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Hydrothermal enrichment of nitrogen in altered oceanic crust: sources, mechanisms, budget, and implications to subduction-zone nitrogen cycle

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It is well known that hydrothermal alteration increases volatile elements/components (e.g., H_2O, C, N and S) in the oceanic crust. Different to the enrichments of H_2O, C, and S which are relatively easy to constrain due to the occurrence of secondary minerals with OH^-, C or S as major constituting elements, N enrichment is more difficult to understand because of the lack of such minerals. Here, based on the investigation of N concentrations and isotope compositions of a large number of altered basalts, sheeted dikes and gabbros, and serpentinized peridotites recovered by DSDP/ODP/IODP drillings in global seafloors, we confirm that secondary N exists ubiquitously in AOC. In relative to the low mantle-inherited N in fresh samples (<2 ppm, $d^{15}N$ = –5‰), altered basalts show the most variable N concentrations (2 - 48 ppm; mean: 10 ppm) and $d^{15}N$ values (–20‰ to +8‰), whereas altered sheeted dikes/gabbros (N = 3 — 34 ppm; mean: 8 ppm; $d^{15}N$: –4‰ to +5‰) and serpentinized peridotite (N = 3 — 19 ppm; mean: 9 ppm; $d^{15}N$: –3‰ to +4‰) show more restricted ranges in N concentrations and $d^{15}N$ values. Although a wide range of alteration temperatures (from zeolite to granulite facies) were recoded in these lithologies, no significant effect of alteration temperature on N enrichment is observed. Modeling suggests that, although the contribution of microbial biomass cannot be completely excluded, most of the enriched N resides as ammonium in secondary minerals such as clay minerals, plagioclase, chlorite, amphibole and/or serpentines. The secondary ammonium was mainly derived from overlying sediments but can be also derived by mineral reduction of (atmospheric or mantle) N_2 in the fluids. These data gave a new N inventory of 3 - 5 × 10^{18} moles in global AOC and an annual subduction flux of 2.1 – 4.5 × 10^{10} moles into global trenches. Comparison with the output N flux from global arc volcanoes suggests that a significant amount (>50%) of slab N can be subducted beyond the sub-arc depth and recycled further downward into the deep mantle.