The Aleutian island arc near Adak as a GeoPRISMS focus site: Finally, a Subduction Factory that actually makes continental crust?

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Volcanic arc systems are one of only two environments on Earth that produce unsubductable and therefore (by one definition) "continental" crust. However, a fundamental discrepancy — the so-called "andesite paradox" — appears to exist between the bulk composition of continental crust (~andesite) and the bulk composition of island arcs studied to date (~basalt), as inferred from both seismic surveys and geochemical studies. Recent studies in the Izu-Bonin-Marianas arc have only deepened the mystery: despite the presence of thin mid-crustal layers that might be relatively silicic (e.g., [*Kodaira et al.*, 2007; *Suyehiro et al.*, 1996]), the seismic velocities of the island arc crust are significantly higher than that of continental crust and indicate a bulk composition, and primary magma, that is essentially basaltic [*Tatsumi et al.*, 2008]. This raises important questions: Have island arcs ever been a significant contributor to continental growth? If so, does this imply that island arc compositions in Earth's past were different than today? Are there any modern island arcs that produce crust that looks "geophysically" like continental crust?

The best place in the world to address these questions is the central Aleutians near Adak Island. Lavas and (especially) plutons near, and west of, Adak are more similar to the composition of

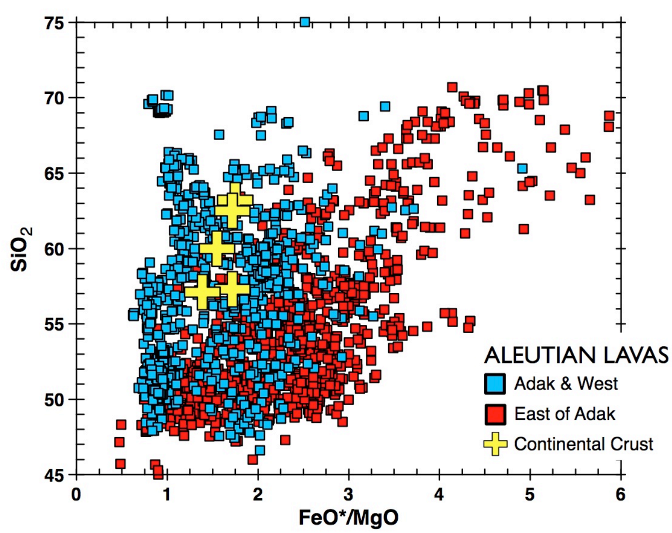

Figure 1. Silica vs. FeO/MgO plot of Aleutian lavas, including both dredge hauls and lavas sampled from volcanoes. Note the similarity between lavas at and west of Adak and the values for continental crust. Lavas east of Adak are dominantly basaltic in composition and predict faster bulk crustal velocity, as found in the 1994 Aleutians seismic survey.

continental crust than are magmatic rocks from any other oceanic arc (e.g., Fig. 1). This is true of both major and trace element chemistry (e.g., [*Yogodzinski and Kelemen*, 2007]). Aleutian lavas show a fundamental, first-order along-arc change in major-element composition on a regional scale, from dominantly tholeiitic east of Adak to dominantly enriched, calc-alkaline west of Adak. A similar trend is seen in trace elements, but the systematic along-arc change in *major elements* presents a rare opportunity to link arc geochemistry with seismic velocity structure. Given existing geophysical surveys in the Aleutians east of Adak [*Fliedner and Klemperer*, 1999; *Holbrook et al.*, 1999; *Lizarralde et al.*, 2002; *Shillington et al.*, 2004; *Van Avendonk et al.*, 2004], similar surveys further west would enable such comparisons.

We suggest that a crustal-scale seismic survey (Fig. 2), combined with geochemical sampling and modeling, of the Aleutian arc near and west of Adak will provide a fundamental test of the hypothesis that island arc magmatic processes can (and therefore may have in the past) produce crust that, both chemically and geophysically, resembles continental crust. The data compiled in Figure 1 suggest that if there is *anyplace* on Earth where actively forming island arc crust should have the geophysical characteristics of average continental crust, it is in the central and western Aleutians. Failure to find such crust here would effectively close the case on modern island arcs as analogs for continental crust. This area thus enables a *definitive* hypothesis test of the "andesite paradox."

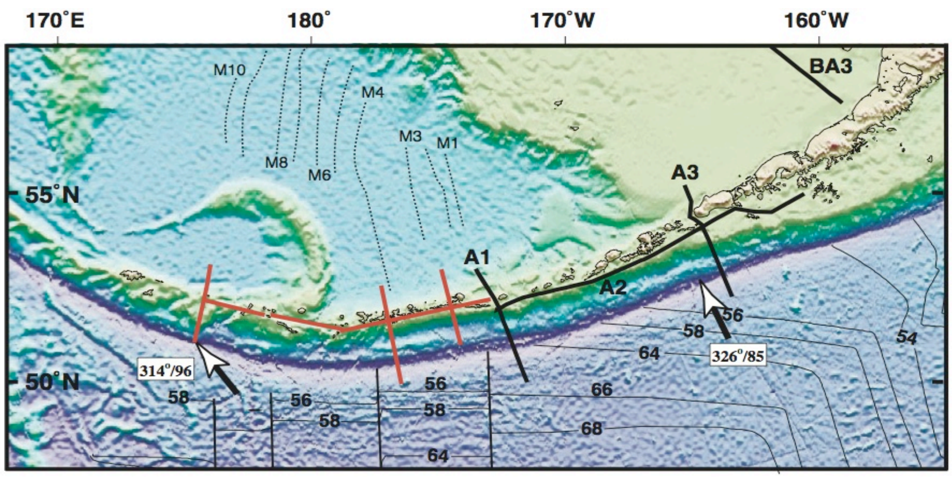

Figure 2. Notional seismic survey across the central/western Aleutians. Red lines show one possible layout of deep-crustal seismic surveys; bold lines labeled A1, A2, A3, and BA3 are MCS/wide-angle seismic lines of the 1994 Aleutian seismic experiment. Lighter labeled lines on the Pacific plate are oceanic lithosphere isochrons in m.y., and dashed lines in the Bering Sea are Cretaceous magnetic lineations of the relict Kula plate. Large arrows indicate Pacific plate motion vectors, labeled with azimuths and speeds in km/my.

Other compelling reasons exist for selecting the Aleutians as a GeoPRISMS focus site. First, the central Aleutians are the intact product of ~50 m.y. of island arc magmatism and offer a relatively pristine, simple setting to study subduction processes. The lack of intra-arc rifting is crucial because it enables the time-integrated magma flux and the bulk composition of the arc to be directly measured by seismic methods; only a relatively simple correction is necessary for pre-existing oceanic crust, whose structure is readily obtainable. Second, the Aleutians encompass systematic along-arc changes in "input" (forcing functions) and "output" (lava chemistry). Well-documented, systematic along-strike variations in subduction parameters make the Aleutians the best place in which to evaluate the effect of input forcing functions on magma flux, lower and mid-crustal composition, and mantle wedge structure in a pristine island arc (Figure 3). Third, existing reconnaissance reflection/refraction studies, especially the 1994 Aleutians experiment, provide an important framework for designing modern, higher-level studies. The 1994 experiment established that active-source airgun arrays can provide clear vertical-incidence and wide-angle returns from the arc Moho and the slab, at depths up to 50 km [*Holbrook et al.*, 1999]. Finally, the Adak region has very well-characterized seismicity for a purely oceanic arc segment. Monitoring began in 1965 [*Engdahl*, 1971] and continued through the early 1990's [*Taber et al.*, 1991]. This wealth of data, coupled with numerous earthquake studies means that the geometry and structure of the slab are known to first-order.

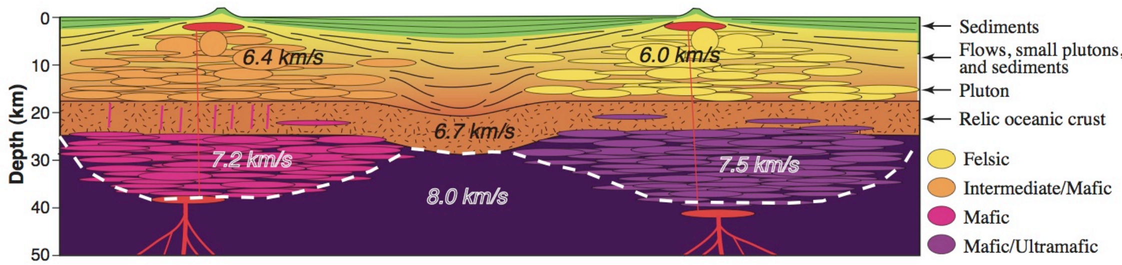

Fig. 3. Cartoon to illustrate one possible scenario of along-arc variations in crustal structure and to highlight our generally poor understanding of magmatic emplacement processes in volcanic arcs. Melt extraction that becomes focused in the mantle results in focused magmatic accretion, producing along-arc crustal thickness variations. Estimates of flux and composition based on cross-arc measurements alone could be misleading for this situation. Also indicated are two end-member scenarios for fractionation of a uniformly basaltic primary magma. On the left, little fractionation takes place and basaltic lavas are erupted, as at Atka.

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