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Complex zoning in apatite from the Idaho batholith: A record of magma mixing and intracrystalline trace element diffusion

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ABSTRACT

Apatite crystals in a sample of biotite granodiorite from the Idaho batholith display complex chemical zoning, characterized by abrupt changes in REE+Y+Si content, more subtle variations in S, Na, La/Yb, and Mn contents, and petrographic evidence for multiple episodes of partial resorption. The zoning is attributed to changes in melt composition, resulting from magma mixing and differentiation, although the possibility that some rounded cores may be inherited cannot be disproved. High S contents in apatite cores and the presence of an included anhydrite grain indicate crystallization from an oxidized host magma. Divalent cations that occupy the apatite Ca sites (Sr, Mn, Fe) show evidence of having been redistributed between zones by intracrystalline diffusion, whereas cations that participate in coupled substitutions involving the tetrahedral site (Si, Y, REE, Na, S) were not readily redistributed. The main REE substitution in this case is $REE^{3+} + Si^{4+} \leftrightarrow Ca^{2+} + P^{5+}$, and REE diffusion is rate-limited by slow Si diffusion. However, exchange of LREE (e.g., $LaSm_{-1}$) on the Ca sites does not involve Si and proceeds more rapidly, resulting in homogenization of La/Sm between zones within individual crystals. Relative diffusion rates inferred from zoning profiles in this study are: Mn, Sr, Fe, and $LaSm_{-1}$ are faster than Na, S, and $LaYb_{-1}$, which are faster than Si. These data imply that REE patterns can be decoupled from REE abundances during diffusion, and that even apatite zones or cores that appear sharply bounded in backscattered electron images may not retain their original chemical or Sr-Nd isotopic traits.