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FIELD TRIP GUIDE TO THE SERIDÓ PEGMATITE PROVINCE

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Abstract

The pegmatites of the Seridó Pegmatite Province show a granitic bulk mineralogical composition, composed of K-feldspar, albite, quartz, muscovite and occasionally biotite. Detailed mineralogical studies of the major minerals are scarce. There is, on the other hand, a relatively larger number of published contributions concerning pegmatite accessory minerals. This field trip guide focus on the mainly occurrence locations of these last minerals, which are group here by their most frequently recovered rare metals and gems: (1) Ta-Nb: Tantalite-columbite is the main mineral group, even though other rare varieties may occasionally be recovered as microlite, tapiolite, strueverite, simpsonite, ixiolite, among others. Their grain size varies from the centimeter to decimeter scale. The mineralization is disseminated (less frequently), in pockets, or as aggregates of crystals, usually associated with "replacement bodies" at the contact between Zone III and the quartz core. They also occur sporadically in Zone II and occasionally in homogeneous pegmatites, as crystals in subcentimeter to centimeter scale, frequently disseminated in the quartz-feldspar-muscovite groundmass. In this case, they display lamellar habit and normally lower Ta concentration. (2) Be: Beryl is the main Be-mineral present. Its grain size varies from centimeter to meter, it is normally prismatic and shows diverse colors (white, green, blue, pink, yellow), with green and white prevailing. It occurs in Zones II, III and IV (quartz core), as well as in association with the "replacement bodies". In homogeneous pegmatites, it occurs as centimetric crystals, disseminated in the groundmass. Some pseudoconical forms are also observed, and contain muscovite and quartz inclusions. The gem varieties (aquamarine, morganite, heliodor) are scarce. Beryl and the Ta-Nb minerals, are the main ores exploited in these pegmatites. (3) Li: Li-minerals recovered from the pegmatites are spodumene, lepidolite and amblygonite. The spodumene prevails over amblygonite and lepidolite, although the reserves of Li are still not completely known. Spodumene occurs in individual crystals or aggregates in decimeter to meter dimensions, rarely forming individualized zones. Lepidolite occurs mainly in albitized pegmatites associated with deep blue tourmalines (named Paraíba Tourmaline). Amblygonite occurs in pockets of decimeter to meter width and may be associated with other phosphates such as lithiophilite, triphylite, siclerite, tavoríte, among others. (4) Sn: Cassiterite is the main Sn-ore, although Sn is also present in the crystallographic structure of Ta-Nb minerals. It is found disseminated in centimeter grain size in the "replacement bodies" or in Zone I of heterogeneous pegmatites, and occurs occasionally in some homogeneous pegmatites. Cu (e.g. djurleite), U (e.g. uraninite) and REE (e.g. xenotime) minerals are considered important resources exploted or as potential for further exploration.

Keywords: Pegmatite; Borborema Province; Gemstones; Ta-Nb-Be-Li Minerals.

1. Introduction

The Seridó Pegmatite Province (SPP) in Northeast Brazil became well known during the World War II as one of the world's most important Ta-Be producers as well as to produce beautiful specimens of "exotic" tantalates (e.g. tapiolite, strueverite, simpsonite, ixiolite) and top-quality gem specimens, being referred as type locality for many of them (Beurlen, 1995). In the last two decades it became important also as supplier of raw materials for the Brazilian ceramics industry and of gemstones, including aquamarine, morganite and the turquoise to deep blue Cu bearing "Paraíba Tourmaline (PT)". Several important questions remain unsolved or were never addressed in the classical literature about the SPP. These include the regional metal zoning distribution and the identification of the granitic (or other source, as defined by Sallet et al., 2015).

This work is intended for undergraduate and graduate students, professors and professionals in the field of geosciences/engineering, and aims to present a field guide with six of the most representative pegmatites bodies found in the Seridó region (Paraíba (PB) and Rio Grande do Norte (RN) states) (Fig. 01), accompanied by geologic information and field notes.

2. Geological Setting

With over 750 registered Rare-Element mineralized granitic pegmatites, the SPP extends over an area of about 100 x 150 Km, in the eastern-southeastern part of the Seridó belt – Rio Grande do Norte Tectonic Domain, in the Paraíba and Rio Grande do Norte states, located in the northern part of the Borborema Province, Northeast Brazil. This province is distinguished by a Paleoproterozoic basement, Archean nuclei and Meso- to Neoproterozoic supracrustal rocks affected by deformational, metamorphic and magmatic events during the Brasiliano-Pan-African Cycle (650–500 Ma; Brito Neves et al., 2000; Van Schmus et al., 2003 and Santos et al., 2010).

The Seridó belt in this area consists of the rocks of the Neoproterozoic Seridó Group, which are constituted, from bottom to top, by the Jucurutu (paragneisses, calcsilicates and marbles), Equador (quartzites and metaconglomerates) and Seridó Formations (aluminous to feldspathic micaschists) (Brito Neves and Fuck, 2013). Most (80%) of the over 750 known rare-element-mineralized pegmatite and granitic pegmatite bodies are intruded in garnet-cordierite and/or sillimanite-biotite schists of the upper Seridó Formation. Less than 10% are emplaced in the underlying quartzites, metarkoses and meta-conglomerates of the Equador Formation (Da Silva et al., 1995). The remaining bodies are hosted by paragneisses and skarns of the Jucurutu Formation, by late to post-tectonic granites or by gneisses and migmatites of the Paleoproterozoic basement. The regional metamorphism of the Seridó Group attained the amphibolite facies (Van Schmus et al., 2003) (Fig. 01).

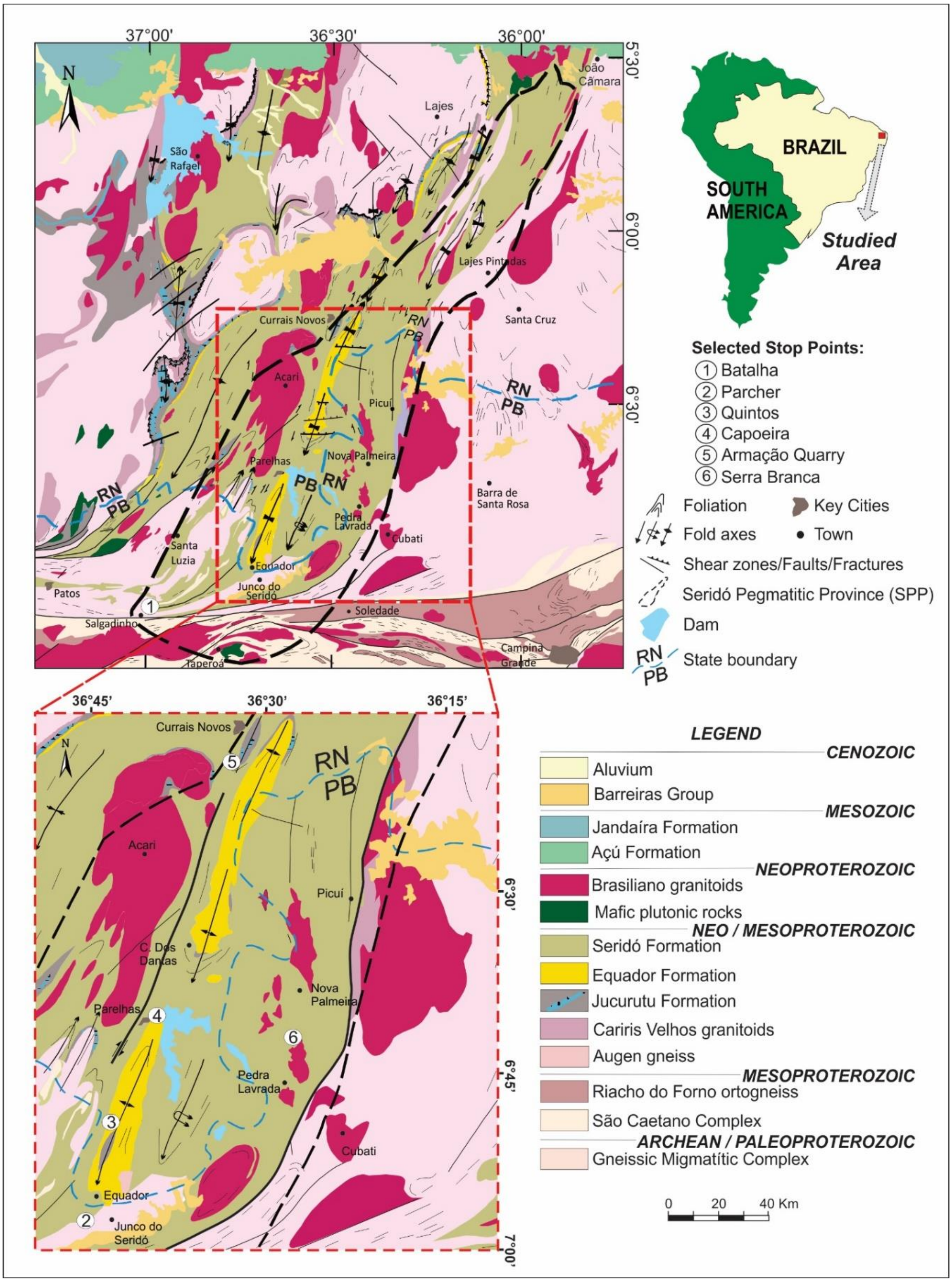

Figure 1: Simplified geology of the Seridó belt, in the northern domain of the Borborema Province, based on geological maps of the Rio Grande do Norte (Angelim et al., 2006) and Paraíba States (Santos et al., 2002). The black dotted line is the limit of the Seridó Pegmatitic Province (SPP). The dotted reddish rectangle corresponds to the zoomed map and represents area of the main concentration of productive pegmatites.

The pegmatites of the SPP were first classified based on the internal structure by Johnston Jr. (1945), distinguishing two types of pegmatites: a) Homogeneous mineralogical composition, including quartz, feldspar and mica in variable amounts, structurally simple, and, b) Heterogeneous mineralogical composition, well defined internal zonation and structurally complex (Fig. 02).

Concerning the heterogeneous pegmatites, from the wall rock contact to the center, the following zones can be identified (Fig. 02):

- Zone I (Border Zone), at the contact with the wall rock, is dominantly coarse-grained, comb-textured muscovite, perpendicular to the pegmatite margins, intergrown between quartz and some albite as essential minerals. Black tourmaline, garnet and, sometimes, cassiterite are common accessories. The usual thickness of a few centimeters may occasionally reach up to one meter.
- Zone II (Wall Zone) is identical to the homogeneous pegmatites, with feldspar content and grain size increasing from the contact with Zone I towards the center of the pegmatite. Graphic intergrowths of quartz and feldspars are conspicuous. Centimetric replacement bodies (quartz+muscovite) are commons.
- Zone III (Intermediate Zone) is almost monominerallic, composed of K-feldspar crystals in decimeter to meter scale (blocky K-feldspar). It could be divided into External (blocky K-feldspars with graphic intergrowths) and Internal (pure blocky K-feldspars).
- Zone IV (Innermost zone or quartz core) is the preferential locus for the growth of large crystals of some ore minerals (beryl, columbite-tantalite, spodumene, amblygonite, other phosphates) and subsolidus replacement bodies (albite and small quartz pockets), but with a more diverse mineralogical composition that contain mica and many other minerals, replacing quartz and K-feldspar.

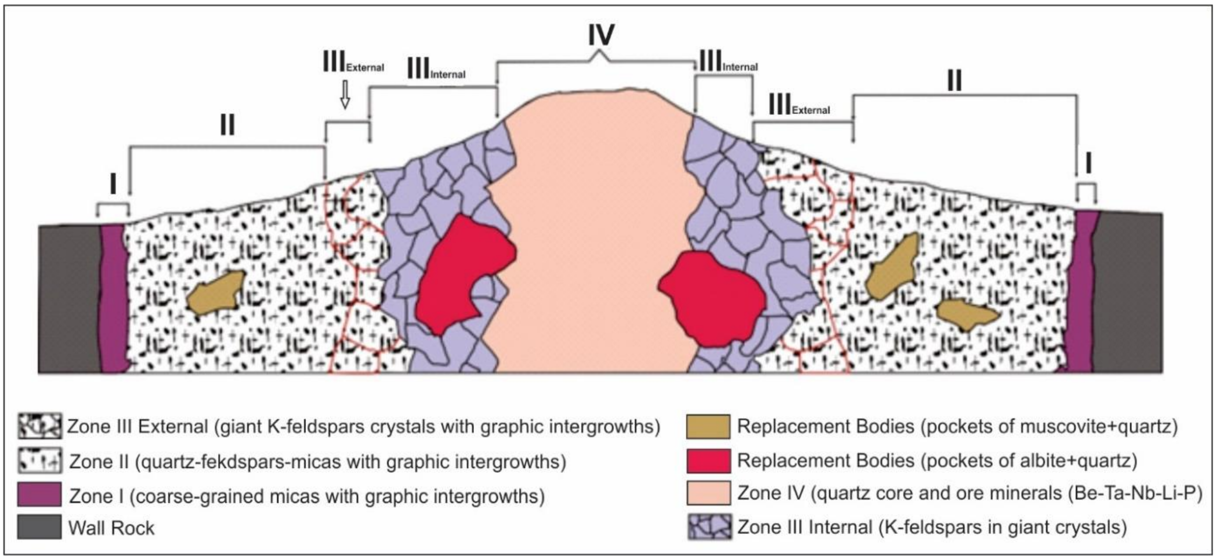

Figure 2: Schematic cross-section of the heterogeneous (zoned) pegmatites. Abbreviations: I, II, III and IV represent zones of heterogeneous pegmatites. Horizontal scale ranging from 1m up to 100m. Modified from Johnston Jr. (1945).

3. Field Trip Logistics

The proposed trip to visit the Seridó Pegmatite Province has a four-day duration program, totaling approximately 1,065 Km, departing from Recife, capital of the Pernambuco (PE) state, towards the center-north and center-south part of the Paraíba and Rio Grande do Norte states, respectively, as seen in Fig. 03 and detailed below.

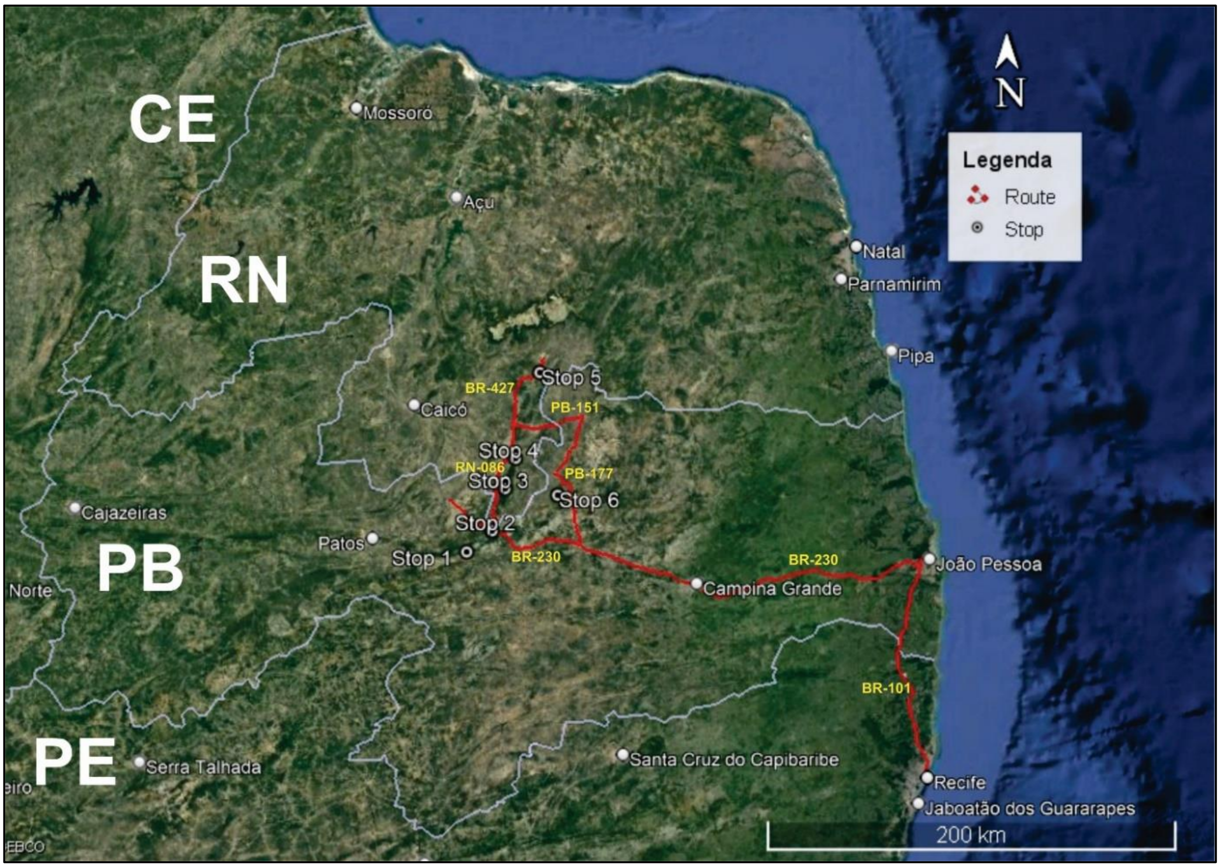

Figure 3: Location map of the six selected points (black-centered white point) as field trip guide through Seridó Pegmatite Province (SPP). Background image (Landsat/Copernicus), main cities (white points) and routes (red lines accompanied by yellow codes) were obtained through the Google Earth application. Abbreviations: CE – Ceará State; RN – Rio Grande do Norte State; PB – Paraíba State; PE – Pernambuco State.

Day One:

7:00 a.m.	Meeting point at the front desk of the Centro de Tecnologia e Geociências (CTG)/Universidade Federal de Pernambuco (UFPE), Recife city – capital of the Pernambuco state.
7:15 a.m.	Departure from UFPE/Recife city. Trip northward to João Pessoa city through BR-101 federal road and then eastward to Campina Grande city through BR-230 federal road.
11:15 a.m. to 12:00	Stop for lunch at Campina Grande city, 210 Km northwest from Recife.

2:00 p.m. to 5:00 p.m.	**Stop 1 - Batalha Pegmatite**, 130 Km east from Campina Grande city (95 Km on RB-230 until Barra district, 10 Km on PB-228 until Assunção town and plus 25 Km through unpaved road.
5:00 p.m.	Depart to Santa Luzia town, 75 Km northwestward to Stop 1 (returning 35 Km to the district of Barra, following further 40 Km northwestward on BR-230).
6:00 p.m.	Overnight accommodation at Santa Luzia Hotel, Santa Luzia town.

Day Two:

6:00 a.m.	Breakfast in Santa Luzia Hotel.
7:00 a.m.	Departure from Santa Luzia Hotel, Santa Luzia town.
8:00 a.m. to 12:00 a.m.	**Stop 2 - Pacher Pegmatite**, 28 Km eastward from Santa Luzia town through BR-230 federal road.
12:00 to 1:00 p.m.	Stop for lunch in Junco do Seridó town, 5 Km east from Stop 2.
1:30 p.m. to 5:00 p.m.	**Stop 3 - Quintos Pegmatite**, 38 Km north from Junco do Seridó town (30 Km through RN-086 and 8 Km on unpaved road).
5:00 p.m.	Depart to Parelhas town, 20 Km northward from Stop 3 (8 Km via unpaved road plus 18 Km along RN-086).
6:00 p.m.	Overnight accommodation at Venezza Park Hotel, Parelhas town.

Day Three:

6:00 a.m.	Breakfast in Venezza Park Hotel.
7:00 a.m.	Departure from Venezza Park Hotel, Parelhas town.
7:30 a.m. to 11:30 a.m.	**Stop 4 - Capoeira 1 Pegmatite**, located on the outskirts of Parelhas town (5 Km from the center, by unpaved way).
12:00 to 1:00 p.m.	Stop for lunch in Parelhas town, in the surrounding of the Stop 4.
2:00 p.m. to 5:00 p.m.	**Stop 5 - Armação Quarry**, 62 Km north from Parelhas town (22 Km through RN-086, 36 Km through BR-427 federal road and 5 Km on unpaved road).
5:00 p.m.	Return to Parelhas town, 62 Km south, through the same roads.
6:00 p.m.	Overnight accommodation at Venezza Park Hotel, Parelhas town.

Day Four:

6:00 a.m.	Breakfast in Venezza Park Hotel.
7:00 a.m.	Departure from Venezza Park Hotel, Parelhas town.
9:00 a.m. to 11:00 a.m.	**Stop 6 - Serra Branca Pegmatite**, 120 Km to northeast way of Parelhas town (22 Km north and then 23 Km east through RN-086, 15 Km eastward on PB-151 until Picuí town, 52 Km on the south way in the PB-171 and 8 Km to west on unpaved road).
12:30 p.m. to 1:30 p.m.	Stop for lunch at Campina Grande city, 95 Km southeast from Stop 6 (8 Km to east on unpaved road, 27 Km to south in the PB-171 until Soledade town, and further 60 Km east through BR-230 federal road).
1:30 p.m. to 5:30 p.m.	Return to Recife city, 210 Km distance from Campina Grande city, through the same federal roads carried out on day 1.

4. Outcrops

The localization and geological details of the six stops are given below:

Stop 1 - Batalha Pegmatite (Coordinates: S 07º 04' 57.2" and W 36º 50' 35.5")

Geological details:

Batalha pegmatite is located 130 Km east from Campina Grande city (95 Km on RB-230 until Barra district, 10 Km on PB-228 until Assunção town and plus 25 Km through unpaved road. Since 1987 fine quality transparent turquoise or deep blue tourmalines have become available in the gem market came from Batalha mine, also commercially known as “Paraíba Tourmaline”. The material has been produced in an occurrence near the village São José da Batalha town, in Paraíba State.

The local geology of Batalha pegmatite (Fig. 01) consist of 8 parallel heterogeneous pegmatite dikes, dipping 70°- 80° N30°W, crosscutting subconcordantly a hard muscovite quartzite country rock of the Equador Formation of the Neoproterozoic Seridó Group. The dikes have a thickness of about 1,5 m in average, always below 5 m. They are mined at a depth of up to 60 m (Fig. 04). This blue color of tourmalines from Batalha has never been observed before 1987 in the world. The color is due to the presence of copper and according Rossman et al. (1991), copper occurs in many gem tourmalines in the range of single-digit parts per million (ppm) to tens of ppm concentrations. The origin of the copper in Brazilian Paraíba tourmaline localities is still an open question, but some researchers have attributed it to copper enrichment of the host pegmatites or pegmatite-independent hydrothermal activity (Beurlen et al., 2011 and references therein). Albite-type feldspars have all been completely altered to white kaolinite. Gem-quality tourmaline crystals are found only in four of the dikes known. They are embedded in kaolinite within the inner intermediate zone (Zone III internal) and within small clay-filled pockets (filled geodes) in the core zone (Zone IV) of the pegmatites. In some cases, the quartz core zone exhibits also up to 20 cm long spodumene crystals. Some blue tourmaline crystals have been broken by lately brittle tectonics, and present severe etching features in the core zone pockets. Some crystals are partially or completely replaced by lepidolite. Other minerals occurring in the Batalha pegmatite include lepidolite, schorlite, dark green non-cuprian elbaite, as well as Nb-Ta oxides, amethyst, garnet, gahnite, uranium minerals (uraninite and autunite) and apatite.

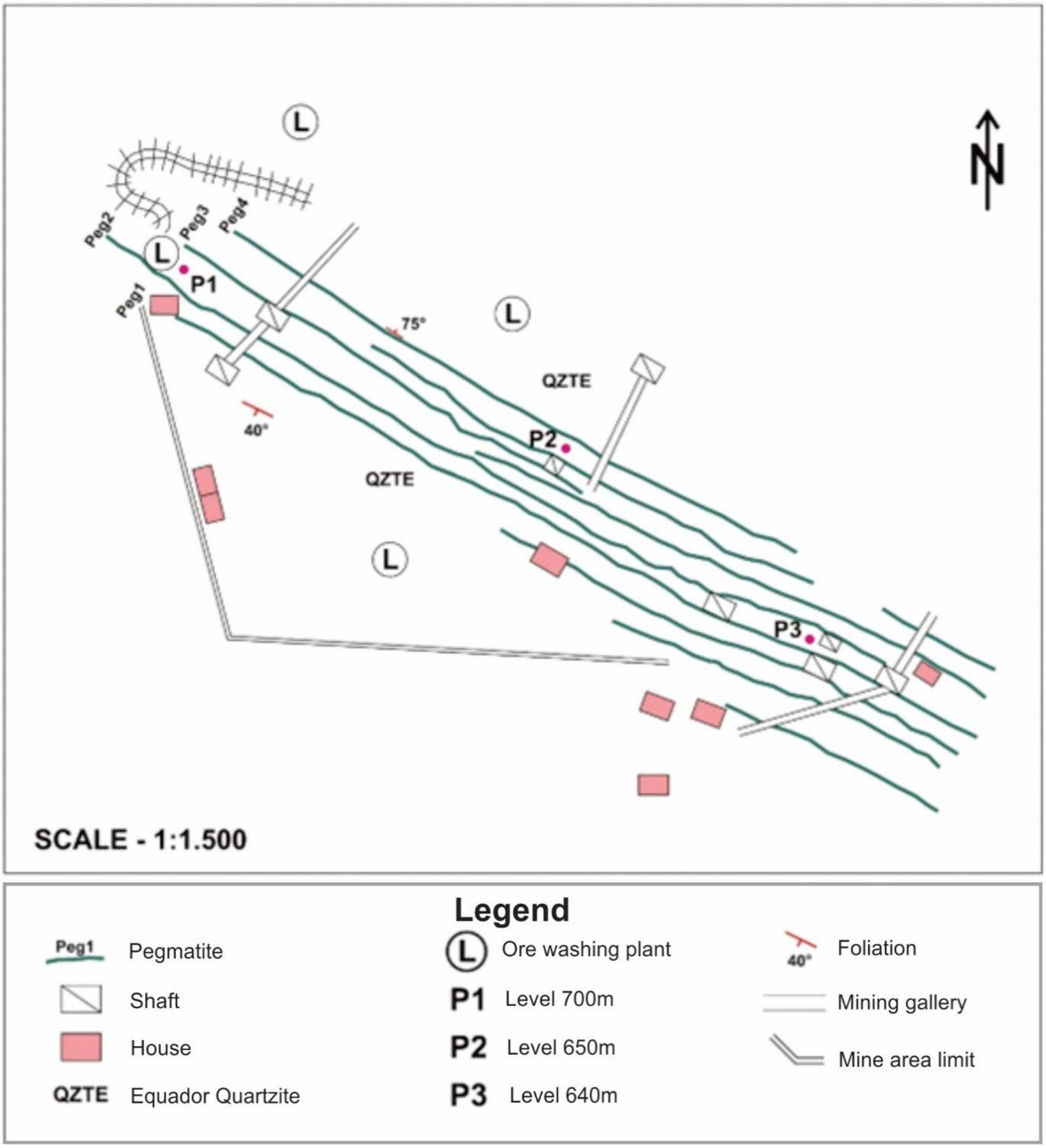

Figure 4: Schematic map of the Batalha pegmatite. Reference: Moura, O.J.M., unpublished company report.

Stop 2 - Pacher Pegmatite (Coordinates: S 06º 59' 30.9" and W 36º 44' 05.1")

Geological details:

The Pacher pegmatite (Fig. 01) is located about 5 Km southwest of town of Junco do Seridó, State of Paraíba. This heterogeneous pegmatite shows a general strike of N60ºE; with sub vertical dip. It intruded concordantly the biotite-schist/paragneiss of the Ediacaran Seridó Formation. The body is about 150 m long and average a width of 45 m (Fig. 05). It is being primarily mined for feldspar (both, k-feldspar and albite), at the level 45m below surface.

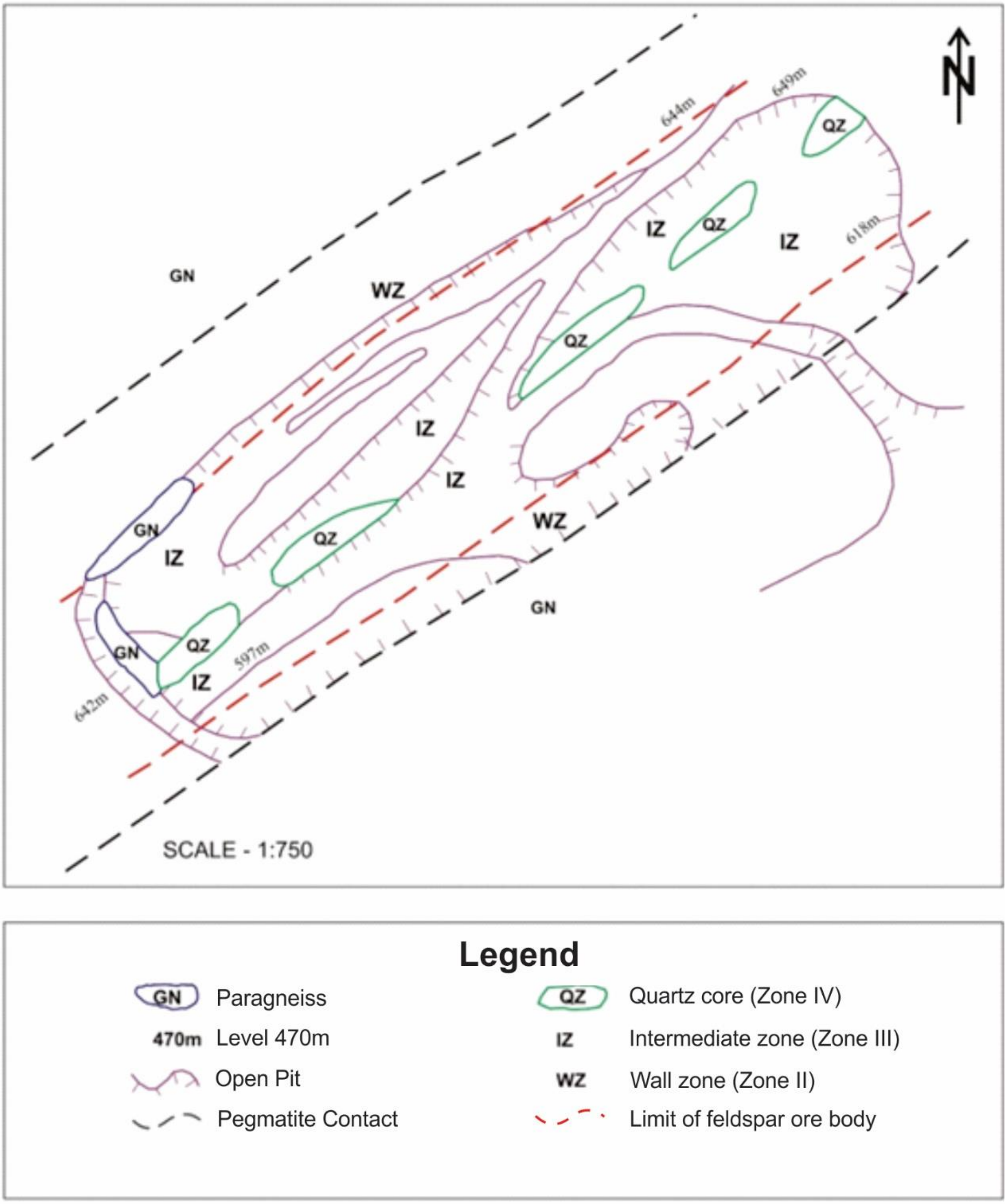

Figure 5: Schematic map, plan view, of the Pacher pegmatite. Reference: Moura, O.J.M., unpublished company report.

The heterogeneous pegmatite is an open pit mine for K-feldspar (minor albite) and shows three distinct mineralogical and textural zones: 1) wall zone (1-4m wide) with K-feldspar, albite, quartz and muscovite, besides black tourmaline (schorlite), and garnet; 2) the intermediate zone, which is the main zone, with some large graphic textured and blocky K-feldspar crystals and "books" of muscovite, besides beryl (blue aquamarine and light yellow “golden beryl” heliodor and the common one green colored), tourmaline (elbaite), and phosphates (lithiophilite, triphylite) as accessory minerals; and 3) discontinuous massive quartz core zone (Fig. 05).

Stop 3 - Quintos Pegmatite (Coordinates: S 06º 48' 46.1" and W 36º 40' 44.2")

Geological details:

The second place in the world where the miners found "PT" was in the Quintos pegmatite, 50 Km north from São José da Batalha, in the State of Rio Grande do Norte (Fig. 01). The Quintos pegmatite is hosted in quartzites of the Equador Formation, near to the contact with the overlaying biotite schists of the Seridó Formation. It is a typical heterogeneous pegmatite and a conspicuous feature of this pegmatite is the replacement bodies around the discontinuous spodumene-quartz core. Albite in tabular aggregates is the main mineral of this replacement body and usually includes the colored elbaite crystals. The larger Paraiba Tourmaline crystals start in the quartz core zone, with the end enclosed in the frequently light bluish albite, like a collar around the quartz core (specimens). The "PT" occurs also associated with lepidolite aligned crystals that stop in pockets filled with clay minerals, quartz, lepidolite, apatite, uraninite, pink beryl, spessartite, gypsum, and others. Small-sized clay minerals and lepidolite aligned crystals may envelop single "PT" crystals in vugs, as well as other commons specimens of tourmalines (black schorlite and dark green non-cuprian elbaite).

The pegmatite appears at the level 540m and the main access gallery to it is in the level 500m. The mine stops in the end of the body at the level 410m (Fig. 06). The visit will be between levels 500m and 450m, in the main productive sector, where still remains a reserve of blue tourmaline around the core zone, which can be following for about 40m.

Stop 4 - Capoeira 1 Pegmatite (Coordinates: S 06º41'04.1" and W 36º38'02.9")

Geological details:

The Capoeira 1 pegmatite (Fig. 01) is located on the outskirts of Parelhas town (5 Km from the center, by unpaved way), and it is encompassing at least four bodies (named as 1, 2, 3, and 4, also known as Mulungu Mine, Fig. 07), which each one varies up to 50 m width and 300 m long (E-W), cross-cuts almost orthogonally metaconglomerate layers (Equador Formation). It is a heterogeneous well-zoned body, with a dravite-rich border zone (Zone I; sub-meter thickness), followed by a wall zone (Zone II, up to 8 m thick), grading into an intermediate zone (Zone III, varying from 1 to 5 m thick) formed exclusively of large, blocky K-feldspar with large replacement bodies (pockets) of muscovite and selvages of bladed albite halos. Sporadic spots of copper sulfides (djurleite and minor chalcopyrite) occur in the Zone III, and large lenses of massive milky-quartz in the core (Zone IV). The pegmatite was mined for feldspars with a subordinate production of beryl, tantalum ore concentrate (columbite-group and microlite). Some smaller bodies, possibly apophyses, which are parallel to the main body (Fig. 06), are famous to produce "Paraíba Tourmaline" (Capoeira 2 and 3).

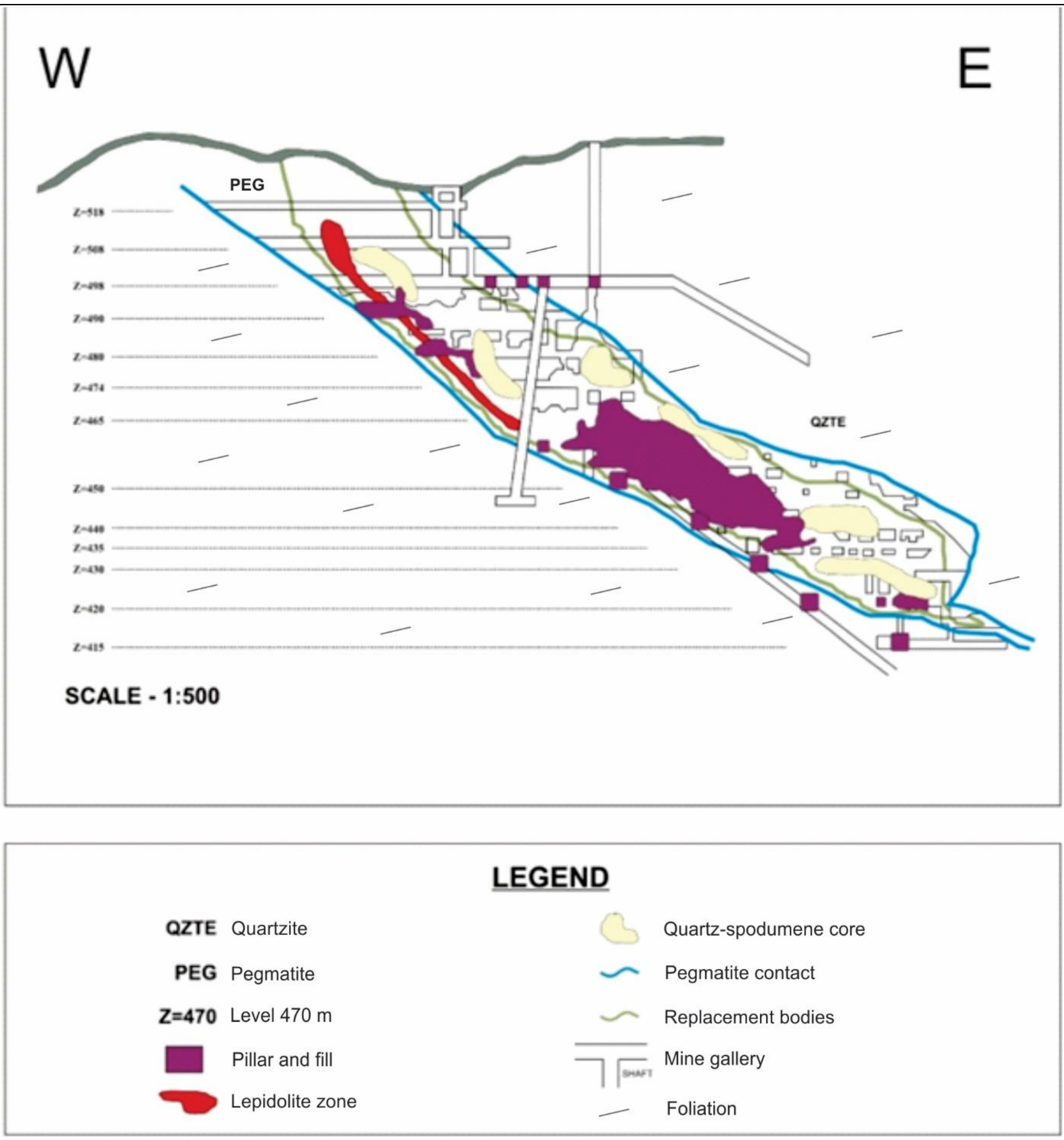

Figure 6: Schematic cross-section of the Quintos pegmatite. Reference: Moura, O.J.M., unpublished company report.

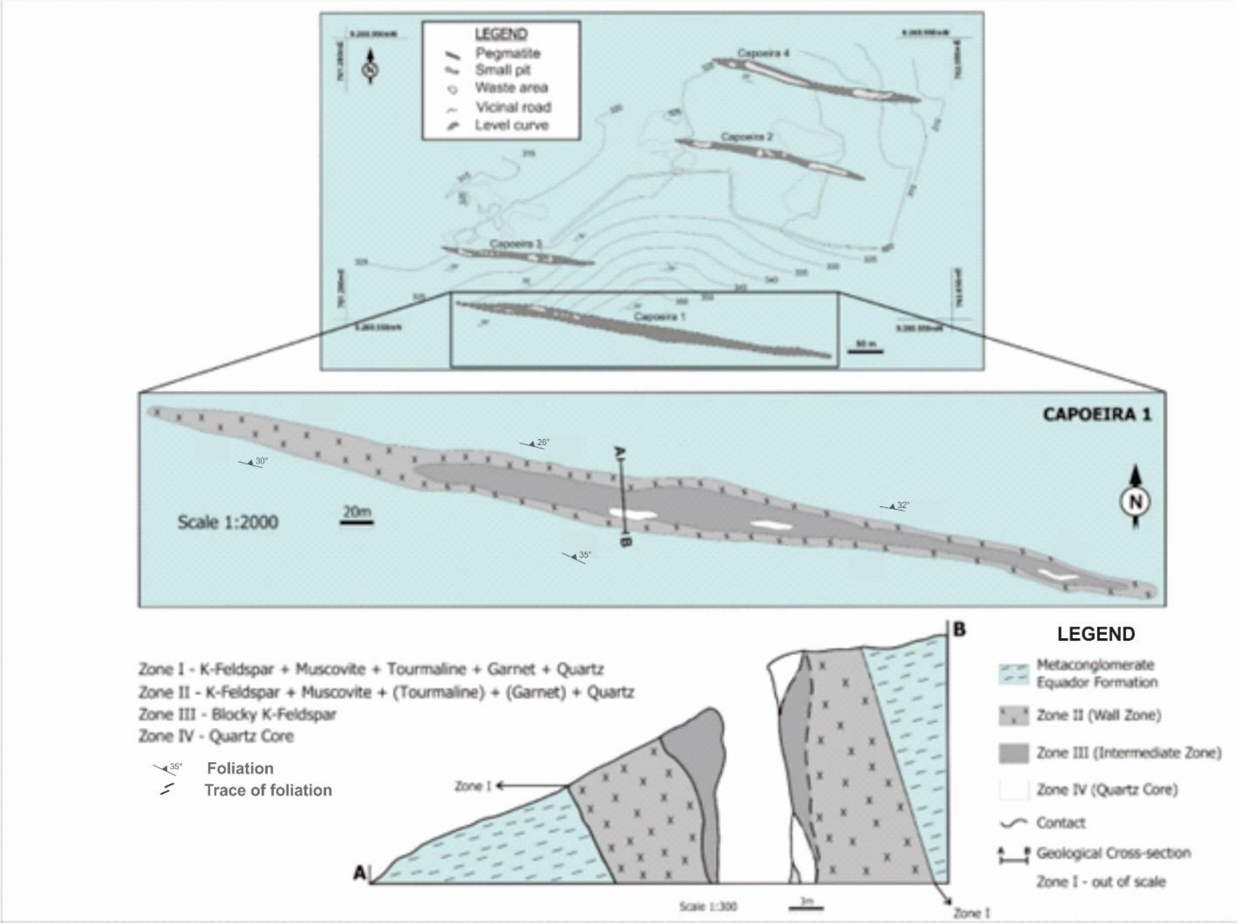

Figure 7: Schematic map and section of the Capoeira pegmatite. Reference: Moura, O.J.M., unpublished company report.

Stop 5 - Armação Quarry (Coordinates: S 06º 19' 11.7" and W 36º 31' 44.3")

Geological details:

In the Armação Quarry (Fig. 01), located at 62 Km north from Parelhas town and about 5 Km south from Currais Novos town, a pegmatitic granite body is exploited as dimension stones mine. This intrusion as formed by sub-homogeneous dyke of pegmatitic granite intruded the schists of the Seridó Formation, striking NNW, 0.2 Km wide and 0.8 Km long. The intrusions of this rock type are widespread in the SPP. They form small bodies, with less than 1 Km2 of exposed area, occurring usually as dykes, several hundred meters wide and less than 1 Km long. This is probably the reason why intrusions of this granite type are not represented in most of the geological maps of the area, which are in 1:500.000 or 1:250.000 scales. Even some larger intrusions, up to 4 to 40 Km2 of exposure area, are omitted in many geological maps of the Seridó Belt. More than a dozen of such intrusions has already been recognized in this region, and some of them, according Sallet et al. (2021), have been examined with some detail. Their recent use as dimension stones provided good sampling conditions.

The most prominent features common to most of these intrusions are an overall leucocratic to hololeucocratic character and decimeter to meter sized compositional and textural banding, commonly with more or less regular cyclic repetition of the different petrographic facies (pegmatite and equigranular facies, graphic quartz/K-feldspar phenocrysts, banded aplite) (Fig. 08). These facies of the discoidal or tabular intrusions of this granite type are similar to those observed in plutons considered to be the source of mineralized pegmatites worldwide (Thomas et al., 2012).

Stop 6 - Serra Branca Pegmatite (Coordinates: S 06º 50' 27.1" and W 36º 27' 13.2")

Geological details:

The Serra Branca pegmatite (Fig. 01), is located between the towns of Pedra Lavrada (10 Km to the north) and Nova Palmeira (12 Km to the south). It is of the heterogeneous type, measuring up to 50 m wide and 250 m long, crosscutting garnet-biotite schists of the Seridó Formation. The general strike of the heterogeneous pegmatite is N85ºE with sub-vertical dip. It is a well zoned pegmatite, mined out mainly for feldspars, although elbaite and tantalite are eventually been exploited (Fig. 09). Besides these main minerals, it is outstanding for a variety of phosphate minerals, specially the lithiophilite and serrabrancaite (Witzke et al., 2000), named for this pegmatite locality where it was first recognized. Unusual and exotic accessory F-bearing minerals (e.g. colquiriite and ralstonite) are also found in this pegmatite (Wegner et al., 2002).

Figure 8: View of a 6 m high and 8 m wide bench of the Armação pegmatitic granite quarry, showing decimeter to meter sized compositional and textural banding. Professor Sandra B. Barreto seen in this picture as scale. Modified from Beurlen et al. (2014).

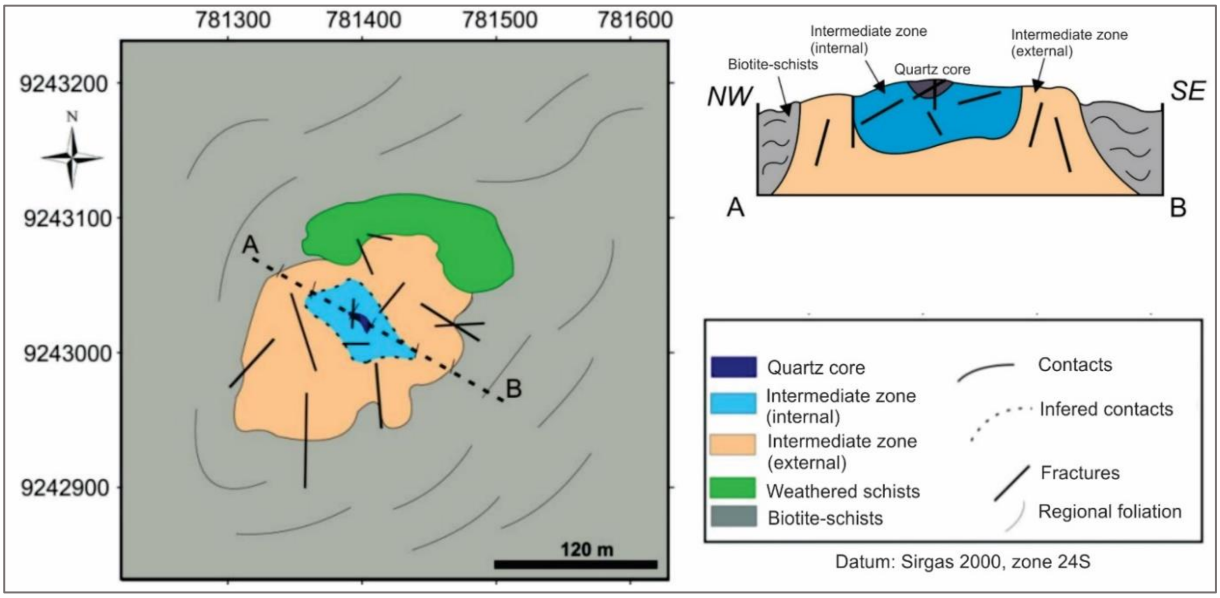

Figure 9: Schematic map and section of the Serra Branca pegmatite. Reference: Sales et al. (2015).

5. Final Comments

Research on pegmatites of the Seridó Pegmatite Province in Northeast Brazil were tested as tools for the diagnosis of the metallogenetic potential of rare metals in individual pegmatites and in the province as a whole along the last dozens of years. The results allowed to establish the nearly isobaric (3.8 kbar) crystallization conditions of the pegmatites between approximately 580 °C (liquidus) and 400 °C (solidus) from a peraluminous melt saturated in an aquo-carbonic medium to low salinity volatile phase (Beurlen et al., 2001), and an immiscible peralkaline flux-enriched (H_2O, CO_2, F, B, Li etc.) melt fraction, based on melt and fluid inclusion studies (Thomas et al., 2006). It was also possible to identify several pegmatitic granite intrusions with textural and lithogeochemical characteristics also found in source granites of pegmatite provinces elsewhere. Preliminary chemical U-Th-Pb geochronological determinations in uraninite and xenotyme crystals of these pegmatitic granites indicate an age of 520 ± 10 Ma (Beurlen et al., 2009), whereas Ar-Ar in mica (Araújo et al., 2005) and U-Pb ages in columbite-group minerals (Baumgartner et al., 2006) shown ages between 518-525 Ma and 509-515 Ma for pegmatitic granites and homogeneous pegmatites, respectively. Additional tests are recommended to confirm the preliminary results of mineral chemistry as exploration tools on a larger number of pegmatites and geochronological data to confirm the existence of an older generation of pegmatites in the SPP, as well as the presence of the potential economic concentration of further ores, like Li (e.g. spodumene, lepidolite and amblygonite), Cu (e.g. djurleite), U (e.g. uraninite) and REE (e.g. xenotime and monazite).

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