

SEQUENCE OF CRYSTALLISATION OF PEGMATITES: THE ANGOLA CASE

Antonio Olimpio Gonçalves¹
Joan Carles Melgarejo²
Pura Alfonso Abella³

¹ Depto. Geologia, Univ. Agostinho Neto, Luanda, Angola, tonyolympio72@hotmail.com

² Dept. Cristal·lografia, Mineralogia, Dipòsits Minerals, Univ. Barcelona, joan.carles.melgarejo.draper@ub.edu

³ Dept. Enginyeria Minera i Recursos Naturals, Univ. Politècnica de Catalunya, pura@emrn.upc.edu

INTRODUCTION

The Precambrian basement of Angola contains several pegmatite fields, although most of them have not been studied yet. Some of them include pegmatites devoid of rare elements, as those found close to Caxito, about 100 km ENE Luanda. These pegmatites are exploited for the production of industrial minerals. Moreover, some rare element pegmatite fields occur close to Namibe, in the desertic part of the southwest of the country. These pegmatites were prospected for Be and Ta in the 1960's. The distribution of the pegmatite types, as well as the exceptional quality of the outcrops, due to lack of weathering or soil cover, allow a complete sampling in order to study the evolution of a pegmatite field, from parental granites to barren pegmatites, beryl-columbite-phosphate pegmatites and spodumene pegmatites. Furthermore, the internal evolution of each pegmatite type has been also studied.

GEOLOGY

The first pegmatite outcrops occur about 15 km at the East of Namibe, and the pegmatite field extends in direction NNW-SSE following the Giraul river. The pegmatite field is 25 km long and 7 km

wide (Fig. 1). The region forms part of the Angola craton, which is in contact, by faults, with a periocenic Cretaceous graben. It is constituted by series of Upper Archaean age that consist of an interbedding of metabasites with flyshoid metasediments, metapelites and metagreywackes. The volcanic-sedimentary pile can achieve more than 2 km in thickness. The series have been affected by syn-tectonic regional metamorphism in amphibolite facies. Deformation produced tight folds trending NNW-SSE with an axial plane cleavage

This ensemble was intruded by a sequence of plutonic rocks, ranging in composition from mafic to acid: gabbro-norites, hornblendites, biotite-hornblende quartz-diorites, biotite-hornblende tonalites, biotite-hornblende granodiorites, biotite-hornblende granites and, finally, biotite-muscovite leucogranites and granite pegmatites. These rocks form small stocks of rounded shape. They may represent a differentiated suite. The earliest terms are syn-tectonic and show evidences of deformation, whereas the more differentiated terms cross-cut the main regional foliation, and may be considered as late-tectonic. Contact metamorphism is not developed, thus suggesting an emplacement in mesozonal

environments. The major and trace element geochemistry of these plutonic rocks is compatible with calc-alkaline I-type granites, although the leucogranites are slightly peraluminous and its $\epsilon_{\text{Nd}}(t)$ of -2,217 indicate a high degree of crustal contamination. According to the U-Pb and Sm-Nd radiogenic isotope data, the pegmatites and the granites are cogenetic, and were produced in the late events of

the Eburnean orogenesis (2230 ± 48 Ma according a Sm/Nd isochrone; discordant ages of 1795 ± 41 Ma and 1728 ± 2.5 Ma according U/Pb).

All the Precambrian outcrops were peneplanized during early Cretaceous, and Cretaceous conglomerates unconformably overlies the ensemble. Some diabase dykes, trending NW-SE or NE-SW, probably late Cretaceous in age, cross-cut all the above rocks.

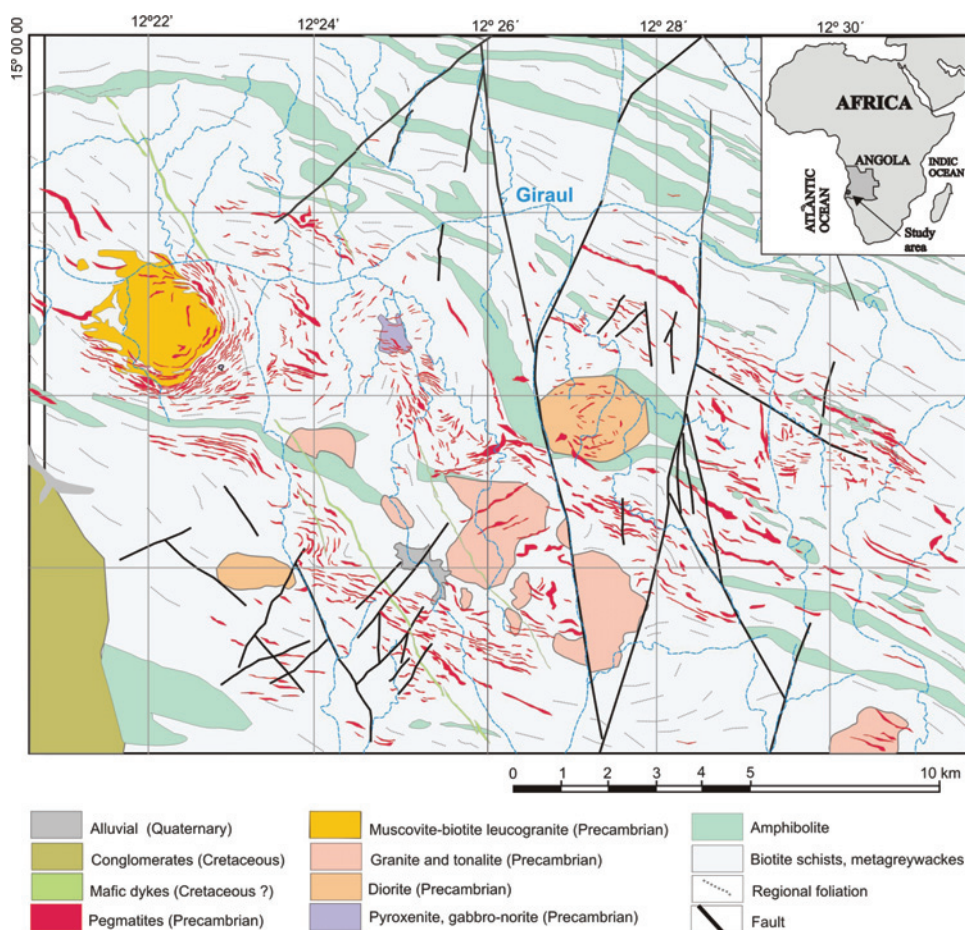


Figure 1- Geological map of the Giraul pegmatite field.

THE PEGMATITES

About 600 pegmatite bodies outcrop in the area. Most of them are lens-shaped, although some have a droplet shape. The length ranges from 5 m up to 1 km. The pegmatite dykes are arranged WNW-ESE following the regional foliation. The pegmatites can intrude all the Precambrian rocks of the area. The contacts between the pegmatites and the host rocks, including most of igneous rocks, are generally sharp. However, the contacts between pegmatites and the leucogranite host are gradual, thus indicating that these pegmatites could be produced by fractionation of the most evolved granite magmas.

Based on field criteria, as the mineralogy and internal structure, 5 types of pegmatites have been established in the pegmatite field, all them corresponding to the LCT class. In order of increasing complexity, there are the next types:

- a) Type I pegmatites. They are hosted by leucogranites and are almost devoid of rare elements. They occur as bodies of all sizes, and generally are tabular. They have a simple internal structure and mineralogy: do not have border zones, and they grade to the host leucogranite. The first intermediate zone may be considered as a coarse-grained granite, and a second intermediate zone is constituted by blocky K-feldspar intergrown with quartz. Accessory minerals are rare, but green beryl can be common in the contact with the quartz core; other minerals include muscovite, biotite, tourmaline and almandine. Quartz core can be constituted by rose quartz.
- b) Type II pegmatites. They have many similarities with type I pegmatites, but these are hosted by the metamorphic precambrian rocks and include border and wall zones. Blue apatite is common, particularly, in the second intermediate zone.
- c) Type III pegmatites. They may be considered as a transitional type, and contains abundant green beryl in the second intermediate zone. Moreover, blue apatite is common, and columbite is found in the second intermediate zone.
- d) Type IV pegmatites. They are rich in Li, as evidenced by the development of holmquistite crystals replacing the metamorphic amphiboles in the amphibolitic hosts. They are mineralized in the earlier zones. The border zone is coarse grained and consists of quartz, K-feldspar, oligoclase, muscovite, tourmaline, almandine and blue apatite. The first intermediate zone (coarse grained) is mainly constituted by reddish K-feldspar, quartz, albite, muscovite, green beryl and schorl; it contains skeletal crystals of phosphates (triphylite, ferrisicklerite, heterosite), and small amounts of Nb-rich members of the columbite series. The second intermediate zone (blocky) contains similar minerals, but the phosphates tend to develop euhedral crystals of several meters in length. Green beryl and ferrocolumbite are also very abundant in these zones. The third intermediate zone is mainly constituted by blocky white K-feldspar and white beryl, with lesser amounts of muscovite. Finally, some late veins, filled with quartz, albite, muscovite, tantalite, elbaite and montebrazite, pass across all the above mentioned units, producing the replacement of the above units. No quartz cores have been found up to the present.
- e) Type V pegmatites. These pegmatites do not have a well defined zonal structure.

They can also have holmquistite and tourmaline in the exocontacts, and the constitution of the earlier zones is similar to those mentioned for the less evolved pegmatites. However, in a late blocky unit they have Li-rich paragenesis, comprising spodumene, petalite, lepidolite, coloured elbaite (rose or green) and amblygonite; tantalite is also common in these pegmatites.

Type I are the most abundant pegmatites and are distributed through all the field; following the regional foliation. Type IV and V pegmatites are scarce (2-3 representative bodies of each type). They are found in the same areas of the type I pegmatites, but the most evolved pegmatites seem to have been produced in late episodes, because they use to intrude in late joints, perpendicular to the main regional foliation.

EVOLUTION OF THE MINERAL CHEMISTRY

Enrichment in LILE and HFSE is found in most minerals of the Giraul pegmatite field, from the less to the most evolved pegmatites, thus suggesting a common origin by fractionation processes. In addition, similar trends are found for the composition of each mineral during the sequence of crystallisation, for each pegmatite type.

In K-feldspar the contents of Rb, Cs, Ga, Sn and P in micas increase according the complexity of the pegmatite, following neat trends from type I to type V. The most meaningful are found in Rb (from 230 to 7100 ppm), Cs (2 to 2000 ppm) and P (450-6150 ppm); Ga and Sn show also enrichments, although not so strong. Contrastingly, Ba, Pb and Sr display depletion trends in the same sense.

Muscovite have enrichment trends similar to those found in feldspars: Rb (260-8700 ppm), Cs (7-2000 ppm), Ga (28-180 ppm), Sn (5-8220 ppm), and P (70-1000 ppm). In addition, the next elements have similar trends: Nb (33-360 ppm), Ta (6-170 ppm), Zn (50-760 ppm) and Li (51-4340 pm). The rare element content is also higher in lepidolite, and Cs mica (nanpingite) occur in late stages in type V pegmatites. Ba, Pb and Sr have also depletion trends.

Garnet has a strong Mn content, which increases from type I to type V (from almandine to spessartine), and Mg and Ca exhibit the inverse trend.

Tourmaline corresponds mainly to the alkali type, showing strong changes from schorl-dravite in all the types to elbaite in the late units of the most evolved pegmatites, types IV and V. Tourmaline crystals are concentrically zoned in all the pegmatite units. As a general rule, the cores are rich in Fe and the borders in Mg and Ti, thus indicating a trend of contamination from the host rocks at the end of crystallisation of each pegmatite unit. In the most evolved pegmatites, the F and Li contents increase from the earlier to the late units.

However, the enrichment trends in some other minerals are not as strong as those observed in the most evolved pegmatites worldwide. Hence, the HfO₂ content in zircon increases with the complexity of the pegmatite, it is never higher than 14 wt%. The alkali enrichment in beryl is not high, and the Rb and Cs contents are also low in white beryl from the evolved pegmatites. Similarly, the enrichment trend in Ta and Mn of the columbite group is not extended up to the extreme terms. In other minerals, as in apatite, there are no significant changes in composition along all the field.

CONCLUSIONS

The LCT pegmatite field of Giraul was formed by magmatic fractionation from a calc-alkaline suite, in particular, from the leucogranites. Thus, since these leucogranites do not have high contents in rare elements, the pegmatite field cannot achieve extreme enrichments in these elements, and the economic potential for them (Ta, Cs, Rb, Li) is only moderate.

This rock suite is connected with the late Eburnean regional granitization in Angola, and its emplacement took place after the main stages of deformation and the regional metamorphism. Magmatic fractionation produced at the same time enrichments in some LILE and HFSE, P, Li and alkalis, favouring the development of five pegmatite types.

The internal structure of the pegmatites was produced in a series of cyclic pulses determining the crystallisation of the intermediate zones; at the end of each pulse there was an episode characterized by the reaction of the magmatic fluids with the host rocks. Undercooling during the crystallization of these units can be responsible of the widespread skeletal textures in many minerals, particularly phosphates and tourmaline.

The distribution of the rare elements is determined by the degree of fractionation, producing enrichments from type I to type V; similar trends, although at minor range, are found inside each pegmatite type from border to inner zones, and finally to the late veins.