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SPECIAL COLLECTION: APATITE: A COMMON MINERAL, UNCOMMONLY VERSATILE

Magmatic graphite inclusions in Mn-Fe-rich fluorapatite of perphosphorus granites (the Belvís pluton, Variscan Iberian Belt)

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Abstract

Three Mn-Fe-rich fluorapatite types have been found in the highly evolved peraluminous and perphosphorous granites of the Belvís pluton. One of these apatite types includes abundant graphite microinclusions, suggestive of a magmatic origin for the graphite. The Belvís pluton is a reversely zoned massif composed by four highly fractionated granite units, showing a varied accessory phosphate phases: U-rich monazite, U-rich xenotime, U-rich fluorapatite, and late eosphorite-childrenite. The strong peraluminous character of the granites determines an earlier monazite and xenotime crystallization, so the three types of fluorapatite record late stages of phosphate crystallization. The earlier type 1 apatite is mostly euhedral, small and clear; type 2 apatite is dusty, large (<2800 μm) and mostly anhedral, with strong interlobates interfaces with the main granite minerals, more abundant in the less fractionated units and absent in the most evolved unit; type 3 is subeuhedral to anhedral, shows feathery aggregate texture, and only appears in the most evolved unit. Apatite composition was acquired by electron microprobe analyses, laser ablation inductively coupled plasma-mass spectrometry and electron energy loss spectroscopy. Type 1 and type 2 apatite display similar broad compositional ranges showing high MnO (up to 4.30 wt%) and FeO (up to 2.88 wt%) contents, without traces of carbon in apatite structure. Type 2 differs from type 1 by having slightly higher LREE and Sr contents. REE spectra also differ, with type 1 displaying both variable LREE slope and negative Eu anomaly, whereas type 2 shows constant LREE slope and higher negative Eu anomaly, although both display similar HREE slope. Type 3 apatite displays higher FeO contents (up to 5.09 wt%), positively correlated with higher Cl-Na-Li-Be-B-Zn contents and extremely low Y-REE contents when compared to the other apatite types. Cation substitution indicates that part of the Fe content is as Fe^{3+}. Graphite has been found exclusively as abundant microinclusions in type 2 apatite, parallel or randomly distributed, and heterogeneously grouped in clusters within the crystals. High-resolution electronic images show that graphite occurs with unusual habits: filaments of stacked hexagonal flakes up to 15 μm length and up to 0.5 μm width. Textural and chemical features suggest a highly crystallized melt, which favor compartmentalizing in compositional microdomains where the apatite types would have crystallized. The cocrystallization of type 2 apatite and graphite suggests a C-F-P-rich melt, sufficiently saturated to acquire an immiscible character with the highly evolved silicate melt in late-magmatic stages. As type 2 differs from type 1 apatite by higher LREE and Sr contents, we interpret that fluxing components were favorably concentrated in those residual less-depleted LREE-Sr fraction melts, once monazite and zircon (and xenotime) would have crystallized. Type 3 apatite records a change in the ultimate melt stage: an increase of the oxygen fugacity coupled with high undercooling by volatile lost of highly fractionated residual Cl-richer melts. The presence of biogenic carbon in granite peraluminous melts derived from metasedimentary sources and its later crystallization as graphite filaments opens a discussion on the carbon behavior during magma evolution, especially in highly polymerized melt framework.

Keywords: Mn-Fe-rich fluorapatite, graphite, granite, melt immiscibility, carbon isotope, perphosphorous, peraluminous