BRAZILIANITE, A NEW PHOSPHATE MINERAL

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CONTENTS

ABSTRACT

Brazilianite is a new monoclinic phosphate mineral, $Na_2Al_6P_4O_{16}(OH)_8$. $a:b:c=1.1056:1:0.6992$; $\beta=97°22'$, $p_0'=0.6377$, $q_0'=0.6992$, $x'=0.1293$. Perfect (010) cleavage. $H=5\frac{1}{2}$, S.G. $=2.94$, vitreous luster, yellow-green, translucent to transparent. Biaxial $+$, $\alpha=1.598$, $\beta=1.605$, $\gamma=1.617$. 2V large (60–70°). Dispersion $r<v$. Occurs in large crystals in pegmatite near Cons. Pena, Minas Geraes, Brazil.

INTRODUCTION

In the course of mineralogical work in Brazil, a large yellow-green crystal was shown to F. H. Pough by a dealer who claimed it to be chrysoberyl. The symmetry and hardness at once showed that it could not be that mineral, but none was known which seemed to fit the properties. Shortly after this and a second specimen of comparable quality were acquired for The American Museum of Natural History from the owner, Sr. Oswaldo Correia of Belo Horizonte, a third crystal, identical in habit with one of the two acquired was seen at the Divisão do Geologia e Mineralogia, in Rio de Janeiro. The Curator of this collection, Dr. Evaristo P. Scorza, had received this specimen some weeks before from a mining engineer and had made a spectrographic determination of its composition in an endeavor to identify it. From the composition he assumed it to be fremontite, a very close approximation in view of his limited facilities.

[1] Published with permission of Secretary of the Smithsonian Institution.

FIG. 1. The two large brazilianite crystals of the collection of The American Museum of Natural History.

FIG. 2. 19 and 23 carat gem stones of brazilianite.

On return to this country a more extensive study was made to establish the identity of this mineral. Every one who saw these specimens was reluctant to believe it could possibly be a new mineral, yet the preliminary study of the optical and chemical properties gave this indication.

A few grains of the material were given to K. J. Murata of the U. S. Geological Survey for a spectrographic examination. He confirmed Dr. Scorza's findings that the mineral was essentially a sodium-aluminum-phosphate. The minerals fremontite and amblygonite are chemically about as closely related to the composition of the new mineral as any

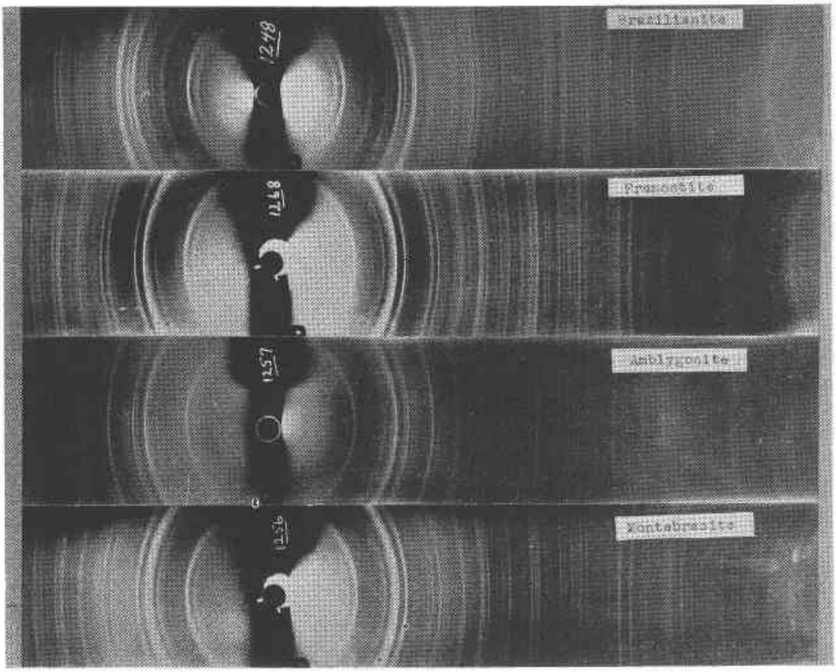


FIG. 3. *X*-ray powder photographs of allied phosphate minerals by J. M. Axelrod.

material found, assuming that the lithium of amblygonite had been replaced by sodium. In order to establish the relationship between these two minerals and brazilianite, J. M. Axelrod, also of the U. S. Geological Survey, took *x*-ray photographs of all three (Fig. 3). The photographs definitely proved that brazilianite is distinct from either of these minerals and a more detailed examination of the crystallography convinced the authors that this mineral is new to science.

Subsequently a series of additional specimens were obtained. One exceptionally large crystal weighing 973 grams was located and has been added to the Canfield collection of minerals of the U. S. National Museum. On a second trip to Brazil, the co-author, F. H. Pough, obtained about 15 additional crystals; although much smaller, many of them were well suited for goniometric study.

The authors decided that such an important mineral should bear the name of its country of origin. Brazilite would have been our preference, but unfortunately this name had already been applied to baddeleyite, and therefore not available. Our next choice was *brazilianite*.

Crystallography

Forms. Brazilianite crystallizes in the monoclinic system. The angle-table (Table 1) shows the axial ratios and the forms noted. The calculations are based upon two-circle goniometric measurements of thirteen crystals and contact measurements upon two large crystals.

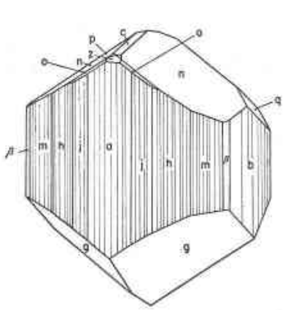
Table 1. Brazilianite Angle-Table

Monoclinic prismatic: $\frac{2}{m}$

$a:b:c=1.1056:1:0.6992$; $\beta=97°22'$; $p_0:q_0:r_0=0.6324:0.6934:1$; $r_2:p_2:q_2=1.4421:0.9122:1$; $\mu=82°38'$; $p_0'=0.6377$, $q_0'=0.6992$, $x'=0.1293$.

Forms

		ϕ	ρ	ϕ_2	$\rho_2=B$	C	A
c	001	90°00′	7°22′	82°38′	90°00′	0°00′	82°38′
b	010	0 00	90 00	—	0 00	90 00	90 00
a	100	90 00	90 00	0 00	90 00	82 38	0 00
β	340	34 22	90 00	0 00	34 22	85 51	55 38
m	110	42 22	90 00	0 00	42 22	85 03	47 38
i	210	55 23	90 00	0 00	55 23	83 57	34 37
h	310	69 42	90 00	0 00	69 42	83 06	20 18
j	610	79 39	90 00	0 00	79 39	82 45	10 21
n	011	10 22	35 38	82 38	55 02	67 09	83 59
z	101	90 00	37 29	52 31	90 00	30 07	52 31
x	$\bar{1}01$	−90 00	26 57	116 56	−90 00	34 19	116 56
w	$\bar{2}01$	−90 00	48 54	138 54	−90 00	56 16	138 54
v	$\bar{3}01$	−90 00	60 43	150 43	−90 00	68 05	150 43
p	113	55 43	22 28	71 08	77 34	16 53	71 36
o	111	47 25	46 10	52 31	60 47	40 59	57 55
g	$\bar{1}11$	−35 48	40 59	116 56	57 52	45 36	112 34
s	211	63 21	57 32	35 27	67 46	51 01	41 03
q	$\bar{1}21$	−19 59	56 06	116 56	38 44	58 52	106 29



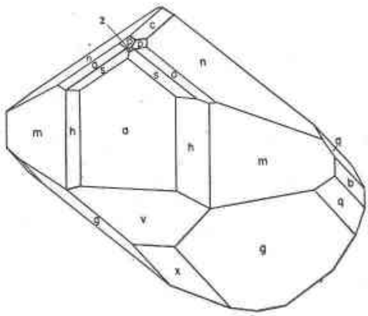


FIG. 4 (left). Brazilianite crystal of the less common slightly prismatic habit.
FIG. 5 (right). Brazilianite crystal of characteristic habit.

Habit. Crystals are of two habits, the less frequent being that shown in Fig. 4 in which the prisms are slightly elongated and so numerous in oscillatory intergrowths that the crystal is somewhat rounded in outline. One of the large crystals shows this habit as well as two of the smaller ones. Much more often we find the prism zone to be a narrow one with the attachment of the crystals at the back and the principal development in the [100] zone. Most of the smaller crystals reveal this habit and three of the larger ones, including the one at the U. S. National Museum and that of the Divisão in Rio, Fig. 5.

DISCUSSION

The prism zone is characteristically striated parallel to the *c*-axis, and all of the forms in this zone show striations. This facilitates the study of incomplete crystals; together with the cleavage the striations permit rapid orientation on the goniometer. The dominant prism is *m*, but *a* and *b*, the two pinacoids, are always present. This is well shown in the Relative Size Table[2] (Table 2) where $G_m = 55$, $G_a = 80$, and $G_b = 64$. A surprising aspect of the prism zone is the frequency of *h* (310) which is present nine out of fifteen times, with a size proportion of 53. Harmonically the prism series is not good.

The base is a relatively frequent face, as seen by its frequency index of 80, but it is always narrow and sometimes present only as a slender truncating hair's breadth form. In only one case did it show nice accessories,[3] on this crystal it was marked by a series of downward pointing symmetrical hillocks (Fig. 6), the reflections from their sides trailing off in the

[2] See Goldschmidt, V., Über Grösse und Häufiigkeit der Flächenarten: *Beiträge zur Kristal.*, **2,** 98–99 (1923).

[3] Goldschmidt, V., Über Wachstums-Gebilde: *Beiträge zur Kristal.*, **2,** 167–175 (1923).

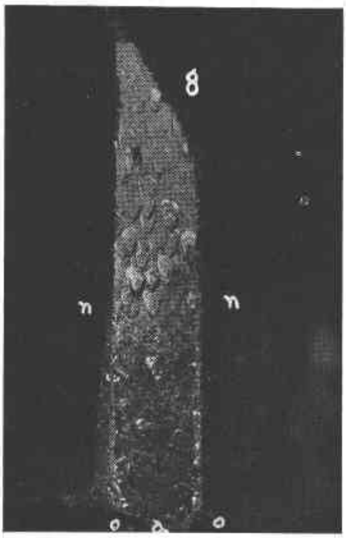
TABLE 2. RELATIVE SIZE AND FREQUENCY STATISTICS

$$H=100\,\frac{h}{n}$$ H = frequency %. h = number of observations. n = number of crystals studied = 15.

$$G=g\,\frac{100}{3n}$$ G = Relative size of faces; g = 3i + 2k + 1

i = occurrences as a large face
k = occurrences as a medium face
l = occurrences as a small face

FORMS	H	G	FORMS	H	G
c	80%	53%	*z*	67%	31%
b	100	64	*x*	47	22
a	100	80	*w*	6	4
β	33	22	*v*	93	55
m	100	55	*p*	53	22
i	6	4	*o*	87	40
h	60	53	*g*	100	100
j	13	11	*s*	53	29
n	100	100	*q*	53	36



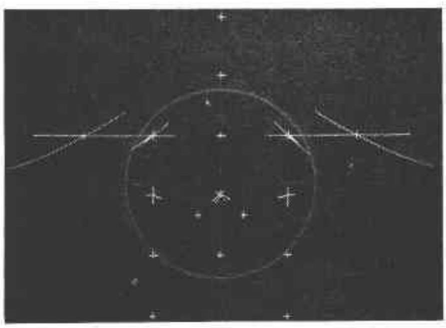
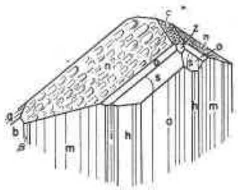


FIG. 6 (left). Growth accessories on *c*. ×9.
FIG. 7 (right). Signals and trains-of-reflection in gnomonic projection of terminal forms. 5 cm. circle base.

direction of (111) and (211) (Fig. 7). The contrasts in size and frequency, brought out by the tabulations, is well shown in the case of this form, which has a size index of 53, the same as *h*(310), though the latter has a frequency index of only 60.

The prism forms are rarely dominant on the crystals of brazilianite, usually the most prominent faces are those of the negative bipyramid *g* ($\bar{1}$11), and next in importance, the clinodome *n* (011). The surfaces of the two pairs of faces are different in detail, and it is possible to identify the forms by a study of the accessories. *n* is marked by elongated plateaus whose edges parallel the outline of the face itself (Figs. 8, 9, 10). The



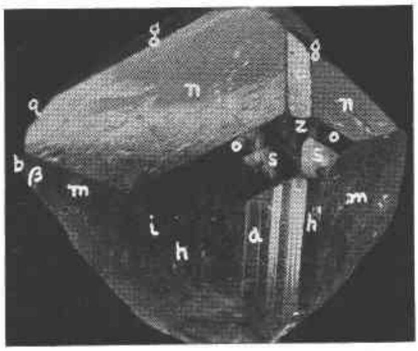


FIG. 8 (left). Characteristic growth accessories on principal faces of brazilianite.
FIG. 9 (right). Photograph of crystal in Fig. 8, showing characteristic growth accessories. ×2.

elongation is in the [100] zone. This is distinctly shown in the gnomonic projection of the trains-of-reflection from these faces (Fig. 7). The accessories, which are undoubtedly growth accessories as none of the crystals show etching phenomena of any significance, are common and were seen on most of the *n* faces; in contrast to the rarity of such irregularities on *c*. The dominant character of *n* is well shown by its size and frequency index figures, 100 and 100.

The same percentages characterize the negative bipyramid *g*. In general its appearance is similar to that of *n*, and without other forms being present it might be difficult to immediately identify these faces, were it not for the accessories, which are very different in appearance. Occasionally there are terraces shaped somewhat like those on *n*, but the elongation lies in the zone [010]. In addition, there is a frequent striation also in this direction. The truncating edges of the elongated terraces, however,

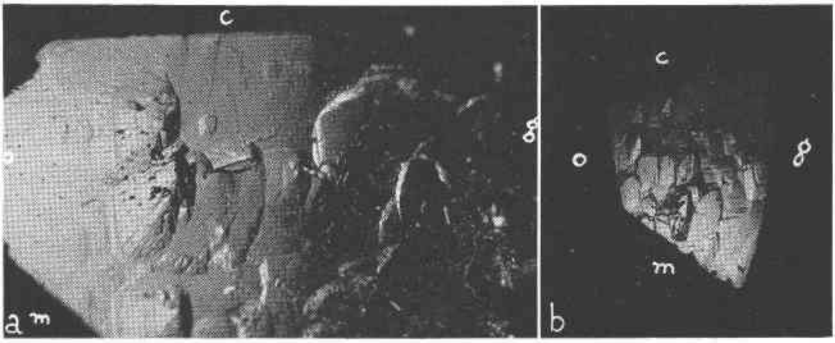


FIG. 10. Growth accessories on *n* (a). ×9.
(b). ×4.

cut at an angle across them, making the train-of-reflection cross, whose arms lie at about 60° to each other (Fig. 11). These sides approximately parallel the edges of the rare form *w* ($\bar{2}01$) and a form (021) which was not observed. The adjoining negative bipyramid *q* ($\bar{1}21$) is marked by a series of striations in the [010] zone and its train-of-reflections is a simple streak.

The other forms do not show any pronounced characteristic accessories, even though a number of them are relatively frequent in occurrence and large in size. The negative orthodomes *x* ($\bar{1}01$) and *w* ($\bar{2}01$) are rare, *x* making a slender truncation between the faces of *g* in about half of the crystals. *w* was observed but once, on the large crystal now in the U. S. National Museum collection (U.S.N.M. No. C-5797), and in this case it is a fair-sized and well developed form, but no indication of it

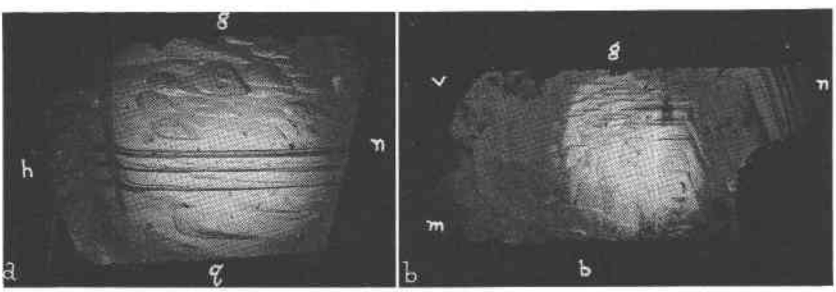


FIG. 11. Growth accessories on *g* (a). ×3.75.
(b). ×4.65.

was seen in any other crystal. *v*, on the other hand, is a common form, usually present and is the form which permits the proper orientation of the crystals by inspection. Its size and frequency index of 55 and 93, respectively, are indicative of its importance.

Composition

Brazilianite is distinct from any known mineral in both its physical and chemical properties. It appears to be the first reported compound of a new group of minerals, and by replacement of some of the elements in brazilianite, it may some day be expanded into quite a series of minerals.

In the following table brazilianite is compared with turquoise, chalcosiderite, and fremontite because these minerals have the closest approach in chemical composition to brazilianite. Sodium in brazilianite takes the place of the copper in the turquoise and chalcosiderite formulas and although this case is not an isomorphous series, it resembles the relationship between polyhalite and leightonite where the copper has replaced sodium in polyhalite.

Name	*Composition*					*Crystal System*
Turquoise	Cu	Al_6	P_4	O_{11}	$(OH)_{18}$	Triclinic
Chalcosiderite	Cu	Fe_6	P_4	O_{11}	$(OH)_{18}$	Triclinic
Brazilianite	Na_2	Al_6	P_4	O_{16}	$(OH)_8$	Monoclinic
Fremontite	Na_2	Al_2	P_2	O_8	$\left.\begin{matrix}(OH)_2\\(F)_2\end{matrix}\right\}$	Monoclinic

Numerous tests were made to detect the presence of fluorine in brazilianite, but all gave negative results. In order to further confirm these results, K. J. Murata prepared known standards and qualitatively tested them by spectroscopic methods, and he reported no fluorine, vanadium or arsenic in brazilianite. One of the co-authors, E. P. Henderson, used the method described by J. J. Fahey for the determination of fluorine.[4]

There are many possible substitutes in the brazilianite formula and in addition to the replacement of the Na by other elements, iron may replace aluminum, and it is quite possible that vanadates and arsenates will substitute for phosphates.

Brazilianite is a hydrous sodium aluminum phosphate and its formula is: $Na_2O\cdot 3Al_2O_3\cdot 2P_2O_5\cdot 4H_2O$.

[4] Fahey, Joseph J., Colorimetric determination of fluorine with ferron: Analytical edition, *Industrial and Engineering Chemistry*, **11**, 362 (July 15, 1939).

ANALYSIS OF BRAZILIANITE

E. P. Henderson, *Analyst*

		Ratios		Theoretical composition
Al_2O_3	43.82	.4288	3×1405	42.25
P_2O_5	37.97	.2668	2×1334	39.23
Na_2O	8.42	.1358	1×1397	8.56
K_2O	.37	.0039		
H_2O	9.65	.5356	4×1439	9.96
				100.00
Cl	trace			
F	none			
	100.23			

PHYSICAL PROPERTIES

Cleavage (010) perfect. Brittle, conchoidal fracture. H. $=5\frac{1}{2}$, G. $=2.94$. Luster vitreous, color chartreuse yellow, streak white. Translucent to transparent.

OPTICAL PROPERTIES

Biaxial positive, $\alpha=1.598$, $\beta=1.605$, $\gamma=1.617$. 2V large, 60–70°. Dispersion $r<v$.

TESTS

Difficultly fusible, colors flame yellow. Mineral slightly expands on heating, forming a white product. Yellow color is expelled at low temperatures and the mineral becomes colorless. In closed tube brazilianite slightly decrepitates and gives off water; insoluble in hydrochloric acid.

OCCURRENCE

It was very difficult to obtain any data regarding the exact occurrence of the mineral. It is obviously a pegmatite mineral for small crystals of muscovite are to be found all around the base of the crystals, and one or two green tourmalines may be seen included in portions of the clear crystals. White albite feldspar is associated with the muscovite in the matrix.

The locality given by Sr. Correia was not far from Arrasuahy, whereas the locality on the specimen in Rio was near Conselheira Pena, both in the State of Minas Geraes. Recently a communication from Sr. M. Pimentel de Godoy describes the source as follows: "The deposit is an altered pegmatite dike about 1 meter in width, between walls of weathered biotite schist. The brazilianite appears to be associated with mica, feldspar and quartz. The locality is the south slope of a hill which divides the Rio Doce and the Rio São Matheus, near the head of a small tributary of the Divino River, which runs in turn into the Laranjeiras and then joins the Rio Doce. The deposit belongs to the mica group of the Conselheira Pena district, in the eastern part of the State of Minas Geraes."

Description of Specimens

Brazilianite is especially noteworthy as a new mineral because of the size and perfection of the crystals. The first two crystals obtained were of mammoth proportions. The prismatic crystal is about 85 mm. long in the direction of the *c*-axis and about 80 mm. from front to rear. It weighs 868 gms. The second, and more common type of crystal has a narrow striated prism zone, the faces themselves being only 15 to 40 mm. long, and the longest direction along the *c*-axis is only about 70 mm. Along the *a*-axis, from front to rear, on the other hand, it measures about 100 mm., and along the *b*-axis it is about 75 mm. This crystal weighs, with its mica and feldspar matrix, 852 gms. (Fig. 1).

The crystals are transparent when they are unflawed, and they include many flawless areas. The side pinacoid cleavage is pronounced and cracks are to be seen within the crystals paralleling this cleavage direction. The color appears to vary slightly; some portions of one of the crystals, however, are definitely greener than others. Other than the flaws, the only inclusions noted were some slender crystals of green tourmaline and muscovite.

Brazilianite possesses an attractive yellowish-green color, not greatly different from chrysoberyl, and when clear pieces were found it was decided to recover a gem stone. A large, clear fragment supplied by Dr. Scorza was cut by Anthony Espositer of New York City, and two large stones were obtained, one an emerald cut of 23 carats and the other a 19 carat oval brilliant (Fig. 2). The larger stone was sent to Dr. Scorza for the collection of the Divisão do Geologia e Mineralogia in Rio, and the other is in the collection of The American Museum of Natural History.

The emerald cut stone appears to have a slightly deeper green color than the oval brilliant. This may be due to the difference in orientation of the two stones with respect to the original crystal; or to the optical effect such as loss of refracted light from the sides of the stone, or perhaps to the fact that the original crystal was not absolutely uniform in color. Dichroism is slight. Mr. Espositer reported that the cutting was no more difficult than any other stone of equal hardness and that the perfect cleavage of brazilianite caused no trouble.

It is of interest to gem collectors to find a new gem stone, but it is of greater pleasure to the mineralogist who is so fortunate as to describe a new mineral of such excellent quality that it can be used as a gem stone. Brazilianite is soft and therefore will never become an outstanding or popular stone, regardless of the beauty it may possess. The refractive indices being near to 1.60 and its low dispersion indicates that brazilianite can hardly exceed yellow beryls in brilliance, and it will be less durable than beryls.

Acknowledgments

The authors acknowledge the suggestions given during this study by W. T. Schaller and M. Fleischer of the U. S. Geological Survey, in addition to those mentioned directly in the paper.