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Amphibole fractionation and its potential redox effect on arc crust: Evidence from the Kohistan arc cumulates

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Abstract

Arc magmas, a major contributor to continental crust growth, are thought to be more oxidized than mid-ocean ridge basalts as reflected by an enrichment in ferric iron relative to ferrous iron. But how arc magmas become oxidized is hotly debated. It is acknowledged that the fractionation of common Fe-rich phases (e.g., amphibole) may change the Fe valence of the derivative melt. Amphibole has Fe-rich compositions commonly found in arc systems. We present high-precision (±0.01%) Fe valence data of amphibole and cumulates from the Kohistan arc determined by Mössbauer spectroscopy and bulk cumulate $Fe^{3+}/\Sigma Fe$ ratios by wet chemistry. We evaluate the $Fe^{3+}/\Sigma Fe$ trend of Fe-rich amphibole during arc magma fractionation. Our results show that bulk $Fe^{3+}/\Sigma Fe$ ratio of cumulates in mature island arc settings is mainly controlled by amphibole due to its abundance and decreases (from 0.4 to 0.2) with decreasing Mg# as $Fe^{3+}/\Sigma Fe$ ratios decrease in amphibole (from 0.35 to 0.2). Our modeling suggests that amphibole fractionation from parental arc magmas to $Fe^{3+}/\Sigma Fe$ above 0.2 may lead to an increase in $Fe^{3+}/\Sigma Fe$ ratios of middle–late stage residual melts by 0.1–0.3, and the partitioning of ferrous Fe into amphibole increases with the evolution of arc magmas. Our findings highlight the importance of petrological processes in the magma that contribute to the production of fertile arc crust.

Keywords: Amphibole, iron valence, Kohistan cumulate, redox state, porphyry deposit