Pb Systematics of Klyuchevskoy Volcano, Kamchatka and north pacific sediments: implications for magma genesis and crustal recycling in the Kamchatkan Arc

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The continuous interaction between a subducting slab, overlying mantle wedge and crustal lithosphere profoundly affects the chemical evolution of the Earth. In terms of chemical mass balance, the interactions between the subducting components (oceanic crust, sediment and fluid) and the overlying mantle wedge are far from understood and their precise role in the genesis of arc magmas much debated. Controversy surrounds: 1) whether or not oceanic sediments are subducted, and if so, whether they are melted and recycled into the arc crust via magmatism, or continue into the deep mantle, 2) whether the oceanic slab is partially melted and incorporated into the arc crust, and 3) the role and composition of metasomatic fluids resulting from both the dehydration of sediments and altered oceanic slab. Determination of the chemical fluxes in island arc systems is central to debates concerning global geochemical recycling, modeling island arc magma genesis, and ultimately understanding the differentiation of the mantle and generation of the crust.

We have completed a Pb radiogenic isotope study on the volcanic rocks from Klyuchevskoy, Kamchatka as well as oceanic sediments collected near the Kamchatkan trench during Ocean Drilling Program, Leg 145. Klyuchevskoy volcano was chosen as it is well characterized and has erupted some of the most primitive basaltic magmas found in island arc settings thereby minimizing the effects of lithospheric involvement in magma generation. Continuously cored sediments collected parallel to the Kamchatkan trench provide the best analog for sediments previously subducted beneath the Kamchatkan arc.

Klyuchevskoy is the world's most active volcano, producing primarily basaltic material from high-MgO ($\sim$12 wt%) to high-Al_2O_3 ($\sim$18 wt%) basalts (Kersting and Arculus, 1994). The samples chosen for this study span the entire chemical range of erupted lavas. The overwhelming majority of sediments recovered from Leg 145 were diatomaceous oozes. The majority of sediments analyzed in this study were oozes, although two claystone and two nannofossil chalk samples were also analyzed. The North Pacific sediments analyzed represent approximately 50 million years of sedimentary deposition from the Eocene through the Pliocene.

The Pb isotope ratios of the Klyuchevskoy basalts plot within a narrow range in the Pacific MORB field and are the least radiogenic island arc basalts measured to date. In contrast, the North Pacific sediments plot well above the Pacific MORB field and exhibit considerably more scatter in their Pb isotopic ratios. Although the Pb concentrations of the different sediment types range from 2 ppm (nannofossil chalk) to 22 ppm (clay-rich sediment), the Pb isotopic ratios of the sediments are relatively constant from the Eocene through the Pliocene. There is no correlation between sediment type and Pb isotopic composition or between the Pb isotopic ratio of the sediments and their respective Pb concentration.

If previously subducted sediments were mixed into the overlying mantle wedge beneath the Kamchatkan arc (assumed to have a Pacific MORB Pb isotopic signature), the Pb isotope ratio of the erupted Klyuchevskoy lavas should lie somewhere between the two end-member components (MORB and North Pacific sediments). This is not observed. The entire erupted Klyuchevskoy suite plots within the Pacific MORB field. If the Klyuchevskoy lavas were produced from a mixture of sediment and MORB, they should plot along a linear mixing line between these two end-member compositions. Instead they have a narrow, isotopically homogenous range with respect to Pb. We conclude that the subducted oceanic sediments were not involved in the genesis of the Klyuchevskoy lavas. We further suggest that the dominant chemical source in the production of the Klyuchevskoy lavas is the mantle wedge plus a fluid flux resulting from the dehydration of altered oceanic crust, imparting a relatively unradiogenic MORB Pb composition.

In contrast to the above results, strong evidence for the subduction and incorporation of sediments in the source region of some arc magmas comes, in part, from recent ^{10}Be data studies (e.g. Brown *et al.*, 1982; Morris and Tera, 1989). The presence of elevated ^{10}Be concentrations in some island arcs volcanic rocks compared to MORB has been interpreted as evidence for sediment involvement in the source of these arc magmas. It is still not clear why ^{10}Be isotopic anomalies are found in some arcs (e.g. Aleutians, Kuriles) and not others (e.g. Japan, Marianas). Tera *et al.* (1993) analyzed a series of young volcanic rocks from Kamchatka and reported no elevated ^{10}Be isotopic anomalies. Clearly, no single generalized model is adequate to explain both the apparent lack of sediments involved in the source magmas beneath Klyuchevskoy, Kamchatka and the inferred incorporation of sediments in the Aleutian and Kurile arc magmas.

Whether or not subducted sediments are intimately involved in the source regions of arc magmas or further incorporated into the deep mantle is determined by a complex interplay of critical parameters such as age of the subducting crust, the rate and angle of subduction, and depth to the Wadati-Benioff zone. The extent by which sediments chemically influence arc magmagenesis or deep mantle heterogeneity will vary from arc to arc reflecting real differences between geodynamical constraints that ultimately influence melting and dehydration reactions occurring between the slab-mantle interface. The contrasting behavior of subducted sediments in different island arcs points out the need to look for unique features in individual arcs rather than relying solely on similarities in order to govern our understanding of the major factors controlling arc evolution.

References

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