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## **An Occurrence of Bjarebyite in the Buranga Pegmatite, Rwanda**

By *Oleg von Knorring*\*) and *André-Mathieu Fransolet*\*\*)

With 2 figures and 5 tables in the text

### **Abstract**

A second occurrence of bjarebyite,  $\text{Ba}(\text{Mn,Fe})_2(\text{Al,Fe})_2(\text{PO}_4)_3(\text{OH})_3$  is described from Buranga pegmatite in Rwanda. This rare pegmatitic phosphate is closely associated with bertossaite, trolleite, apatite and lazulite.

The monoclinic unit cell dimensions, calculated from the powder pattern data, are:  $a = 9.103$ ,  $b = 12.204$ ,  $c = 4.959 \text{ \AA}$  and  $\beta = 100^\circ 28'$  with  $Z = 2$ . Specific gravity is 3.90. Complete chemical analyses are given. The optical properties are:  $\alpha = 1.724$ ,  $\beta = 1.727$ ,  $\gamma = 1.749$  and  $2V = (+) 38^\circ$ . The pleochroism is strong.

An infrared spectrum is given and briefly discussed.

### **Introduction**

Buranga is noted for its exceptional variety of phosphate minerals which have been described by THOREAU et al. (1950–1957), ALTMANN (1961) and GALLACHER and GERARDS (1963). During four brief visits to this pegmatite area between 1964–1969, specimens were collected mainly for a comparative study in connection with pegmatite investigations in south-west Uganda. As a result of laboratory examination many rare minerals including four new phosphates have been noted. (VON KNORRING and HORNUNG, 1965, VON KNORRING and MROSE, 1966 and VON KNORRING, 1965, 1969, 1970, 1972, 1973.)

The Buranga pegmatite is situated about 0.5 km north of the Minétain company's headquarters at Gatumba ( $29^\circ 31' \text{ E.}$ ,  $1^\circ 55' \text{ S.}$ ), some 50 km south of the administrative town of Ruhengeri in northern Rwanda. The rocks in this area belong to the Burundian system, comprising schists, quartzites, amphibolites and often dome-like granitic intrusives; they have a northerly

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trend and are continuous with the Karagwe-Ankolean rocks on the Uganda side of the border to the north. Granite pegmatites are of common occurrence and many have been mined for cassiterite in the past.

The Buranga occurrence is dominated by a NNW-striking quartz core, some 10 metres wide, in the southern part of pegmatite. In relation to the main quartz core the pegmatite is asymmetrical and is less well developed on the eastern side where it is in contact with a tourmalinized amphibolite; westwards the pegmatite passes gradually into a pegmatitic granite. There is a marked zoning around the quartz core which contains conspicuous lath-shaped voids after giant spodumene crystals – a characteristic feature of many pegmatites in northern Rwanda and adjoining parts of south-west Uganda. Nodules and aggregates of phosphate minerals, some of gigantic proportions, are commonly observed within the quartz core or along the core margin. Next to the core there is a zone of albite and muscovite, partly kaolinized. Pockets of beryl and occasional aggregates of manganotantalite have been found in this zone, in addition to zircon, microlite and some uraniferous minerals.

A pistachio – to dark-green phosphate (now bjarebyite, MOORE et al. 1973) was observed at Buranga in 1965 and was subsequently identified by Miss MARY E. MROSE of the U.S. Geological Survey in Washington, who was then investigating an identical mineral found at the Palermo and Smith mines in New Hampshire.

#### Phosphate mineralization

The phosphate minerals in the Buranga pegmatite may be divided into three major associations as follows:

1. Manganese-iron nodules containing lithiophilite, heterosite-purpurite, ferri-sicklerite, alluaudite, barian arrojadite, tavorite, barbosalite, lipscombite, frondelite, strengite, metastrengite, stewartite, bermanite and a mitridatite-like mineral.
2. Amblygonite (montebrasite) with minor lazulite (scorzalite), apatite, eosphorite and berlinite.
3. Aggregates containing variable amounts of lazulite (scorzalite), trolleite, bertossaite, amblygonite, brazilianite, augelite, with some apatite, bjarebyite, crandallite, wavellite, wardite and three new fibrous phosphates under investigation.

Muscovite and quartz may be present in these associations.

#### Paragenesis

Bjarebyite belongs to the third major assemblage of the phosphate minerals from the Buranga pegmatite that VON KNORRING (1970) distinguished.

This very complex phosphates association is mainly characterized by abundance of aluminium.

VON KNORRING (1969, 1970 and 1972) noted many species in it: amblygonite, trolleite, brazilianite, lazulite, augelite, berlinite, bertossaite with crandallite and wavellite. Quartz, apatite and muscovite also occur in the association.

Bjarebyite is pistachio-or dark-green in colour, striated and rather like tourmaline in appearance. It is found intimately intergrown with bertossaite, though it is usually confined to small cavities, lined with quartz and fibrous apatite, in trolleite or bertossaite.

Under the microscope, this Ba-bearing phosphate appears in hypidiomorphic forms, frequently associated with quartz and a blue phosphate of the lazulite-scorzalite series. Sometimes, it shows an interstitial structure with this blue phosphate, in trolleite.

## Crystallography

### Single-crystal X-ray data

Rotation and Weissenberg photographs were obtained from a short, striated, prismatic crystal of bjarebyite from Buranga pegmatite, using nickel filtered copper radiation.

The diffraction data show monoclinic symmetry, compatible with space group  $P 2_1$  and  $P 2_1/m$ .

The recent determination by MOORE et al. (1973) confirms  $P 2_1/m$  as the correct space group.

Preliminary cell parameters were obtained from measurements of these films. They were used to obtain the refined cell data from the powder diffraction diagram.

### X-ray powder diffraction data

A diffractogram of bjarebyite was recorded on a Philips' diffractometer with an internal standard of oxammite (A.S.T.M. 14-801), using Ni-filtered copper radiation ( $\text{CuK}_\alpha = 1.5418 \text{ \AA}$ ).

Powder data are listed in table I where patterns of bjarebyite from Palermo mine are also listed for comparison.

The unit cell dimensions were computed with the least-squares refinement FORTRAN program of Cox (1967). The results are compared in table II with those recently reported by MOORE et al. (1973). The unit cell dimensions of bjarebyite from Buranga are greater and this seems to be related to the higher MnO amount in the formula (table IV).

Table I. *X-ray powder data for bjarebyite*

Buranga (this report)				Palermo (MOORE et al., 1973)		
I/I <sub>0</sub>	d(Å) <sub>obs</sub>	hkl	d(Å) <sub>calc</sub>	I/I <sub>0</sub>	d(Å)	hkl
100	8.952	100	8.952	7	8.81	100
5	7.237	110	7.218			
5	6.096	020	6.102			
15	5.042	120	5.042	4	4.97	120
15	4.649	10 $\bar{1}$	4.651	2	4.59	101
15	4.529	011	4.528	4	4.47	011
5	4.473	200	4.476			
10	4.201	210	4.202	1	4.124	210
20	3.607	220	3.609	2	3.564	220
10	3.482	21 $\bar{1}$	3.491	1	3.447	211
5	3.336	121	3.339	1	3.295	121
80	3.122	031	3.124	2	3.090	031
		22 $\bar{1}$	3.128			221
35	3.058	13 $\bar{1}$	3.062	3	3.024	131
		040	3.051			
15	3.009	230	3.010			
40	2.943	211	2.945	4	2.910	211
45	2.896	310	2.899	2	2.852	310
15	2.846	131	2.848	2	2.811	131
1	2.778	30 $\bar{1}$	2.780			
45	2.710	31 $\bar{1}$	2.710	7	2.681	221
35	2.680	320	2.681	3	2.643	320, 311
1	2.580	041	2.586			
1	2.550	14 $\bar{1}$	2.551	1	2.514	141
10	2.519	240	2.521	2	2.495	321
15	2.470	10 $\bar{2}$	2.469	2	2.444	102
15	2.432	231	2.432	1	2.413	002
10	2.406	330	2.406	1	2.377	330
5	2.318	311	2.318	1	2.310	202
10	2.281	21 $\bar{2}$	2.285	2	2.261	212
1	2.236	400	2.238			
20	2.201	321	2.202	2	2.177	410
		410	2.201			
15	2.196	40 $\bar{1}$	2.190			
10	2.158	15 $\bar{1}$	2.161	3	2.137	151
		41 $\bar{1}$	2.156			
5	2.138	250	2.143			
5	2.132	340	2.133			
10	2.106	13 $\bar{2}$	2.112	1	2.090	122
		420	2.101			
5	2.077	151	2.082			
15	2.057	34 $\bar{1}$	2.055			
15	2.052	31 $\bar{2}$	2.053	2	2.039	312
15	2.032	060	2.034	10	2.010	060, 232
15	2.027	25 $\bar{1}$	2.028			
10	2.014	23 $\bar{2}$	2.019			
5	1.987	160	1.983			
10	1.965	212	1.968	2	1.956	132
		132	1.970			
1	1.927	43 $\bar{1}$	1.928			
5	1.894	222	1.896	2	1.880	222
5	1.863	16 $\bar{1}$	1.864			
5	1.817	421	1.820	1	1.786	402
		161	1.812			
40	1.790	500	1.790	1	1.759	500, 412
		232	1.791			
		50 $\bar{1}$	1.789			
30	1.786	44 $\bar{1}$	1.779			

Buranga (this report)				Palermo (MOORE et al., 1973)		
I/I <sub>0</sub>	d(Å) <sub>obs</sub>	hkl	d(Å) <sub>calc</sub>	I/I <sub>0</sub>	d(Å)	hkl
10	1.775	26 $\bar{1}$	1.776			
10	1.770	510	1.771	1	1.733	510
		51 $\bar{1}$	1.770			
1	1.740	302	1.740			
5	1.718	520	1.718	1	1.702	342
		52 $\bar{1}$	1.717			
5	1.696	351	1.697	1	1.681	351
5	1.680	360	1.681			
5	1.676	322	1.673			
5	1.671	242	1.669	1	1.659	252
5	1.666	43 $\bar{2}$	1.663			
5	1.636	530	1.639	2	1.624	530
		53 $\bar{1}$	1.638			
5	1.632	17 $\bar{1}$	1.633			
		45 $\bar{1}$	1.630			
5	1.616	441	1.617	2	1.600	441
10	1.588			2	1.578	501
5	1.565			3	1.556	162
10	1.541					
10	1.538			3	1.528	514
10	1.508					
15	1.502			5	1.495	033, 601
10	1.477					
10	1.473					

Table II. Unit-cell parameters for bjarebyite

	Buranga (this report)	Palermo (MOORE et al., 1973)
a	9.103 ± 0.003 Å	8.930 Å
b	12.204 ± 0.004 Å	12.073 Å
c	4.959 ± 0.002 Å	4.907 Å
β	100° 28' ± 1'	100.15°
v	542 ± 2 Å <sup>3</sup>	521.8 Å <sup>3</sup>
Space group	P 2 <sub>1</sub> or P 2 <sub>1</sub> /m	P 2 <sub>1</sub> /m
Z	2	2
G (mes)	3.90 (24° C)	3.95 ± 0.02
G (calc)	3.924	4.02

### Optical properties

Bjarebyite is biaxial positive. The refractive indices, measured in sodium light and determined with Cargille oils by the double variation method, are  $\alpha = 1.724$ ,  $\beta = 1.727$  and  $\gamma = 1.749$  all values are accurate to  $\pm 0.001$ .

Birefringence, as observed with the Berek's compensator, is 0.022 and  $(\gamma - \alpha) = 0.025$ . The optic axial angle is (+) 38°, measured conoscopically on the universal stage. This value compares with (+40° 56'), calculated from refractive index data, and lies within the limits of error of the refractive indices as determined.

A strong pleochroism is observed:

Z, colourless to pale brownish yellow,  
Y, brownish green,  
X, apple or olive green.

Extinction angle between Z and  $c$  is  $8^\circ$  by universal-stage measurements and  $7^\circ$  as observed in thin section.

Y is assumed to be parallel to  $b$  and Z seems to lie in (010) in the acute angle  $\beta$ . Sections more or less normal to Z show strong dispersion ( $r < v$ ) and two perfect cleavages, probably (010) and (100) (MOORE et al. 1973) (fig. 1).

These results are compared in table III with those obtained by MOORE et al. (1973). The difference between the optical data cannot be explained by chemical differences alone, in particular by the ratio Mn/Fe.

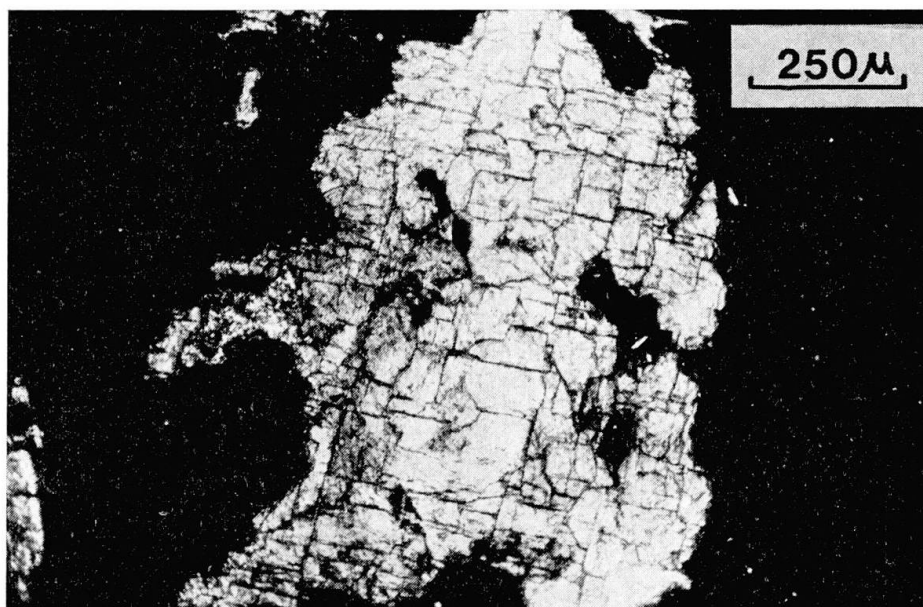


Fig. 1. Bjarebyite. Section nearly normal to Z showing two cleavages. Polarized crossed light.

Table III. *Optical data for bjarebyite*

	Buranga (this report)	Palermo (MOORE et al., 1973)
$\alpha$	1.724	1.692
$\beta$	1.727	1.695
$\gamma$	1.749	1.710
$\gamma - \alpha$	0.025	0.018
$2 V_{\text{obs}}$	(+) $38^\circ$	(+) $35^\circ$
$2 V_{\text{calc}}$	(+) $40^\circ 56'$	—
$Z \wedge c$	$8^\circ$	—
Pleochroism	strong	weak
	X = apple green	
	Y = brownish green	
	Z = $\pm$ colourless	
r	$< v$	$\gg v$

### Chemical analysis

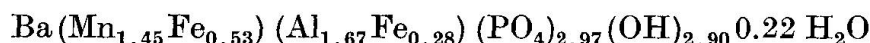
The results of two chemical analyses are given in table IV and are compared with those performed with electron microprobe by MOORE and al. (1973).

Table IV. *Chemical analyses of bjarebyite*

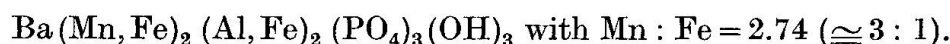
	1	2	2	4	5
P <sub>2</sub> O <sub>5</sub>	—	32.74	32.5	32.96	0.190
Al <sub>2</sub> O <sub>3</sub>	13.43	13.33	12.9	13.25	0.214
Fe <sub>2</sub> O <sub>3</sub>	—	3.74	2.8	3.30	0.290
FeO	8.67	5.54	6.2	5.94	0.187
MnO	9.56	15.84	15.8	15.98	0.191
MgO	—	—	—	—	—
BaO	23.69	23.35	23.9	23.87	0.127
SrO	1.57	—	—	—	—
H <sub>2</sub> O	—	4.81	4.5	4.70	0.340
Insol.	—	0.30	0.4	—	—
Total		99.65	99.0	100.00	

1. Bjarebyite from Palermo mine. Oxides calculated from Moore' results (1973).
2. Analyst: O. VON KNORRING } Bjarebyite from Buranga pegmatite.
3. VON KNORRING (1973) }
4. Mean of the two analyses (2 and 3).
5. Specific refractive energies (Larsen and Berman, 1934).

The mean of the two analyses (4), the measured specific gravity 3.90 and the unit cell volume 542 Å<sup>3</sup> suggest a cell content Z=2 and a formula of



or an idealised formula of



The calculated specific gravity 3.924 is in good agreement with G. meas. = 3.90.

The mean index of refraction, calculated by the Gladstone and Dale rule (IV, 5) from the mean of the two analyses is 1.735, compared to the mean measured index of 1.733.

### Infrared absorption spectrum

The IR spectrum was recorded with a Beckman IR-12 spectrophotometer in the 200 cm<sup>-1</sup>–4000 cm<sup>-1</sup> region. The sample was prepared with 2 or 3 mg of bjarebyite diluted in pressed tablets of KI.

The infrared absorption spectrum of bjarebyite is given in figure 2. The wavenumber in cm<sup>-1</sup> and the characteristics of the peaks are given in table V.



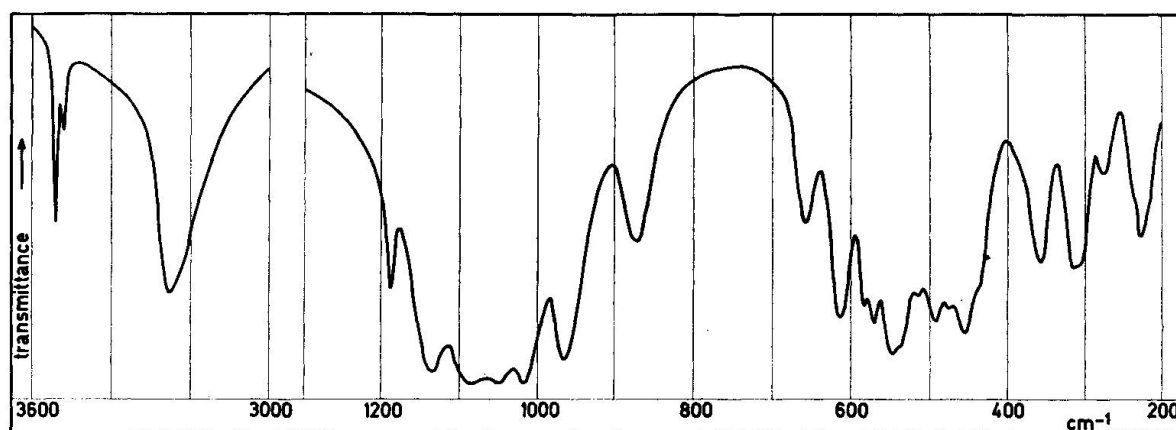


Fig. 2. Infrared absorption spectrum of bjarebyite.

Table V. *Infrared absorption bands of bjarebyite*

Wavenumber (cm <sup>-1</sup> )	Wavenumber (cm <sup>-1</sup> )
225 s	582 w
275 m b	612 s
313 s b	655 m
355 s	871 s b
384 w	964 s
435 sh	1015 m b
452 s	1050 w b
472 w	1085 w b
491 m	1133 m b
513 w	1187 s
535 sh	3250 s b
545 s	3520 s
568 m	3540 s

s strong, m medium, w weak, b broad, sh shoulder

For the 200 cm<sup>-1</sup>–700 cm<sup>-1</sup> region assignments of absorption peaks are very difficult and the complexity of the spectrum after 400 cm<sup>-1</sup> is probably due to the bending vibrations of isolated PO<sub>4</sub> tetrahedra, mixing with Al-O vibrations in the [Al<sub>2</sub>O<sub>6</sub>(OH)<sub>3</sub>] chains, described by MOORE and ARAKI (1973) in the bjarebyite structure.

The numerous and strong frequencies from 900 cm<sup>-1</sup> to 1200 cm<sup>-1</sup> are these of the stretching vibrations of apparently distorted PO<sub>4</sub> tetrahedra.

The 871 cm<sup>-1</sup> band is certainly the bending vibration of OH<sup>-</sup> groups.

The region of the stretching vibrations of OH<sup>-</sup> groups between 3200 and 3600 cm<sup>-1</sup> shows a large and strong band at 3250 cm<sup>-1</sup>, proving the existence of OH<sup>-</sup> groups with hydrogens bonds and a sharp doublet at 3520 and 3540 cm<sup>-1</sup> due to free OH<sup>-</sup> groups. This deduction is in good agreement with observations of MOORE and ARAKI (1973). Indeed there are two OH<sup>-</sup> sites, located in 0(8) and 0(9) in the bjarebyite structure.

Following MOORE and ARAKI (1973),  $O(9) = OH^-$  forms a hydrogen bond with  $O(5)$ , the distance being 2.60 Å and that appears in the IR spectrum at  $3250\text{ cm}^{-1}$ . On the other hand the doublet is the stretching vibrations of  $OH^-$  groups located in  $O(8)$  separated from  $O(1)$  by a distance of 3.65 Å, too long to allow a hydrogen bond.

### Conclusions

Bjarebyite, described in this paper, is to be added to the exceptionally long list of phosphate minerals occurring in Buranga mine. The new mineral is interesting and furnishes details about the geochemistry of this pegmatite.

From a geochemical point of view the presence of barium in the Buranga pegmatite is of some importance. In addition to the barium-rich bjarebyite, a barian arrojadite with 5.36 per cent BaO and another new barian phosphate containing 3.5 per cent BaO have been noted (VON KNORRING, 1972, 1973).

The paragenesis of bjarebyite in Buranga is also noteworthy. MOORE et al. (1973) described bjarebyite in Palermo from a complex association with the following phosphate minerals: amblygonite, augelite, childrenite, scorzalite and palermoite. This environment is nearly the same as that in Buranga. In this latter pegmatite it seems that Ca is more common than Sr, so the role of palermoite is taken by bertossaite.

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