

Seismic structure of the Aleutian island arc near Adak: Finally, a Subduction Factory that actually makes continental crust?

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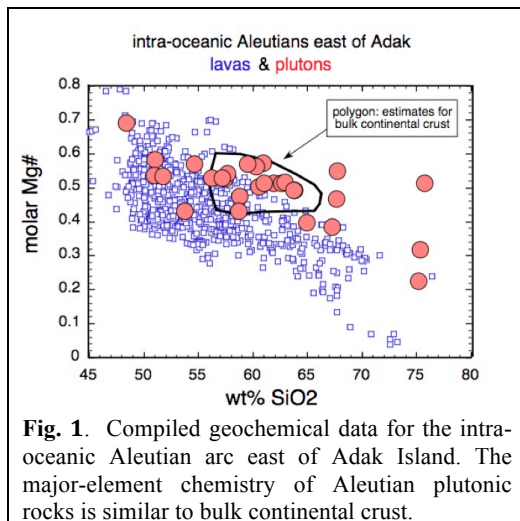
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An important goal of the GeoPRISMS program will be to answer the following question: “What are the geochemical products of subduction zones, from mantle geochemical reservoirs to the architecture of arc lithosphere, and how do these influence the formation of new continental crust?” This question is driven in large part by the long-standing “andesite paradox” – that is, the discrepancy between the bulk composition of continental crust (~andesite) and that of island arcs studied to date (~basalt). 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 (“boninite”), the seismic velocities of the island arc crust are significantly higher than that of continental crust and indicate a bulk composition that is essentially basaltic. 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 this question is the central Aleutians near Adak. Lavas and (especially) plutons near Adak are more similar to the composition of continental crust than are magmatic rocks from any other oceanic arc (Fig. 1). This is true of both major and trace elements. The compositional contrast between lavas, which tend to be more basaltic, and plutons, which tend to be intermediate to felsic, raises fundamental questions about the composition of primary magma(s) in the arc and the fractionation processes that take place within the crust.

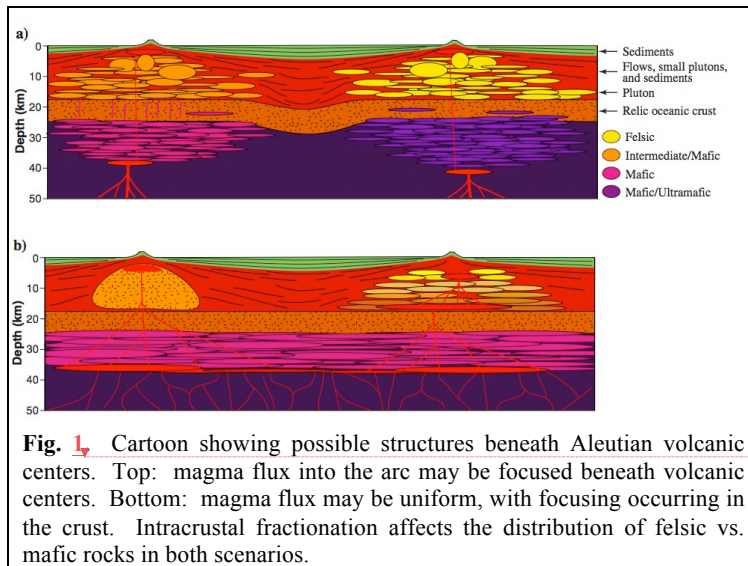


Lavas erupted from the Aleutian arc show a fundamental, first-order along-arc change in major-element composition on a regional scale, from dominantly tholeiitic east of Adak to dominantly enriched, calc-alkaline west of Adak. Presumably, this contrast indicates that fundamentally different magmatic processes occur in the eastern and western Aleutians. Two hypotheses that can explain this contrast are: 1) the composition of the primary magma might vary along the arc, from basaltic to (high-Mg) andesitic, perhaps due to changes in mantle wedge processes, sediment flux, or slab melting as subduction becomes oblique; and 2) primary arc magmas might be relatively invariant (basaltic) along the arc, but fractionation processes might vary, following a tholeiitic trend

east of Adak but a calc-alkaline trend to the west

These hypotheses predict substantially different seismic structures along the arc. Fractionation processes may present a variety of crustal structures, summarized in Fig. 2, depending on at what depth both fractionation and magmatic focusing occurs. This figure depicts basaltic-composition magmas crossing the Moho. Along-arc changes in primary-magma bulk composition would be expressed in these cartoons as a bulk shift to higher silica. A successful

test of these two hypotheses thus requires well-resolved images of internal crustal structure and well-constrained estimates of bulk composition. It also requires that the fundamental assumption of such a test be true, namely that crustal structure reflects a simple time integration of quasi steady-state arc crustal construction processes. On this last requirement, the Aleutians also excels as a primary site for such a study. Unlike the now well-studied arcs of the western Pacific, the Aleutians has not had a long history of arc rifting, and it is not actively rifting now. The time-integrated crustal products of arc magmatism are intact. In addition, the oceanic lithosphere upon which the arc was built is quite simple – it has not, for example, been affected by LIP magmatism. This simplicity, including the lack of active back-arc basin processes, will be crucial for identifying the potential effects of a third process that could alter the bulk composition of the crust, lower-crustal delamination. We would argue that it is only within a very simple arc setting, lacking complex mantle-wedge dynamics, and through a program where ancillary geodetic and passive seismic programs are likely to occur, that this substantial “X factor” can be assessed.



A crustal-scale seismic survey of the Aleutian arc near and west of Adak (Fig. 3) will test several critical hypotheses regarding the role of island arcs in forming continental crust: (1) Island arc magmatic processes can (and thus may have in the past) produce crust that resembles continental crust chemically and geophysically. (2) Bulk crustal composition changes along the arc and correlates with lava chemistry, subduction velocity and/or subducted sediment flux; and (3) Magma flux in the

Aleutians changes in concert with bulk crustal composition. Total magma flux can be estimated by determining crustal thickness; major-element crustal composition can be estimated from crustal P- and S-velocities. In concert with studies of the ages and geochemistry of Aleutian lavas and plutonic rocks likely to occur through GeoPRISMS, such a study has the potential to finally put to rest the “andesite paradox.”

