<br>composition | Wt. %      | Atoms based<br>on P = 2 |      |
| FeO                           | -                          | 14.3 ± 0.2 | Fe                      | 0.88 |
| MnO                           | 47.21                      | 32.6 ± 0.5 | Mn                      | 2.03 |
| P <sub>2</sub> O <sub>5</sub> | 31.49                      | 32.2 ± 0.2 | P                       | 2.00 |
| H <sub>2</sub> O              | 17.75                      |            |                         |      |

1. For formula  $\text{Mn}^{2+}\text{Mn}_2^{3+}(\text{PO}_4)_2(\text{OH})_2 \cdot 4\text{H}_2\text{O}$  with  
 $\text{Mn}_2\text{O}_3 + \text{MnO}$  recalculated as  $\text{MnO}$ .

2. Data for the Buranga mineral.

*Table III* Microprobe analysis of bermanite, Buranga, Rwanda. Average of three analyses.

The mineral shows a complicated and variable twinning optically visible in sections parallel to (001). In this section the crystal appears as a fourling with the outlines of the form {110}. The composition planes (twin planes) are (010) and (100). The quadrants are banded parallel to {110}. The appearance resembles that described by HURLBUT and ARISTARAIN (1968, Fig. 7) in a monoclinic notation except that the crystal core of the Buranga mineral is homogeneous with an undulating extinction.

#### *Dufrenite-like mineral*

This mineral, brown to yellow brown in color, occurs as radial-fibrous masses (Fig. 4), sometimes in rounded spherulitic aggregates.

Several unsuccessful attempts were made to determine the fiber period with an X-ray rotation photograph about the fiber axis. The seemingly single fibers lack parallelism of the individual fibrils and are too small in size. No X-ray single crystal photographs could be obtained of the available material, and the X-ray powder pattern is rather poor. The latter was recorded with the Philips wide angle goniometer using filtered copper and iron radiation without a standard and with a spinel standard, respectively. In addition, a rounded spherulite was photographed with a 57.3 mm powder camera in filtered iron radiation. Table IV shows the results of these measurements. A few poor unmeasurable lines were omitted. The powder pattern can be indexed on the basis of a monoclinic cell with  $a = 6.44 \text{ \AA}$ ,  $b = 6.93 \text{ \AA}$ , both  $\pm 0.02 \text{ \AA}$ ,  $c = 19.43 \pm 0.03 \text{ \AA}$  and



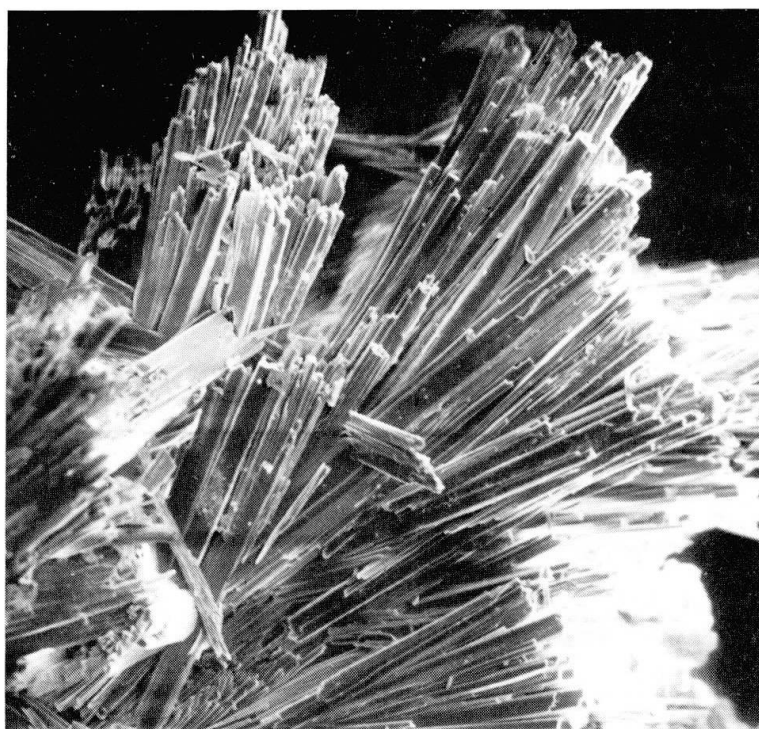


Fig. 4 Dufrenite-like mineral, Buranga, Rwanda. Area of figure  $0.24 \cdot 0.24$  mm. Scanning electron micrograph.

$\beta = 93^\circ 15' \pm 15'$ , volume =  $866 \text{ \AA}^3$ . The fiber axis is crystallographic  $c$ . The indexing of some lines must be considered provisional and should be checked when single crystal photographs of the mineral become available. The indexing of the lines with  $d < 3.00$  is meaningless. The cell data calculated from the X-ray powder pattern were checked with electron diffraction photographs which revealed no systematic extinctions. The space group would, accordingly, be  $P2_1$ ,  $Pm$  or  $P2_1/m$ .

A microprobe analysis is reproduced in Table V. The standard was the same as for the microprobe analysis of strengite. No additional elements were detected in an energy-dispersive X-ray graph. Qualitative optical spectroscopy showed no Li, Be or B.

The small size of the fibrils makes accurate optical characterization difficult. The mineral is slightly yellowish under the microscope. The extinction is almost straight with the optical  $\alpha$ -direction parallel to the fiber axis. The pleochroism is weak with an absorption scheme  $\gamma > \beta \sim \alpha$ . The positive optic axial angle is small.  $\alpha \sim 1.80$ ,  $\gamma \sim 1.85$ .

The Buranga mineral differs from dufrenite both in its X-ray powder pattern (MOORE, 1970) and in its unit cell dimensions (MROSE, 1955). On the other hand, the powder pattern of the Buranga mineral resembles that published by FRONDEL (1949, Table 16) of an unnamed and unanalyzed, fibrous phosphate



| I  | hkl                                                            | d <sub>meas.</sub> | d <sub>calc.</sub>                                               | I         | d <sub>meas.</sub> |
|----|----------------------------------------------------------------|--------------------|------------------------------------------------------------------|-----------|--------------------|
| w  | 010†                                                           | 6.93               | 6.93                                                             | vw        | 2.75               |
| vw | 100†                                                           | 6.43               | 6.43                                                             | m         | 2.63               |
| w  | 102†                                                           | 5.22               | 5.22                                                             | vw        | 2.51               |
| m  | 004†                                                           | 4.86               | 4.85                                                             | m         | 2.44               |
| vw | 103†                                                           | 4.43               | 4.43                                                             | vw        | 2.30               |
| w  | $\begin{Bmatrix} \bar{1}12 \\ 112 \end{Bmatrix}$               | 4.23               | $\begin{Bmatrix} 4.31 \\ 4.17 \end{Bmatrix}$                     | vw        | 2.22               |
| vw | $\bar{1}04?$                                                   | 4.03               | 3.98                                                             | vw        | 2.18               |
| vw | $\bar{1}13†$                                                   | 3.88               | 3.89                                                             | vw        | 2.15               |
| w  | 113†                                                           | 3.734              | 3.735                                                            | vw        | 2.12               |
| vs | 020†                                                           | 3.464              | 3.465                                                            | vw        | 2.08               |
| s  | 022†                                                           | 3.264              | 3.263                                                            | vw        | 2.04               |
| s  | 200†                                                           | 3.218              | 3.215                                                            | vw        | 1.98               |
| m  | $\begin{Bmatrix} \bar{2}01 \\ 201 \end{Bmatrix}$               | 3.151              | $\begin{Bmatrix} 3.201 \\ 3.143 \end{Bmatrix}$                   | w         | 1.95               |
|    | $\begin{Bmatrix} 120 \\ \bar{1}21 \\ 121 \\ 202 \end{Bmatrix}$ | 3.020              | $\begin{Bmatrix} 3.050 \\ 3.026 \\ 3.001 \\ 3.001 \end{Bmatrix}$ | vw        | 1.88               |
| vw |                                                                | 2.95               |                                                                  | vw        | 1.85               |
| vw |                                                                | 2.88               |                                                                  | vw        | 1.82               |
| vw |                                                                | 2.82               |                                                                  | vw        | 1.79               |
|    |                                                                |                    |                                                                  | vw        | 1.75               |
|    |                                                                |                    |                                                                  | w         | 1.73               |
|    |                                                                |                    |                                                                  | - - - - - |                    |

Table IV X-ray powder pattern of the dufrenite-like mineral from Buranga, Rwanda. vw = very weak, w = weak, m = medium, s = strong, vs = very strong. † = used for calculating the unit cell dimensions.

|                               | Wt. %      |    | Ratios |
|-------------------------------|------------|----|--------|
| FeO                           | 31.5 ± 0.6 | Fe | 0.438  |
| MnO                           | 21.9 ± 0.6 | Mn | 0.309  |
| P <sub>2</sub> O <sub>5</sub> | 30.8 ± 0.5 | P  | 0.434  |

Table V Microprobe analysis of the dufrenite-like mineral. Average of eight analyses. FeO-MnO: total iron-manganese.

mineral from the Rothläufchen mine, Waldgirmes, Hessen. The parallelism between these two powder patterns suggests that the Rwanda mineral represents a manganoan (manganian) analogue of Frondel's Waldgirmes mineral. As was pointed out by FRONDEL (1949) and later by MOORE (1970), the family of the wa-

ter and/or hydroxyl bearing iron manganese phosphates has long been inadequately explored and still is. Therefore, even if the Buranga mineral possibly represents a distinct species, no new name will be proposed for it in this paper. The naming of the mineral should be made only after additional material of it becomes available from other localities.

#### *Phosphosiderite*

The small amounts of pale bluish phosphosiderite occurs in anhedral, finely crystalline cavity fillings. Its X-ray powder pattern corresponds to that of the ASTM card 15-390. An energy-dispersive X-ray graph shows strong P and Fe, weak Al and very weak Mn.

#### *Cryptomelane*

The opaque cryptomelane found in the bermanite matrix was identified by X-ray powder pattern. Its energy-dispersive X-ray graph shows strong Mn, medium K, weak Al (from impurity?) and no Fe and Na.

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