Radioactive REE and Y mineralized zone in Highland Falls, New York: petrogenesis and metasomatic reactions

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In southeastern New York State, within the Mesoproterozoic Grenville Orogen, the Hudson Highlands inlier is metamorphosed to granulite facies, consisting primarily of locally migmatitic paragneiss, and is intruded by late tectonic granites and pegmatites. At a contact between the migmatite and paragneiss (apparently conformable), a narrow vein-like zone is composed almost entirely of monazite and xenotime (mz-xt zone), and surrounded by a metasomatic biotite envelope. The mz-xt zone is approximately 0.25 m wide and >4m in extent in the outcrop, while the biotite envelope is up to 0.75 m wide. It is weakly deformed, steeply dipping (80°), and strikes NNE. The mineralized zone contains up to 1.0% U, 3.0% Th, 25% total REE, and 13% Y, with Eu/Eu* = 0.03 and La/Yb = 3.0. Previous studies of this zone have investigated age and mineral trace-element characteristics; cores of zircon, monazite, and xenotime in the mz-xt zone have a U-Pb age of 1036 ± 5 Ma, and a series of rims were dated between ca. 1034–890 Ma, formed during subsequent metasomatic events. This zone postdates the host paragneiss (ca. 2065–1270 Ma) and the local granitic intrusions (1058 ± 14 Ma). In this study, the host paragneiss and metasomatic biotite zone are examined via lithogeochemistry, biotite mineral chemistry, and petrography to understand the source of metasomatic fluids. Based on electron probe microanalysis (EPMA), biotite in this system is classified as magnesian siderophyllite and is highly enriched in Cl, with up to 2.3 wt.% Cl. Using Henry et al. (2005) Ti-inbiotite geothermometry, the biotite in the metasomatic zone formed at 542 ± 24 °C. Cl and F concentrations in the biotite and charge balance methods were used to estimate fugacities in the system. Average $\log(f H_2O)/(f HCl) = 2.8$, and $\log(f H_2O)/(f HF) = 4.3$, values more Cl-dominated than most published alteration systems. Using whole-rock chemical compositions of the metasomatic zone versus unaltered host-paragneiss, mass balance methods were used to calculate the compositional losses and gains of the biotite zone associated with metasomatism. The main elements lost were Si, Na, Ca, and Sr, consistent with the reaction of alkali feldspars with KCl and $FeCl_2$ to form Ferich biotite (~ 550 °C and 5 kbar). The very high chlorine activity, along with salt-rich fluid inclusions in albite and monazite, and the extreme enrichment in incompatible elements suggest that the vein-like mz-xt zone was formed from a hypersaline brine with low Ca, probably derived from a highly fractionated, late tectonic pegmatite.

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