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Geodynamic cycles of sulfur, carbon and nitrogen

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Sulfur has important roles not only in biological activities but in industry and medicine. However, its geochemical cycle between the mantle and the surface environments has not been well quantified. ^{3}He, one of the primordial noble gas isotopes, is useful to investigate to evaluate S cycles. ^{3}He fluxes from the mantle to atmosphere and ocean are well constrained, which enables us to use this isotope to estimate other volatile fluxes. The recent study reported S and C fluxes from the mantle to the surface environments based on He, S, and C isotopic compositions in MORB, hydrothermal fluids, and volcanic gases [1]. The fluxes were estimated with the recently reported ^{3}He flux at ridges, 530 mol/y [2]. The S/^{3}He ratio at MOR was calculated to be 1.9x10^8 as an average of S/^{3}He ratios in six MORB vesicles (13N, 17S on EPR; 15N, 37N on MAR; 24S-25S on CIR) and 10 high temperature (>200 ℃) hydrothermal fluids (11N-47N, 17S-19S on EPR; 23N-38N on MAR). Multiplying this ratio and the ^{3}He flux together, S flux at ridges was estimated to be 100 Gmol/y. An average S/^{3}He ratio of 15 high temperature (>200 ℃) volcanic gases collected from circum-Pacific regions was calculated to be 6.5x10^9, providing S flux of 720 Gmol/y from arc volcanoes calibrating against ^{3}He flux of 110 mol/y determined by its MOR flux. This flux is higher than that from ridges. However, S in volcanic gases does not originate only from the mantle. S/^{3}He ratios and δ^{34}S values in volcanic gases can be explained by mixing of three components: the upper mantle; subducted sedimentary pyrite; and subducted sulphate. The S contribution from the upper mantle was calculated to be 2.9% in volcanic gases, providing 21 Gmol/y from the mantle at arcs, which is lower than the S flux at ridges. Carbon flux at ridges was calculated to be 1200 Gmol/y using the CO_2/^{3}He ratio of 2.2x10^9 [3] based on compositions of MORB and hydrothermal fluids. An average CO_2/^{3}He ratio of 24 high temperature (>200 ℃) volcanic gases collected from circum-Pacific regions was calculated to be 2.0x10^{10}, providing C flux of 2200 Gmol/y from arc volcanoes. CO_2/^{3}He ratios and δ^{13}C values in volcanic gases can be explained by mixing of three components: the upper mantle; subducted organic sediments; and subducted limestone with slab [4]. The C contribution from the upper mantle was calculated to be 11% in volcanic gases, providing 240 Gmol/y from the mantle at arcs. The S and C fluxes from the mantle to atmosphere and ocean are 121 Gmol/y and 1440 Gmol/y, respectively. The C/S flux ratio was calculated to be 12, which is comparable to the surface inventory ratio of 13 [5]. This suggests that the main source of surface S and C is the upper mantle. Assuming steady-state surface environments, subducted amounts of S and C become 820 Gmol/y and 3400 Gmol/y, respectively. Then 15% of subducted S and 42% of subducted C do not return to the surface environments and recycle back into the depth. Nitrogen cycles will also be quantified and discussed in the current study.

Reference: [1] Kagoshima et al. (2015) *Sci. Rep.* **5**, 8330. [2] Bianchi et al. (2010) *EPSL* **297**, 379-386. [3] Marty & Tolstikhin (1998) *Chem. Geol.* **145**, 233-248. [4] Sano & Marty (1995) *Chem. Geol.* **119**, 265-274. [5] Hilton et al. (2002) *RiMG* **47**, 319-370.

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