STRÜVERITE AND SCANDIUM BEARING TITANIAN IXIOLITE FROM THE CANOAS PEGMATITE (ACARI – RIO GRANDE DO NORTE) IN THE BORBOREMA PEGMATITIC PROVINCE, NE-BRAZIL.

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RESUMO Descreve-se a primeira ocorrência de cristais de strüverita (variedade de rutilo com alto teor de Ta) bem formados na Província Pegmatítica da Borborema, no pegmatito Canoa, município de Acari, Estado do Rio Grande do Norte, Brasil. O pegmatito hospedeiro é heterogêneo e encaixado no granito porfirítico do batólito de Acari-Pau Pedra (580 Ma), por sua vez intrusivo nos biotitaxistos neoproterozóicos do Grupo Seridó. Os cristais de strüverita apresentam hábito tabular pseudo-ortorrômbico a –hexagonal devido a geminações segundo (0k1). Estas formas atípicas, distintas do prisma tetragonal esperado, e o traço castanho escuro a preto podem levar à confusão com columbitas comuns. No núcleo os cristais apresentam zonas com inclusões esqueletiformes de titano-ixiolita com Sc, formando intercrescimentos gráficos, supostamente gerados por exsolução a partir de uma fase precursora de composição intermediária. Análises de microssonda eletrônica revelam 20 a 30%peso de Ta_2O_5 (até 40% Ta_2O_5+Nb_2O_5) na strüverita. Observa-se, nas bordas de três dos quatro cristais estudados, a substituição por um intercrescimento de ilmenita manganesífera, microlita e esfeno nióbio-tantalífero subordinado, provável produto de alteração num estágio tardio da cristalização, já com maior presença de fluidos voláteis, do pegmatito. Os dados químicos revelam, ainda, um fracionamento intenso de Ta e Fe em favor da strüverita e de Nb e Mn (e Sc e Zr) em favor da titano-ixiolita, como também é observado em intercrescimentos semelhantes destas duas fases em outras províncias pegmatíticas mundiais. O limite de solubilidade da fase ortorrômbica na strüverita se aproxima dos 45mol %, enquanto que a ixiolita coexistente contém até 15mol% de TiO_2 (+SnO_2). Este quimismo dos óxidos de Nb-Ta, em concordância com a presença de biotita como acessório freqüente, indica um grau de fracionamento baixo do pegmatito hospedeiro, se comparado com outros pegmatitos da Província Pegmatítica da Borborema.

Palavras chave: strüverita; titano-ixiolita com Sc; pegmatito; química mineral; Província Pegmatítica da Borborema.

ABSTRACT The first occurrence of well developed strüverite crystals in the Canoa Pegmatite, Borborema Pegmatitic Province, State of Rio Grande do Norte-NE-Brazil is described. The hosting heterogeneous pegmatite is enclosed in the porphyritic granite of the

Acarí-Pau Pedra batholith (580Ma) intruded in the biotite-schists of the Neoproterozoic Seridó Group. The strüverite crystals present a tabular pseudo-orthorhombic to –hexagonal habit, due to germination along 0k1,. Because of the atypical forms different from the expected tetragonal prisms for minerals of the rutile group, and the dark-brown to black strike, the crystals can be easily mistaken for common columbite. In the core of the crystals there are zones with skeletal scandian-titanian ixiolite inclusions, forming graphic like intergrowths, supposedly produced by breakdown from a precursor phase with intermediate composition According to EMP analyses, Ta_2O_5 contents in strüverite range from 20 to 30 wt.% (and Ta_2O_5+Nb_2O_5 up to 40wt.%). A peculiar peripherical replacement of the crystals to an aggregate of manganoan ilmenite, microlite and subordinated Nb-Ta-bearing sphene, was formed during a late stage of the pegmatite crystallization, probably already enriched in volatiles. Intense fractionation of Ta and Fe in favor of the strüverite and of Nb and Mn (and Sc + Zr) in favor of the coexisting titanian ixiolite is also observed, in agreement with literature data on similar occurrences in other pegmatite provinces. The limit of solubility seems to be around 45 mol% of the orthorhombic phase in the strüverite, while the coexisting ixiolite contains up to 15mol% TiO_2 (+SnO_2). The mineral chemistry of Nb-Ta oxides, in agreement with the presence of biotite as one of the most important accessory minerals indicates that this pegmatite is less fractionated than the remaining pegmatites of the Borborema Pegmatitic Province.

Key words : strüverite; Sc bearing titanian ixiolite; mineral chemistry; pegmatite; Borborema Pegamatitic Province.

INTRODUCTION

The first occurrence of stüverite – a variety of rutile bearing up to 45 wt.% Ta_2O_5 – in the Borborema Pegmatitic Province (**BPP**) was reported by Beurlen et al. (2003) and Beurlen et al. (2005) as an aggregate of 50 micra sized polygonal grains included in cassiterite from the Corredor pegmatite. In the present case, a second occurrence of strüverite in the BPP deserves a special attention because of its well individualized crystals up to 5 cm in size, interesting intergrowths with Sc-bearing, high titanian ixiolite and a peculiar alteration to an aggregate of manganoan ilmenite, microlite and subordinated niobian titanite. While the largest prismatic specimen was provided by *garimpeiros* (precious stone seekers) with the information of its provenience from the Canoa pegmatite, in the County of Acarí, State of Rio Grande do Norte, other three, smaller tabular crystals 1 to 3cm in size, could now be collected in the dumps of this pegmatite, confirming the previously only supposed provenience.

The pegmatite may be reached leaving the main road from Acarí to Caicó, 8.8 km southwards from Acarí, following to WSW by a secondary gravel road 1.9km to the Pitombeiras pegmatite, then following this road for other 0.3km and than to the left (SSW) for other 1.6km to the small farm of Canoas. Both, the Pitombeiras and Canoa pegmatites are being worked sporadically for the production of aquamarine, producing also beautiful samples of feldspar crystals and bismutinite.

GEOLOGY

The Canoa-Pitombeiras pegmatite group occurs cca. 1.5 km westwards from the intrusive contact of the hosting APP granite with cordierite-sillimanite-garnet-biotite xists of the Seridó Formation, in the top of the Neoproterozoic Serido Group (Van Schmus et al. 2003).

The APP granite facies in this area is characterized by its proeminent white K-feldspar phenocrysts and fine to medium grained biotite rich matrix, studied in detail by Jardim de Sá et al. (1981, 1986). According to geochemical data the calcalcaline to shoshonitic I type magma resulted dominantly of the melting of a cca. 2.0 Ga old granitic crust with subordinated participation of juvenile (transition to A type) and/or metassedimentary rocks. Ages of 555 and 579 Ma were obtained for the APP batholith respectively by Legrand et al. (1991) and Jardim de Sá (1994), both using U/Pb in zircons. These ages are much higher than the 480 to 533 Ma supposed for the pegmatites of the BPP (Ebert 1969, Almeida et al. 1970 and Araújo et al. 2003).

Canoa is one of this pegmatite swarm, with nearly ESE strike and NNE dip, enclosed in the southern part of the Acari-Pau Pedra granitic batholith (**APP**) (Fig.1). A fast transition from decimetric homogeneous pegmatite veins with high NE dips to metric or decametric, gently (30 to 50º) dipping zoned lenses with subordinated discontinuous quartz cores is observed and seams to be a characteristic feature of most of the pegmatites in this area, contrasting with the usually well zoned larger pegmatites of the Parelhas-Equador area.

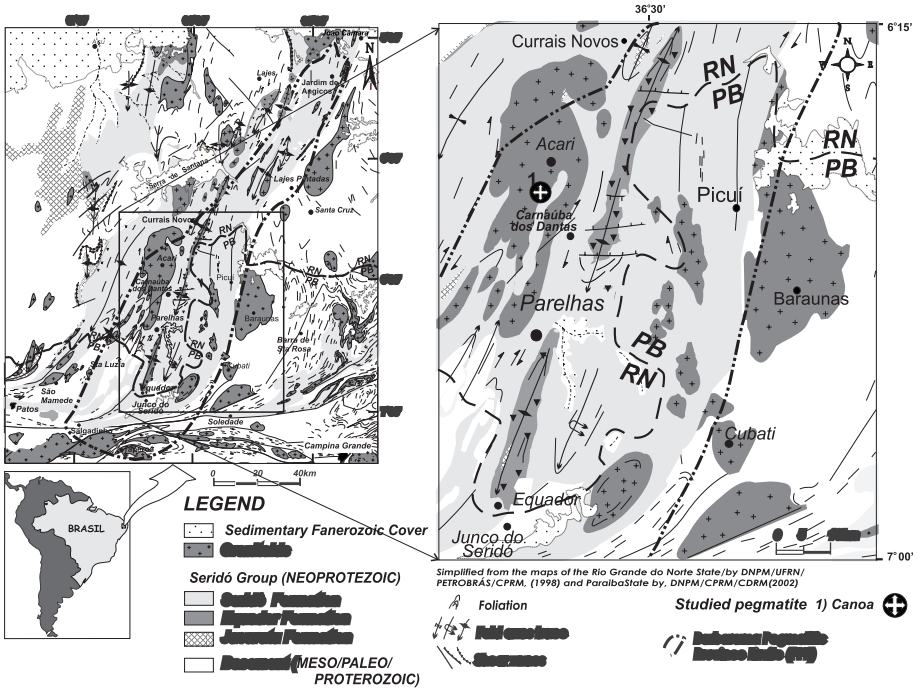

Figure 1The Borborema Pegamtitic Province, NE-Brazil, on a simplified geologic base.

The zoned parts of the Canoa pegmatite is formed by a medium to coarse grained (1 to 5cm grain size) wall zone, formed by quartz, albite and K-feldspar, sporadic biotite plates growing normally to the contact with the enclosing granite, and accessory garnet, muscovite, beryl, magnetite and black tourmaline, grading towards the center to a blocky feldspar + milky quartz zone with individual crystals reaching up to 0.5 to 1.0 m. Discontinuous lenses of massive, mostly milky but, very locally also with masses of rose quartz, occur in the center (Fig. 2A). Black, saccharoidal tourmaline aggregates in thin veins crosscut the quartz core and blocky feldspar or form decimetric, coarse grained, replacement pockets at the transition to the quartz core. Centimetric beryl crystals are sporadically observed in all zones with yellowish-green colors predominating in the wall zone while gem quality aquamarine blue colors may be sometimes observed in the transition between the blocky feldspar and quartz core.

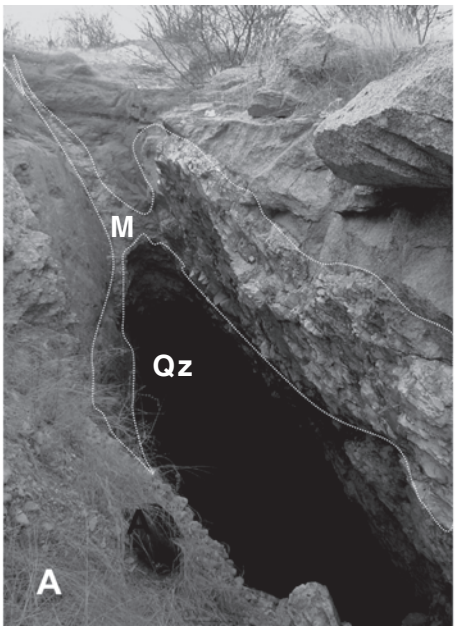

Figure 2A View from E to W of the Canoa pegmatite. An intensive thickening, with a 0.15m thick, almost homogeneous pegmatite (M) at the surface, and a 2.0 m thick pegmatite with a distinct quartz core (Qz) in depth, is observed. The dip changes from almost vertical to 35°N.

PETROGRAPHY

The strüverite crystals were found in dump samples as idiomorphic tabular inclusions and overgrowths in/on large K-feldspar and/or albite or beryl crystals. According to the large size of the feldspar crystals all the samples are from the ("blocky feldspar") intermediate zone, certainly formed close to the quartz core. Many examined samples of the contact zone contained only magnetite as frequent opaque mineral. The geometry of the strüverite crystals simulate hexagonal or orthorhombic symmetry due to geminations along (0k1), with the plates formed by the conjugation of 001 faces of two or more individuals (Fig. 2B). The dark brown to black strike and the tabular habit may be easily mistaken for common columbite.

Two of three polished samples allowed to distinguish a pro-eminent zoning of the strüverite, with a pure core surrounded by a zone of strüverite with skeletal inclusions of ixiolite, forming graphic like intergrowths, supposedly produced by unmixing (Fig. 2C), and an outermost replacement zone formed by bundles of sometimes slightly radially disposed tabular grains of ilmenite with interstitial microlite and subordinated niobian sphene (Fig. 2D).

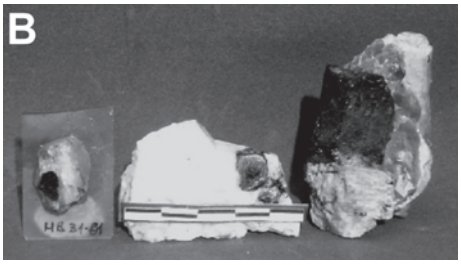

Figure 2B Three strüverite crystals. The two smaller ones at the left are tabular pseudo-hexagonal or –orthorhombic and were collected in the dumps of the pegmatite.

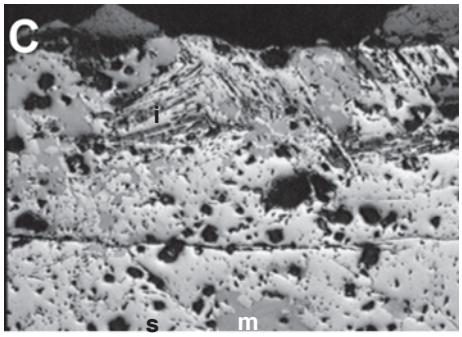

Figure 2 C The polished face of the central crystal of fig.2B, allows to distinguish a replacement rim formed by an intergrowth of radial aggregates of tabular ilmenite (i, light gray) and microlite (m, dark gray). In the lower part the strüverite (s, light gray) is replaced by microlite.

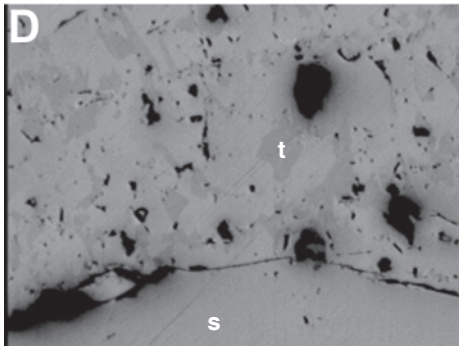

Figure 2D The core of the same crystal is formed by strüverite (s) alone, enveloped by a graphic intergrowth of strüverite and titanian ixiolite (t, darker gray). The microphotographs 2C and 2D are 3mm wide.

Only a very careful observation allows distinguishing these different mineral phases under the petrographic microscope, not only because the literature on ore-microscopical data on Nb-Ta-oxides are extremely incomplete but also, because of the strong pleochroism, similar reflectivity and microhardness of strüverite, ixiolite and ilmenite (McLeod & Chamberlain, 1976 and Antony et al. 1997) at one hand and of titanite and microlite at the other: the strongest reflectivity position of ilmenite (cca. 21%) overlaps the reflectivity of strüverite in its darkest position, both minerals with shades varying from creamy-pink to light creamy-gray. The ixiolite reflectivity, in its lightest position, with slightly brownish-green-gray to light gray shades, is a hue darker than the darkest reflectivity of the ilmenite. Only in some scratched grains a certain relief is possible to be observed between the strüverite and the slightly softer ixiolite, while no difference in hardness could be observed between strüverite and ilmenite, mostly because the contacts are frequently disturbed by microlite films and or fractures. Small internal reflections in the ilmenite are more intense and frequent than those rarely observed in usual ilmenite elsewhere and, together with a pronounced perfect cleavage, and stronger pleochroism are features due probably to the high manganese contents indicated by SEM and EMP data. These are also the main characteristics for its petrographic distinction from strüverite, whose internal reflections are also not common but, when observed, range from colorless to dark orange. The lower reflectivity and less frequent internal reflections of strüverite distinguish this mineral from common rutile, but make a distinction from ilmenite more difficult, or even impossible in grains without lamellar cleavage.

Very frequent white to creamy-orange shaded internal reflections and much lower reflectivity (around 14%) allow to distinguish microlite easily from strüverite and ilmenite, but may be confused with the properties of rare titanite grains (found only fortuitously, by BSE Imaging).

A clear and doubtless distinction of each grain of these phases and their intergrowth patterns are only possible by BSE imaging (Fig. 3A and B).

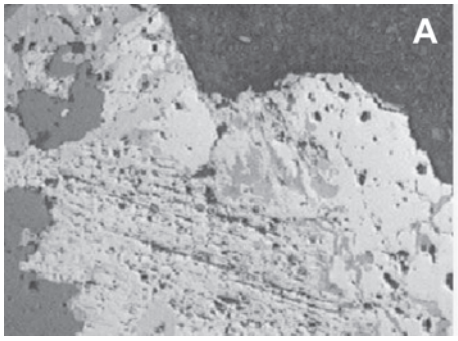

Figure 3A Microphotography of a polished section of the larger crystal of Figure 2B with relics of graphic intergrowth of strüverite (s,light gray at the right) and high titanian ixiolite (t, darker), beeing replaced by a fan like aggregate of lammelar ilmenite (i, intermediate gray, at left) and microlite (m) and sphene (dark gray).

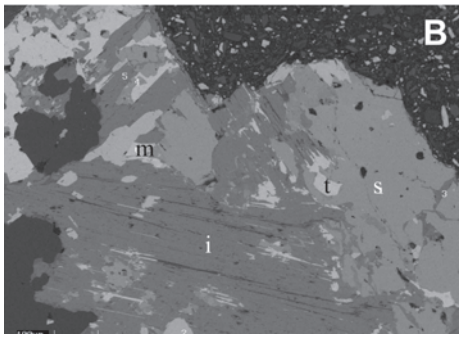

Figure 3B BSEI of the same section as Figure 3A. The lightest portions now are microlite (m) and high titanian ixiolite (t), while strüverite (s) is intermediate gray and ilmenite (i) and sphene are dark gray. Both microphotos are 2mm wide.

MINERAL CHEMISTRY

Methods EMP analyses were obtained at the GeoForschungsZentrum Potsdam-Germany, using a Cameca SX 100 EMP at 20 kV and 40 nA, with acquisition times of 20 seconds for Fe Ka, Mn Ka, Ti Ka, Sc Ka Mg Ka, Al Ka, Ca Ka, Na Ka,Si Ka, K Ka, 30 seconds for Nb La, Sn L a, Sb La, Zr La Hf Ma, Y La, Cs La, Ba La, and 50 seconds for Ta La, Bi Ma, U Ma, PbMa, Th Ma, Ce La, La La, using the following standards: albite (Na), ilmenite (Fe, Ti), cassiterite, orthoclase (K,Al), titanite (Si,Ca,Ti,), zircon, Nb^o, Ta^o, Th^o, U^o, vanadinite, $BaSO_4$, $CePO_4$, $LaPO_4$, YPO_4, $ScPO_4$, InSb, MgO, HfO_2, $MnTiO_3$, Bi_2S_3, pollucite.

BSE images with the SEM and qualitative chemical compositions were obtained at the University of Campinas São Paulo using a SEM LEO 430i, Cambridge, EDS mod. Cat. B, using the following working conditions: 20Kv, 30 seconds acquisition time, using the following standards: Ta^o (Ta Ma), Nb^o (Nb La), Sn^o(Sn L a), Ti^o(Ti Ka), V^o (V Ka), Sb^o (SbL a), Bi^o Bi Ma) Zr^o (Zr La), U^o (UM a),Hf^o (Hf Ma) PbF_2 (PbMa), BCR2 (Fe Ka, Mn Ka, Al Ka, Ca Ka, Na Ka,Si Ka, K Ka).

X-ray diffractograms for confirmation of the mineral identification were obtained using a D 5000 Siemens X-ray Diffractometer and a CuKa tube in the Department of Phisics of the Federal University of Pernambuco.

RESULTS Selected representative EMP analyses of strüverite and the different coexisting Nb-Ta-bearing phases in the Canoa pegmatite are presented in table1. The examined strüverite presents lower Ta2O5+Nb2O5 (30 to 40wt%) contents and lower atomic Ta/Nb ratios (1.4/1.1) than the occurrence of the Corredor pegmatite (with 52wt% and 4/1 ratio respectively, as described by Beurlen et al. (2005). Nevertheless the dominance of Ta over Nb is still very clear corroborating the classification of the mineral as strüverite, instead of the more common niobian rutile. The obtained X-ray diffractogram confirms this identification (Fig. 4), and allows a clear distinction from ixiolite and wodginite.

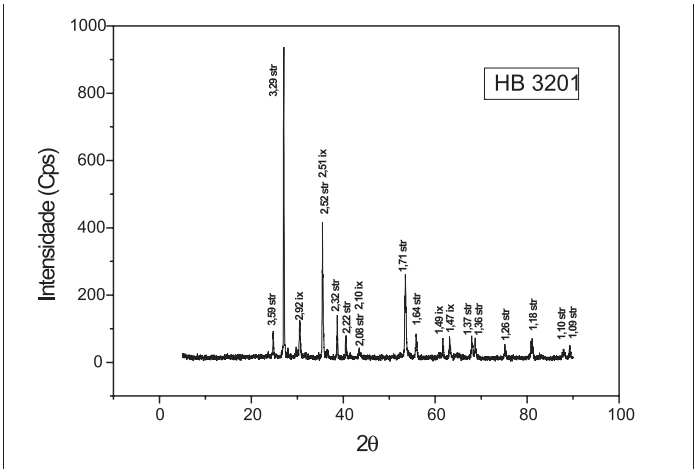

Figure 4 X-Ray diffractogram of a strüverite crystal from the Canoa pegmatite, Acarí – RN, with strüverite peaks(str) much more intensive than those of the high titanian ixiolite (ix) inclusions

In the case of the strüverite from the Corredor pegmatite, the cationic proportion of Ti is less than 50% of the total (5.25/12.00). Therefore, the normative molecular proportion of tantalite/tapiolite surpassing 50mol%, allows to argue in favor if its classification as a different mineral species. By contrast, in the strüverite from the Canoas pegmatite, the cationic proportion of Ti varies from 7.0 to 8.6/12.0, always above 50% of the cation sum, arguing in favor of its characterization as an unusually high Ta-variety of rutile, identified in the literature as strüverite.

The plot of the analytical data between the tie-lines connecting rutile and columbite (tantalite, tapiolite) and rutile with $Fe^{3+}(Nb,Ta)O_4$ and the sum of cations surpassing 12 per 24 oxigens (Table 1, Fig.5A) are suggestive of an important participation of oxidized iron.

The skeletal shaped inclusions forming graphic like intergrowths with strüverite present TiO_2+SnO_2+Sc_2O_3 (11 to 13wt%). These contents are too high to allow its chemical classification as normal ferrocolumbite. According to Wise et al. (1998) maximal contents in columbite group minerals are 3.6, 2.0 and 3.0wt% respectively for TiO_2, SnO_2 and Sc_2O_3 while in ixiolites up to 16.0% TiO_2 and/or 19.0% Sc_2O_3 are found. These compositions, including the unusual high Sc contents, are also reported for titanian ixiolite by Uher et al. (1998), Černý et al. (1998), Černý & Ercit (1989). A distinction between ixiolite and columbite by X-ray diffractometry in the present case is impossible because of the intimate intergrowth of this phase with strüverite and the partial alteration of both to ilmenite and microlite. By the same reason a definitive X-ray distinction from a possible ferrotitanowodginite is also impossible, but, the very clear dominance of Nb over Ta (atomic ratio of 4.6/2.0, not considered in fig. 5A), in spite of the plot in the area of the wodginite group compositions (also observed by Černý et al. 1998) is incompatible with minerals of this group (Ercit et al. 1992a; 1992b, Tindle et al. 1998). The most probable identification of this phase therefore is as titanian ixiolite, in accordance to similar intergrowths with rutile phases referred to in the literature on Nb-Ta-oxide mineralogy. Still in accordance with the literature data the analytical data of the

Canoa strüverite lie on the iron richest side of the Fe/Mn/Ta/Nb quadrilateral (Fig. 5B) while the coexisting ixiolite spread in the center of the diagram with Fe/Mn ratios close to 1 and Ta/Nb ratios close to 2/3, indicating a strong partitioning of Fe and Ta in favor of the rutile phase as also observed by Černý et al. (1998).

The ilmenite formed together with microlite and subordinated sphene, by peripherical alteration of the strüverite and ixiolite, corroding and replacing both of these, presents an unusual high MnO content (up to 18wt%) with atomic Mn/Fe ratios reaching almost 0.4. Elevated Mn-contents (but much less than in the present case) are typical for pegmatitic ilmenites (ergo. Uher et al.1998, up to 7wt% MnO, Černý & Ercit 1989 or Haggerty 1976, 8%). According to Haggerty (op.cit.) MnO contents higher than 10wt% are reported only from peralcaline granites. As similar high Mn contents were found in primary ilmenites of the quartz core of the Pitombeiras 2 pegmatite, in this case showing beautiful exsolutions of scandian columbite and cassiterite, side by side with hematite (Beurlen et al. in prepartation), a late but still primary formation of both ilmenite and microlite at the borders of strüverite, probably during a late hydrothermal stage is indicated.

Ta is the dominant cation in the B site of the other main alteration product of strüverite, and discards its determination as betafite or pyrochlore. Ca beeing the dominant A site cation, with Ca/Na ratios ranging around 6/1, without significant contents of other elements in this site, leads to its identification as common microlite (Hoggarth 1977). In comparison with primary or alteration microlites of other pegmatites in the BPP (see Beurlen et al. 2004) the Nb,Ti and Sn contents of this microlite of Canoa are distinctly higher, indicating its formation at a lower degree of evolution.

Table 1: Selected representative chemical EMP data on coexisting primary strüverite and ixiolite and alteration products ilmenite, microlite and niobian titanite.

HB19	P51	P58	P60		P36	P50	P59		P43	P53	P61		P42	P44	P54		P32	P40	
%Peso óx.	strüverite			média (4)	ixiolite			média(4)	ilmenite			média(8)	microlita			média 5	titanita		média 4
Ta_2O_5	22,70	30,17	27,88	24,21	27,25	30,92	36,42	30,07	1,41	0,43	0,89	0,80	54,95	56,69	55,88	55,81	7,77	4,13	5,26
Nb_2O_5	8,53	9,72	13,18	11,64	44,59	41,84	34,20	42,02	0,63	0,45	0,93	0,65	15,36	14,29	15,25	14,80	4,67	2,39	3,87
TiO_2	57,12	47,14	43,28	50,45	7,61	6,64	7,79	7,32	50,45	52,14	50,49	50,57	4,44	4,09	3,96	4,25	22,67	29,67	25,67
ZrO_2	0,00	0,00	0,06	0,03	0,72	0,72	0,91	0,73	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
MnO	0,09	0,02	0,03	0,05	6,50	7,16	6,38	6,77	17,98	11,96	17,45	16,16	0,19	0,19	0,18	0,20	0,04	0,03	0,04
FeO	8,93	11,07	12,72	10,92	9,54	8,64	8,95	8,98	28,07	32,92	30,37	31,71	0,12	0,11	0,24	0,12	1,28	1,84	1,56
SnO_2	1,46	1,43	1,35	1,40	0,77	1,05	2,62	1,47	0,04	0,04	0,03	0,04	1,89	1,84	2,52	2,07	4,09	0,53	2,79
MgO	0,00	0,00	0,00	0,00	0,08	0,09	0,02	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CaO	0,00	0,00	0,00	0,01	0,03	0,06	0,01	0,23	0,19	0,03	0,01	0,04	17,16	17,43	17,82	17,52	25,68	25,53	25,71
Na_2O	0,02	0,01	0,04	0,02	0,01	0,01	0,02	0,03	0,03			0,03	1,58	1,47	1,66	1,68	0,16		0,11
Al_2O_3	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00			0,00	0,00	0,00	0,00	0,00	3,49		3,35
UO_2	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,70	0,83	0,00	0,44	0,00	0,00	0,00
BaO	0,00	0,00	0,00	0,00	0,53	0,49	0,34	0,42	0,00			0,00	0,00	0,00	0,00	0,00	0,00		0,00
SiO_2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	27,02		27,24
Sc_2O_3	0,15	0,16	0,39	0,27	3,34	3,17	2,73	2,93	0,03	0,01	0,02	0,02	0,17	0,15	0,16	0,16	0,53	0,00	0,38
outros	0,14	0,15	0,11	0,09	0,17	0,20	0,11	0,14	0,04	0,00	0,00	0,02	0,36	0,43	0,16	0,34	0,08	0,00	0,10
Soma	99,15	99,86	99,07	99,10	101,13	100,98	100,50	101,17	98,87	97,98	100,21	100,02	96,92	97,53	97,82	97,40	97,46	64,11	88,41
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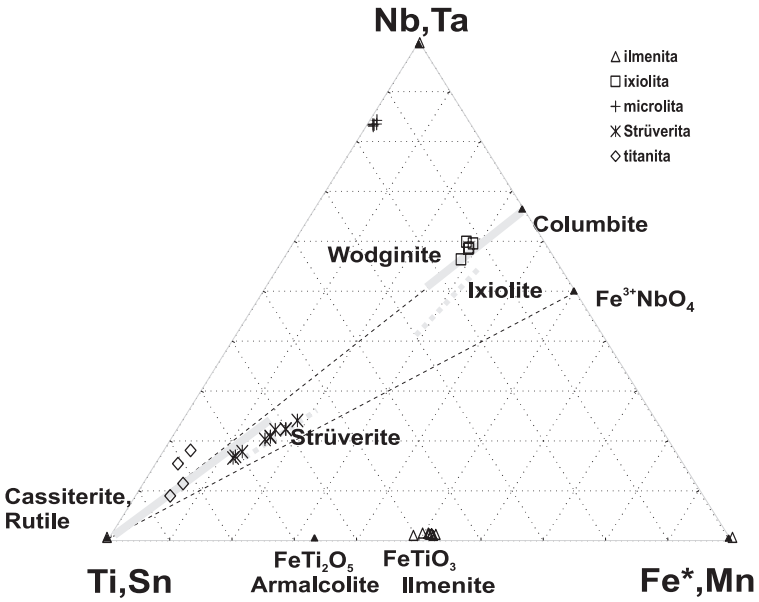
Ta	1,24	1,74	1,63	1,36	1,78	2,06	2,51	2,00	0,08	0,02	0,05	0,04	4,28	4,43	4,32	4,34	0,37	0,34	0,29
Nb	0,77	0,93	1,29	1,09	4,84	4,64	3,91	4,62	0,06	0,04	0,09	0,06	1,99	1,86	1,96	1,91	0,37	0,33	0,34
Ti	8,59	7,52	7,02	7,82	1,38	1,23	1,48	1,34	7,81	8,05	7,73	7,76	0,96	0,89	0,85	0,92	2,97	6,74	4,06
Zr	0,00	0,00	0,01	0,00	0,08	0,09	0,11	0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mn	0,02	0,00	0,01	0,01	1,32	1,49	1,37	1,40	3,14	2,08	3,01	2,79	0,05	0,05	0,04	0,05	0,01	0,01	0,01
Fe	1,49	1,96	2,29	1,89	1,92	1,77	1,90	1,83	4,83	5,65	5,17	5,41	0,03	0,03	0,06	0,03	0,19	0,46	0,27
Sn	0,12	0,12	0,12	0,12	0,07	0,10	0,26	0,14	0,00	0,00	0,00	0,00	0,22	0,21	0,29	0,24	0,28	0,06	0,20
Mg	0,00	0,00	0,00	0,00	0,03	0,03	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ca	0,00	0,00	0,00	0,00	0,01	0,02	0,00	0,06	0,04	0,01	0,00	0,01	5,27	5,37	5,42	5,37	4,80	8,26	5,66
Na	0,01	0,00	0,02	0,01	0,00	0,00	0,01	0,02	0,01			0,01	0,88	0,82	0,91	0,93	0,05		0,04
Al	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	0,72		0,69
U	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,05	0,00	0,03	0,00	0,00	0,00
Ba	0,00	0,00	0,00	0,00	0,05	0,05	0,03	0,04	0,00			0,00	0,00	0,00	0,00	0,00	0,00		0,00
Si	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00	4,71		4,73
Sc	0,03	0,03	0,07	0,05	0,70	0,68	0,60	0,62	0,01	0,00	0,00	0,00	0,04	0,04	0,04	0,04	0,08	0,00	0,06
outros	0,01	0,01	0,01	0,01	0,02	0,02	0,01	0,01	0,00	0,00	0,00	0,00	0,03	0,04	0,02	0,03	0,00	0,00	0,01
Soma	12,27	12,33	12,46	12,36	12,19	12,18	12,21	12,19	15,98	15,85	16,06	16,08	13,78	13,79	13,90	13,87	14,55	16,20	14,98



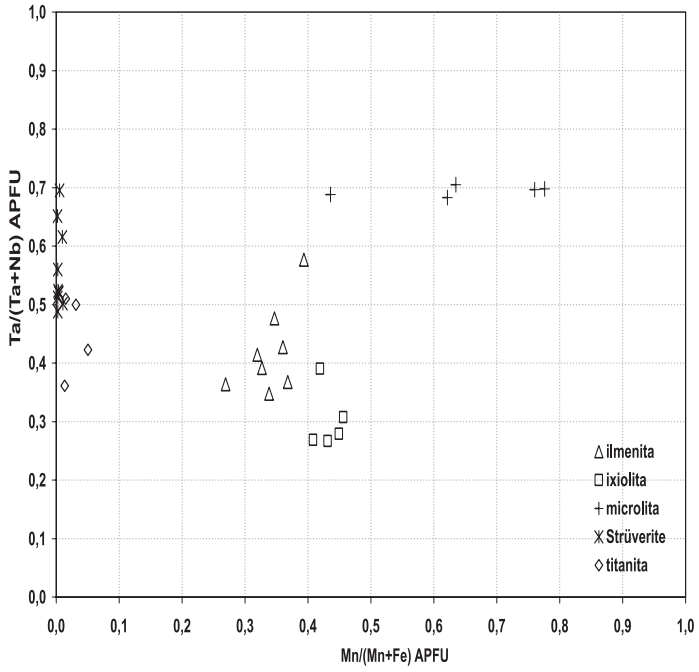


Fig. 5 Chemical data of the coexisting strüverite-ixiolite-ilmenite and microlite phases in the cationic Nb-Ta-Fe-Mn quadrilateral plot and the ternary Nb+Ta vs. Ti+Sn vs. Fe+Mn plot.

DISCUSSION AND CONCLUSIONS

By the first time the occurrence of well formed, independent crystals of the Ta-rich rutile variety strüverite could be described from the BPP. In the present case, the strüverite contains skeletal inclusions of titanian ixiolite whose graphic like intergrowth is suggestive of formation by break-down or exsolution of a precursor phase with intermediate composition. While the coexistence and intergrowth of Nb-Ta-rutile phases with orthorhombic Nb-Ta-oxides are referred in several papers dealing with Nb-Ta-Ti-oxide mineralogy in pegmatites, only a few cases of "true exsolutions" are reported according to Černý et al. (1998) and give the opportunity to try to establish the miscibility limits and stability conditions of these phases. In the analysed crystal an intense fractionation of Ta and Fe in favor of the tetragonal rutile phase and of Mn and Nb in favor of the orthorhombic phase is observed, in accordance with the observations of Černý et al. (op. cit.). The solubility limit of the orthorhombic phase (either of the columbite or ixiolite group) in the strüverite reaches around 45mol% in the described case, while up to 15mol % rutile+cassiterite are dissolved in the orthorhombic phase, supposedly a scandian-titanian ixiolite. This issue will be discussed with more detail in a forthcoming study, together with a larger number of data, including other cases of equilibrium coexistence of the tetragonal and orthorhombic Ti-Nb-Ta oxides from other occurrences in the BPP (Quintos, Capoeira, Corredor and Feio pegmatites).

The predominance of Ti, Fe and Nb in the Nb-Ta-oxide mineralogy of the Canoa pegmatite, in agreement with the presence of biotite as one of the main accessory minerals of this pegmatite and the finding of primary ilmenite in the core of other pegmatites of this area, indicate a very low degree of fractionation of these pegmatites, despite its heterogeneous structure. These features distinguish this group of pegmatites clearly from the other classical heterogeneous pegmatites – ergo. Parelhas-Picuí-Pedra Lavrada areas – (Rolff 1944, Johnston Jr 1945, Da Silva et al. 1995) in the BPP and open a new perspective on the possibility of different stages and origins of pegmatite formation in the province.

Finally the presence strüverite and ixiolite as, so far unknown, low Ta-grade ore minerals, opens the possibility of the use of these ores to blend high grade ore concentrates increasing the production and reserve of Ta-ores in the BPP.

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