The Genesis of Hydrothermal Fluorite-REE Deposits in the Gallinas Mountains, New Mexico

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Abstract

Breccia-hosted fluorite-bastnaesite deposits associated with epizonal quartz syenite intrusions in the Gallinas Mountains, New Mexico, provide an important example of hydrothermal rare earth element (REE) mineralization, and an excellent opportunity to investigate the transport and deposition of the REE under hydrothermal conditions. Fluid inclusion studies show that mineralization commenced with the deposition of quartz at a temperature of approximately 400°C from sulfate-rich NaCl-KCl brines having a salinity of ~15 wt percent NaCl equiv. These fluids are interpreted to have been of orthomagmatic origin. Fluorite and bastnaesite deposition occurred at slightly lower temperatures, and coincided with the introduction of separate CO_2-bearing and sulfate-poor NaCl brines into the system. These fluids are considered to have been of external origin, the latter being a formation water that circulated in surrounding Permian sandstones and limestones. Evaluation of the available thermodynamic data on the aqueous speciation of REE, and the preliminary data on the chemistry of the fluids obtained in this study, suggest that the REE were dissolved primarily as fluoride complexes. A model is proposed in which the REE were transported by the orthomagmatic fluids, and deposited as bastnaesite owing to destabilization of REE-fluoride complexes. The latter occurred in response to the sharp reduction in F^- activity that accompanied large-scale deposition of fluorite as a result of mixing of the orthomagmatic fluids and formation waters. This mixing also led to the deposition of anhydrite and barite owing to the interaction of externally introduced calcium and barium ions with orthomagmatic sulfate ions. The later stages in the evolution of the Gallinas Mountains hydrothermal system were marked by increased incursion of external fluids, and the alteration of bastnaesite to Ca bastnaesite and minor deposition of Ca bastnaesite and parisite owing to lowered F^-/CO_3 ratios and/or increased Ca^{2+} activity. The study suggests that Ca-free, REE fluoride-bearing fluids are an important ingredient for REE mineralization, that mixing of such fluids with Ca-, carbonate-bearing fluids or interaction with carbonate rocks is a major control of REE-fluorocarbonate mineral deposition, and that the occurrence of fluorite could provide an important guide in the exploration for economic REE deposits.