ENERGY FILTERED TRANSMISSION ELECTRON MICROSCOPY OF RED GRANITES

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Major constituents of red granites, pink clouded feldspars with tiny inclusions were analyzed to identify the minute iron bearing mineral grains precipitated in pores and grain boundaries. The seams of the pores were amorphous silicon and potassium-rich material, next to normal mineral phases [1].

Two granite samples (A,B) were prepared as thin sections with 30 micron thickness and analyzed in a transmitted light microscope with crossed polars. For TEM analysis, 3mm discs were removed from the thin sections and glued to a copper grid. Final thinning was performed with a Gatan Duo-mill ion polishing system. EFTEM analysis was performed in a JEOL 3010 EX TEM, equipped with an EELS spectrometer and elemental mapping device (Gatan Image Filter GIF). The elemental maps were acquired with the three window method [1], on specified edge distances. High Resolution images were acquired with a 1 Mpixel Peltier-cooled CCD camera attached to the GIF, using energy filtering (zero loss images).

In thin section all samples showed abundant precipitates in pores of a perthitic intergrowth of feldspars. The granite A, from Itapoã, Brazil (Fig. 1a) shows a coarse intergrowth of albite and K-feldspar. Granite B, from Vånga, Sweden (Fig. 1b) shows finer lamellae. Many of the pores contain hematite precipitates, in the form of tiny needles (aspect ratio 1:10) or agglomerates of needles. The agglomerates were almost parallel in orientation (batchlike) or were more randomly oriented (nestlike). Fig.2 shows TEM images of agglomerated hematite precipitates in the pores of feldspars at grain boundaries between K-feldspar and albite or albite and quartz. Fig. 2a shows a bunch of hematite needles from the granite A, the longest needles are 1-2 µm long and seem to be 200 nm wide. Higher magnification reveals a subdivision of the batch with needles approximately 50 nm wide. Fig. 2b shows a nestlike agglomerate of hematite needles from granite B. The needles are less then 1 µm long and 70-100 nm wide and are located on the grain boundary between K-fesldspar and albite.

In Fig.3 a conventional TEM image of a hematite aggregate in a silicate matrix next to pores at a quartz grain boundary is shown. The pores are around 200 nm wide, the hematite needles around 400 nm long and 20 nm wide. Outlined in white is the area where elemental distribution maps were obtained. A thickness profile was obtained in the same area.

A thickness profile in t/λ units computed from zero-loss filtered and unfiltered micrographs is shown in Fig.4. It shows that the hematite needles are much thicker than the silicate matrix. The light grey areas in the inset are not pores, their thickness is around 0.5 t/λ, corresponding to approximately 50 nm, while the darker grey homogeneous area (upper right quadrant) is around 1.0 t/λ, corresponding to 100 nm thickness.

The electron micrographs and the compositional information from elemental maps show that hematite forms in pores and next to non-crystalline, non-stoichiometric silicate material, containing the elements related to feldspars, but lacking the order and compositional constraints. Pores and precipitates together bring to mind the presence of fluids, and the additional observation of non-crystalline material substantiates this assumption. The observation of this phenomenon was made in red feldspar samples coming from different places, having in common only their reddish coloration. This allows the interpretation that pink-red feldspars are the result of large-scale metasomatic alteration of a pre-existing rock, and that the introduction of Fe into the feldspar is a by-product of this process. Given the widespread occurrence of pink-red feldspars in granitic rocks, interpretation of their geochemical and isotopic characteristics must take into account the likelihood of pervasive sub-solidus rock-fluid interaction involving the introduction of alkalis as well as other components [1].

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References:

[1] Putnis, A.; Hinrichs, R.; Putnis, C.V.; Golla-Schindler, U.; Collins, L.G.; Lithos 95 1-2 (2006)10-18.
[2] Egerton, R.F., 1996, Electron Energy-loss Spectroscopy in the Electron Microscope, Plenum, New York, 1996.

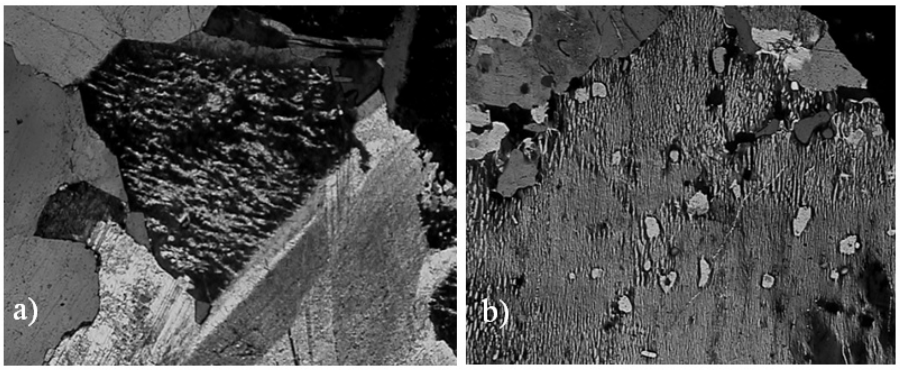

Figure 1 – Optical microscope images with crossed polars of (a) granite A (Itapoã,Brazil) and (b) granite B (Sweden).Width of images: 4 mm

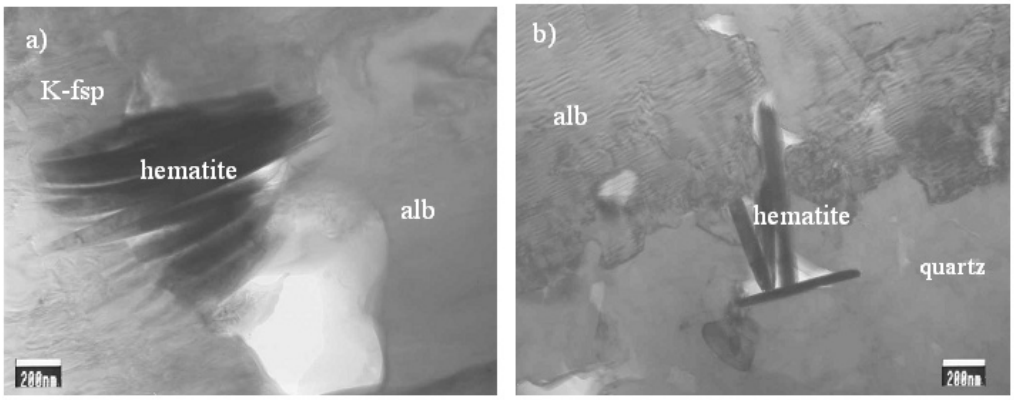

Figure 2 – TEM images of porous grain boundaries between K-fsp and albite showing hematite needles in the pores; a) batchlike agglomerate in the Brazilian granite and b) nestlike agglomerate in the Swedish granite at the grain boundary between K-fsp and albite. Scale bare is 200 nm

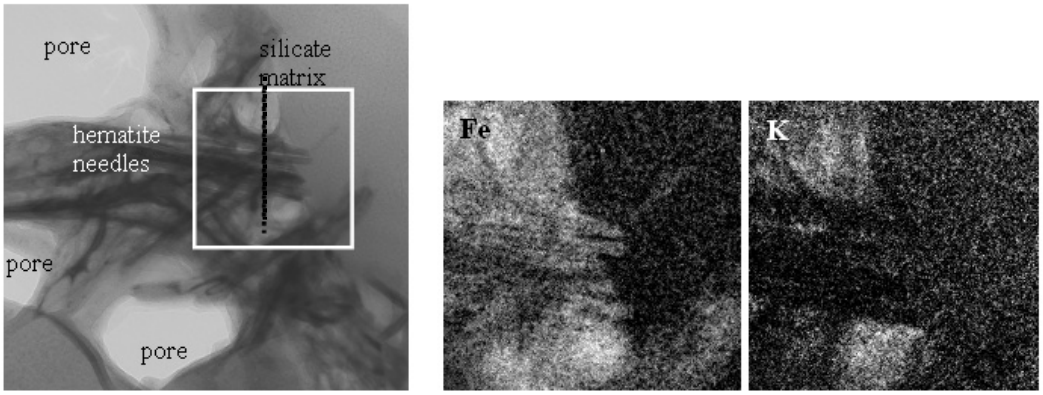

Figure 3 – On the left: conventional TEM image, showing hematite needles next to several pores, image width 0.9 µm. On the middle and right elemental maps of the outlined area (350 nm wide) showi the distribution of iron and potassium. On the dashed line a thickness profile was obtained (see Fig 4).

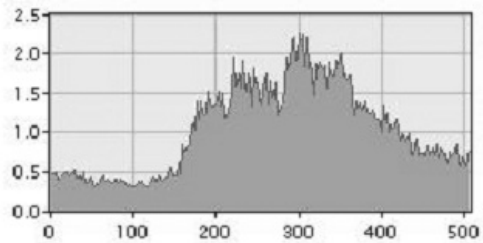

Figure 4 – A thickness profile (along the dashed line of Fig.3) shows that the hematite needles are much thicker then the silicate matrix. Profile is 350 nm long.