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Phosphate mineralization in the Vergenoeg fluorite deposit (RSA) and its implication for the origin of REE-bearing fluid alteration

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The Vergenoeg volcanic pipe, located in the central part of the Bushveld Complex (Republic of South Africa), hosts one of the economically most significant fluorite deposits on Earth. Its iron-oxide – fluorite – fayalite assemblage is well known for marked enrichment of rare-earth elements (REE) and phosphate. Previous studies reported the presence of apatite and a number of REE-rich accessory minerals, particularly phosphates [1, 2, 3]. Here we present a systematic study of REE-phosphates (monazite, xenotime) from the hematite-fluorite zone of the Vergenoeg orebody. Links between mineral chemical variations, paragenesis, and microstructural aspects are examined. The results are used to elucidate the genesis of REE-phosphate mineralization in the Vergenoeg fluorite deposit.

For this study, both apatite-bearing and apatite-free samples from the hematite-fluorite zone were selected. Scanning electron microscopy-based image analysis has been performed in order to identify and spatially map the distribution of rare-earth phosphates as well as rock-forming minerals throughout the samples in polished sections. Subsequently, the mineral chemistry of the phosphates has been determined by means of electron probe microanalysis.

Two major fabric types can be distinguished: First, fine-grained monazite and xenotime form euhedral pseudomorphs in the presence or absence of apatite. Second, they occur as infill of interstices and microfractures. Mineral associations of monazite with xenotime, iron-oxide, fluorite or their joint assemblage have been identified, applying to every fabric type. The combination of mineral chemistry data and microstructural observations suggests a link between the spatial occurrence of REE-phosphates and their chemical composition. Different mineral associations also have an effect on the chemical composition. In addition, the depletion of certain elements suggests microstructural and mineralogical changes as controlling factors, respectively.

The mineral chemistry of monazite is in line with the monazite-(Ce) of type 2 from Graupner et al. [3]. Xenotime data point to Y-rich compositions, corresponding to the secondary xenotime generation proposed by Graupner et al. [3]. Besides regular monazite, the presence of grains with comparatively low analytical totals between c. 90 wt% and 98 wt% may reflect altered compositions, resulting from hydration under low-temperature conditions giving rise to formation of hydrated monazite (or even rhabdophane) [e.g., 4, 5]. Similarly low analytical totals for xenotime may also represent hydration. Increasing sulfur contents with decreasing analytical totals for both rare-earth phosphates indicate enhanced sulfur activity of the overprinting fluid.

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