

PHOSPHATE FRACTIONATION IN PEGMATITES OF PEDRA DA MOURA II CLAIM – PONTE DA BARCA – PORTUGAL

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INTRODUCTION

The Pedra da Moura pegmatite group - in the proximity of Ponte da Barca village, Northern Portugal (Fig.1) - is a rosary like alignment of irregular shaped pegmatite

bodies located along the most leucogranitic stripe of an inner granite, mixing-mingling corridor, which was established between two distinctive facies of two-mica granites – one coarse grained, essentially biotitic and the other porphyroid also biotitic.

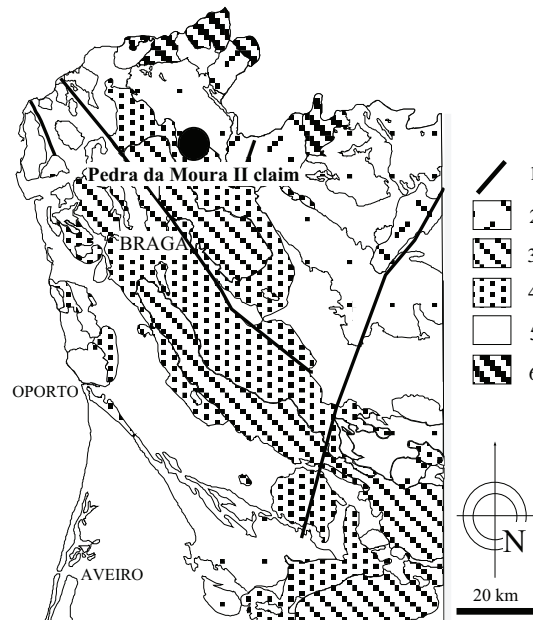


Fig. 1 – Location of the studied pegmatite group within the Pedra da Moura II claim. Symbols: 1- major tectonic lineaments; 2 – Post- tectonic granites in relation to D_3 Variscan folding phase; 3 - D_3 late tectonic granitoids related with ductile shear; 4 - D_3 syntectonic granitoids related with ductile shear; 5 – two-mica granites sin - tectonic in relation to D_3 ; 6 – restitic-two mica granites and migmatites.

Transition zones towards the hosting granites are enriched in white mica, garnet and graphic pegmatite with coarse, radial to plumose mica intergrowths (Fig 2).

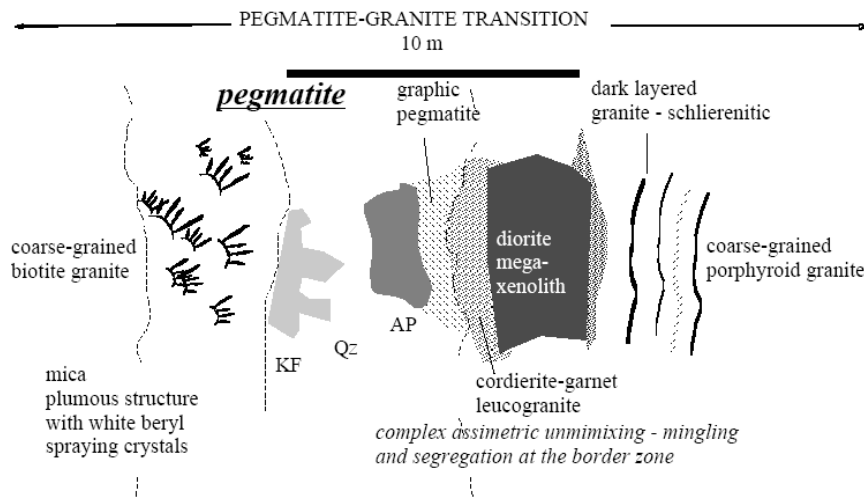


Fig. 2 – Current asymmetrical transition between the two-mica granites, the leucogranite and the pegmatites. KF – microcline; Qz – quartz; AP – undifferentiated apatite mass.

Geological setting is complicated by the near presence of a Silurian metasedimentary roof pendent and several flux-oriented swarms of xenoliths suggesting the proximity of the cupola of the magma chamber. Magmatic lineation (flux lineation) is marked by megafeldspar

trajectory, $46^{\circ} \Rightarrow 134^{\circ}$, parallel to the magma ascent - planar arrangement of K-feldspar is $130^{\circ}/90^{\circ}$. At the enclave swarms, ascent lineation is mainly, $66^{\circ} \Rightarrow 116^{\circ}$. The general orientation of the mingling corridor, 132° , reveals a sense of injection to the NW (Fig. 3).

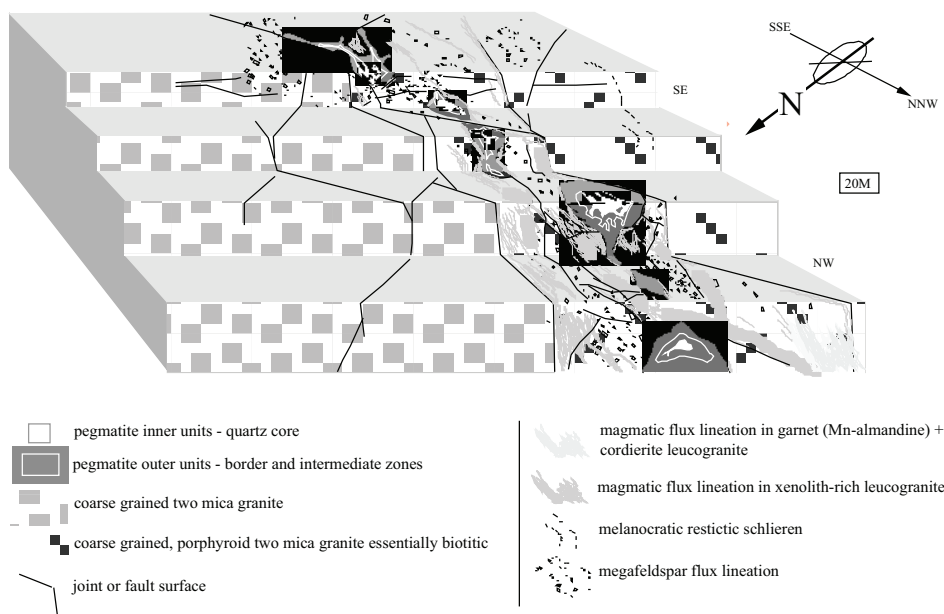


Figure 3 – Structure and anatomy of Pedra da Moura pegmatite group (inner granite), situated along a mixing-mingling magma corridor - 3d perspective bloc with the approximate location referred in fig. 1; 1999 is the reference for the image present in fig.4 and obtained in the year 1999.

Pegmatite bodies are heterogeneous, asymmetrically zoned and contact gradually with the different types of granites, thus, the cinematic interpretation is compatible with a late-Variscan emplacement and “in situ” gradual and direct fractionation from the host stripe of transitional leucogranite.

These pegmatites are quartz-rich. At the zones with the coarser crystals, inside de graphic boundary, quartz cores frequently occupy more than 2/3 of the volume and the gemmy variety, pink quartz, may be predominant, and typically located at the periphery of the core. White and hyaline varieties are nuclear. Albite and orthoclase to microcline feldspar occur in equal quantities and phosphate assemblages can accomplish as much as 10% modal volume of coarse pegmatite.

PRIMARY ACCESSORY MINERALS

The mineral assemblages were characterized and its suites and stable members discriminated by X-Ray diffractometry. Paragenetic relations were established using geometric criteria and the interpretation of crystal intergrowths.

The major accessory minerals are beryl, Nb-Ta-Ti oxides and mainly, primary phosphates - such as F-apatite, isokite, triplite-zwieselite, triphylite-litiophyllite, eosphorite, or berlinite – as well as, several sulphides, sulphosalts and carbonates, mainly oligonite. Hypothetically they correspond to early stages of the paragenetic evolution, predating the centripetal completeness of primary fractionation. They are located mainly at transition between inner intermediate zone

and quartz core and so possibly represent an equilibrium episode of depuration of excess phosphorous, materialized as a mineralogical threshold and assuming the form of a structural front, coherent with the model of “in situ” crystallization (fig. 4).

Northwest pegmatites are more fractionated (high Li in mica and lower K/Rb in microcline) and have more complex phosphate assemblages: triphylite-litiophyllite > triplite-zwieselite > F-apatite > eosphorite > withlockite > reddingite - TRIPHYLITE-LITIOPHYLLITE SUITE. Sulphide minerals are rare. Typical multiple phosphate composite aggregates include primarily and sequentially equilibrated: triphylite-litiophyllite => wolfeite => withlockite => F-apatite => eosphorite => reddingite => oligonite => triplite - zwieselite and F-apatite => wolfeite.

The southeast bodies have less diversified assemblages and typically sulphides are associated with phosphates and quartz. F-apatite + pyrite ± sphalerite + arsenopyrite + quartz occur in great masses at the border of the quartz core. Besides apatite, triplite-zwieselite and the paragenetically dependent isockite are the main phosphate phases determining the TRIPLITE-ZWIESELITE SUITE: triplite - zwieselite => isockite => F-apatite + pyrite => clorite (chamosite) + F-apatite ± pyrite, arsenopyrite, chalcopyrite, sphalerite. The Pb - Bi - Ag sulphides and sulphosalts coexist with sphalerite and quartz graphic intergrowths at the close vicinity of F-apatite + pyrite intergrowths and include matildite, cosalite, eskimoite, bismuthinite and galenobismuthite. From a spatial point of view, and from SSE to NNW, it seems to exist a trend of magma/fluid evolution and crystallization in the sense of Li and Mn enrichment at the phosphate assemblages. This trend accompanies the sense of igneous mass dislocation, which is deduced from geometric and cinematic analysis.

PARAGENETIC EVOLUTION

The more stable primary phosphates occur at the younger, sometimes miarolitic, hydrothermal stages of quartz core formation - berlinite (occasionally with pink gem quality) and a late population of zoned F-apatite are typical of this stage.

In the other cases, each one of the primary phosphates can generate a specific and independent evolutionary sequence depending on peculiar combinations and succession of deuteritic to meteoric conditions, however, *liquidus-subsolvus* to *subsolidus* and meteoric evolution are much more complex when affecting triplite-litiophyllite.

In *liquidus* state triphylite-litiophyllite evolves to wolfeite and in *liquidus* to *subsolvus* conditions evolves to eosphorite, sometimes collected as an interstitial phase in triple junctions; in *subsolvus* to *subsolidus* the same mineral tends towards a fairfieldite + vivianite ± hureaulite (*subsolidus*, hydrothermal evolution and triphylite aureole formation) ± sicklerite assemblage; in *subsolidus* it evolves to heterosite and/or purpurite.

In *subsolvus* conditions F-apatite can evolve to wolfeite and in *subsolidus* can evolve to OH-apatite and later to CO₃-OH-apatite.

Frequently the change products are maintained inside the original contour of the pristine crystal. This means that the cardinal minerals of the paragenesis (mainly silicates) persist in equilibrium.

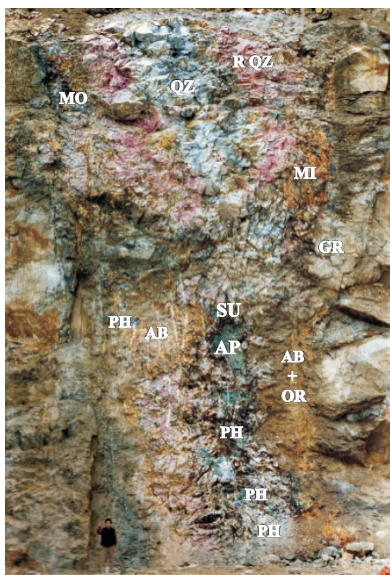
In what concerns hydrothermal alteration several phosphates can be affected simultaneously for example when a given later fracture affects different mineral species. In this case evolutionary suites can mix, resulting several textures, which can be ascribed to individualized phenomena:

A) *Corrosion* - explains some cavernous cavities and box-work like textures circumscribed to earlier volumes

of primary crystals; in these conditions the departure volume of initial crystal is reduced and phosphate anion as well as Ca^{2+} , Fe^{3+} , Fe^{2+} , Mn^{2+} are removed; the resulting contaminated fluids can re-precipitate second generation phosphates inside the corrosion cavities. B) “*In situ*” transformation – corresponds mainly to hydration processes with volume enhancement, which can generate irradiating sets of ruptures at the surrounding minerals; the fractures can be replenished with late generation phosphates. Sometimes in almost closed systems it is possible to identify phase transitions by direct hydration. This is the case of direct transition from berlinite to variscite. C) *Exsolution/exsudation* – reflects some sort of unbalance and isochemical transformation; exsolution generates a small volume reduction yet sufficient to attract fluid influx capable of produce an aureole of newly precipitated, reactional, assemblage – some vivianite can be generated in this way.

Later hydrothermal to supergenic alteration promotes a first diverging evolution, which produces corrosion cavities with re-equilibrated walls and ion leaching. The latest reactions are convergent and promote ion fixation and replenishment of the vacuoles.

Vacuolar like textures are enhanced in supergenic state of evolution and include a large set of minerals specially when the hostage is triphylite-litiophyllite: sicklerite, heterosite-purpurite, frondelite-rockbridgeite and barbosalite. Vacuole replenishment includes deposition of childrenite, ritmannite, mitridatite, duffrenite, witmoreite, cacoxenite, strunzite, jahnsite, strengite, hureulite II, cyrilovite, paravauxite, tynsleite, bermanite, fairfieldite II, kryzhanovskyite, laueite, stewartite, OH-ellestadite, henschelite, kalunigite, Fe-sicklerite, messelite, lithiophosphate, Mn-segelerite and lithiophorite. Supergenic evolution seems to end up with supergenic rockbridgeite-frondelite.



MINERAL LOCATION:

- GR – graphic texture
- AB – albite – pillow aspect
- MO – white mica
- R QZ – rose quartz
- QZ – other quartz varieties
- MI – microcline
- AB+OR – quartz+ortose+albite blocky intergrowth
- AP – graphic apatite intergrowth with sulphides
- PH – non apatite phosphates
- SU – sulphides concentration

MORFOLOGY: hourglass form

HOST-ROCK: garnet, cordierite leucogranite

PARENTAL GRANITE: porphyroid, essentially biotitic, coarse grain

DOMINANT SUITE: triplite-zwieselite

Figure 4 – Image of a mining front obtained during the year of 1999. The same number is used as a position reference in the bloc diagram of fig. 3.