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Genesis of high-Mg andesites (HMA) through shallow fractionation of primitive arc basalts at elevated oxygen fugacities (and low initial water contents)

Georg Zellmer (1,2) and Gregory Shellnutt (1)

(1) Academia Sinica, Institute of Earth Sciences, Taipei, Taiwan (gzellmer@earth.sinica.edu.tw), (2) Lamont-Doherty Earth Observatory, 61 Route 9W, Palisades, NY 10964, USA

The petrogenesis of high-Mg andesites has been linked to a variety of processes, including partial melting of hydrous mantle peridotite, re-equilibration of partial melts of the subducting slab with the mantle wedge, and assimilation of lower crustal cumulates into dacitic melts. Yet none of these processes can explain the recently identified association of adakitic andesites, many of which are high-Mg andesites, with regions of elevated surface heat flux that are related to unusually shallow magma ponding levels in the upper crust (Zellmer, 2009).

Using MELTS modeling, we demonstrate here that at elevated oxygen fugacities (NNO+2, which based on whole-rock Fe^{3+}/Fe^{2+} ratios is appropriate for the Western and Central Aleutians, the Trans-Mexican Volcanic Belt, and the Setouchi Volcanic Belt), shallow crustal pressures (0.7 kbar), and initial H_2O contents between 0.5 and 4 wt%, iron-magnesium spinel will be fractionated from primitive arc basalts, producing andesitic residual melts with elevated Mg#. Subsequent assimilation of a few percent of autocrystic mafic phases makes typical high-Mg andesites with forsteritic olivines. Orthopyroxenes in equilibrium with these melts are Cr-rich due to increased uptake of Cr into orthopyroxene ($D^{opx/lq} \geq 25$) at lower temperatures ($\leq 1130^{\circ}C$) and elevated oxygen fugacities (NNO+2).

While arc magmas with high initial H_2O contents will undergo early degassing induced crystallization and viscous stagnation, lower primary melt H_2O contents will result in delayed crystallization and shallower magma ponding levels, accounting for elevated surface heat flux. Our findings are therefore consistent with the location of many high-Mg andesites in areas of high surface heat flux, and challenge the commonly accepted notion that these compositions are particularly hydrous primary melts generated in equilibrium with mantle peridotite.

Reference: Zellmer G.F. (2009) Petrogenesis of Sr-rich adakitic rocks at volcanic arcs: insights from global variations of eruptive style with plate convergence rates and surface heat flux. Journal of the Geological Society 166, 725-734. DOI:10.1144/0016-76492008-0721