

Recent mineral discoveries in the Coronel Murta, Taquaral, and Medina pegmatite fields, northeastern Minas Gerais, Brazil

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Abstract

The occurrence of five rare minerals in the Eastern Brazilian Pegmatite Province, northeastern Minas Gerais, is described and discussed: bergslagite $[\text{CaBe}(\text{AsO}_4)(\text{OH})]$ from the Manoel Fonseca mine, Coronel Murta county; herderite $[\text{CaBe}(\text{PO}_4)\text{F}]$ from the Funil mine, Medina county; lithiophosphate $[\text{Li}_3\text{PO}_4]$ from the Cachoeira mine, Araçuaí/Itinga counties; lithiotantite $[\text{Li}(\text{Ta},\text{Nb})_3\text{O}_8]$ from the Murundu mine, Itinga county; and kosnarite $[\text{KZr}_2(\text{PO}_4)_3]$ from Mario Pinto mine, Itinga county. The host pegmatites of these minerals, with their respective main chemical and/or mineralogical features are also presented. As a consequence of such discoveries, Raman spectra for lithiotantite and lithiophosphate were made available, and crystal structure refinement for lithiotantite was performed.

Keywords: pegmatites, mineralogical discoveries, Minas Gerais State.

1. Introduction

The Eastern Brazilian Pegmatite Province is very important for its production of industrial minerals (quartz, feldspar, mica and beryl), as well as for gemology and mineralogical collection purposes. Several pegmatite districts are known, and two of them (Pedra Azul and Araçuaí) are focused in this paper (Figure 1). Pegmatites from this province are characterized by the presence of rare minerals, some of them are Brazilian type minerals: 28 of the 67 minerals described for the first time from Brazilian samples were originally found in this large region, i.e.

almost 42% of all Brazilian type minerals.

Nevertheless, mineralogical studies about deposits from this wide region are still scarce. In recent years, the authors of the present work have been attempting to reverse the scenario of minor importance given to Brazilian minerals. A research line devoted to the identification of possibly new mineral species, through detailed studies on the mineralogy of deposits considered promising has enabled the finding of rare minerals.

The description of five of such findings with their mineralogical and

chemical characterization and geological context, represent the aim of this paper. All the minerals were also confirmed by X-ray diffractometry. For EMP analysis (Microscopy Center - UFMG), samples were mounted on polished sections and metalized with C. For bergslagite and herderite, the following standards were used: fluorite - F, apatite - P_2O_5 , FeAs_2 - As_2O_5 , and apatite - CaO; for kosnarite, the standards used were: MgO - MgO, magnetite - FeO, monazite - P_2O_5 , Al_2O_3 - Al_2O_3 , HfSiO₄ - HfO₂, ZrSiO₄ - ZrO₂, ZrSiO₄ - SiO₂, and sanidine - K₂O.

2. Bergslagite $[\text{CaBe}(\text{AsO}_4)(\text{OH})]$ from the Manoel Fonseca mine (Olho d'Água farm, Coronel Murta county)

Originally described in Sweden (Langban mine, Bergslagen region)

by Hansen *et al.* (1984), this mineral was found later in Germany (Fuchs

quarry, Franconia, Bavaria), Norway (Tennvatn pegmatite, Nordland), Italy

(Mt. Cervandone), and Switzerland (Fallota, Fianel mine, and Cavradi gorge). It is monoclinic, isostructural with herderite $[\text{CaBe}(\text{PO}_4)\text{F}]$ and hy-

droxylherderite $[\text{CaBe}(\text{PO}_4)(\text{OH})]$, and can be colorless, whitish or greyish, with a vitreous luster. The Manoel Fonseca mine (805130E / 8170236N

– Figure 2a) where it was found is located around 15 km north of Coronel Murta town, in the pegmatite field of the same name.

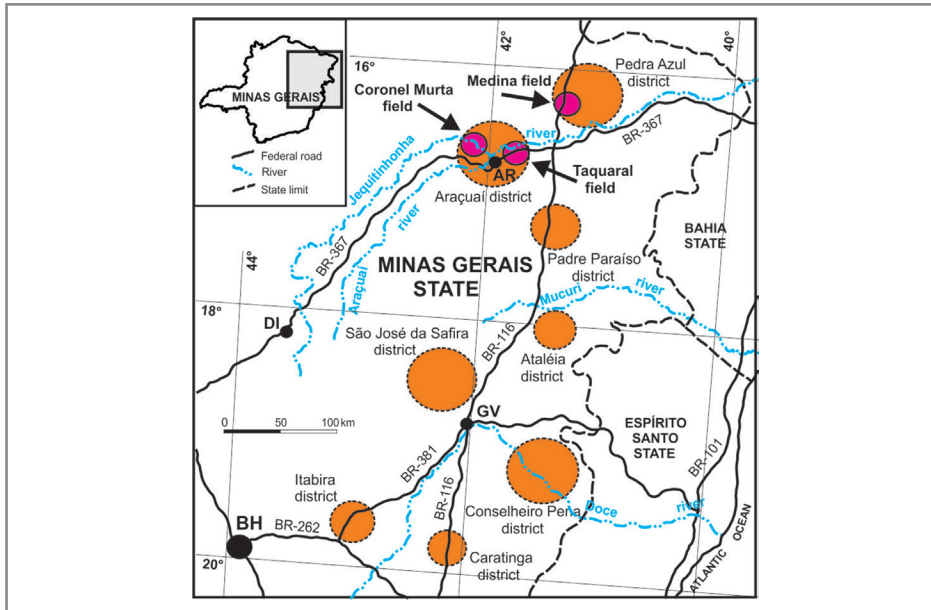


Figure 1
Schematic geographic map showing the eight main pegmatite districts in the Eastern Brazilian Pegmatite Province, emphasizing the focused ones in Northeastern Minas Gerais, the Coronel Murta, Taquaral and Medina fields. Towns: BH, Belo Horizonte (capital of the State); GV, Governador Valadares; DI, Diamantina; AR, Araçuaí.

Biotite schist and quartzite of the Macaúbas Group predominate in the region, in the vicinity of the contact with a relatively small pegmatoid granite stock. The pegmatite with about 8 m thick, and more than 100 m long is intruded in the schist, and is concordant with the wall rock foliation (approximate direction and dip, N65°E/40°NE). It is a zoned body, composed by lower and upper domains, separated by 1 m of schist. The upper domain (NE), from where the studied samples came, produced topaz, and is nowadays abandoned.

The lower domain (SW), current-

ly active, is 4 m thick. The wall zone extends to the contact with the country rock, is fine-grained, and consists predominantly of peritic microcline with intercalations of quartz (graphic texture), and small amounts of muscovite and schorl. The intermediate zone is constituted by microcline (thicker grains), quartz, muscovite, albite, and schorl. The quartz core is discontinuous and can reach 1 m thickness or more; decimetric replacement bodies of albite occur around it, where millimetric crystals of apatite with a light green-bluish to brown color are abundant, together with milky herderite.

Two quartz crystals with about 15 cm length were collected at this pegmatite; their faces are coated with several small white crystals, about 3 mm each (Figure 2b). Electron microprobe analyses have identified a bergslagite core, bordered by a herderite layer about 0.1 mm thick (Table 1). Figure 2c shows a scanning electron microscopy image by backscattered electrons of one of those crystals. The empirical formulae are: bergslagite $\text{Ca}_{1.06}\text{Be}_{1.00}(\text{As}_{0.96}\text{P}_{0.04})_{\Sigma 1.00}\text{O}_{4.00}[(\text{OH})_{0.53}\text{F}_{0.33}\text{O}_{0.14}]_{\Sigma 1.00}$, and herderite $\text{Ca}_{0.95}\text{Be}_{1.00}(\text{P}_{0.92}\text{As}_{0.08})_{\Sigma 1.00}\text{O}_{4.00}[\text{F}_{0.48}(\text{OH})_{0.42}]_{\Sigma 0.90}$.

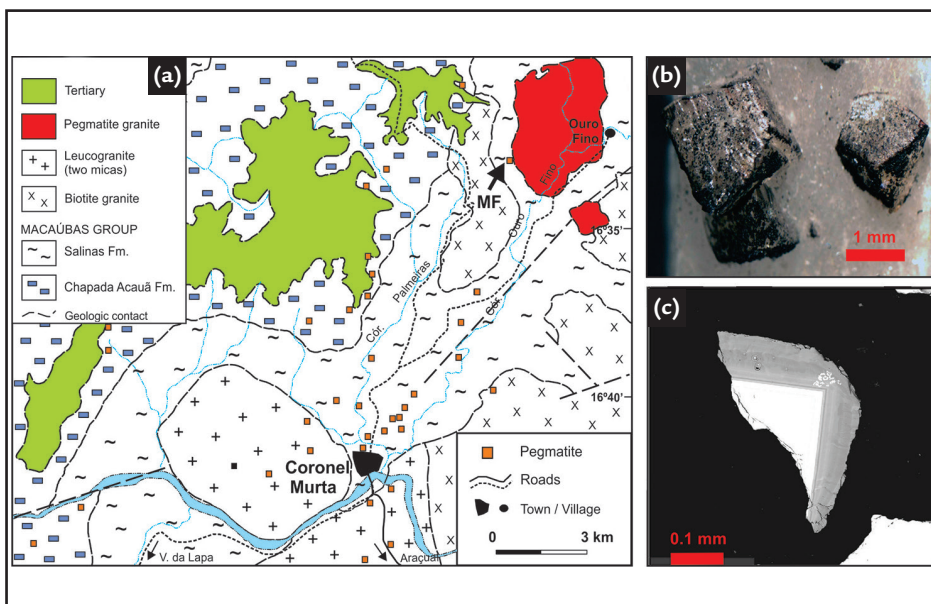


Figure 2
(a) Geology of the Coronel Murta pegmatite field, with its main pegmatites. MF: Manoel Fonseca mine (modified from Pedrosa-Soares, 1996).
(b) Bergslagite on quartz.
(c) Backscattered electron image of the crystal analyzed according Table 1, showing a bergslagite core (lighter phase) and a herderite rim.

Table 1
Electron microprobe analyses of bergslagite (be) and herderite (he) from the Manoel Fonseca mine (wt %). (*) 20 spots average; (**) BeO content calculated for 1 Be apfu; (***) H₂O calculated for charge neutrality; (****) oxygen equivalent.

Sample	F	P ₂ O ₅	As ₂ O ₅	CaO	BeO(**)	H ₂ O(***)	Total	O=F(****)	Total2
26B1-be (*)	2.97	1.49	52.16	28.17	11.83	2.26	98.88	(-1.25)	97.63
26B1-he (*)	5.54	39.64	5.30	32.05	15.15	2.26	99.94	(-2.33)	97.61

3. Herderite [CaBe(PO₄)F] from the Funil mine (Medina county)

Herderite was originally described by Haidinger (1828), at the Sauberg mine, Saxony, Germany; hydroxylherderite, CaBe(PO₄)(OH), was found by Penfield (1894) at the Paris county, Maine, USA. There are conflicting interpretations in the literature, and it is common to refer to any of those two minerals by the generic name herderite. Over the past two decades, all attempts of confirmation of the existence of herderite had failed, and Back & Mandarino (2008) emphasized: “*Herderite (a doubtful species), symmetry unknown, no chemical data with F>OH are known, may form a series with hydroxylherderite...*”. The mineral is monoclinic, and can be colourless, pale yellow, beige, greenish-white or purplish, with a vitreous luster.

The Funil mine (238222E / 8204543N) is located in the Medina pegmatite field (Figure 3A), which is included in the Pedra Azul pegmatite district, according to Pedrosa-Soares *et al.* (2011). Pegmatite bodies from this district are internal to proximal (marginal) source granite; they are generally small to medium (up to 5 m thick) and homogeneous, biotite-rich and tourmaline-poor or -free; lithium minerals are also absent. Deposits from that area aim the extraction of gemologic beryl and topaz; green and

yellow fluorapatite is a common accessory mineral in the replacement bodies. This pegmatite is zoned, quite weathered, with thickness about 3 m and is directed to E-W. Near to the surface, the body is subvertical, while in greater depths it dips approximately 40°S. The wall zone exhibits thinner grains, and the intermediate zone is composed by weathered microcline, with quartz grains and biotite sheets, both measuring few centimeters. Albite-rich zones wholly kaolinized, with several centimeters width, are considered to be guides for aquamarine search. The quartz core is discontinuous and has normally few decimeters of thickness.

The analyzed herderite samples came from a set of euhedral and centimetric crystals, with a greenish grey color, and were collected near the hanging wall, where, in the 1990's important topaz findings occurred. Topaz is F-rich and tends to crystallize upwards in pegmatite bodies due to thermal – gravitational diffusion of volatile components (Pedrosa-Soares *et al.*, 2011). Topaz materializes the higher fluorine content concentrated in residual melts, and thus it coexists with F-enriched terms of herderite – hydroxylherderite series. In August 2009, a sample of herderite (Table 2) from the Funil mine was supposed to be

the first one in the world with confirmed provenience; that mine would then become the mineral's type locality, and that sample's crystal structure would be studied. However, at the same time Harlow & Hawthorne (2008) described and studied the crystal structure of herderite from Mogok, Myanmar (with 8.7%). Those authors mention, in that paper, another occurrence, from Yichung, China (7.25% F), found as an inclusion within a topaz crystal. Thus the studied specimen represents the world's third occurrence (7B1 grain from Table 2).

Another small group of crystals was discovered in 2011 (26A grains from Table 2), with the same aspects as the previous one, including faces coated with thin schorl crystals. The fluorine content in those samples is even higher, according to chemical analyses on two different crystal fragments, one removed from the crystal rim and the other close to the core; no significant differences between them can be observed. The empirical formulae for herderite are: Ca_{0.95}Be_{1.00}(PO₄)_{1.00}[F_{0.56}(OH)_{0.36}]_{20.92} (sample 7B1), and Ca_{0.96}Be_{1.00}(PO₄)_{1.00}[F_{0.69}(OH)_{0.23}]_{20.92} (sample 26A). Data for Medina herderite was published by RRUFF database R100064 (free access through www.rruff.info).

Table 2
Electron microprobe analyses of herderite from the Funil mine (wt.%). Samples: 7B1, 4 spots average; 26A, 40 spots average; (*) BeO content calculated for 1 Be apfu; (**) calculated for charge neutrality; (***) oxygen equivalent.

Sample	F	P ₂ O ₅	CaO	BeO(*)	H ₂ O(**)	Total	O=F(***)	Total2
7B1	6.59	44.09	33.19	15.55	2.02	101.44	(-2.77)	98.67
26A	8.16	43.97	33.38	15.52	1.29	102.32	(-3.44)	98.88

4. Lithiophosphate [Li₃PO₄] from the Cachoeira mine (Barreiro, Araçuaí/Itinga counties)

This mineral was first described in the Voroya tundra, Kola peninsula, Russia, in the 1950's (Matias & Bondareva, 1957). Some other occurrences were later reported in Canada (Tanco mine,

Manitoba), USA (Foote mine, Cleveland, North Carolina and Tip Top mine, Custer, South Dakota) and Morocco (Mirrat pegmatite, Marrakesh). It is orthorhombic, has a vitreous luster and can

be colourless or slightly rose-coloured.

The Cachoeira mine is operated by the Brazilian Lithium Company (CBL) since 1990, aiming underground extraction of spodumene as lithium ore, and

is considered the most important of this kind in the country. It is located at the margins of the Piauí river, which locally limits the border between Itinga and Araçuaí counties. Currently it is being operated in its western front, in the latter county (mine office center: 189721E / 8142540N – Figure 3b).

According to Romeiro & Pedrosa-Soares (2005), the deposit is constituted

by a swarm of pegmatites, generally tabular and with lateral continuities up to hundreds meters. They are homogeneous and have rare replacement bodies. Their minimum thickness ranges between 3 and 4 m, and the essential mineralogy is composed of microcline, spodumene, albite, quartz and muscovite. Accessory minerals are montebrasite, beryl and niobium-tantalates.

Spodumene crystals are light green, tabular along (110) and can reach up to 1.5 m in length, but their average size ranges, in general, between 10 and 20 cm. Most of the bodies are parallel to the foliation of the surrounding schist (N50°E/ 45°NW), although one of the most important is discordant, directed to NE with subhorizontal to subvertical SE-dipping.

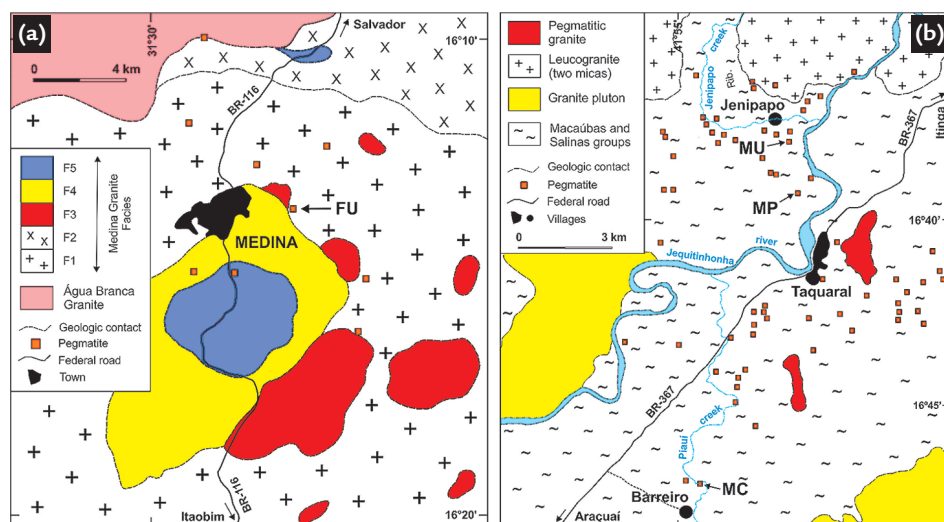


Figure 3 (a) Geology of the Medina pegmatite field. FU = Funil mine (modified from Pinto, 2008). (b) Geology of the Taquaral pegmatite field, highlighting the Cachoeira (MC), Murundu (MU) and Mario Pinto (MP) pegmatites (modified from Paes *et al.*, 2008).

Even if the several pegmatite bodies that occur in that area have an apparently simple mineralogical behavior, a systematic study has been conducted in small replacement bodies (generally with a diameter of less than 5 cm) aiming the possible localization

of rare minerals. Such research led to the identification of the lithiophosphate species, in crystals with size and perfection undoubtedly never reported before (Figure 4a). The mineral occurs in cavities filled by albite, quartz, muscovite and cookeite, as millimetric

prismatic, striated crystals, isolated or in druses. All of those minerals are partially covered by submillimetric spheres of fluorapatite.

Data for lithiophosphate from the Cachoeira mine is now available in the RRUFF database R100092.

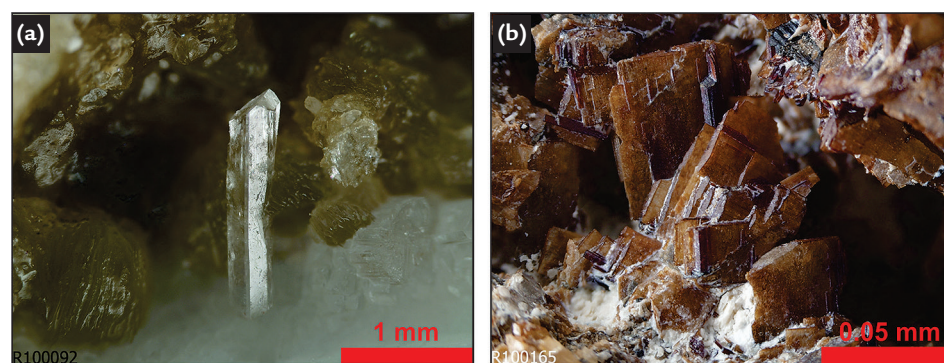


Figure 4 (a) Photo of prismatic crystal of lithiophosphate in albite with cookeite from the Cachoeira mine. (b) Detailed image of perfect lithiotantite crystals from the Murundu pegmatite.

5. Lithiotantite [Li(Ta,Nb)₃O₈] from the Murundu mine (Jenipapo, Itinga county)

Lithiotantite was first described in the tantalum deposit of Ognevka, Kazakhstan, by Voloshin *et al.* (1983). A second occurrence at the Ungursai tantalum Deposit, Irtysh River, Kalba Range, Eastern Kazakhstan Province (Shyghys Qazaqstan Oblysy; Vostochno-Kazakhstanskaya Oblast') was quoted by Pekov (1998). The third and fourth occurrences were described by Uher *et al.* (2008) at the Urubu mine, Itinga, Minas Gerais, and the

Manono granitic pegmatite, Democratic Republic of Congo, but its structure was still unknown by the time of the finding at the Murundu mine, which is the fifth one worldwide. Unlike the first description (transparent, colorless), the mineral is dark red (Figure 4b). It is monoclinic, in tabular and twinned crystals upon milky quartz, or associated with reddish brown prismatic tantalite, and black cassiterite.

The Murundu pegmatite has been

previously described by Cassedanne & Cassedanne (1980, 1985), concerning its main minerals and geological aspects, although its location was imprecise (now defined: 192974E / 8156119N – Figure 3b), besides it was erroneously designated as “Mulundu”. It is constituted by a large pegmatite body, subhorizontal, hosted in the Salinas schist, with well-defined internal zoning and a thick quartz core. The pegmatite was operated at the surface until

the end of the 1980's, mainly for industrial feldspar, beryl and montebrasite. Cavities rich in well-formed quartz crystals and yellow muscovite were frequently found in the core and commercialized as collection pieces; several small pockets containing gemological elbaite (green and blue) and/

or cassiterite and/or columbite-tantalite were found in replacement bodies around the core.

Electron microprobe analyses of lithiotantite from Murundu pegmatite are presented in Table 3. The empirical formula is: $(\text{Li}_{0.96}\text{Mn}_{0.02}\text{Fe}_{0.01}\text{Na}_{0.01})$

$\Sigma_{1.00}(\text{Ta}_{2.18}\text{Nb}_{0.79}\text{Sn}_{0.03}/\Sigma_{3.00}\text{O}_{8.00})$. The crystal structure refinement was obtained by Menezes Filho *et al.* (2012). As for lithiophosphate, the University of Arizona has incorporated a new page about the Raman spectrum of this mineral in its RRUFF database R100165.

Table 3
Electron microprobe analyses of lithiotantite from the Murundu mine, 6 spots average (wt %; total iron as FeO; Li_2O calculated).

Sample	Ta ₂ O ₅	Nb ₂ O ₅	TiO ₂	Na ₂ O	MnO	FeO	SnO ₂	Li ₂ O	Total
14A	78.80	17.24	0.00	0.07	0.23	0.07	0.86	2.35	99.62

6. Kosnarite [KZr₂(PO₄)₃] from the Mario Pinto mine (Jenipapo, Itinga county)

Kosnarite was first described by Brownfield *et al.* (1993), from samples of two very close North-American localities, Mount Mica quarry and Black Mountain pegmatite, Oxford county, Maine. Shortly afterwards, the mineral was identified in Wyche Proof, Victoria, Australia (Birch *et al.*, 1994). In both countries, studied specimens are extremely small, submillimetric, showing trigonal (pseudocubic) crystals; color ranges from pale blue to blue-green to nearly colorless, with a vitreous luster. Hyrsl *et al.* (2003) described kosnarite samples from the Limoeiro mine, Virgem da Lapa, and Frost *et al.* (2012) studied material from Jenipapo area (Taquaral

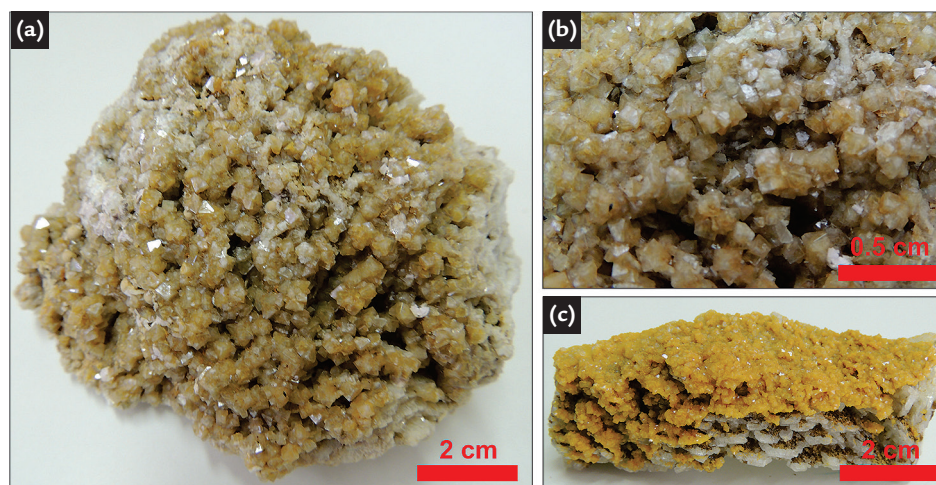
field), in the same State. Kosnarite from the Jorge pegmatite, also in the Jenipapo area, is quoted in Mindat (<http://www.mindat.org/locdetailed-205524.html>). Kosnarite from Jenipapo is recorded in the RRUFF database (R060250). This occurrence is of great importance due to its superior size and high quality.

The Mario Pinto mine (193465E / 8154143N – Figure 3b) is also located in the Taquaral pegmatite field, 2.5 km south of Murundu pegmatite. It is a zoned pegmatite hosted in biotite schist of the Salinas Formation, that strikes N40° and dips vertically. The workings have uncovered the pegmatite for an extension of about 30

x 10 m. The pegmatite is medium-grained size, composed essentially by muscovite and feldspar on both sides of an irregular quartz core, with small pockets in the vicinity, and some rose quartz crystals. The maximum thickness of the body varies around 15 m.

Kosnarite occurs as beautiful millimetric druses, beige or vivid to pale yellow, with pseudo-octahedral crystals up to 2 mm generally upon albite (cleavelandite), and associated or not with brown spherulites of zanzaziite (Figures 5a, b, and c). Electron microprobe analyses of kosnarite from the Mario Pinto mine are presented in Table 4.

Figure 5
(a) Beige kosnarite druse from the Mario Pinto pegmatite.
(b) Detailed aspect of the central part of the pseudo-octahedral crystals from “photo A”.
(c) Another sample, showing the rare vivid yellow color of the kosnarite aggregate on albite.



Sample	ZrO ₂	P ₂ O ₅	K ₂ O	HfO ₂	SiO ₂	MgO	FeO	Al ₂ O ₃	Total
Kos1	46.46	42.02	9.04	2.33	0.05	0.00	0.00	0.00	99.90
Kos2	45.96	41.56	9.51	2.11	0.00	0.05	0.01	0.02	99.21
Kos3	46.90	41.72	9.17	2.28	0.00	0.01	0.02	0.00	100.10
Kos4	45.64	42.28	9.07	2.97	0.04	0.00	0.08	0.04	100.10
Kos5	47.51	40.52	9.39	2.08	0.04	0.06	0.00	0.01	99.59

Table 4
Electron microprobe analyses of kosnarite from the Mario Pinto mine (wt %; total iron as FeO).

7. Concluding remarks

The Eastern Brazilian Pegmatite Province can still be considered very poorly studied, besides the 28 new minerals found in it. As example, some mines or mining districts globally known, where many more minerals have already been described, can be cited: Khibiny alkaline massif, Kola peninsula, Russia – 116 species; Franklin zinc mine, New Jersey, USA – 71

species; Langban iron and manganese mine, Sweden – 71 species; Tsumeb lead and copper mine, Namibia – 71 species, Katanga mining district, Republic of Congo – 65 species. Still in this regard, in a country with very little mining tradition as Italy, 312 minerals have been described. However, the mineralogical research line being developed by this group of authors has

brought advances in this respect, resulting in the recent findings of new pegmatite minerals, such as carlosbarbosaite (Atencio *et al.*, 2012), cesarferreiraite (Scholz *et al.*, 2014) and correianevesite (Chukanov *et al.*, 2014). Likewise, findings reported in this paper (bergsлагite, herderite, lithiophosphate, lithiotantite and kosnarite) also highlight this important initiative.

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