



Globally Consistent Recognition of Slab-Derived Components in Volcanic Arcs, with Distinctions Based on Subduction-Zone Thermal Structures

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When one examines boron isotope systematics, or variations of “fluid-mobile” elements (B, Cs, As) among different volcanic arcs globally as compared to variations in lithophile trace elements that have been associated with material inputs from subducted sediment and crust (i.e., Ba, Th, Sr, Rb, K), one observes systematics indicating the presence of three distinguishable slab components: a) a “mantle” component with low trace element abundances and low $\delta^{11}\text{B}$; b) a component with elevated Ba and Th ratios, but low “fluid mobile” element concentrations and very low $\delta^{11}\text{B}$; and c) a component with variably elevated “fluid-mobile” element ratios, $\delta^{11}\text{B} > +3\text{\textperthousand}$ and Ba and Th ratios that range from similar to component b), to even more extremely elevated.

In terms of its Ba and Th systematics, component b) is consistent with subducted sediments as described by Elliott et al (1997) and Plank and Langmuir (1993; 1998). However, the implied very low abundances of B, Cs, and other fluid-mobile species relative to their abundances in marine sediments, the implied very low $\delta^{11}\text{B}$, entail that this sedimentary component must have undergone extensive devolatilization before being sampled at arc depths. This inference is consistent with current thermal models for the slab-mantle interface, presuming continuous dehydration of the downgoing plate (e.g., Syracuse et al 2010).

Component c) presumably represents an H_2O -rich fluid phase. Its very selective enrichment in fluid-mobile species and very high $\delta^{11}\text{B}$ are not consistent with a basaltic crust origin as some have proposed (e.g., Ishikawa and Nakamura 1994), but are similar to the elemental and isotopic signatures of serpentinites, such as have been observed erupting at forearc seamounts in the Mariana subduction system from 30 km slab depths. Slab-derived serpentinites have been proposed as sources for subducted H_2O at depth (Rupke et al 2002) but recent thermal models suggest that dehydration of slab serpentinite may not occur in many settings (Syracuse et al 2010). Wedge-derived serpentinite transported along the slab-mantle interface will not be stable to arc depths, but the formation of chlorite and like mantle phases due to serpentine dehydration may permit the transport of this “serpentinite component” to arc volcanic roots (e.g., Grove, et al 2006). Across-arc declines in fluid-mobile element enrichments and $\delta^{11}\text{B}$, observed in essentially all arcs thus far studied, are consistent with shallow-mantle origins for such a component, and its rapid removal via hydrous mineral breakdown during magmatism in the wedge.

A pronounced dichotomy is evident in the makeup of the slab-derived component observed in arcs globally: those recognized as part of “hot” subduction systems (i.e., downgoing plates <30 Ma at the trench, slow and/or oblique convergence) show no evidence of component c), and the systematics of erupted lavas is explained via mixing of a sediment-derived slab component and the depleted upper mantle. By contrast, in those arcs where component c) is a prominent constituent, mixing arrays extend between components b) and c), with the mantle playing a negligible role in the overall trace element signatures of lavas. Thus the geodynamic framework of subduction systems impact the geochemistry of their eruptive products as a step function that is most likely associated with the thermal stability of shallowly-formed hydrous mineral assemblages in the mantle wedge.