Evaluating the role of crustal assimilation on the oxidation state of arc magmas

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Oxygen fugacity governs magmatic evolution, phase assemblage, and gas speciation. Arc rocks tend to be several orders of magnitude more oxidized than those at mid-ocean ridges, however the processes that lead to oxidation have not been identified. Arc rocks may be more oxidized as a result of processes in the arc crust or variations in the oxygen fugacity (fO2) of the mantle source. Fractional crystallization and degassing processes appear unable to explain the disparity between the oxidation states of arc and mid-ocean ridge rocks. Here, we explore two additional mechanisms that may influence the oxidation state recorded by arc rocks: 1) assimilation of continental crust and 2) post- or syn-eruptive alteration. We use several proxies to estimate the fO2 recorded by natural samples from the Central Volcanic Zone of South America. Samples, including lavas, pumice and scoria were selected from a geographically constrained region (16°- 26°S) to ensure that they are the product of a similar mantle source. Samples span a range of crustal contribution, as indicated by their radiogenic isotope compositions ($^{87}Sr/^{86}Sr$ = 0.705-0.712), and cover the full range of magma compositions erupted during the Neogene history of the arc (52 - 74 wt.% SiO_2). Oxygen fugacity was estimated using three techniques: 1) whole rock Fe3+/∑Fe ratios, 2) Fe3+/∑Fe ratios in quartz- and olivine-hosted melt inclusions using micro X-ray absorption near-edge structure (XANES) spectroscopy, and 3) magnetite-ilmenite oxybarometry. Fe3+/∑Fe ratios range from 20-80% in these samples. This full range is observed for all stages of magmatic differentiation (basaltic andesites to rhyolites) and crustal assimilation (30-100%), and all eruptive products (lavas, pumice and scoria). Between volcanic centers we see large ranges in $^{87}Sr/^{86}Sr$ and no associated systematic variation in Fe3+/∑Fe as measured by wet chemistry. Samples from the same volcanic center but different eruptive events can span a large range in Fe3+/∑Fe ratios (20-65%) measured by wet chemistry yet show little to no variation in degree of crustal assimilation. In some cases, Fe3+/∑Fe ratios preserved in melt inclusions are inconsistent with whole rock ratios, suggesting that whole rock Fe3+/∑Fe ratios may be modified by eruptive or weathering processes. The three techniques employed in this study (micro-colorimetry, XANES, and magnetite-ilmenite oxybarometry) indicate that crustal assimilation does not systematically oxidize continental arc magmas. In addition, there appears to be no systematic variation in the range of Fe3+/∑Fe ratios as a function of fractionation, consistent with prior work.

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