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Crustal Assimilation at Mid-Ocean Ridges Using Major and Trace Elements, Volatiles, Oxygen Isotopes and Petrologic Modeling

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While the majority of eruptions at spreading centers produce lavas with relatively homogeneous mid-ocean ridge basalt (MORB) compositions, the formation of tholeiitic andesites and dacites at mid-ocean ridges (MOR) remains a petrologic enigma. Andesitic and dacitic lava flows have been observed and sampled at several different locations along the global MOR system; including propagating ridge tips at ridge-transform intersections on the Juan de Fuca Ridge and eastern Galápagos spreading center, and at the 9°N overlapping spreading center on the East Pacific Rise. Despite the formation of these lavas at different ridges, MOR dacites show remarkably similar major element trends, incompatible trace element enrichments, and isotopic signatures suggesting similar processes control their chemistry. Although most geochemical variability in MOR basalts is consistent with low-pressure fractional crystallization of various mantle-derived parental melts, our geochemical data from MOR dacitic glasses suggest that contamination from a seawater-altered component is important in their petrogenesis. MOR dacites are characterized by elevated U, Th, Zr, and Hf and relatively low Nb and Ta, and P. Al2O3 and K2O concentrations in the dacites are higher than expected from fractional crystallization alone. Very high Cl and H2O concentrations and relatively low oxygen isotope ratios ($\sim$5.6 vs. expected values $\sim$6.9) in the fresh dacite glasses can be explained by magmatic contamination from a component of ocean crust altered by hydrothermal fluids. Crystallization of silicate phases and Fe-oxides causes an increase in delta18O in the residual magma but assimilation of material altered at high temperatures will result in the lower delta18O values. Additionally, petrologic modeling of MOR dacite compositions suggests that partial melting and assimilation are both integral to their petrogenesis. Extreme fractional crystallization of a MORB parent combined with partial melting and assimilation (AFC) of amphibole-bearing altered crust produces a hybrid magma with geochemical signatures consistent with MOR dacites. Most of the andesitic lavas are the result of mixing between evolved FeTi basalt and a highly evolved dacitic melt. Our data support the hypothesis that crustal assimilation is an important process in the formation of highly evolved MOR lavas and may be significant in the generation of evolved MORB in general. Additionally, these processes are likely to be more common in regions of episodic magma supply and enhanced magma-crust interaction, such as at the ends of ridge segments where MOR andesites and dacites erupt.