Geophysical Research Abstracts
Vol. 14, EGU2012-877, 2012
EGU General Assembly 2012

The oxidation state of Fe in subduction zone basalts and implications for mantle oxygen fugacity

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The oxidation state of Fe (i.e. $Fe3+/\sum Fe$) in basalt is a sensitive indicator of the oxygen fugacity (fO_2) of magmatic systems. New μ-XANES analyses of global basaltic glasses provide constraints on $Fe3+/\sum Fe$ ratios, and thus fO_2, in glasses and melt inclusions at previously inaccessible spatial scales ($\sim$9 μm). Our results show that mid-ocean ridge basalts are more oxidized than previous studies have indicated (ave. $Fe3+/\sum Fe = 0.16 \pm 0.01$, n=103), shifting the fO_2 of the MORB source to conditions near the QFM buffer. The $Fe3+/\sum Fe$ ratio in MORBs increases with indices of fractional crystallization (e.g., decreasing MgO) along a trend consistent with crystallization of magmas in a system closed to oxygen exchange. Subduction zone basalts are more oxidized than basalts from other tectonic settings (e.g., higher $Fe3+/\sum Fe$), and this contrast may play a central role in the unique geochemical transformations that generate arc and continental crust. The processes that create oxidized arc magmas, however, are poorly constrained, although they appear inherently linked to subduction. Near-surface differentiation processes unique to arc settings might drive oxidation of magmas that originate in equilibrium with a relatively reduced mantle source. Alternatively, arc magmas could record the oxidation conditions of relatively oxidized mantle sources. Our results, examining $Fe3+/\sum Fe$ variations among co-genetic suites of olivine-hosted melt inclusions from arc settings, show dominant trends of magmatic reduction, rather than oxidation, during arc basalt differentiation. Magmatic reduction is often accompanied by S degassing, suggesting that the least degassed magmas are the most oxidized of a given melt inclusion suite, and that differentiation does not drive significant magmatic oxidation. The origin of elevated fO_2 of arc magmas must thus be a property of the arc mantle source. The $Fe3+/\sum Fe$ ratios of arc magmas correlate positively with minimally degassed magmatic H_2O contents, suggesting that the oxidation is strongly linked to the delivery of fluids from the subducted oceanic plate, which itself is oxidized, to the arc mantle wedge.