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New data on the crystal morphology of brazilianite (Galiléia, Minas Gerais, Brazil)

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Morphology of brazilianite $NaAl_3(PO_4)_2(OH)_4$ crystals from the Galiléia area, Minas Gerais, Brazil (collection Ilia Deleff; Museum of Unique Crystals "Ilia Deleff", University of Mining and Geology "St. Ivan Rilski", Sofia) is studied by goniometry in order to determine the crystal forms. On 29 samples are decribed 25 crystallographic forms, among them 14 new forms. The majority of crystals are single terminated, spearhead-shaped, elongated along the [001] zone, with dominant crystal forms for the majority of the studied crystals: *a* {100}, *b* {010}, *w* {$\bar{2}$01}, *i* {210}, *q* {121}, *γ* {$\bar{2}$21} and *δ* {$\bar{2}$23}. In several cases are found the faces of the following forms *x* {$\bar{1}$01}, *z* {101}, *θ* {301}, *μ* {230}, *g* {$\bar{1}$11}, *o* {111}, *ε* {$\bar{3}$21}, *ι* {253} and *ρ* {122}. Crystal forms found in single cases are: for sample N4 *ν* {012}; for sample N10 *c* {001}, *ζ* {332}, *η* {546}, *κ* {$\bar{1}$32}; *λ* {$\bar{5}$32}; for sample N26 *ξ* {130}, *n* {011}; for sample N27 *π* {223}. A new specific for the area prismatic crystal habit of brazilianite is described – spearhead shaped long-prismatic habit. Brazilianite has a $2a/(b+c) = 1.29$ ratio, which is representative for the $(I)^a$ structural type, according the crystal habit types of the paragenetic and crystal and chemical systematic of minerals. For the studied crystals the dominant crystal habit can be denoted as $(I)^a_{[001]}$.

Keywords: brazilianite, crystal habit, morphology.

INTRODUCTION

Brazilianite $NaAl_3(PO_4)_2(OH)_4$ has been reported for the first time from the Córrego Frio pegmatites, in the district of Linópolis, Minas Gerais in Brazil [1-6], and later on from several other occurrences in the country [7]: Minas Gerais – Araçuaí pegmatite district – Jenipapo[8], Conselheiro Pena pegmatite district – Divino das Laranjeiras [9], Telírio pegmatite, near Linópolis [5, 8, 10] as well as Gentil, Mendes Pimentel pegmatites [11, 8] and São Geraldo do Baxio pegmatites [8]; Espírito Santo – Santa Teresa and Mantena [12]; Paraíba – Pedra Lavrada – Alto Patrimônio; Rio Grande do Norte – Equador (Alto do Giz pegmatite) and Parelhas (Boqueirão or Boqueirãozinho pegmatite). Beside Brazil, the mineral is reported from pegmatites in several countries worldwide [13]. Brazilianite belongs to the class of phosphates and crystallizes in the $P2_1/n$ space group of the Monoclinic System, with a=11.233 (6) Å, b=10.142 (5) Å, c=7.097 (4) Å and β=97.37 (2)° [14].

EXPERIMENTAL

Brazilianite crystals and aggregates from the Galiléia pegmatites in the Rio Doce Valley, about 40 km southeast from Governador Valadares, south of Divino das Laranjeiras, Minas Gerais, are on display at the Museum of Unique Crystals "Ilia Deleff" at the University of Mining and Geology "St. Ivan Rilski" in Sofia (labeled Galiléia, Minas Gerais; collection Ilia Deleff). The Galiléia mine area includes also the type locality for brazilianite Córrego Frio mine. The pegmatites belong to the pegmatite district Conselheiro Pena, which is part of the Eastern Brazilian Pegmatite Province in the state of Minas Gerais. Most of the pegmatites in that region are hosted in the quartz biotite-schist of the São Tomé formation linked to the Urucum granite – they are orientated in most cases in the NW-SE direction [8]. Brazilianite is described as a hydrothermal mineral in phosphate-rich zones of the granite pegmatites. The mineral association for the Córrego Frio type

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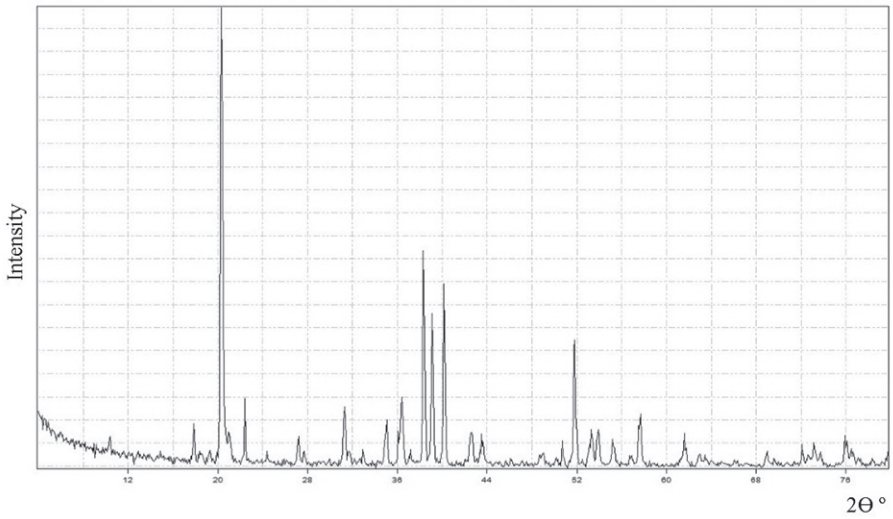

Fig. 1. X-ray powder diffraction of brazilianite

pegmatite is: muscovite, albite, quartz, fluorapatite, souzalite, scorzalite, arsenopyrite, beraunite, childrenite, dufrenite, frondelite, garnet, jahnsite, roscherite, sabugalite, strunzite, tapiolite, tourmaline, uraninite, wyllieite and zircon [5].

Twenty nine brazilianite crystals from the Galiléia area, Conselheiro Pena district, state of Minas Gerais in Brazil were chosen for study. The majority of brazilianite crystals are not double terminated. Most of the brazilianite samples are fragments of crystals or such of a poor termination. They are transparent to semi-transparent (Fig. 2–3). In some of the large brazilianite aggregates the crystals are whitish and not transparent. The brazilianite crystals (University of Mining and Geology – mainly from inv. N K222; Sofia University N M6229), were measured on a optical contact (Optische Universal-Winkelmesser, Carl Zeiss) and one-circle (E. Fluess, Steglitz, Berlin) goniometer to determine crystal morphology. The average dimensions for the largest 16 crystals are: 3.6×2.2×1.3 cm.

X-ray data were received on a TUR-M62 (Faculty of Geology and Geography, University of Sofia "St. Kliment Ohridski") powder diffractometer in the region 2Θ 4–80°, $Co_{K\alpha}$ radiation, 40 kV, 15 mA and on a Bruker-D2 Phaser (with a Diffrac. eva V4.0 search-match software) in the region 2Θ 5–70°, $Cu_{K\alpha}$ radiation, 30 kV, 10 mA (University of Mining and Geology "St. Ivan Rilski").

RESULTS AND DISCUSSION

The X-ray pattern of brazilianite (Fig. 1) corresponds to the standard one [15]. The X-ray patterns of the Palermo and Brazilian material also correspond – for the Palermo mine, New Hampshire, USA d (Å): 5.04 (10), 2.98 (8), 2.73 (8), 2.68 (8), 2.87 (7), 1.44 (5), 3.77 (4) [16]. The X-ray powder pattern in several crystals yielded a peculiarity in the range of 4–64°: the °2Θ diffraction lines 311, 122, 231, 510, 142, 251, 611 and 433 are widened or even doubled in all investigated samples, with additional lines of smaller intensity on lower °2Θ (e.g. on ~31° 2Θ) [8].

Twenty five crystallographic forms were recorded (Table 1). Dominant are the forms: *a* {100}, *b* {010}, *w* {$\bar{2}$01}, *i* {210}, *q* {121}, *γ* {$\bar{2}$21}, and *δ* {$\bar{2}$23} (Fig. 2, 4). Drawings are made with the help

Fig. 2. Brazilianite crystal with double termination faces (sample N5; 4×2×1.5 cm)

Table 1. Distribution of more than one observed crystal forms on the studied brazilianite crystals

N	*a* {100}	*b* {010}	*w* {$\bar{2}$01}	*x* {$\bar{1}$01}	*z* {101}	*θ* {301}	*i* {210}	*μ* {230}	*q* {121}	*g* {$\bar{1}$11}	*o* {111}	*γ* {$\bar{2}$21}	*δ* {$\bar{2}$23}	*ε* {$\bar{3}$21}	*ι* {253}	*ρ* {122}
1	+		+				+		+			+				
2	+	+	+				+		+			+				
3	+	+	+				+		+			+	+			
4	+		+				+		+		+	+	+			
5	+	+	+				+		+			+	+			
6	+		+				+					+				
7	+		+				+		+		+	+	+	+		
8	+	+	+	+			+		+	+		+	+			
9	+	+	+				+		+			+	+			
10	+						+									
11	+	+	+			+	+		+				+	+		
12	+	+	+	+		+	+		+	+		+	+			
13	+	+	+	+		+	+		+	+		+	+			
14	+		+	+			+		+	+		+	+			
15	+	+	+				+		+			+	+			
16	+		+				+		+			+	+			
17	+	+	+	+			+		+	+		+	+			
18	+	+	+	+			+		+	+		+	+			
19	+		+	+			+		+	+		+	+			
20	+		+				+		+			+	+			
21	+		+	+			+		+			+	+			
22	+		+				+		+			+	+			
23	+		+	+			+		+	+		+	+			
24	+	+	+				+		+				+			
25	+	+	+				+					+				
26	+					+?	+	+								+
27	+					+	+	+								+
28	+	+	+		+	+	+								+	
29	+		+		+	+	+								+	

of a VESTA program [17]. Some faces in the [001] zone are striated along the crystallographic axis *c* or display striations in a curvilinear pattern. All striated forms in the [001] zone exhibit multiple signals. Crystals are typically prismatic, or spearhead-shaped, elongated along the [001] zone, with large faces of the forms *w* {$\bar{2}$01}, *i* {210}, and *γ* {$\bar{2}$21}, and subordinate or rare forms as *a* {100}, *c* {001}, *b* {010}, *q* {121}, as well as *x* {$\bar{1}$01}, *g* {$\bar{1}$11}, *o* {111}, *ε* {$\bar{3}$21}, *ζ* {332}, *η* {546}, *θ* {301}, *ι* {253} and *z* {101}. The front (1st) pinacoid *a* {100} and 2nd pinacoid *b* {010} are represented by elongated narrow faces in the prism zone. The basal (3rd) pinacoid *c* {001}, as a tiny face, is rarely observed. Two brazilianite crystals (N28-29) display a similar prismatic zone morphology with the majority of crystals, but with a different termination including forms *θ* {301}, *ι* {253} and *z* {101}. They can represent a morphological subtype (Fig. 3, 5). Sample N10 also displays a different bipyramidal-type habit. In several cases are found the faces *x* {$\bar{1}$01},

Fig. 3. Brazilianite crystal with single termination faces (rare crystal habit; sample N1; 4×3×2 cm)

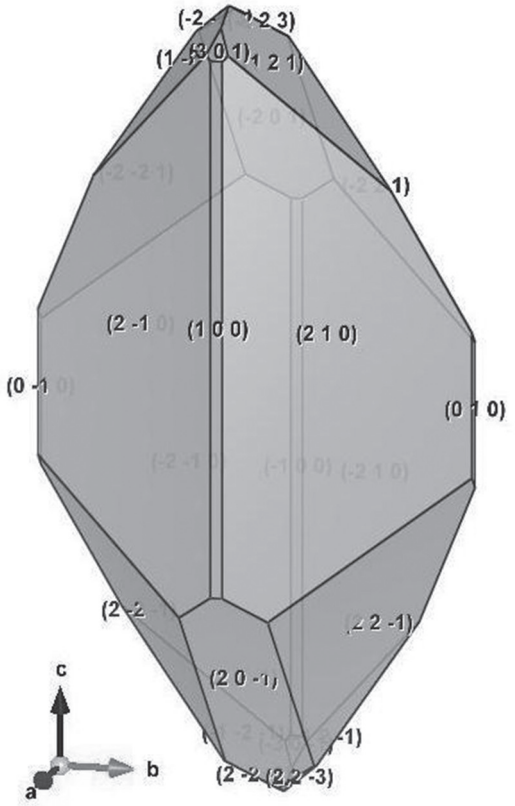

Fig. 4. Drawing of a typical crystal habit with common crystal forms for the majority of the studied brazilianite crystals in standard orientation (VESTA program)

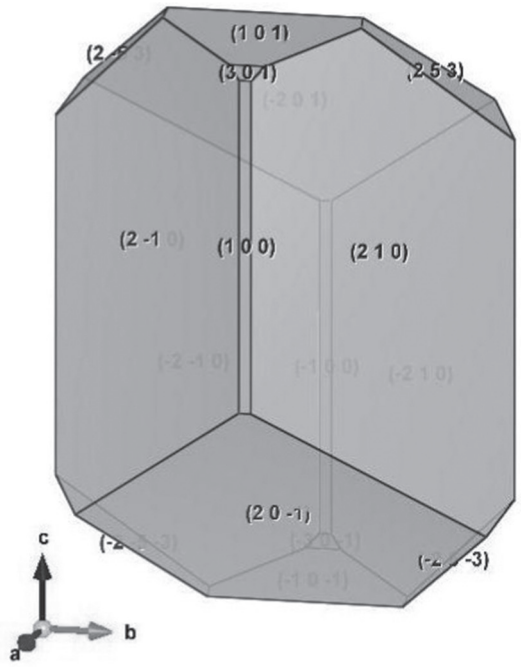

Fig. 5. Drawing of the rare crystal habit for brazilianite (VESTA program)

z {101}, θ {301}, μ {230}, g {$\bar{1}$11}, o {111}, ε {$\bar{3}$21} ι {253}, and ρ {122}. Crystal forms found in single cases are: for sample N4 ν {012}; for sample N10 c {001}, ζ {332}, η {546}, κ {$\bar{1}$32} and λ {$\bar{5}$32}; for sample N26 ξ {130} and n {011}; for sample N27 π {223}.

In the first publication on brazilianite 18 crystal forms have been distinguished, but some crystallographic descriptions (as "bipyramid"; "dome") turn to be incorrect, including the spherical coordinates for the m {110} form [1]. Several different habits of investigated brazilianite crystals have been distinguished, primarily on the basis of the elongation and orientation of the crystal, but relative development of the forms was considered as well [8]: the first group of crystal habits is represented by the elongation along [101] (this group could be divided into four subgroups on the basis of different form development); the second habit is represented with crystals from the Jenipapo pegmatite, Araçuaí district, which are elongated along [001] and terminated with a large {011} form, giving the crystal the form of a sharp column; the third group (new habit) is represented with crystals from the Gentil pegmatite (G5) and the São Geraldo do Baixio group (S1) – the crystal S1 is tabular, flattened along [001] with a large development of {101}, while crystal G5 exhibits a similar, although slightly less flattened habit; the fourth group (new habit) is represented by a crystal from the São Geraldo do Baixio group (S3) which appears somewhat isometric, due to the large development of {110} prism as well as {010}; the fifth group is represented with crystals from the Rapid Creek, Yukon, Canada, with an extremely elongated along [001] crystal habit.

In another morphological overview four types of crystal habits are distinguished: short-prismatic to the c-axis with the crystal forms {100}, {010} and {110} parallel to the c-axis ("Brazil habit"); short-prismatic to the a-axis with crystal forms {100}, {110}, {$\bar{1}$01}, {$\bar{3}$01}, {011}, {111}; "dipyramidal" on the a-axis with crystal forms {011}, {111} ("Palermo habit"); "dipyramidal" on the c-axis [13].

The arrow-like or spearhead shaped prismatic habit is also a new crystal habit among the described brazilianite habits from Brazil. Such prismatic habit can be placed between the S3 short prismatic brazilianite type habit from São Geraldo do Baixio group pagmatites in Brazil and the extremely long prismatic habit of crystals from Rapid Creek area, Yukon, Canada [8].

According to its structural anisometricity, brazilianite can be regarded as of a pseudo-isometric type structure – one can compare the forms of the similar in symmetry monacite-(Ce) in the monoclinic system [18]. The structure of brazilianite with a $2a/(b+c) = 1.29$ ratio is representative for the $(I)^a$ structural type. For the studied crystals the dominant crystal habit can be denoted as $(I)^a_{[001]}$ according the crystal habit types of the paragenetic and crystal and chemical systematic of minerals [18].

CONCLUSIONS

Goniometric studies of 29 crystals of brazilianite from the Galiléia area (Minas Gerais, Brazil) revealed 25 crystallographic forms, among them 14 new forms. The majority of crystals are single terminated, spearhead-shaped, elongated along the [001] zone, with dominant crystal forms *a* {100}, *b* {010}, *w* {$\bar{2}$01}, *i* {210}, *q* {121}, *γ* {$\bar{2}$21} and *δ* {$\bar{2}$23}. In several cases are found the forms *x* {$\bar{1}$01}, *z* {101}, *θ* {301}, *μ* {230}, *g* {$\bar{1}$11}, *o* {111}, *ε* {$\bar{3}$21}, *ι* {253} and *ρ* {122}, and in single cases the forms *v* {012}, *c* {001}, *ζ* {332}, *η* {546}, *κ* {$\bar{1}$32}; *λ* {$\bar{5}$32}, *ξ* {130}, *n* {011} and *π* {223}. A new specific for the area prismatic crystal habit of brazilianite is described – spearhead-shaped long-prismatic habit, denoted as $(I)^a_{[001]}$.

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НОВИ ДАННИ ВЪРХУ КРИСТАЛОМОРФОЛОГИЯТА НА БРАЗИЛИАНИТ (ГАЛИЛЕЯ, МИНАС ЖЕРАИС, БРАЗИЛИЯ)

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(Резюме)

Изучена е кристаломорфологията на 29 кристали от бразилианит $NaAl_3(PO_4)_2(OH)_4$ от района Галилея в щат Минас Жераис в Бразилия (колекция на Музея на уникалните кристали „Илия Делев“ при Минно-геоложкия университет „Св. Иван Рилски“, София). Установени са 25 кристални форми, от които 14 нови кристални форми. Повечето от бразилианитовите кристали са еднокрайни, копиевидно оформени, удължени по [001] зоната, с доминиращи кристални форми *i* {210}, *a* {100}, *w* {$\bar{2}$01}, *γ* {$\bar{2}$21}, *q* {121}, *δ* {$\bar{2}$23} и *b* {010}. Описан е нов дългопризматичен хабитус за този минерал, който съгласно парагенетичната и кристалохимичната класификация на минералите може да се отнесе към $(I)^a_{[001]}$ хабитусния тип.