High-magnesian andesite from Mount Shasta: A product of magma mixing and contamination, not a primitive melt: COMMENT AND REPLY

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Streck et al. (2007) state that primitive andesite lavas (Mg# > 0.6; 53–63 wt% SiO_2) from Mt. Shasta are not primary melts, but instead are mixtures of evolved, high-Sr/Y, low-Mg# dacite with primary, low-Sr/Y, high-Mg# basalt. They propose that this mixing forms primitive andesites worldwide, and they dismiss the idea that primitive andesite is an end member in arc magmatism.

Magma mixing is evident in primitive Aleutian andesites (e.g., Kay, 1978; Kelemen et al., 2003a; Yogodzinski and Kelemen, 1998) and xenoliths (e.g., Conrad et al., 1983; Yogodzinski and Kelemen, 2007). Streck et al. imply that our data support their hypotheses, but Aleutian mixing requires a primitive andesite end member with the highest Mg#, Cr, Ni, Th, Ba, Sr and light rare Earth elements (REE), and lowest Y and heavy REE. We show this with Sr/Y versus Mg# (Fig. 1A). High-Sr/Y lavas are mixtures of a low-Mg#, low-Sr/Y component and a high Sr/Y, high Mg# component. The high Sr/Y component is an andesite (Fig. 1B) with Mg# ~0.7, in Fe/Mg equilibrium with mantle olivine. There are no low Mg# lavas with higher Sr/Y, so the Streck et al. process did not form end-member Aleutian primitive andesites.

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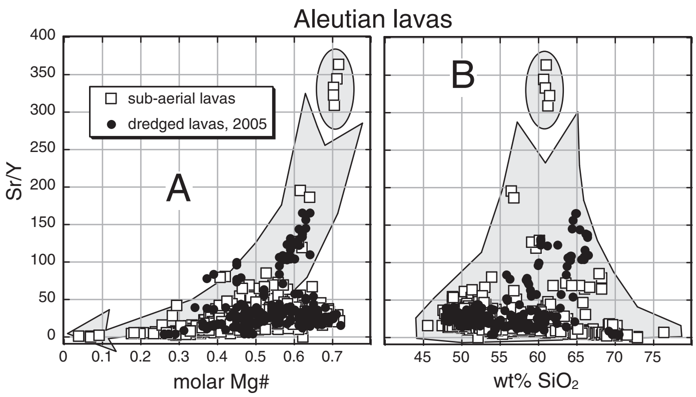

Figure 1: Compositions of lavas from the oceanic Aleutian arc (compiled by Kelemen et al. [2003a], plus lavas dredged on the 2005 Western Aleutian Volcano Expedition). Yb*9.6 used instead of Y for samples with Sr data but no Y. One sample with discrepant Y and Yb is omitted.

Mt. Shasta data (Fig. 2) are similar to that from the Aleutians, with a mixing trend extending toward a high-Sr/Y, high-Mg# andesite end member, nearly perpendicular to the mixing proposed by Streck et al. If their process formed any lavas at Mt. Shasta, they are rare. In any case, by analogy with the Aleutians, their dacite end member (Mg# 0.61) formed from a primitive andesite.

Streck et al. also misrepresent Pb isotope data for arc lavas. Citing our work (Kelemen et al., 2003b), Streck et al. (2007, p. 353) write, "elevated Pb isotopic signatures of [primitive andesites] worldwide could be interpreted in terms of a crustal contribution." However, Kelemen et al. (2003b, our Figure 9; 2003a, our Figures 7–11) show that Aleutian primitive andesites have the most depleted, least "crustal" Sr, Nd, and Pb isotopes of any arc magmas worldwide.

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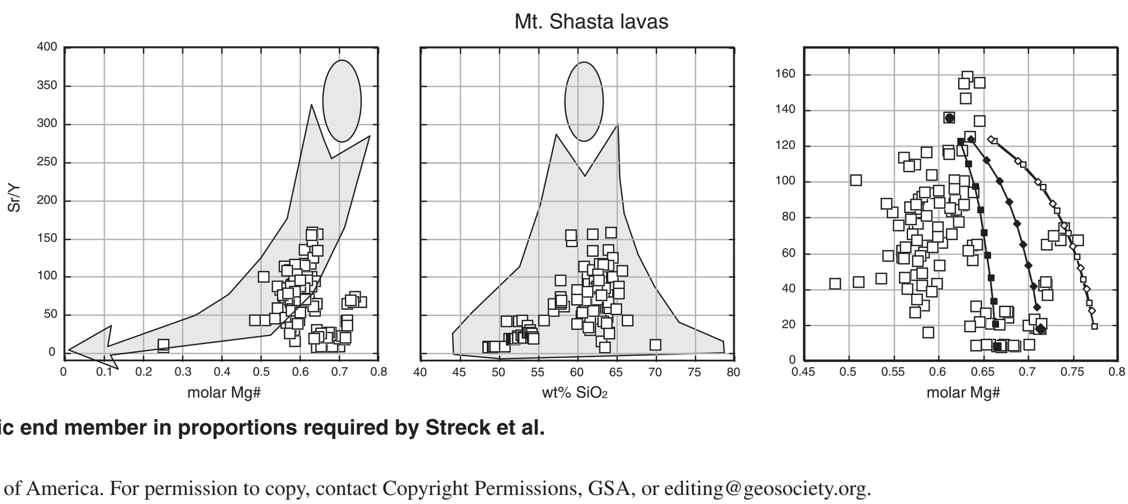

Figure 2: Compositions of lavas from Mt. Shasta (Grove et al., 2002, 2005). Right panel, with expanded vertical axis, illustrates lava data and mixing trajectories from Streck et al. (2007). Along these mixing trajectories, symbols are as follows: Circle—"dacite;" square—"high alumina olivine tholeiite" (HAOT); diamond—"basaltic andesite" (BA); filled symbols—lava mixing alone; open symbols—lava mixing after harzburgite is added to mafic end member in proportions required by Streck et al.

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The comment by Kelemen and Yogodzinski (2007) criticizes extrapolation of our results for Mt. Shasta high-Mg andesite (S-HMA) to interpretations of other occurrences of HMA. Our intent was to encourage the petrologic community to re-examine all HMAs to better understand their petrogenesis on an individual basis. Where mixing is evident, it is critical to identify the end members involved and their origins. Although we did not specifically link our study to Aleutian HMAs (A-HMA), Kelemen and Yogodzinski suggest the latter could be a common high-Mg# and high-Sr/Y end member with global significance to arc petrology, including Mt. Shasta.

S-HMA can be explained as a mixture of high-Sr/Y dacite and low-Sr/Y basalt, with ultramafic contaminants (Streck et al., 2007). S-HMA differs from A-HMA in having significantly higher MgO, Ni, Cr, etc. (Fig. 1). However, the presence of reversely zoned clinopyroxene with Fe-rich cores (Mg# ≤75) in some of the highest-Sr/Y A-HMAs (Yogodzinski and Kelemen, 1998; Kelemen and Yogodzinski, 2007), indicate that these lavas may also be mixtures of low- and high-Mg# magmas. We do accept that they are unique, but we question their role as being globally significant and that they contribute to formation of magmas at Mt. Shasta (Figs. 1 and 2).

Although Mt. Shasta dacites with narrow ranges in SiO_2 (62–64 wt%) and MgO (3–4 wt%) appear to project toward A-HMA (Kelemen and Yogodzinski, 2007, their Fig. 2) (our Fig. 1A), in diagrams such as Sr versus Ba and Sr/Y versus La (Fig. 2), the field for A-HMA lies well off the Shasta dacite trend (as well as opposite the dacite trend from S-HMA) and appears to be a poor end member. It is conceivable that the Mt. Shasta dacite trend (with a large range in Sr/Y) may be an artifact of generating dacites via fractional crystallization and/or of partial melting of variable protoliths at variable pressure. It is also possible that source Sr/Y could vary in response to the addition of variable amounts of high-Sr/Y slab-derived fluid. However, if the dacites are crustal melts, then slab fluids might play little part, but rather the amount of garnet (and/or amphibole) versus plagioclase in the crust would control melt compositions. In any case, A-HMA is unusual in having low MgO but high Mg#; this implies low Fe^{2+} content—could this be a consequence of oxidation of iron? Shasta dacites similarly have high Mg#—coincidence, or is there a connection?

Finally, our comment regarding Pb isotope data was paraphrased from Kelemen et al. (2003, p. 616) who state: "In all of these localities [referring to other HMA localities], other than the Aleutians, most high Mg# andesites have elevated $^{208}Pb/^{206}Pb$, compared to MORB. Thus lead isotope data suggest the presence of a component derived either from recycling of lead from subducted sediment, or from crustal interactions of primitive basalts with older, continental crust and continentally derived sediment."

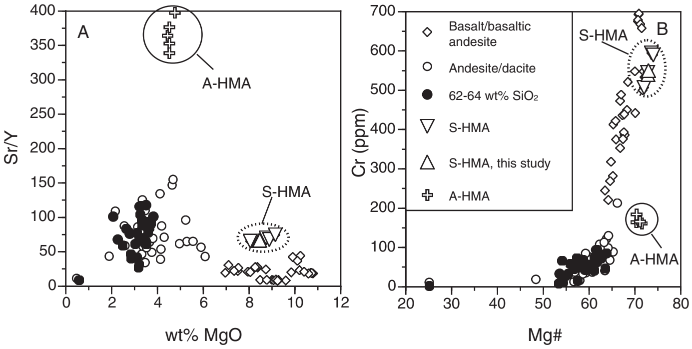

Figure 1. Mt. Shasta data (Baker et al.,1994; Grove et al., 2005; and this study) compared to Aleutian high-magnesian andesite (A-HMA) of Yogodzinski et al. (1995,). Circle with solid line encloses primitive A-HMA mixing end member proposed by Kelemen and Yogodzinski (2007).

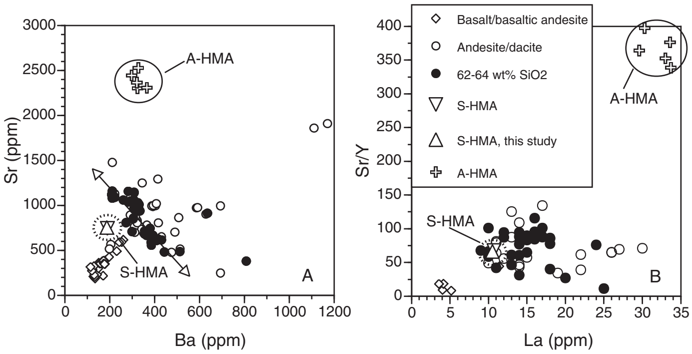

Figure 2. Mt. Shasta lavas compared to Aleutian high-magnesian andesite (A-HMA) (data sources and legend as in Fig, 1 and Grove et al. [2002]). Double-headed arrow defines trend in Mt. Shasta dacites (62–64 wt% SiO_2).

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