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Experimental calibration of an Fe^{3+}/Fe^{2+}-in-amphibole oxybarometer and its application to shallow magmatic processes at Shiveluch Volcano, Kamchatka

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Abstract

Oxygen fugacity is an important but difficult parameter to constrain for primitive arc magmas. In this study, the partitioning behavior of Fe^{3+}/Fe^{2+} between amphibole and glass synthesized in piston-cylinder and cold-seal apparatus experiments is developed as an oxybarometer, applicable to magmas ranging from basaltic to dacitic composition. The partitioning of Fe^{2+} is strongly dependent on melt polymerization; the relative compatibility of Fe^{2+} in amphibole decreases with increasing polymerization. The Fe^{2+}/Mg distribution coefficient between amphibole and melt is a relatively constant value across all compositions and is, on average, 0.27. The amphibole oxybarometer is applied to amphibole in mafic enclaves, cumulates, and basaltic tephra erupted from Shiveluch volcano in Kamchatka with measured Fe^{3+}/Fe_{Total}. An average Fe^{3+}/Fe^{2+} amphibole-glass distribution coefficient for basalt is used to convert the Fe^{3+}/Fe_{Total} of amphibole in samples from Shiveluch to magmatic oxygen fugacity relative to NNO. The f_{O_2} of primitive melts at the volcano is approximately NNO+2 and is faithfully recorded in amphibole from an amphibole-rich cumulate and the basaltic tephra. Apparently, higher f_{O_2} recorded by amphibole in mafic enclaves likely results from partial dehydrogenation of amphibole during residence in a shallow andesite storage region. We identify three pulses of mafic magma recharge within two weeks of, a month before, and two to three months before the eruption and find that, at each of these times, the host andesite was recharged by at least two magmas at varying stages of differentiation. Application of the amphibole oxybarometer not only gives insight into magmatic f_{O_2} but also potentially details of shallow magmatic processes.

Keywords: Amphibole, oxybarometer, subduction zones, XAFS, experimental petrology