Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SCG089-03 Room: 101 Time: May 27 11:15-11:30

Slab dehydration versus melting: primary arc magma genesis for arc crust formation

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Whether subducting slab melts or simply dehydrates is a key question for understanding the generation of primary magmas above subduction zones. Chemical composition of the primary magma is the fundamental constraint, both for understanding crust formation and mantle return in subduction zones. There are two endmember ideas about arc primary magma genesis; one suggests mantle melting by slab fluid fluxing (basalt to high-Mg andesite) and the other suggests slab melting to form primary magma immediately (adakite) or after slab melt-mantle reaction (high-Mg andesite to basalt). Geodynamic and petrological models suggest that both are plausible, depending on the temperature structure in the mantle wedge and slab. To test these models, we have improved our petrological/geochemical model (ABS2; Kimura et al. G-cubed 2009)), which we now call ABS3, to additionally simulate (1) prograde metamorphism and melting phase relationships of the slab to calculate slab fluid/melt compositions, and (2) mantle peridotite melting induced by slab fluid/melt-fluxing for the primary arc magma compositions. The ABS3 model uses 23 incompatible trace elements and Sr-Nd-Pb isotopes to fit primary basalt/andesite compositions found in arcs and can be adjusted for variable subduction zone inputs via oceanic slab subduction and mantle peridotite convection. Intensive and extensive parameters for slab dehydration/melting and mantle peridotite melting conditions are found by iterative fitting, providing geochemical constrains for the primary magmas and slab-mantle conditions. We have compared magmas from old-cold subduction zones (NE Japan, Izu arcs) and young-hot subduction zones (SW Japan, early Bonin arcs). The results indicate that low-K volcanic front tholeiites in cold subduction zone alone are from slab fluid fluxed mantle melting whereas medium-K rear arc basalts in the same arcs are slab melt fluxed. High-Mg andesites and some adakites can be generated by intensive slab melt flux to the mantle wedge whereas boninites require ultra-depleted high-T mantle wedge with slight addition of both slab melts and fluids.

Keywords: slab, melting, dehydration, primary magma, arc crust