MINERALOGY AND PETROGRAPHY OF PHOSPHATE MINERALS FROM SAPUCAIA AND BOCA RICA PEGMATITES, MINAS GERAIS, BRAZIL

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INTRODUCTION

In Brazil occurs one of the most important pegmatite provinces in the world, the Eastern Brazilian Pegmatite Province (EBPP). Around year 1500, rumours of very rich occurrences of precious stones spread around and "garimpeiros" began to look for gemstones. Brazil is now still famous for gemstones like watermelon tourmaline, aquamarine, topaz, brazilianite and kunzite.

Because of the economic potential of brazilian pegmatites, the mineralogy of most famous pegmatites, as for example Aci, Cruzeiro, Ipê, Sapucaia, Rocinha, and Córrego Frio, is relatively well known. Several authors like A.L. Barbosa, W.T. Pecora, P.B. Moore, M.L. Lindberg, and J. Cassedanne contribute to the description of several new mineral species. Recently, Atencio (2000) published a mineralogical inventory of Brazil, including 39 mineral species with their type localities in the country.

Descriptive mineralogy of Brazilian pegmatite phosphates is thus relatively well known, but the petrographic relationships among these minerals have never been investigated in detail. The knowledge of the crystal structures of phosphates, of their stability, and of their petrographic relationships, constitutes a powerful tool to understand the pressure-temperature-oxygen fugacity conditions which prevailed in granitic pegmatites (Hatert et al. 2006). Moreover, as recently shown by Roda et al. (2004, 2005), the relationships between phosphates and silicates are absolutely necessary to include phosphates in a wider geological context.

One year ago, we visited several pegmatites in Minas Gerais, Brazil, to collect phosphate minerals, to observe their relations with silicates on the field, and to establish the variations in their spatial distribution. A good mapping of the investigated pegmatites was necessary, in order to observe the variations of mineral assemblages corresponding to the different zones of the pegmatites, and to correlate these variations with the chemical compositions of phosphates and associated silicates. This approach will help us to better understand the crystallisation processes of these pegmatites. The first observations, realized on the "Lavra of Sapucaia" and on the "Lavra da Boca Rica", are presented in this study.

GEOLOGICAL SETTING

The investigated pegmatites occur in the Eastern Brazilian Pegmatite Province (EBPP), which is one of the three pegmatite provinces in South America but also one of the most important pegmatite provinces in the world. This province is mainly located in the State of Minas Gerais but encompasses also parts of the States of Bahia, Espírito Santo and Rio de Janeiro (Paiva 1946, Putzer 1976, Correia Neves et al. 1986).

During the Brasilian orogeny (650-450Ma), several pre-, syn-, and post-tectonic granitoïds took place in the EBPP (Bilal et al. 2000) and are at the origin of most pegmatites of the EBPP (Bilal et al. 2000, Morteani et al. 2000).

Two of them are the "Lavra da Sapucaia" and the "Lavra da Boca Rica", located respectively at 14 and 18 km NNE of Galileia, in the Rio Doce valley, Minas Gerais, Brazil. The Galileia granitoid (595 Ma) is a metaluminous suite characterized by an expressive polydiapiric batholith consisting mainly of granodiorite with tonalite and granite (Nalini et al. 2000). These rocks are associated with the precollisional magmatism of the Brasilian orogeny. The Sapucaia pegmatite and the Boca Rica pegmatite were settled in "garnet"-, "biotite"-, and sillimanite-bearing schists of the São Tomé Formation (Rio Doce group, Late Proterozoïc).

The Sapucaia pegmatite is well zoned and seems to have an elliptic shape (40x100 m). We can distinguish three main zones: the wall zone with quartz, feldspars, micas ("biotite" and muscovite with sometimes a sheaf-like facies), small schorl crystals, and some accessory beryl; the intermediate zone with quartz, feldspars, cauliflower-like muscovite, large schorl and large spodumene crystals (2m long); and the core zone with quartz, spodumene, and zinnwaldite. The core zone is partially replaced by "cleavelandite". Several phosphate nodules were sampled in all the different zones; their size can reach around one meter length.

The mine of Boca Rica was not accessible last year due to a landslide, but we found phosphate minerals with interesting petrographic textures in the dumps.

MINERALOGY AND PETROGRAPHY

Petrographic observations, X-ray diffraction measurements, and electron-microprobe analyses were performed on the phosphates, which allowed us to confirm the identification of these minerals, to calculate their unit-cell parameters, and to characterize their chemistry.

From a mineralogical point-of-view, some similarities exist between the Boca Rica and Sapucaia mines. Indeed, the only primary phosphate is triphylite [$LiFe(PO_4)$], which is progressively transformed in ferrisicklerite [$Li_{1-x}(Fe^{3+},Mn^{2+})(PO_4)$] and in heterosite [$(Fe^{3+},Mn^{3+})(PO_4)$], according to the so-called "Quensel-Mason" sequence (Quensel 1957, Mason 1941). During this sequence, the contents in Fe, Mn and Mg do not show significant variation as already shown by Mason (1941) and Fontan et al. (1976). However, in the two mines, ferrisicklerite and heterosite seem to be significantly enriched in Ca (0.04-0.31 wt. % CaO), as already observed by Fransolet et al. (1985, 1986) in Tsaobismund (Namibia) and in Angarf-Sud (Morocco). We also note a notable increase in K, reaching 0.01 wt. % K_2O in triphylite, 0.06 wt. % K_2O in ferrisicklerite, and 0.45 wt. % K_2O in heterosite. According to Ginsburg (1960), the intense albitisation, occurring at the end of the K stage in the geochemical evolution of the pegmatite, provokes an increase of several elements like Si, K, Li or Rb; an increase which can probably explain the K enrichment observed in ferrisicklerite and heterosite.

Triphylite is frequently replaced along cleavage planes by ferrisicklerite, jahnsite, kryzhanovskite, barbosalite, and frondelite-rockbridgeite (Fig. 1). Fe-Mn-oxides and late phosphates as phosphosiderite or cyrilovite are also observed. Associated silicates are quartz, feldspars and micas, but we also found close relationships between triphylite (or ferrisicklerite) and "garnets" or schorl.

Triphylite in the two mines is primary, but shows interesting chemical variations (Fig. 2). At Boca Rica, two generations of triphylite occur: the first one is enriched in Fe and Mg [$Li_{1.00}(Fe^{2+}_{0.64}Mn^{2+}_{0.24}Mg_{0.06}Fe^{3+}_{0.04})_{\Sigma=0.98}PO_4$] with a $Fe_{tot}/(Fe_{tot} + Mn)$ ratio of 0.74, and the second one is richer in Mn [$Li_{1.00}(Fe^{2+}_{0.52}Mn^{2+}_{0.42}Fe^{3+}_{0.05})_{\Sigma=0.99}PO_4$] with $Fe_{tot}/(Fe_{tot} + Mn)$ ratio reaching 0.58. This Mn-rich triphylite probably crystallized at a lower temperature. At Sapucaia, triphylite [$Li_{1.00}(Fe^{2+}_{0.62}Mn^{2+}_{0.25}Mg_{0.13})_{\Sigma=1.00}((P_{0.99}Si_{0.01})_{\Sigma=1.00}O_4)$] is relatively enriched in Mg in comparison with the two triphylites from Boca Rica, but the $Fe_{tot}/(Fe_{tot} + Mn)$ ratio reaches 0.71, which is almost the same ratio than Boca Rica high-temperature triphylite.

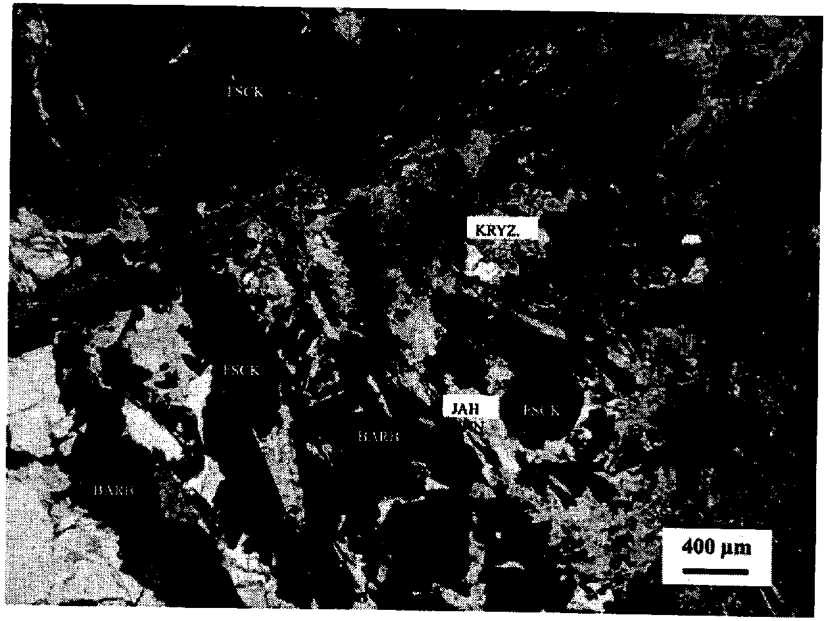

Figure 1 - Replacement of ferrisicklerite (FSCK) by jahnsite (JAH), kryzhanovskite (KRYZ), and barbosalite (BARB). Plane polarized light, sample Boca-6, Boca Rica, Minas Gerais, Brazil.

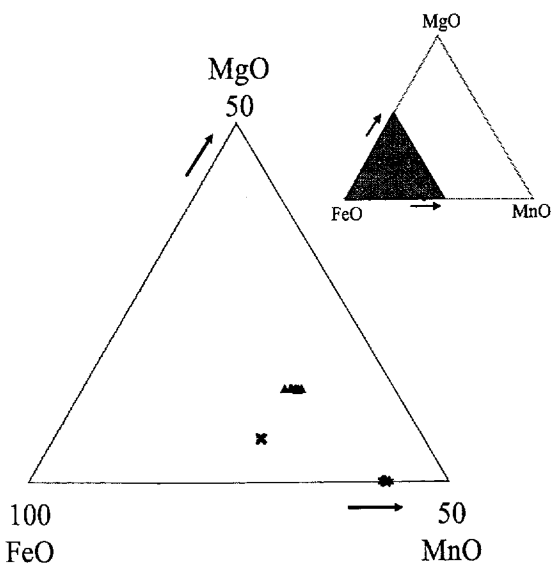

Figure 2- Ternary Mg-Fe-Mn diagram showing the composition of triphylites.
▲: Sapucaia triphylite; ×: Boca Rica triphylite (Boca-6); *: Boca Rica triphylite (Boca-23)

REFERENCES

Atencio, D. 2000. Type mineralogy of Brazil: preliminary edition. São Paulo, Instituto de Geociências/USP. 114p.

Bilal, E., Horn A.H., Nalini, H.A. Jr., Mello, F.M., Correia-Neves, J.M., Giret, A.R., Moutte, J., Fuzikawa, K., Fernandes, M.L.S. 2000. Neoproterozoic granitoid suites in southeastern Brazil. *Revista Brasileira de Geociências,* 30 : 51–54.

Correia Neves J. H., Pedrosa-Soares, A. C., Marciano V. R. P. R. O. 1986. A Província pegmatitica Oriental do Brasil à luz dos conhecimentos atuais. *Revista Brasileira de Geociências,* 6(1) : 106 - 118.

Fontan, F., Huvelin, P., Orliac, M., Permingeat, F. 1976. La ferrisicklerite des pegmatites de Sidi-bou-Othmane (Jelibet, Maroc) et le groupe des minéraux à structure de triphylite. *Bulletin de la société française de minéralogie et cristallographie* 99 :274-286.

Fransolet, A-M., Abraham, K., Speetjens J-M. 1985. Evolution génétique et signification des associations de phosphates de la pegmatite d'Angarf-Sud, Plaine de Tazenakht, Anti-Atlas, Maroc. Bulletin minéralogique 108 : 551-574.

Fransolet, A-M, Keller, P., Fontan, F. 1986. The phosphate mineral associations of the Tsaobismund pegmatite, Namibia. Contrib. Mineral. Petrol, 92: 502-517.

Ginsburg, AI. 1960. Specific geochemical features of the pegmatitic process.21st Intern. Geol. Congress Session Norden Rept Part 17: 111-121.

Hatert, F., Fransolet, A.-M. & Maresch, W.V. 2006. The stability of primary alluaudites in granitic pegmatites: an experimental investigation of the $Na_2(Mn_{1-x}Fe^{2+}{}_x)_2Fe^{3+}(PO_4)_3$ solid solution. *Contribution to Mineralogy and Petrology*, 152: 399-419.

Mason, B., 1941. Minerals of the Varuträsk pegmatite. XXIII. Some iron-manganese phosphate minerals and their alteration products, with special reference to material from Varuträsk. *Geol. Fören. Förhandl.* 63 (2): 117-175.

Morteani, G., Preinfalk, A., and Horn, A.H., 2000. Classification and mineralization potential of the pegmatites of the eastern Brazilian pegmatite province. *Mineralium Deposita* **35**: 638–655.

Nalini, H.A. Jr., Bilal E., Correia-Neves, J.M. 2000. Syn-collisional peraluminous magmatism in the Rio Doce region: mineralogy, geochemistry and isotopic data of the Neoproterozoic Urucum suite (Eastern Minas Gerais State, Brazil). *Revista Brasileira de Geociências,* 30(1): 120-125.

Paiva, G. de 1946. Província pegmatíticas do Brazil. DNPM, DGM, 78:13-21

Putzer, H. 1976. Metallogenetische Provinzen in Südamerika. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 316p.

Quensel P 1957. The paragenesis of the Varuträsk pegmatite, including a review of its mineral assemblage. Arkiv för Mineralogi och Geologi 2(2): 9-125

Roda, E., Pesquera, A., Fontan, F. & Keller, P. 2004. Phosphate mineral associations in the Cañada pegmatite (Salamanca, Spain): Paragentic relationships, chemical compositions, and implications for pegmatite evolution. *American mineralogist,* 89, 110-125.

Roda, E., Pesquera, A., Gil-Crespo P.P., Torres-Ruiz, J. & Fontan, F. 2005. Origin and internal evolution of the Li-F-Be-B-P-bearing Pinilla de Fermoselle pegmatite (Central Iberian Zone, Zamora, Spain). *American mineralogist,* 90, 1887-1899.