Structural Analysis and Pegmatite Differentiation in the Ancient Claim, Giraúl IV, Namibe Pegmatite District, Angola

Carlos Leal Gomes 1*)

1*) Lab2PT – University of Minho, Gualtar, 4710-057 Braga, Portugal; email: lgomes@dct.uminho.pt; https://orcid.org/0000-0001-6854-5398

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Abstract

Since the early 60´s, in the past XX century, the Giraúl pegmatites have been known for their resources of beryl, mica and feldspars, which were exploited in a regular basis from Giraúl claims I to IV till 1974, during the Portuguese administration of Angolan territory. A broader exploration of this pegmatite field was performed by the ancient Lobito Mining Company (LMC) engaged in detailed geological mapping of the granitic pegmatites and the structural constraints of their location. A structural map of the region was than elaborated, combining the interpretation of aerial photographs with field work performed by the LMC geologists. Recently, a growing economic interest is attributed to these claims, in the region of Bulamucolocai, Pitau and Muvero desert-dry rivers (locally known as "Mulolas"), considering the Li, Cs, and Ta (LCT) metallic specialization of some pegmatite bodies and the occurrence of beryl and tourmaline gemstones, mainly, morganite (Cs-beryl), aquamarine and also elbaite-liddicoatite. Giant crystals of spodumene, up to 6 m in length, define individualized quartz + spodumene units inside some of the more typical LCT pegmatite bodies. Pollucite was identified in the main pegmatites of Giraúl IV claim and not in the adjacent igneous leucocratic breccias. These, in turn, correspond to a complex pegmatite assemblage, very peculiar in what concerns its selective metasomatic effect over some surrounding rocks, with the formation of rims of holmquistite amphibole in contact with gabbro and norite and schorl-dravite tourmaline in contact with gneissic to metapelitic hosts. The breccia-like granitic rock combines clasts of spodumene an K-feldspar with a matrix mainly composed of some quartz, albite and mica including tourmaline, garnet and F-apatite, as accessory minerals. In the same area, huge potassic pegmatites hold giant crystals of microcline and orthoclase and very little quartz, being unusual due to its high content of triplite – zwieselite and triphylite – lithiophilite primary phosphates. The overall composition of these pegmatites is more likely syenitic (low quartz content) than truly granitic. A high-resolution structural analysis of the LCT ensemble (pegmatite plus related lithotypes) is now proposed enhancing the unusual relations between granite breccia plugs, sill-like more typical pegmatites, irregular shaped isodiametric bodies and products of metasomatism. This approach will lead to the understanding of the true dimension, anatomy and inner fraccionation of the different LCT facies and rare-metal deposits with obvious consequences regarding mineral detection and resource – reserve estimation, through the proposal of a more suitable conceptual model to rule its exploration.

Keywords: structural analysis, pegmatite, mineral, angola

Introduction

From the Damaran event, swarms of pegmatites are typical to the Northern Namibia and the SW of Angola. At the host-rocks, amphibolite facies metamorphism and granite magmatism occurred in response to the closing of the Khomas Ocean as the Kalahari craton subducted beneath the Congo craton. At least a part of Giraúl Pegmatites in Angola may be also related to this event. Continental collison occurred at about 530 Ma, with the peak of mineralization and pegmatite formation at 500 M.y. Some LCT Giraúl - Bero pegmatites, NYF-LCT hybrids from Giraúl and NYF Chitado pegmatites are associated with this late episode of emplacement of residual granite systems. At the end of the Neoproterozoic, the deformation attributed to the NW branch of the Damara Orogeny (correlated with the Pan-African cycle) conditioned the genesis or protolithic reconversion of migmatites, gneisses and granulites of the Namibe region [1] and, therefore, of the area surrounding Giraúl IV, included in what is called the Namibe Group. The ortho-derived gneissic terms that appear in this sequence are considered as Eburnean, tardi-kinematic, proto-granitoids and some pegmatites that cross them, according to [2], with eburnean late-tectonic implantation, revealed a K/Ar age in muscovite of 1996 ±11M.y. According to studies by [3], the red granites of southern Angola follow this set of lithologies in two main episodes. In one case, it concerns red alkaline granites with an age of Rb/Sr, in total rock, of 1430±51M.y. Later on, it concerns some granites, also reddish, with a prevailing pertite microcline, but with a more aluminous character, revealing an age of Rb/Sr, in total rock, of 592±9 M.y. The latter would already be related to the Pan-African event expressed in the Kaokoveld – Damara belt.

Some circumscribed plugs of metamorphosed mafic and ultramafic rocks occur in the same region, in the form of olivine metadolerites to metagabbros and metanorites, which are considered intrusive in Eburnean granitoids. All of these lithologies, later and together, were metamorphosed and metasomatized, possibly at the Damara event. They are affected by pegmatite implantation – intrusion and exo-metassomatism. So, the paragenetically more complex pegmatites in the Giraúl district will be synchronous or late with respect to the Kaokoveld-Damara event. [4] refer to a recent alkaline granite that occurs nearby, with an Rb/Sr age of 432±12M.y. There are indications that a granite stock belonging to this group cuts pegmatites in the Girául district. Possibly, also some pegmatites of an alkaline, microclinic and NYF nature (specialization, geochemical signature and mineralization of Nb, Y and F), which outcrop to the North, may be related to a latest residual-granitic fractionation, being genetically independent of the pegmatitic groups LCT, expressed in the Giraúl IV claim. Lying in discontinuity over the Namibe Group, in which the Girául pegmatitic district is located, heterogeneous conglomerates contain pegmatitic clasts. These conglomerates correspond to the Angolan coastal sedimentary basin of Mesozoic age - Upper Jurassic to Lower Cretaceous.

Also, according to [5], two main pegmatite formation events can be distinguished in the eastern region of Africa, being related to the structuring of orogenic belts with reference ages, 1100 ± 200 MA and 550 ± 100 MA. From the sets of ages of implantation - Archaic (Bikita, Zimbabwe) to Cambrian (Giraúl, Angola and Alto Ligonha, Mozambique) - the Pan-African Orogeny appears as the one that includes the best known pegmatitic provinces in Africa, due to the mining that is taking place in them - for gemstones, mica, feldspar, cassiterite, columbite-tantalite and Li minerals. The term Pan-African is due to [6]. It applies to orogenic areas surrounding cratons dating from the Late Precambrian to the Lower Paleozoic (± 500 MA). The Giraúl district, being part of the Kaokoveld-Damara Belt, encompasses pegmatites whose installation and evolution control is Pan-African. In Angola, the main pegmatite fields are distributed along the coastal region from Ambriz to Namibe, icluding several known groups with LCT geochemical specialization (Li, Cs and Ta mineralizations). Considering the host structures and superimposed deformation they are considered sin to late – orogenic pegmatites. Post-orogenic pegmatites occur dispersed in the same terrains showing less relevant LCT affinity, but frequent mixed geochemical linkages, LCT – NYF. Immediately to the south of Benguela, pegmatitic fields with a NYF signature, are predominant. Some of them are trully syenitic. Even feldspathoid syenitic types have been identified. They are always small in size and may be genetically related to alkaline-carbonatite complexes. This study deals with the most representative LCT pegmatites that occurs inside the area of the ancient Giraúl IV claim, near the Muvero and Bulamucolocai streams, to the south of the main course of Giraúl river. All these streams are typically desert dry. The main goal of this study is the establishment of a conceptual model that encompasses, shape, size, internal structure and paragenesis, looking for the definition of the major characteristics of the extreme fractionation achieved by LCT pegmatites in Giraúl district. Hopefully this might help the various prospecting programs that are increasingly dedicated to the detection of metallic Li resources and reserves.

Materials and Methods

Terrains of the Giraúl pegmatitic district are located along the Giraúl and Bero river basins in Namibe Province, SW Angola. Its beryl mineralizations have been known since the intervention of the Companhia Mineira do Lobito (CML) during the period of Portuguese administration of Angola. A first aerial photograph interpretation, improved with geological survey and mapping, carried out in the concession areas of that Company, is summarized in the thematic map of Fig. 1, whose initial sketch was attached to an unpublished report written by Koepershoek for the CML, in 1974. The position of the former Giraúl IV claim is indicated in that figure, corresponding to a circular area centered on a midpoint where the ownership landmark was implanted, in accordance to the mining legislation then in force. This landmark still persisted in situ, in 2017, remaining practically intact, even after almost 50 years, as an historical testimony of the CML's activity (inset in Fig. 1). In the same Fig. 1, an alignment of WNW-ESE pegmatite swarms is evident, located in the central portion of the represented area, in which, field work showed a greater number of pegmatites of the LCT family.

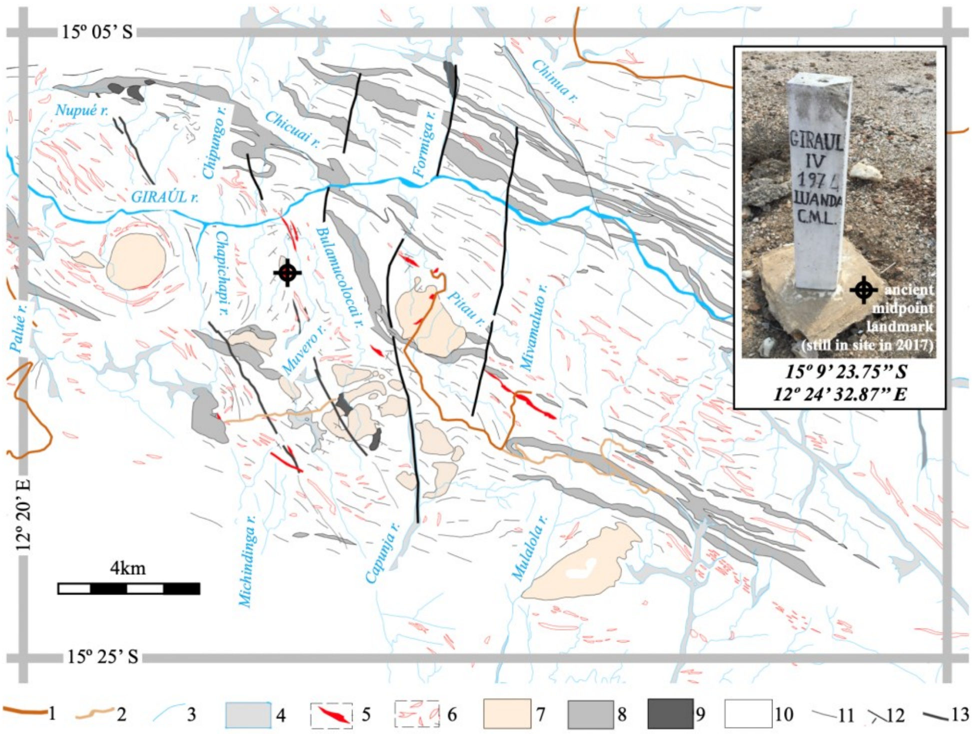

Fig. 1. Thematic geological map of pegmatites and formations that serve as a structural reference in Giraúl area, with the location of Giraúl IV landmark (modification of the original Koepershoek´s map for CML). 1 – major roads; 2 – secondary local roads; 3 – streams, creeks and rivers, dry most of the year; 4 – recent placers; 5 – confirmed pegmatites representative of the LCT family; 6 – outline of pegmatites without a defined specialization; 7 – circumscribed plutons of amphibole rich gneisses with some intercalated meta-mafic compartments; 8 – lenticular crystalline rocks including, gneisses, quartz migmatites, quartzites (amphibole and garnet rich); 9 – more typical metapyroxenites and metagabbros; 10 - undifferentiated crystalline complex corresponding to the Namibe Group – granulitic to amphibolitic metamorphic facies; 11 - trajectories of primitive sedimentary foliation; 12 - superimposed most penetrative metamorphic foliation indicating the sense of dip; 13 – fault lineaments.

Main research was focused in the area surrounding Giraúl IV landmark and included structural and paragenetic analysis of outcrops and pits and trenches that traverse distinct inner units of the pegmatites. Two levels of organization and scales were considered: individual pegmatite body and pegmatite group (see [7]). The regional terranes, were subjected to geological mapping with emphasis on the discrimination of different types of metamorphic lithotypes that compose the Namibe Group. The distinction was petrographic based on polarized light microscopy. Pegmatite paragenesis and mineral specimens, collected in diggings and outcrops, were contrasted and identified in scanning electron microscope (SEM), in back-scattered electron mode (BSE), followed by semiquantitative analysis by energy dispersive spectroscopy (EDS). Mineral intergrowths were also characterized by SEM-BSE. Nb – Ta oxides, looked upon as trustworthy species, indicative of pegmatite fractionation, were analyzed in electron microprobe for the main constituents. Systematically, mineral samples were identified by X-ray diffractometry.

Results and Discussions

At the hole District, the vast majority of pegmatites is barren and do not contain Li minerals. However, inside the area of the claim, systematic analysis of pegmatitic groups and their paragenetic diversity, taking into account, especially, the rare metals mineralization, allowed the distinction of 6 main types of paragenetic situations:

I - Pegmatites with spodumene, Li-micas and Li-tourmaline (LCT);
II - Pegmatites with petalite ± spodumene and clay minerals resulting from petalite alteration (LCT);
III - Pegmatites with predominant lepidolite (LCT);
IV - Pegmatites with Li and Fe-Mn phosphates very rich in microcline (hybrid and LCT);
V – Leucogranites and an igneous breccia with localized pegmatitic differentiations, whose clastic fraction holds spodumene and tourmaline (LCT);
VI – Zoned pegmatites with defined quartz cores (sometimes with papagoite), perthitic microcline amazonite and blue beryl (NYF).

Typical outcrops of regional rocks hosting the pegmatites and some structures associated with pegmatite emplacement are illustrated in Fig. 2.

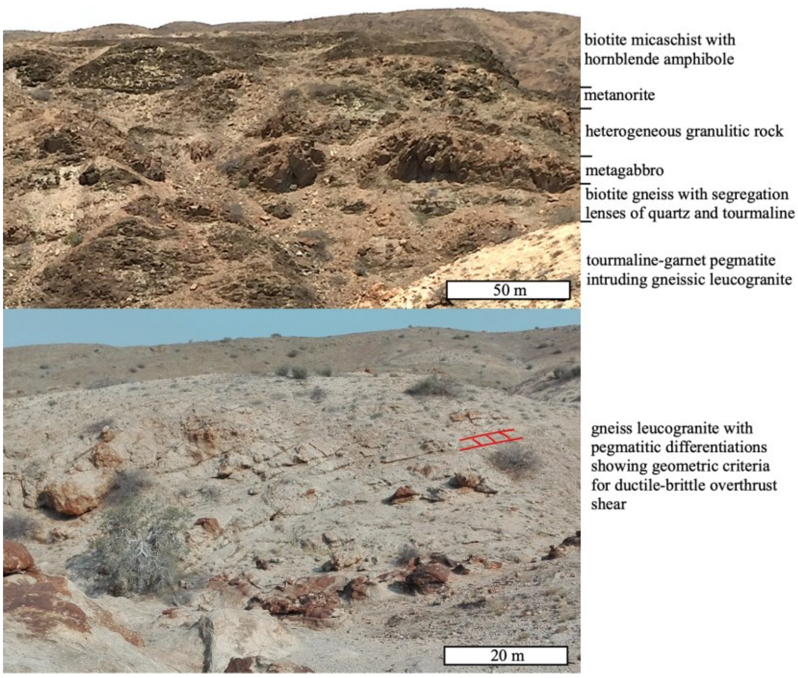

Fig. 2. Outcrop examples of host-rocks and structures spatially related to the intrusion of pegmatites.

The hosting of pegmatites is fairly independent of the regional rock type, being more dependent on regional structures and its attitude changes due to the presence of antecedent or syn-tectonic plutonic bodies. On the contrary, the outer metasomatism caused by pegmatite emplacement is selective, especially in the case of pegmatites with Li minerals (spodumene and Li tourmaline), which cause tourmalization when in contact with metapelites and halos with holmquistite when in contact with amphibolite and meta-ultramafic rocks. There are barren pegmatites and mineralized pegmatites with the same structural relations with the host-rocks. Even so, it is possible to distinguish the following relations between the pegmatites and more prevalent host-rocks:

a) elongated, sill shaped, barren, with some schorl tourmaline, Mn-almandine garnet and eventually magnetite-rich spinel, with inner comb-structure marked by perthite and muscovite and, occasionally, an inner quartz core – these pegmatites, are narrow, almost horizontal, concordant, and could be emplaced according to delamination of strongly foliated metamorphic host-rocks in a late tectonic context (Fig. 3 A);
b) lenticular, sill shaped, LCT-specialized to strongly mineralized, with several tourmaline generations including elbaite, and eventually, spessartine garnet and ghanite-rich spinel, with internal and complex zoning and variable mineral assemblages from the border to the core – these pegmatites can have great thicknesses and extensions, being concordant to discordant to the regional structures and rocks, with variable slopes and sometimes with roots in brechoid or non-brechoid leucogranitic feeding bodies; they may correspond to a syn to late-tectonic context in relation to the last and most penetrative metamorphic surface (Fig. 3 B);

c) anostomosed, tabular dykes (Fig. 4 A), eventually, NYF-specialized, with schorl tourmaline, frequently, with beryl mineralization (Fig. 4 C and D); they suggest an alkaline linkage being much richer in K-feldspar than albite; K-feldspar is perthitic with some sort of amazonitic coloring (Fig. 4 B) or reddened microcline – they are narrow and strongly inclined or almost vertical in general, crosscutting late-tectonic plutons of alkaline biotite granites; they seem to correspond to a last episode of pegmatite generation, post-tectonic, with a geochemical character almost syenitic (with low quartz content expressed in the core).

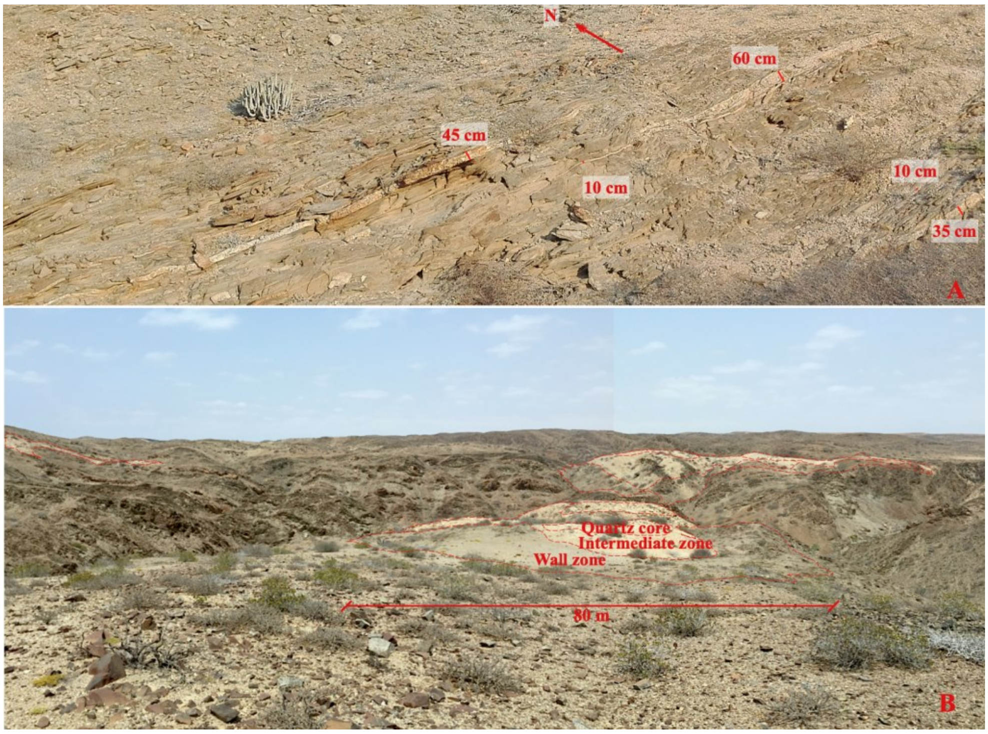

Fig. 3. Sin-tectonic to late-tectonic structural relations of pegmatites and host-rocks. A – comb-structured and slightly inclined pegmatites concordant with hornblende mica-schist foliation; B – zoned, horizontal and thick pegmatite, traversing the contact between hornblende biotite gneiss and meta-mafic rocks.

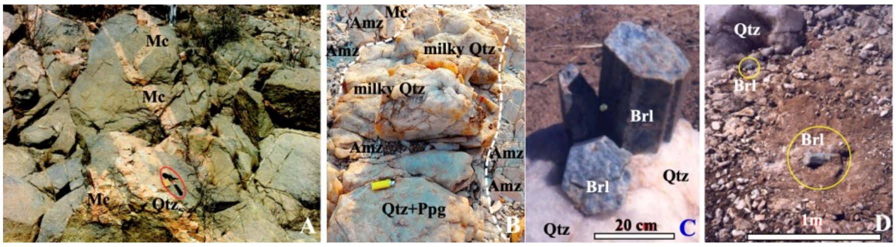

Fig. 4. Inner-granite post-tectonic pegmatite dykes branching from thick deep terms, with some quartz, to narrower and shallower terms, more typically syenitic, consisting mostly of alkali feldspar (A). B – zoned amazonitic pegmatite with a differentiated core showing papagoite inclusions in quartz (zone transition outlined in white); C and D – deep blue beryl at the transition between intermediate zone and quartz core. Mc – microcline; Qzt – quartz; Amz – amazonite feldspar; Ppg – papagoite; Brl – beryl.

Petrography of main lithotypes

At close proximity of the Giraúl landmark different rock types are crosscut by leucocratic granite and pegmatite bodies in a multiplicity of ways that justified a more detailed analysis.

Petrography confirmed the presence of pyroxenitic hosts, specially a metanoritic term (Fig. 5 A) and amphibole rich gneissose lithotypes (Fig. 5 B). Meta-ultramaphic rocks are affected by metasomatism at the immediate proximity of pegmatite and leucogranitic breccia, showing fringes with holmquistite (Fig. 5 D). Garnet rich metasedimentary rocks are also affected by metasomatism at the contact with pegmatites, in this case, showing tourmalinization (Fig. 5 C). The inner tourmaline occurs in several generations being the elbaite variety frequently intergrown with spodumene, with some secondary lepidolite at the interface (Fig. 5 E). One of the earlier pegmatite generations of tourmaline belongs to the schorl-elbaite series, possessing inclusions or inherited nucleus off rossmanite, which seems to be the earliest tourmaline in the internal paragenetic sequence (tur I in Fig. 5 F).

The pegmatite corresponding to the major area of outcrop is Na-Li enriched (LCT family – spodumene + lepidolite + tourmaline paragenetic type) with several generations of lepidolite, tourmaline (elbaite-liddicoatite, rossmanite and foitite) and beryl (including alkaline Cs-beryl).

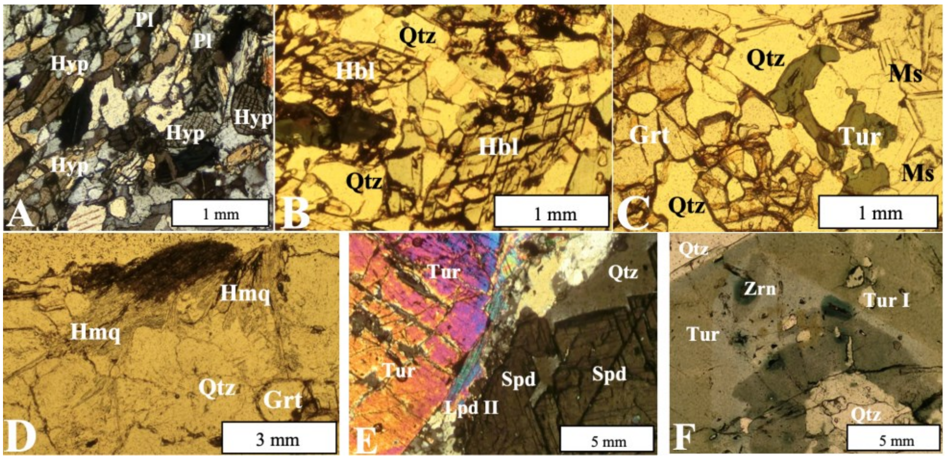

Fig. 5. Selected petrography photomicrographs of host rocks and inner pegmatite mineral intergrowths. A – metapyroxenite with hypersthene (Hyp) and plagioclase (Pl); B – amphibolitic gneisses (hornblende – Hbl, quartz – Qtz); C – metasomatic tourmaline (Tur) in a gneissic biotite-garnet (Grt) rock; D – holmsquistite (Hmq) in a metasomatic fringe from a contact between pegmatite and meta-ultramafic host; E – elbaite (Tur) / spodumene (Spd) intergrowth from inner intermediate zone with secondary lepidolite (Lpd II) and quartz (Qtz) at interface; F – early tourmaline schorl-elbaite with inherited rossmanite nucleus.

Mineral indicators of fractionation

Lithium mica and tourmaline are the most representative minerals useful as markers of paragenetic evolution. The main typomorphic assemblages of the major paragenetic stages are the following: 1. fibrous to acicular schorl with quartz at the contact with metapelites – occur at the outer contact of several types of pegmatites (Fig. 6 B); 2. comb-structured schorl intergrown with quartz feldspar and muscovite – occur at the border zone of several types of pegmatites (Fig. 6 A); 3. comb-structured spodumene intergrown with needles and fine prismatic crystals of elbaite – occur at the inner intermediate zone and the outer core, sometimes inside massive lepidolite (Fig. 6 D and E); 4. lepidolite of first generation with green elbaite, quartz and cleavelandite – occur inside masses of lepidolite at the inner intermediate zone (Fig. 6 E); 5. lepidolite of second generation associated with pink Mn-fluorelbaite – occur at interstitial spaces between spodumene crystals and/or water-mellon iron-rich fluorelbaite crystals (Fig. 6 F); 6. lepidolite of third generation associated with pollucite or crosscunting pollucite crystals (Fig. 6 G). In these late assemblage pollucite represents a stage of paroxysm of the paragenetic evolution and the coexistent lepidolite is the latest in the paragenetic sequence.

Still considering the paragenetic evolution, accessory minerals, such as Nb-Ta oxides are good indicators, showing variable compositions from Fe-columbite, in more feldspathic units, to U-microlite in lepidolite + elbaite coexistence (Fig. 7 and 8). The compositions of this Nb-Ta minerals (table 1) are compatible with the paragenetic stage represented by the mineral assemblage in which they occur. Microlite in fact accompanies lepidolite of the IV stage, being interstitial in relation, to "water-melon" elbaite, one of the last generations of tourmaline.

Disordered iron-rich columbite, in transition to a Ti-ixiolite (diffractometry revealed some crystal domains matching these structure), is characteristic of primary earlier assemblages of schorl tourmaline + K-feldspar + white mica.

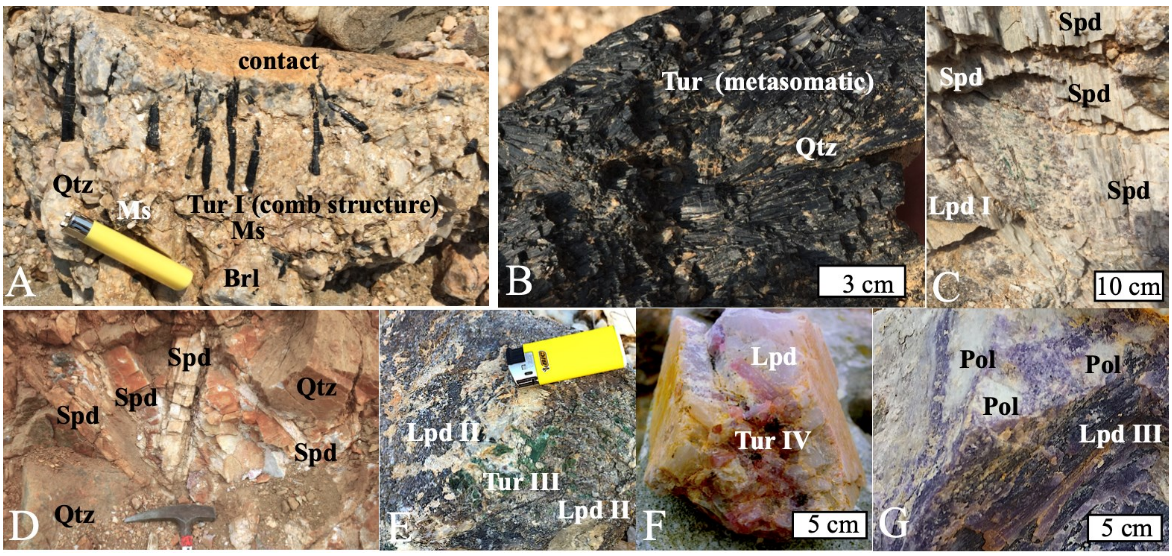

Fig. 6. Selected images of minerals marking the paragenetic evolution. Tur – tourmaline of first (I), third (II) and fourth (IV) generation; Lep – lepidolite of first (I), second (II) and third (III) generation; Spd – spodumene; Qtz – quartz; Ms – muscovite; Brl – beryl. A - comb tourmaline at the roof contact of the pegmatite; B – metasomatic tourmaline outside the pegmatite; C - lepidolite associated with comb spodumene; D – comb spodumene at outer core; E – differentiation of elbaite + lepidolite + quartz + cleavelendite inside massive lepidolite; F - interstitial late elbaite + lepidolite; G - latest assemblage of pollucite + lepidolite.

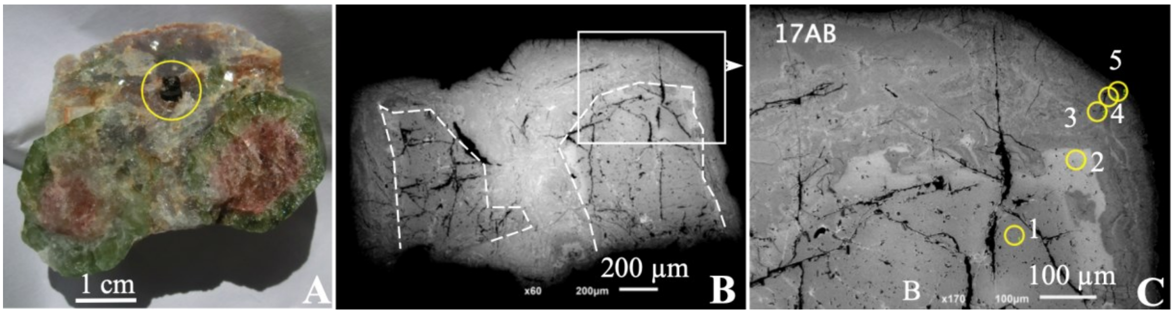

Fig. 7. Location and internal zoning of microlite in a paragenesis representative of evolutionary paroxysm in a late unit with lepidolite. A – chip sample with "water-melon" tourmaline, lepidolite and quartz where microlite crystals are located between tourmaline crystals; B – section with two coupled microlite crystals observed in scanning electron microscope (SEM) - backscattered electron mode (BE) - showing a nuclear zone related to the primary fractionation and an edge zone affected by hydrothermal alteration; C - location of the points analyzed in electron microprobe (table 1).

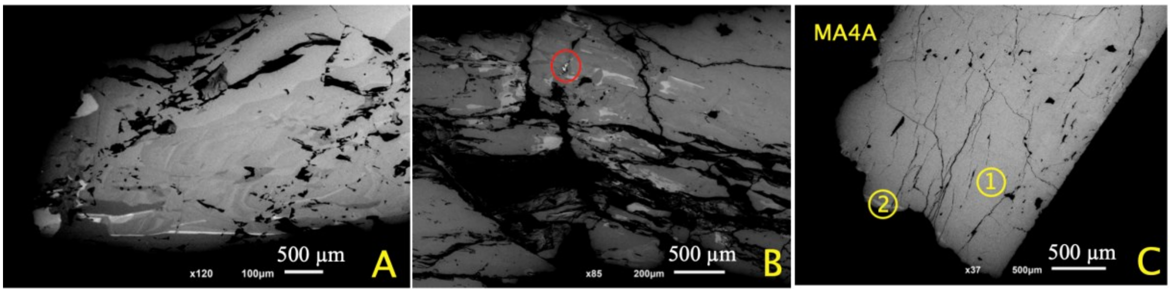

Fig. 8. Images obtained in scanning electron microscope (SEM) and in backscattered electron mode (BE) of representative columbite sections in different crystals of an intermediate zone. A – primary oscillatory normal zoning in SEM-BE; B – secondary patchwork zoning being signaled a native Bi inclusion, in SEM-BE; C - location of some points analyzed in electron microprobe in a progressive zoned primary crystal (table 1).

Tab. 1. Selected chemical analyses (electron microprobe) of microlite coexisting with elbaite "watermelon", lepidolite and quartz (points of analysis 17AB1 to 17AB5 are from the sample described in Fig. 7 C) and structurally disordered columbite, in transition to Ti-ixiolite, coexisting with earlier assemblages of albite + perthite microcline + white mica + milky quartz (points of analysis MA4A1 and Ma4A2 are located in Fig. 8 C).

	microlite					columbite	
Weight %	**17AB1**	**17AB2**	**17AB3**	**17AB4**	**17AB5**	**MA4A1**	**MA4A2**
Ta_2O_5	74,60	73,50	72,90	74,50	74,80	32.10	16.90
Nb_2O_5	6,70	7,60	8,00	8,00	7,10	50.60	63.30
UO_2	0,00	3,70	7,30	6,90	6,70		
Ti O_2						0.60	1.40
CaO	9,20	7,80	7,90	6,90	7,40		
MnO	0,00	0,00	1,10	1,10	1,50	5.70	4.60
Fe O						11.00	13.80
Na_2O	5,50	3,50	2,80	2,50	2,50		
Total	*96,00*	*96,10*	*100,00*	*99,90*	*100,00*	100.00	100.00
apfu							
U^{4+}	0,000	0,070	0,139	0,129	0,127		
Ti^{4+}						0.029	0.063
Ca^{2+}	0,846	0,714	0,722	0,619	0,673		
Mn^{2+}	0,000	0,000	0,079	0,078	0,108	5.70	4.60
Fe^{++}						0.588	0.688
Na^{+}	0,915	0,579	0,463	0,406	0,412		
Ta^{5+}	1,740	1,707	1,691	1,697	1,727	0.558	0.274
Nb^{5+}	0,260	0,293	0,309	0,303	0,273	1.461	1.707
$(OH)^{-}$	1,394	1,712	1,379	1,685	1,520		
O2-	5,606	5,288	5,621	5,315	5,480		
Mn/ (Mn+Fe)						0.344	0.252
Ta/ (Ta+Nb)	0,87	0,85	0,85	0,85	0,86	0.276	0.138

Structure of Giraúl IV area

Fig. 9 synthesizes the result of the geometric analysis of the area originally attributed to the claim Giraúl IV. In that area, surrounding the ancient landmark, several research pits and trenches were excavated. A partial description of its geological survey is illustrated in Fig. 10. There is an intimate association (apparently igneous) between the zoned LCT pegmatites and a surrounding leucogranitic breccia, with feldspar and spodumene clasts and disseminated and oriented tourmaline and garnet.

Cartographic trajectories of the metamorphic most penetrative surface are subhorizontal to slightly inclined, contouring the pegmatite plus breccia outcrops, which suggest a syn to late-tectonic emplacement of the leucocratic suite when compared to the last regional episode of deformation.

Apparently, the spatial envelope of the system, leucogranite breccia plus related pegmatite, seems to assume a diapiric configuration in which the root corresponds to a feeding zone for less evolved differentiates. This structural pattern is probably repeated in other situations of the above-mentioned WNW-ESE corridor, which, in the regional cartographic context, corresponds to the central position of the pegmatite district.

From a more detailed approach to the analysis of Giraúl IV pits and trenches (Fig. 10), it seems that the main LCT pegmatites are hosted in late, vertically dilated environments, probably associated to some apical delamination at the top of residual granite domes, buried and hidden in depth. In fact, LCT sills are subhorizontal and the crystal comb-structures are almost vertical.

Conclusion

Breccias and LCT sills of Giraúl IV correspond to a complex pegmatite suite, suggesting an emplacement in apical dilation environments associated with buried stocks of probable Damaran granites. This apical situation seems to be the more prolific in what concerns the Li, Cs and Ta mineralizations, allowing a vast paragenetic sequence from the expression of early schorl tourmaline and Ti-ixiolite till later assemblages of microlite, elbaite, pollucite and lepidolite. Spodumene concentrations assume a mid-term deposition stage.

More irregular shaped or isodiametric bodies are more likely related to in situ fractionation inside exhumed granitic cupolas and thus show indexes of low fractionation stages, such as, the high content of primary phosphates from de series, triplite – zwieselite and triphylite – lithiophilite (Fe-Mn-Li linkage). One other suite of pegmatites, tabular and narrower, present a mode of emplacement totally distinct. They constitute pegmatite swarms of dykes, vertically branching inside biotite granite plutons. They also intrude LCT pegmatites. Its composition is highly alkaline, potassic, with perthite amazonite and reddish microcline much more abundant than albite. As accessory minerals, deep blue beryl is characteristic at outer core, some topaz may occur in late miarolitic voids and xenotime is characteristic at intermediate zones. This is consistent with a true NYF signature. Occasionally the overall composition of these pegmatites is more likely syenitic (low quartz content) than truly granitic and they seem to represent a post-Damaran generation.

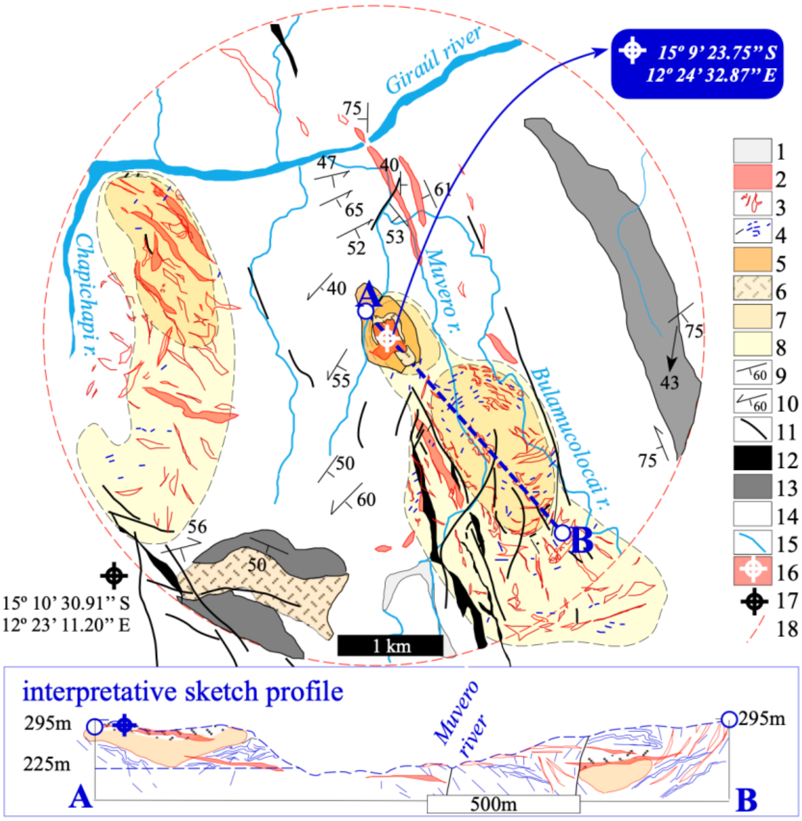

Fig. 9. Structural relations betweeen pegmatites and host-rocks inside de original área of Giraúl IV claim. 1- sandy placer deposits along dry rivers ("mulolas"); 2 – pegmatite bodies belonging to the LCT family (class of rare metals); 3 – outline of other, more inconspicuous, pegmatites; 4 – trajectories of the most penetrative foliations in metamorphic rocks; 5 – amphibolic and metamafic gneiss rocks including metanorites; 6 – leucogranitic breccia, with spodumene and feldspar clasts, garnet-tourmaline dissemination and some inner-fractionated small pegmatite bodies; 7 - interpretative projection to the surface of the roots system that feeds the Giraúl LCT pegmatite group; 8 – more shallower expansion of the same pegmatite system; 9 – most penetrative metamorphic foliations (measured); 10 – primitive foliation affected by a tangential overthrust transport (measured) - eventually a primitive sedimentary surface; 11 – faults; 12 – dykes of ultra-mafic rocks mainly dolerites; 13 - biotitic to amphibolic micaschists and amphibolite; 14 - undifferentiated Namibe group with micaschists, metavolcanics, gneisses and metapsamitic to metaconglomeratic layers with general granulitic to amphibolitic character; 15 – streams, creeks and rivers without surface water flow (dry rivers locally known as "mulolas"); 16 – Position of Giraúl IV landmark and respective coordinates; 17 – another set of coordinates for geographic reference; 18 – outline of the primitive area of CML claim.

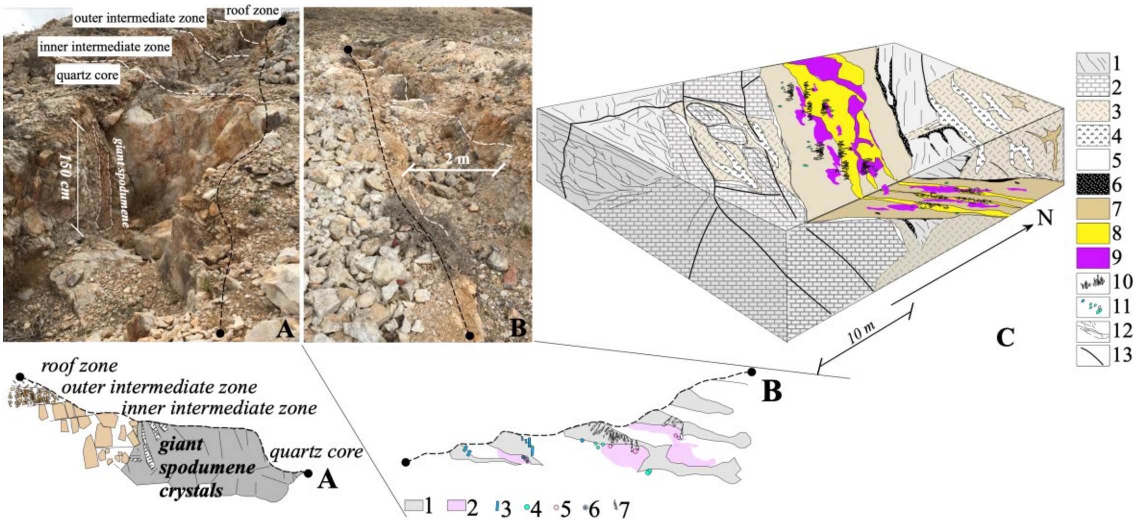

Fig. 10. Results of structural and paragenetic survey dedicated to a pair of orthogonal trenches and conceptual sketch block deduced from it. A – typical inner-zoning and presence of giant spodumene laths at the border of the quartz core; B – rhythmic repetition of quartz cores and lepidolite masses including positioning of distinct mineralizations: 1 – quartz core, 2 – massive lepidolite, 3 – deep blue beryl mineralization, 4 – light blue alkaline beryl, 5 – pink alkaline beryl, 6 – zoned alkaline beryl, 7 – spodumene laths; C – interpretative sketch block: 1- biotite gneiss with garnet and tourmaline including lenses of amphibolite, 2 - metanorite, 3 – foliated leucogranite, 4 - leucogranitic brecha with in situ differentiations of apatite + schorl pegmatite; 5 – holmquistite metasomatic fringes; 6 – schorl metasomatic fringes; 7 – peripheral zones of mica + quartz + feldspar pegmatite; 8 – quartz core; 9 – lepidolite units almost massive; 10 – layers of comb-spodumene in quartz; 11 – alkaline beryl; 12 – complexly arranged late shear surfaces; 13 – faults observed ant interpreted

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