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Spreadsheet mass balance for exploring on element behavior between subducted slab, mantle wedge, and magma

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We have developed the Arc Basalt Simulator version 3 (ABS3), a quantitative calculator to examine the mass balance of (1) slab-dehydration and melting, and (2) slab fluid/melt-fluxed mantle melting, and to quantitatively evaluate magma genesis beneath arcs. Calculation results from the ABS3 model suggest that element re-distribution between the subducted slab and slab-derived liquid controls distinctive trace element signatures found in arc magmas and crust. The slab liquid is derived from various mixtures of fluids and melts from sediment and altered oceanic crust, dependent on the thermal structure of the subducted slab. Slab fluids are mostly generated by slab-dehydration to form the volcanic front (VF) magmas with slab P-T conditions around 3 GPa/ 750(C), whereas slab may melt at 3-6 GPa > 830(C) contributing either to the VF or to rear arc (RA) magmas. Compositions of slab fluids and melts are controlled primarily by breakdown of amphibole and lawsonite for VF and phengite for RA slab depths in association with the residual eclogite mineral phases including garnet, clinopyroxenes, and quartz. Temperature dependent partition coefficients and different partition coefficients between melt/fluid and minerals are additional controls. Minor mineral phases such as zircon and titanite also play important roles for certain elements. The slab liquid fluxed melting of depleted mantle wedge peridotite plays additional role to element re-distribution in subduction zone. The degree of partial melting varies between 17-28 % (VF) and 3-22 % (RA), with a slab flux fraction of 2-4.5 % (e.g., VF fluid) to 1-1.5 % (e.g., RA melt), and at melting depths corresponding to 1-2.5 GPa (VF) and 2.4-2.8 GPa (RA). Addition of fluid-immobile elements from the mantle contributes 78-98 % of the magma mass and controls certain isotopes such as Nd and Hf in arc magmas. However, element addition from the slab liquid modifies the liquid mobile elements/isotopes in the arc magmas significantly. The residual peridotite composition is also altered due to modification by the slab flux addition and melt depletion. Modeled peridotite compositions are similar to some peridotites in supra-subduction zone ophiolites, suggesting that element re-distribution beneath arcs is complex.

Keywords: Geochemistry, slab, mantle wedge, magma, mass balance