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Nitrogen-isotope record of fluid-rock interactions in the Skiddaw Aureole and granite, English Lake District

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ABSTRACT

The Skiddaw Granite and its contact metamorphic aureole in the English Lake District provide an excellent opportunity to test the capability of the N-isotope system to trace devolatilization and large-scale transfer of crustal fluids. In the aureole, Skiddaw Group metasedimentary rocks with relatively uniform lithology and major-element compositions show a dramatic decrease in N content toward the granite contact (from ≥800 ppm at distances >2.5 km from the contact, to <410 ppm ≤0.55 km from the contact). Far from the intrusive body (>1.5 km), these rocks have extremely uniform $\delta^{15}N_{air}$ near +3.7‰, whereas closer to the contact (≤1 km) $\delta^{15}N$ is shifted to higher values (up to +8.7‰). The coupled decreases in N content and increases in $\delta^{15}N$ are compatible with the removal of N having low $\delta^{15}N$ in fluids during continuous, prograde devolatilization reactions involving the breakdown of white mica and the stabilization of biotite-, cordierite-, and andalusite-bearing assemblages. In the same metasedimentary rocks, the lack of obvious trends in major-element concentrations (including SiO_2/TiO_2, SiO_2/Al_2O_3, and the ratios of other major oxides to TiO_2 and Al_2O_3) with distance from the granitic contact is consistent with minimal change in major element composition during the contact metamorphism. Ratios of whole-rock N, B, Rb, and Ba concentrations to whole-rock K_2O content are believed to reflect the differing fluid-mica partitioning (and involving varying relative proportions of white mica and biotite) of these trace elements during devolatilization reactions.

Greisenized Skiddaw Granite from a borehole is enriched in N (range of 17–225 ppm for whole rocks and white mica separates) relative to the unaltered granite (whole-rock <30 ppm), and has $\delta^{15}N$ of +1.0 to +4.8‰. The N concentrations and $\delta^{15}N$ of the wall-rocks and greisenized granites, combined with C isotopic data (carbonate and carbonaceous matter) for the same rocks, are consistent with the mobilization of fluids having low $\delta^{15}N$ and $\delta^{13}C_{PDB}$ values from the devolatilized aureole into the cooling intrusive body. Such transport is consistent with the predictions of recent theoretical models of late-stage hydrothermal evolution in cooling intrusive systems.