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CRYSTAL MORPHOLOGY AND XRD PECULIARITIES OF BRAZILIANITE FROM DIFFERENT LOCALITIES

ANDREA ČOBIĆ*¹, VLADIMIR ZEBEC², RICARDO SCHOLZ³,
VLADIMIR BERMANEC¹ & SANDRA DE BRITO BARRETO⁴

¹Faculty of Science, Institute of Mineralogy and Petrography,
Horvatovac 95, Zagreb, Croatia

²Croatian Natural History Museum, Demetrova 1, Zagreb, Croatia

³Department of Geology, School of Mining,
Federal University Ouro Preto, Ouro Preto, MG, Brazil

⁴Department of Geology, Federal University of Pernambuco,
Av. Academico Hélio Ramos. S/N. 5 andar., Cidade Universitária,
Recife, PE, Brasil

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Forty four brazilianite crystals from several localities in Brazil, Rwanda and Canada were measured on a two-circle goniometer to determine brazilianite morphology. Twenty forms were recorded; six of them have not been recorded before. All faces in the [001] zone are striated along crystallographic axis *c*. All striated forms in the [001] zone exhibit multiple signals. Two of the signals observed on the form {110} are always very clear. There is an exception on one crystal where just one face, (110), exhibits only one clear signal. Five groups of habits were recorded, two of them new to this mineral species.

Eleven samples were examined by X-ray diffraction for calculation of the unit cell parameters yielding $a=11.201(1)\text{--}11.255(2)$ Å, $b=10.1415(5)\text{--}10.155(1)$ Å, $c=7.0885(7)\text{--}7.119(2)$ Å and $\beta=97.431(7)\text{--}97.34(1)$ °. All X-ray diffraction patterns show a peculiarity: some diffraction lines are widened or doubled with the appearance of additional diffraction lines systematically on lower 2θ . These diffraction lines have smaller intensities and cannot be indexed in accordance with brazilianite crystal structure.

Keywords: brazilianite, morphology, two-circle goniometer, Brazil, Canada, Rwanda

Čobić, A., Zebec, V., Scholz, R., Bermanec, V. & de Brito Barreto, S.: Morfologija kristala i rentgenografske osobitosti brazilijanita s različitih lokaliteta. *Nat. Croat.*, Vol. 20, No. 1., 1–18, 2011, Zagreb.

Četrdeset i četiri kristala brazilijanita s nekoliko lokaliteta iz Brazila, Ruande i Kanade je mjereno na dvokružnom refleksnom goniometru u svrhu određivanja morfologije. Zabilježeno je 20 formi, od

* corresponding author: ancobic@geol.pmf.hr

kjih šest do sada nije opisano. Sve plohe u zoni [001] su prutane paralelno kristalografskoj osi *c*. Sve prutane forme u [001] zoni daju višestruke signale. Forma {110} daje višestruke signale od kojih su dva uvijek oštra. Postoji iznimka gdje na jednom kristalu samo jedna ploha, (110), daje samo jedan oštar signal. Zabilježeno je pet grupa habitusa od kojih dva nova za ovu mineralnu vrstu.

Jedanaest uzoraka je snimljeno rentgenskom difrakcijom da bi se izračunali parametri jedinične ćelije: $a=11.201(1)\text{--}11.255(2)$ Å, $b=10.1415(5)\text{--}10.155(1)$ Å, $c=7.0885(7)\text{--}7.119(2)$ Å i $\beta=97.431(7)\text{--}97.34(1)^\circ$. Svi rentgenogrami pokazuju zanimljivost: neke difrakcijske linije su proširene ili podvostručene s pojavom dodatnih difrakcijskih linija sustavno na nižim 2θ . Ove difrakcijske linije su manjeg intenziteta te se ne mogu indicirati u skladu s kristalnom strukturom brazilijanita.

Ključne riječi: brazilijanit, morfologija, dvokružni refleksni goniometar, Brazil, Kanada, Ruanda

INTRODUCTION

Recently, the study of the morphology of minerals has been neglected due to the development of new techniques. In spite of advantages of modern techniques, some old techniques should not be forgotten, for in some aspects of research they have considerable value. Such a method is crystallography, which can give important data about crystal genesis, its paragenesis and environmental characteristics during crystal growth. Specific crystal habits might be typical of particular occurrence(s).

Brazilianite is a phosphate mineral, $\text{NaAl}_3(\text{PO}_4)_2(\text{OH})_4$, which crystallizes in monoclinic system, space group $P2_1/n$, with $a=11.233$ (6) Å, $b=10.142$ (5) Å, $c=7.097$ (4) Å and $\beta=97.37$ (2)° (GATEHOUSE & MISKIN, 1974). It occurs as single crystals or in druses, and is very rarely massive. On the morphology of brazilianite there have not been many published papers since its discovery (POUGH & HENDERSON, 1945; FRONDEL & LINDBERG, 1948; ROBINSON *et al.*, 1992).

Large crystals of brazilianite are of the most interest due to their value as a gem material. But small crystals and massive material are usually neglected.

The importance of crystallogenic study and the possible differences between materials from different localities results in the need for a study of brazilianite crystals recently collected from different pegmatitic occurrences in Minas Gerais, Brazil; Buranga mine, Rwanda and Rapid's Creek, Yukon, Canada.

GEOLOGICAL SETTING

Most of the collected and studied crystals are from the Conselheiro Pena Pegmatite District and Araçuaí Pegmatite District, Eastern Brazilian Pegmatite Province (fig. 1), located in the Araçuaí Orogen (ALMEIDA, 1977). Araçuaí Orogen is a mobile belt developed in the eastern margin of the São Francisco craton during the Brasiliano orogenic cycle (630–490 My – PEDROSA SOARES *et al.*, 2001).

The metallogenetic division of the Eastern Pegmatite province is, according to PEDROSA SOARES (2011) and presented in Fig. 1, divided into Pegmatite Districts.

The pegmatite bodies of Divino das Laranjeiras and Mendes Pimentel are located in the north portion of Conselheiro Pena Pegmatite District. The unnamed pegmatite of the São Geraldo do Baixio group of pegmatites is located in the central part of the Conselheiro Pena Pegmatite District. Most of the pegmatites in that region are hosted in the quartz biotite-schist of the São Tomé formation and are re-

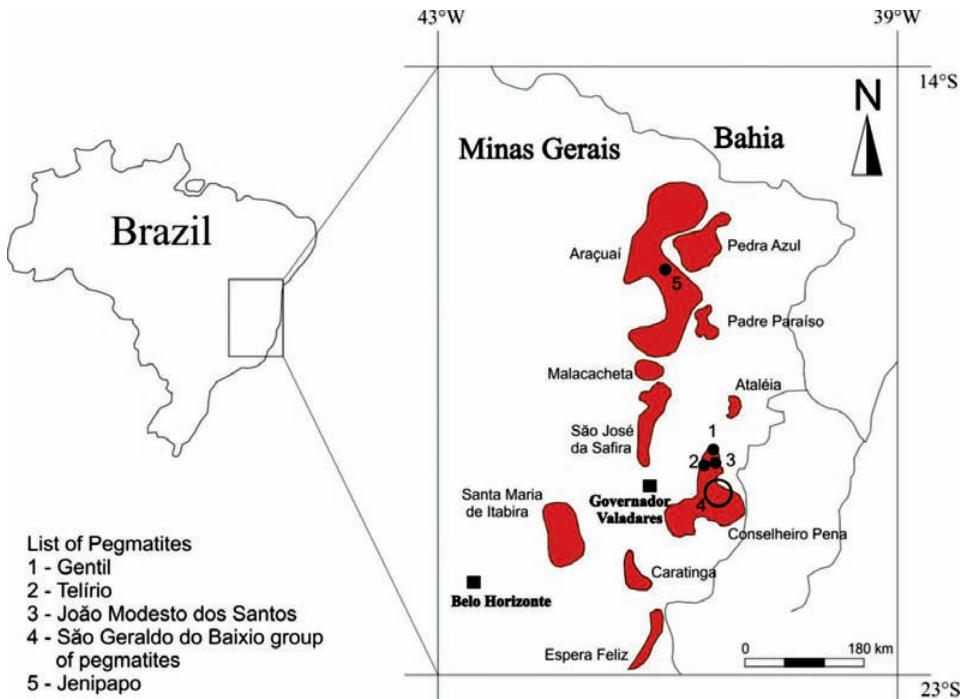


Fig. 1. Schematic overview of Eastern Brazilian Pegmatite Province; red areas represent Pegmatite districts.

lated to Urucum granite. Usually the pegmatites are orientated in the NW-SE direction and have sub-vertical development, with tabular to lens-shaped forms.

The Jenipapo pegmatite is located in the Araçuaí Pegmatite District. It is the only pegmatite with brazilianite in that region. The pegmatites in that region are hosted in schist of the Salinas formation and are derived from plutons of the Itaporé suite and Piauí batholiths. They are orientated in the NE-SW direction and have sub-vertical development, with tabular to lens-shaped forms.

Several crystals come from Rapid Creek, Yukon, Canada. Rapid Creek area is situated in the Richardson Mountains, west of the Mackenzie River Delta in north-eastern Yukon, close to the boundary of Yukon and Northwest Territories (ROBINSON *et al.*, 1992). Crystals of brazilianite from this locality and its geological setting are described by ROBINSON *et al.* (1992).

One massive sample is from Buranga pegmatite, Rwanda. This pegmatite is described by DALTRY & VON KNORRING (1998), with a mention of crystals of brazilianite.

MATERIAL AND EXPERIMENTAL

The investigated brazilianite crystals were gathered from different localities, but most of them come from Conselheiro Pena Pegmatite District (Fig. 1) while several

crystals were gathered in Araçuaí Pegmatite District (Fig. 1), both situated in the Eastern Brazilian Pegmatite Province, Minas Gerais, Brazil. Around 100 crystals, several crystal druses of brazilianite and one massive sample were examined under a stereomicroscope.

Crystals with different morphological features and different colors were chosen for further investigation. Forty four representative crystals were chosen for goniometric measurements.

Twenty six crystals are from Telírio pegmatite (four of them detached from druses, the rest being loose crystals; samples T1 – T26), six from Gentil pegmatite (G1-G6), four from Jenipapo pegmatite (A1-A4), three from São Geraldo do Baixio group (detached from druses; samples S1 – S3), only one from Divino das Laranjeiras (D1) and four from Rapid Creek, Yukon, Canada (R1-R4).

For goniometric measurements, a two-circle goniometer was used. Identification of forms was done using orientation and axial ratio 1.1056:1:0.6992 after POUGH & HENDERSON (1945).

Eleven samples were chosen for X-ray diffraction. Four samples are from Telírio pegmatite (T27 – T30), two from João Modesto dos Santos pegmatite (J1 and J2), one from São Geraldo do Baixio group (S), one from Gentil pegmatite (G), one sample from Buranga pegmatite, Rwanda (BuR), and two from Rapid Creek, Yukon, Canada (R5 and R6).

X-ray powder diffraction data were collected using a Philips PW3050/60 X'Pert PRO X-ray powder diffractometer with Cu tube, accelerated by 40 kV and a current of 40 mA. Step-scan was employed in order to obtain XRD patterns. Step size was 0.02° and counting time 1 s per step. X-ray pattern analyses were performed using HighScore Plus software (PANALYTICAL, 2004). Unit-cell calculations were performed using »Unit Cell« (HOLLAND & REDFERN, 1997).

One greenish-yellow crystal from Telírio pegmatite was gradually heated in an oven up to 300 °C in order to determine color change. There was no record of this kind of experiment in the literature, so the heating rates were chosen in such a way as to be able to identify any approximate temperatures of color loss (Tab. 6).

RESULTS

Crystal morphology

Brazilianite crystals are well developed; most of them are elongated along [101]: several are elongated along [001]. Most of the investigated crystals are attached to the matrix on one end of either elongation, so in most of the measured crystals one side of the crystal is completely or partly missing.

Telírio pegmatite, Divino das Laranjeiras, Minas Gerais

Twenty six crystals from Telírio pegmatite were measured. Identified crystal forms are listed (Tab. 1) and their frequency statistics (H) are compared with data from POUGH & HENDERSON (1945) (Tab. 2).

All forms in the [001] zone of these crystals are striated parallel to crystallographic axis *c* (fig. 2). There is one exception, crystal T8, where only face (110) of

Tab. 2. Comparison of measured crystals and forms from the Telírio pegmatite with data from POUGH & HENDERSON (1945)

Forms	H* (%)		Forms	H* (%)	
	Measured crystals from Telírio pegmatite	Pough & Henderson (1945)		Measured crystals from Telírio pegmatite	Pough & Henderson (1945)
001	20	80	101	24	67
010	100	100	$\bar{1}01$	88	47
100	8	100	$\bar{2}01$	–	6
340	–	33	$\bar{3}01$	4	93
110	100	100	113	–	53
210	8	6	111	8	87
310	4	60	$\bar{1}11$	100	100
610	–	13	211	76	52
011	52	100	$\bar{1}21$	4	52

*H – frequency (%); H = 100 (h/n); h – number of observations; n – number of studied crystal (in this case 26)

{110} is striated, but face ($\bar{1}10$) is not. Striations usually facilitate the orientation of crystals.

The most common forms that occur on all measured brazilianite crystals from Telírio pegmatite are {010}, {110} and $\{\bar{1}11\}$ with frequency of 100% (Tabs 1 and 2, Fig. 2). Signals for {010} range from very good to relatively weak, while signals for {110} are very good and usually multiple (generally with two very strong signals and one to three weaker signals). Faces of {010} are usually elongated and narrow. As well as the two above mentioned forms, $\{\bar{1}01\}$ and {211} (H = 88% and 76%, respectively) as well as {011} (H = 52%) are also common (Tabs 1 and 2). {011} and especially $\{\bar{1}11\}$ occur as dominant forms in most of the crystals studied (14 and 26 crystals, respectively; Fig. 2) while $\{\bar{1}01\}$ generally appears elongated and narrow (Fig. 2). The appearance of {211} is not uniform; it appears as small, elongated and large (Fig. 2).

Four forms not recorded earlier have been found on crystals from this locality (Tabs 1 and 3):

1. – {143} recorded on T2 crystal (Tabs 1 and 3) shows weak signals. The form is elongated and narrow (Fig. 2b);

2. – {520} recorded on T2 crystal (Tabs 1 and 3) shows relatively weak signals;

3. – $\{\bar{6}12\}$ recorded on crystals T11, T12, T17, T18, T20 and T21 (Tabs 1 and 3) and good to perfect signals (Fig. 2d).

4. – for one form, observed on two crystals from Telírio pegmatite (T2 and T3; Fig. 2b), it was impossible to determine the Miller index. The form is very gently

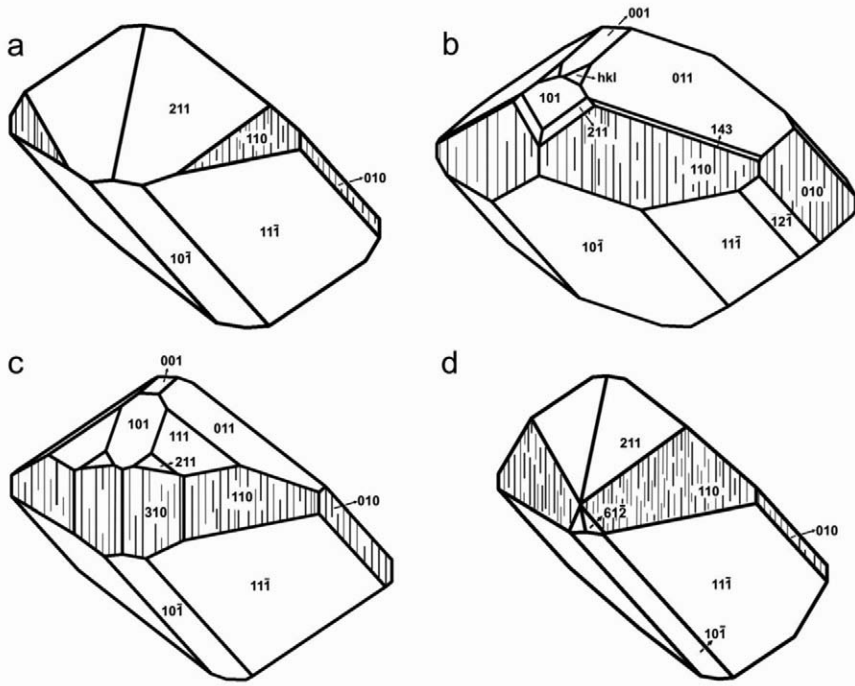


Fig. 2. Morphology of brazilianite crystals from the Telirio pegmatite: a) **T1** ($\{010\}$, $\{110\}$, $\{211\}$, $\{\bar{1}01\}$, $\{\bar{1}11\}$ (last two forms are represented with faces $(10\bar{1})$ and $(11\bar{1})$, respectively); b) **T2** ($\{001\}$, $\{010\}$, $\{110\}$, $\{011\}$, $\{101\}$, $\{211\}$, $\{143\}$, $\{hkl\}$, $\{\bar{1}01\}$, $\{\bar{1}11\}$, $\{\bar{1}21\}$ (last three forms are represented with faces $(10\bar{1})$, $(11\bar{1})$ and $(12\bar{1})$, respectively); c) **T5** ($\{001\}$, $\{010\}$, $\{110\}$, $\{011\}$, $\{211\}$, $\{310\}$, $\{101\}$, $\{111\}$, $\{\bar{1}11\}$, $\{10\bar{1}\}$ (last two forms are represented with faces $(11\bar{1})$ and $(10\bar{1})$, respectively); d) **T18** ($\{010\}$, $\{110\}$, $\{211\}$, $\{\bar{1}01\}$, $\{\bar{1}11\}$, $\{61\bar{2}\}$ (last three forms are represented with faces $(10\bar{1})$, $(11\bar{1})$ and $(61\bar{2})$, respectively)

Tab. 3. New observed forms, their frequency statistics, crystal on which they were measured and span of θ and ρ values of measured forms

New forms	H (%)	Crystals	θ^{**}	ρ^{**}
143	4	T2	17°25'–18°00'	43°21'
520	4	T2	76°35'	90°00'
$\bar{6}12$	27	T11, T12, T17, T18, T20, T21	78°06'–81°31'	62°02'–63°52'
hkl	8	T2, T3	40°52'–42°53'	16°25'–17°18'
322	100*	D1	49°25'	52°18'
013	33	G1, G3	28°44'–30°01'	14°20'–15°08'

* the reader should pay attention that only one crystal from Divino das Laranjeiras was available for investigation; **note that θ and ρ are measured values, not calculated

inclined to $\{001\}$ with index $\{hkl\}$ (Tabs 1 and 3). Signals that appear during goniometric measurements for this form are very clear.

Several different subhabits were observed on the crystals from Telírio pegmatite with the axis of elongation $[101]$. Most crystals from Telírio pegmatite exhibit a narrow prism zone ($[001]$ zone) and marked striations in that zone, parallel to $[001]$, as well as main development in the $[100]$ zone. There are some small differences between habits of crystals due to the different development of forms, e.g. crystal T1 (Fig. 2a) lacks forms of $[100]$ zone that appear on crystals T2 and T5 (Fig. 2b and 2c, respectively). Habits of T2 and T5 types were the first known habits for brazilianite crystals (POUGH & HENDERSON, 1945).

Gentil pegmatite, Mendes Pimentel

Six crystals from the Gentil pegmatite (G1-G6) were measured (Tab. 1). Dominant forms are $\{\bar{1}01\}$ and $\{110\}$ which give the crystals a thick tabular appearance along crystallographic axis c (Fig. 3). Form $\{011\}$ is, in comparison to other brazilianite crystals, relatively small and does not participate significantly in the crystal habit at this locality. It is rather narrow and elongated as in early generations of crystals from São Geraldo do Baixio group (Fig. 5a) which resemble these crystals. One new form of this species appears on these crystals with Miller indices $\{013\}$, and relatively strong and clear signals (Fig. 3; Tabs 1 and 3). The $[001]$ zone is, as in other brazilianite crystals, striated parallel to $[001]$ although the rate of striation appears to be weaker than in other brazilianite crystals.

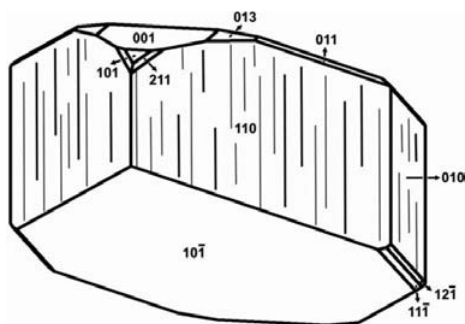


Fig. 3. Morphology of brazilianite crystals from the Gentil pegmatite (G5): $\{001\}$, $\{010\}$, $\{110\}$, $\{011\}$, $\{211\}$, $\{013\}$, $\{101\}$, $\{10\bar{1}\}$, $\{\bar{1}11\}$, $\{\bar{1}21\}$ (last three forms are represented with faces $(10\bar{1})$, $(11\bar{1})$ and $(12\bar{1})$, respectively)

Jenipapo pegmatite, Araçuaí district

Four measured crystals from the Jenipapo pegmatite (A1-A4) appear in two generations (Fig. 4). Early crystals (Fig. 4a) exhibit habits similar to the habit of crystals from the Telírio pegmatite (Fig. 2). Late crystals (Fig. 4b) exhibit the less frequent, prismatic, habit, with elongated prisms along $[001]$ where $\{110\}$ predominates over $\{210\}$ and dominates the crystal. The most common forms, with $H=100\%$, are $\{010\}$, $\{110\}$, $\{011\}$ and $\{\bar{1}11\}$ (Tabs 1 and 4). There is no record of the $\{10\bar{1}\}$ form, which is

Tab. 4. Comparison of measured crystals and forms from the Jenipapo pegmatite with data from POUGH & HENDERSON (1945)

Forms	H* (%)		Forms	H (%)	
	Measured crystals from Jenipapo pegmatite	POUGH & HENDERSON (1945)		Measured crystals from Jenipapo pegmatite	POUGH & HENDERSON (1945)
001	–	80	101	–	67
010	100	100	$\bar{1}01$	–	47
100	25	100	$\bar{2}01$	–	6
340	–	33	$\bar{3}01$	–	93
110	100	100	113	–	53
210	50	6	111	25	87
310	–	60	$\bar{1}11$	100	100
610	–	13	211	50	52
011	100	100	$\bar{1}21$	–	52

very common and even dominant in some crystals from other localities (Tab. 1, Figs. 2, 3, 5, 6 and 7).

The [001] zone is striated as it is in almost every examined brazilianite crystal. The habit of the late crystal (A2) was also one of the first habits to be described for brazilianite on crystals from Conselheiro Pena, Minas Gerais, Brazil (POUGH & HENDERSON, 1945).

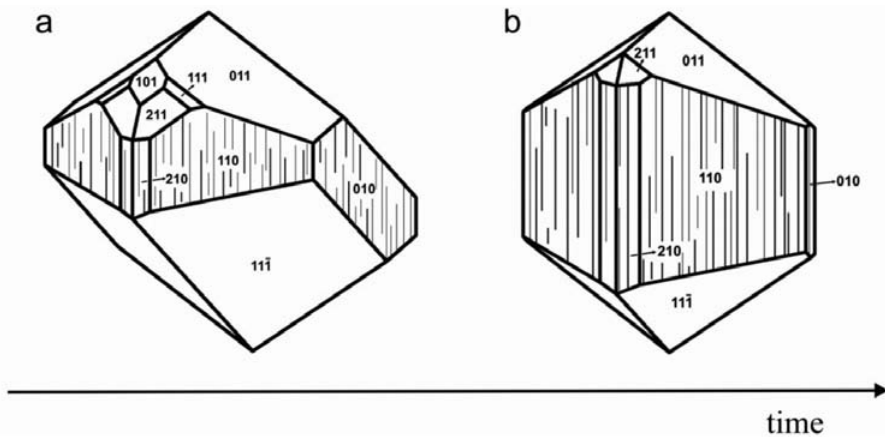


Fig. 4. Morphology and habit development trend of brazilianite crystals from the Jenipapo pegmatite: a) early crystal A1 ($\{010\}$, $\{110\}$, $\{011\}$, $\{210\}$, $\{101\}$, $\{111\}$, $\{211\}$, $\{\bar{1}11\}$) (last form is represented with the face $(11\bar{1})$); b) late crystal A2 ($\{010\}$, $\{110\}$, $\{011\}$, $\{210\}$, $\{211\}$, $\{\bar{1}11\}$) (last form is represented with the face $(11\bar{1})$)

São Geraldo do Baixo group of pegmatites, Minas Gerais

Crystals from the São Geraldo do Baixo group of pegmatites, Doce Valley (S1, S2 and S3), which appear in two generations, as do the crystals from the Jenipapo pegmatite (Fig. 4), show considerably different habits (Fig. 5) from those already recorded (POUGH & HENDERSON, 1945; FRONDEL & LINDBERG, 1948; ROBINSON *et al.*, 1992). The [001] zone is striated parallel to crystallographic axis *c*. Two habits can be distinguished. Early crystal S1 (Fig. 5a) is tabular and flattened along [001] with dom-

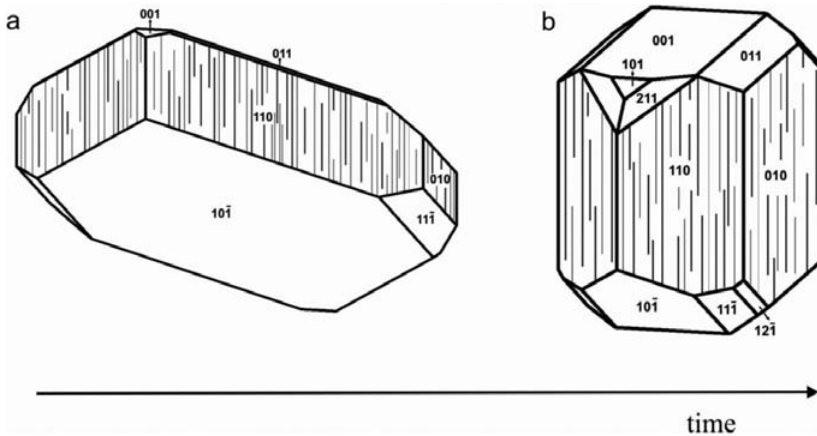


Fig. 5. Morphology and habit development trend of brazilianite crystals from the São Geraldo do Baixo group of pegmatites: a) early crystal S1 ($\{001\}$, $\{010\}$, $\{110\}$, $\{011\}$, $\{\bar{1}01\}$, $\{\bar{1}11\}$ (last two forms are represented with faces $(10\bar{1})$ and $(11\bar{1})$, respectively)); b) late crystal S3 ($\{001\}$, $\{010\}$, $\{110\}$, $\{011\}$, $\{101\}$, $\{211\}$, $\{\bar{1}01\}$, $\{\bar{1}11\}$, $\{\bar{1}21\}$ (last three forms are represented with faces $(10\bar{1})$, $(11\bar{1})$ and $(12\bar{1})$, respectively))

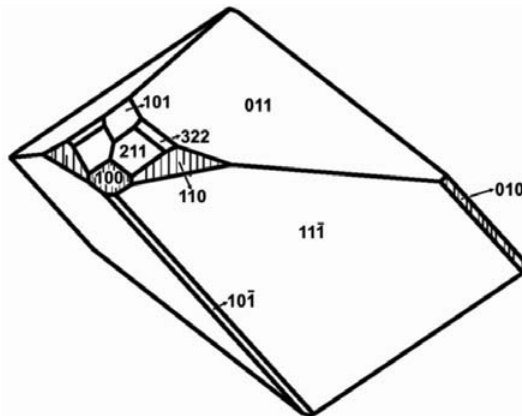


Fig. 6. Morphology of brazilianite crystals from Divino das Laranjeiras (D1): $\{010\}$, $\{100\}$, $\{110\}$, $\{011\}$, $\{101\}$, $\{211\}$, $\{322\}$, $\{11\bar{1}\}$, $\{10\bar{1}\}$ (last two forms are represented with faces $(11\bar{1})$ and $(10\bar{1})$, respectively)

inant form $\{\bar{1}01\}$ and is relatively poor in crystal forms (Tab. 1). Late crystals S2 and S3 (Fig. 5b) have an elongated $[001]$ prism zone which dominates the crystal. In addition, on S1 and S2 four additional forms $\{210\}$, $\{211\}$, $\{\bar{1}21\}$ and $\{101\}$ are developed.

Divino das Laranjeiras, Minas Gerais

One measured crystal from Divino das Laranjeiras (D1) differs somewhat in habit (Fig. 6; Tab. 1) from other observed habits. Its main differences are large development of forms $\{011\}$ and $\{\bar{1}11\}$, which dominate the crystal and give it an extremely elongated appearance. Forms in the $[001]$ zone are striated parallel to crystallographic axis c , as on other crystals in this study. A very similar habit was also noticed by FRONDEL & LINDBERG (1948) on crystals from the Palermo pegmatite, North Gorton, New Hampshire. Nevertheless, there is one distinction: they do not mention striations parallel to crystallographic axis c in the $[001]$ zone.

Form $\{322\}$ (Tabs 1 and 3) with relatively weak signals was noticed on this crystal. The form is small and elongated (Fig. 6) and has not previously been recorded in the literature.

Rapid Creek, Yukon, Canada

Four crystals were detached from a brazilianite druse from Rapid Creek (R1-R4). Measured crystals are very poor in forms, exhibiting only three forms: $\{110\}$, $\{010\}$ and $\{\bar{1}01\}$ (Tab. 1). $\{010\}$ does not appear on every measured crystal, which is in

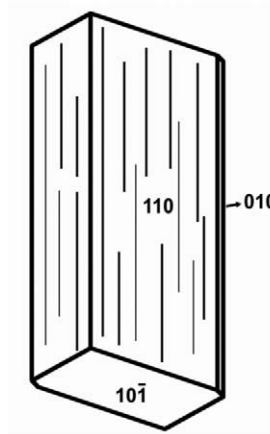


Fig. 7. Morphology of brazilianite crystals from the Rapid Creek area, Yukon, Canada (R1): $\{010\}$, $\{110\}$, $\{\bar{1}01\}$ (last form is represented with $(10\bar{1})$ face)

disagreement with other measurements of brazilianite crystals (Tab. 1). Habit (Fig. 7) is extremely elongated along $[001]$ and the faces are also striated parallel to $[001]$. The $\{\bar{1}01\}$ form is very large in development. This habit was previously described (ROBINSON *et al.*, 1992) with one distinction: they mention striations on the $\{\bar{1}01\}$ form, which is in disagreement with observations in this investigation.

Tab. 5. Unit cell parameters of investigated samples compared to those from literature

Sample*	<i>a</i> (Å)	<i>b</i> (Å)	<i>c</i> (Å)	β (°)
T27	11.245 (2)	10.1494 (5)	7.1062 (7)	97.34 (1)
T28	11.239 (2)	10.1446 (7)	7.1029 (9)	97.362 (9)
T29	11.240 (1)	10.1496 (6)	7.1042 (8)	97.375 (8)
T30	11.244 (2)	10.1483 (6)	7.1055 (7)	97.3635 (9)
G	11.245(3)	10.146(2)	7.102(2)	97.34(2)
S	11.2388 (6)	10.1474 (5)	7.1027 (5)	97.378 (5)
R5	11.249(2)	10.150(1)	7.119(2)	97.41(2)
R6	11.255(2)	10.155(1)	7.108(1)	97.38(2)
BuR	11.201 (1)	10.1415 (5)	7.0885 (7)	97.431 (7)
J1	11.241 (1)	10.1498 (8)	7.1004 (8)	97.367 (9)
J2	11.240 (1)	10.1450 (7)	7.1064 (9)	97.35 (1)
GATEHOUSE & MISKIN, 1974	11.233 (6)	10.142 (5)	7.097 (4)	97.37 (2)

* T27-T30 – the Telírio pegmatite; G – the Gentil pegmatite; S – São Geraldo do Baixio group of pegmatites; R5 and R6 – the Rapid Creek area; BuR – the Buranga pegmatite, Rwanda; J1 and J2 – the João Modesto dos Santos pegmatite;

Color of brazilianite crystals

Crystal color in most of the samples ranges from Ipê yellow to yellowish-green. Crystals from São Geraldo do Baixio group (S1-S3) are colorless, occasionally whitish. Crystals from Gentil pegmatite (G1-G6) are colorless as well, but with blue dotted inclusions (probably matioliite). Crystals from Rapid Creek (R1-R4) are colorless and with blue dotted inclusions (probably lazulite), as well. All crystals are transparent. Only massive samples from Telírio and Buranga pegmatites are translucent.

One Ipê yellow crystal from Telírio pegmatite was heated in the oven at several increasing temperatures (Tab. 6). At lower temperatures, a change of color was not observed, but at higher temperatures there is at first slight loss of color (at 200°C), which becomes discernible (at 250°C) and at the end it is complete (at 300°C), so the crystal becomes colorless. Such loss of color could indicate that the color of brazilianite is a result of color centers.

DISCUSSION

Forms with the highest occurrence frequency in these measurements, e.g. {010} and {110}, have approximately the same frequency, as those described in the literature (POUGH & HENDERSON, 1945) (Tabs 2 and 4). On the contrary, the same parameter of other measured forms, e.g. {100} is generally in disagreement with the literature. Some forms with recorded high frequency in literature, do not occur or occur rarely in the investigated crystals, e.g. {310}, $\{3\bar{0}1\}$ or {113}. Observed differences in frequency statistics could be a result of the different number of measured crystals (e.g. 26 crystals from Telírio pegmatite and four from Jenipapo pegmatite in

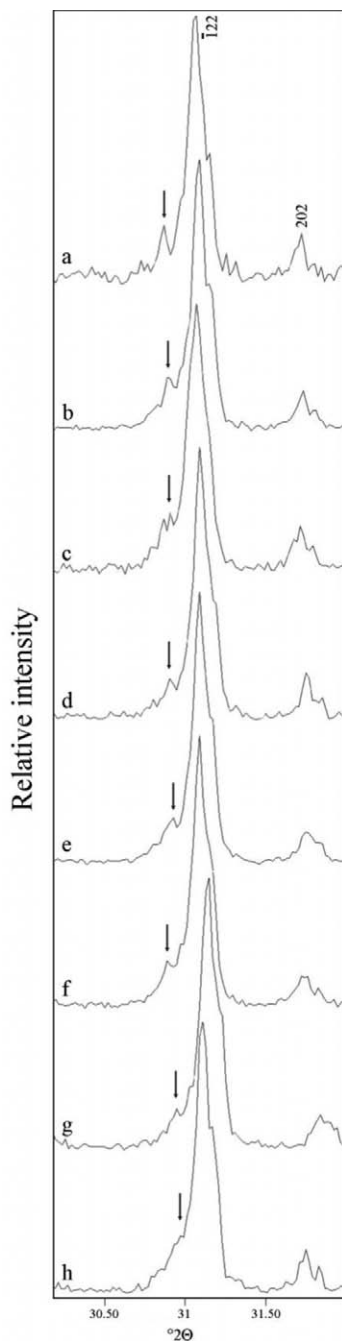


Fig. 9. Comparison of representative $\bar{1}22$ diffraction lines of brazilianite samples with additional lines on lower $^{\circ}2\theta$. Note how sample from Buranga, Rwanda (BuR) is shifted when compared to other samples. a) J1; b) T29; c) R5; d) J2; e) T28; f) S; g) T27; h) BuR; i) R6; j) T30.

Tab. 6. Heating conditions and loss of color of brazilianite crystal from the Telírio pegmatite

Temperature (°C)	Time (h)	Color
50	3	no loss
75	1	no loss
100	1	no loss
125	1	no loss
150	1	no loss
175	4	no loss
200	1	slight loss
250	1	marked loss
300	1	complete loss

these investigations in contrast to 14 in the investigation of POUGH & HENDERSON, 1945) but most probably they are due to the different sampling locality: crystals investigated by POUGH & HENDERSON (1945) originate from a locality the precise position or mine of which is not known (it is near Conselheiro Pena, Minas Gerais, Brazil), so it is questionable if crystals measured in the current investigation originate from the same locality. Most probably all of the newly measured crystals originate from other localities.

Current investigation has shown the appearance of six forms that have not been recorded previously. These forms are (Tabs 1 and 3): $\{143\}$ (Fig. 2b), $\{520\}$, $\{\bar{6}12\}$ (Fig. 2d), $\{013\}$ (Fig. 3), $\{322\}$ (Fig. 6) and one additional $\{hkl\}$ form, at inclination of $\sim 10^\circ$ to $\{001\}$ (Fig. 2b) whose index was not possible to determine. Most of the newly observed forms have relatively weak signals due to the size and roughness of the faces. Nevertheless, these forms have been undoubtedly observed, under the stereomicroscope as well as during the goniometric measurements.

All habits recorded earlier have also been recognized during these measurements (Figs 2, 4, 6 and 7). Besides those, two new habits were described (Fig. 3 and 5).

Habits of crystals from Telírio pegmatite can be distinguished by the number and size of forms. For example $\{211\}$ in T1 crystal (Fig. 2a) is large, whereas this form is relatively small in T2 crystal (Fig. 2b). Also, crystal T1 from Telírio pegmatite (Fig. 2a), almost completely lacks faces in the $[100]$ zone which are relatively common for crystals from this locality (Fig. 2b, 2c). A crystal from Divino das Laranjeiras (D1; Fig. 6) is somewhat similar to crystals from Telírio pegmatite (T2), but differs extremely in the rate of elongation along $[101]$ direction, which is the same as in crystals from Telírio pegmatite. Large development of $\{011\}$ and $\{\bar{1}11\}$ in crystal from Divino das Laranjeiras (D1) give it this more elongated appearance (Fig. 6). Taking these similarities and differences into account, the mentioned crystals should be put in one group, although with a division into subgroups.

The crystal habit noticed on late A2 crystals from Jenipapo pegmatite (Fig. 4b) is distinct from other habits due to elongation of $[001]$ zone along with large development of $\{011\}$. This gives the crystal an elongated appearance along $[001]$ with sharp termination in contrast to the S3 crystal (Fig. 5b). Observing habits of crystals

from Jenipapo pegmatite, it can be concluded that the development from early (Fig. 4a) to late (Fig. 4b) brazilianite crystals is in the [001] direction (Fig. 4).

Crystals from São Geraldo do Baixo group, S1 (Fig. 5a), S2 and S3 (Fig. 5b) were detached from a crystal druse. S2 and S3 crystals were attached on the surface of S1, which leads to the conclusion that S1 is an early phase and S2 and S3 are late phases in crystallization. These crystals are somewhat unusual. Their peculiarity is that early crystals are relatively poor in crystal forms, unlike most of the other brazilianite crystals (Tab. 1). The early crystal, S1, is tabular and flattened along [001] (Fig. 5a). A later crystal, S3 (Fig. 5b), has an elongated [001] zone which dominates the crystal. Besides this main difference, S3 develops new forms $\{210\}$, $\{211\}$, $\{\bar{1}21\}$ and $\{101\}$. From these observations a conclusion, as in the case of crystals from Jenipapo pegmatite, could be drawn: the development of brazilianite crystals is in the direction of [001] (Fig. 5). In this case, appearance of additional forms is also related to late crystals. These two habits have not been previously recorded in literature.

The habit of brazilianite crystals from Gentil pegmatite (Fig. 3) is similar to early brazilianite crystals from the São Geraldo do Baixo group (Fig. 5a) although crystals from Gentil pegmatite exhibit a thick tabular appearance.

The habit of brazilianite crystal from Rapid Creek, Yukon is very simple and consists of just a few forms (Tab. 1, Fig. 7). Elongation is also along the [001], but more extreme than in other brazilianite crystals. The crystal forms and resulting habits are not different from those in the previous investigation (ROBINSON *et al.*, 1992) with the exception of striations: in these measurements, striations appear in [001] while ROBINSON *et al.* (1992) report striations on the $\{\bar{1}01\}$ form.

The investigated brazilianite crystals showed multiple signals in goniometric measurements on some faces, especially in the [001] zone. This is a general characteristic, typical of striated faces. A peculiarity arises from observations of these signals. In the case of striated faces that are the result of e.g. vicinal faces, signals could be continuous. This is not always the case in the current investigation. There are regularly two clearly separated signals with significant difference in ρ values of about $1^{\circ}20'$ and several (one to three, commonly continuous) weaker signals which lead to the assumption that these striations could be the result of the appearance of two alternative faces.

X-ray diffraction patterns show an important shift in the different investigated samples. The biggest difference is observed in the sample from Buranga, Rwanda (BuR), which has the smallest unit cell parameters, while unit cell parameters for other samples are similar (Tab. 5). This could point to a difference in chemical composition which should be investigated. Some diffraction lines are widened or even doubled with lines of smaller intensities (on the lower $^{\circ}2\theta$) of the main line (e.g. $\bar{1}22$, Fig. 9). This appearance of additional diffraction lines could be due to the lowering of symmetry caused by the strain in the crystal structure of brazilianite.

CONCLUSIONS

Six new forms were observed on measured crystals of brazilianite: $\{143\}$, $\{520\}$, $\{322\}$, $\{\bar{6}12\}$, $\{013\}$ and one form, $\{hkl\}$, the index of which was not determined. It is very gently inclined to $\{001\}$ ($\sim 10^{\circ}$) (Tab. 3).

Several habits of investigated brazilianite crystals have been distinguished, primarily on the basis of elongation, but relative development of the forms was considered as well.

The first group of crystal habits is represented by the crystals in Fig. 2, 4a and 6 characterized by the elongation along [101]. The crystal from the Divino das Laranjeiras (D1) (Fig. 6) is more elongated than other crystals in this group due to large development of {011} and $\{\bar{1}11\}$. This group could be divided into subgroups on the basis of different form development. Thus, four subgroups could be distinguished.

The second habit is represented with crystals from the Jenipapo pegmatite, Araçuaí district (A2) which are elongated along [001] and terminated with a large {011}, giving the crystal the form of a sharp column (Fig. 4b).

The third group is represented with crystals from the Gentil pegmatite (G5) and the São Geraldo do Baixo group (S1) (Fig. 3 and 5a, respectively). The crystal S1 is tabular, flattened along [001] with a large development of $\{\bar{1}01\}$, while crystal G5 exhibits a similar, although slightly less flattened habit. This habit was not previously recorded in literature.

The fourth group is represented by a crystal from the São Geraldo do Baixo group (S3) (Fig. 5b). This crystal (as well as S2; not shown here) appears somewhat isometric. This is due to the large development of {110} prism as well as {010}. This habit was also not previously recorded in literature.

The fifth group is represented with crystals from the Rapid Creek, Yukon, Canada (Fig. 7). Habit is extremely elongated along [001].

In an analysis of 11 X-ray patterns of samples from different localities, additional diffraction lines are observed. The sample from Buranga, Rwanda (BuR) shows the biggest difference (smallest values) in unit cell calculations compared to other samples. This suggests the necessity of additional investigation of the sample from Buranga, Rwanda, particularly of its chemical composition.

Combining results attained from X-ray diffraction analyses and the results attained through goniometric measurements, it is obvious that brazilianite crystals do not act according to monoclinic symmetry. Thus, it is questionable if monoclinic symmetry is truly the symmetry of brazilianite.

Further investigation of brazilianite morphology as well as of the crystal chemical properties are needed, particularly in investigating the true nature of the symmetry of brazilianite crystals.

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