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Beryllium Isotope Systematics of Volcanic Arc Cross-chains

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Cosmogenic ^{10}Be (half-life = 1.5 Myr) is incorporated in arc lavas through sediment subduction and recycling. $^{10}Be/^{9}Be$ atom ratios in cross-arc volcanic chains document the changing nature of the slab component with depth, map the pathways of slab-derived elements through the mantle wedge and thence to the surface, and loosely constrain time scales of transport. ^{10}Be and ^{9}Be have been measured in 9 pairs of front- and rear-arc volcanoes from 3 arcs; pairs lie along or close to a single perpendicular to the trench. In the Aleutians, Umnak (volcanic front, ca. 120 km above the seismic zone) has a $^{10}Be/^{9}Be$ atom ratio of 7.5 x 10^{-11}, for this and all subsequent ratios), whereas rear-arc volcano Bogoslof (ca. 220 km above the seismic zone) has a measured value (10/9 m) of 8.5. The $^{10}Be/^{9}Be$ ratio of the rear arc volcano, corrected for additional subduction time relative to the volcanic front (hereafter, 10/9dc) is 21.

In the Bismarck arc, 10/9 ratios have been determined for three cross-arc pairs:

(i) Pago (ca. 95 km, 10/9 m=15) and Makalia (190 km, 10/9 m=11, 10/9dc=16);
(ii) Pago-Garove (ca. 280 km, 10/9 m=4.7, 10/9dc=?9.4);
(iii) Ulawun (ca. 95 km, 10/9 m=24) and Lolobau (ca. 140 km, 10/9 m=18, 10/9dc=23).

Five cross-arc pairs have been studied from the Kurile arc:

(i) Paramushir (ca. 105 km, 10/9 m=3.4) and Alaid (160 km, 10/9 m=6.5, 10/9dc=9.9);
(ii) Onekotan (105 km, 10/9 m=6.4) and Seamount 2.3 (180 km, 10/9 m=4.1, 10/9dc=7.2);
(iii) Aekarma (105 km, 10/9 m=8.5) and Chirinkotan (160 km, 10/9 m=11.3, 10/9dc=17.1);
(iv) Lovushki (105 km, 10/9 m=4.2) and Raikoke (135 km, 10/9 m=6.2; 10/9dc=7.8);
(v) Lvinaya (105 km, 10/9 m=12.1) and Seamount 8.8 (190 km, 10/9 m=2.8, 10/9dc=?5.1). [1]

$^{0}Be/^{9}Be$ ratios for rear-arc lavas were decay corrected using present day geometry and convergence rate. This simplest model assumes that ^{10}Be travels with the slab to a point beneath the volcano, and that ascent time from slab to surface is short wrt the ^{10}Be half-life. For the Aleutian and three of the five Kurile cross-chains, rear-arc volcanoes have measured ^{10}Be concentrations and $^{10}Be/^{9}Be$ ratios comparable to, or greater than those measured at the front. Once corrected for decay during longer transit to rear arc localities, three other pairs show comparable ^{10}Be enrichments front and rear. Only Kurile Smt 8.8 and Bismarck volcano Garove have ^{10}Be concentrations near or below detection limits.

Regardless of the model chosen to correct $^{10}Be/^{9}Be$ ratios for transport to the rear-arc, the observation is that 7 of 9 volcanic cross-chains, in three separate arcs, show elevated $^{10}Be/^{9}Be$ ratios in the rear arc. This has immediate implications for transport of sediment hosted elements from the slab through the mantle wedge. Higher rear-arc ^{10}Be concentrations and 10/9 ratios require either faster transport to the rear arc, or a larger sediment component. Most of these front-arc lavas have U-excess (e.g. Gill, GCA, 1993; George, pers. comm), implying <300 kyr transit time, short relative to the ^{10}Be half-life; it is thus unlikely that differences front and rear are due to ^{10}Be decay in transit. High ^{10}Be and $^{10}Be/9Be$ ratios in the Kurile rear-arc volcanoes correlate with high K and Ba concentrations. They contrast sharply with decreasing B, As, Sb, and Cs concentrations (Ryan et al,1995) and with the pattern of the B isotopes, which also change dramatically across the arc (Ishikawa and Tera, 1997). The cross-arc chemical variations could reflect the changing nature of the slab component with depth. Either the fluids leaving the slab have increased carrying capacity as pressure and temperature increase, or a changeover from fluids to melts is seen from front to rear. Alternatively, elements such as Be, K and Ba could be hosted in hydrous mineral assemblages in the mantle that contribute to the melt over a wide and apparently continuous depth range. The data preclude a simplest model in which a slab component, added to the mantle up-dip of the volcanic front, is completely consumed by melting beneath the front. Retention of elements like Be, K, and Ba in hydrous mantle minerals not completely consumed by melting could explain the evidence for multi-stage modification of the sub-arc mantle (Reagan et al., 1994; Elliott et al., 1997). The corollary is that the recycling efficiency of subducted elements in volcanic arcs may be greater than expected, if retention of slab-derived elements in the mantle and their supply to rear-arc localities is taken into account (e.g. Plank and Langmuir,1993; 1998).

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