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Magma mush chemistry at subduction zones, revealed by new melt major element inversion from calcic amphiboles

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Abstract

We have used multiple-regression methods to calibrate new, pressure-independent empirical chemometric equations to calculate the major element composition of basanitic to rhyolitic melts in equilibrium with calcic amphibole. The equations are based on amphibole stoichiometric formula components ± temperature from published experimental *P-T-X* data and avoid some problems of previous studies associated with uncertainties in pressure determination. Compared with the pressure-dependent equations of Ridolfi and Renzulli (2012), tests run using an independent data set indicate that the new equations yield improved precision and accuracy, in particular for SiO_2, TiO_2, CaO, and K_2O. The results are only marginally more precise when temperature is used as a dependent variable, demonstrating that temperature has a relatively minor role in controlling amphibole crystal chemistry compared with melt composition. This allows us to accept a small decrease in precision in excluding temperature from the analysis, which is very convenient for application of the equations to natural amphiboles where temperature is typically unknown.

Using the new chemometric equations, reconstructed melt compositions in equilibrium with the rims of amphiboles in pumice clasts of the Ongatiti ignimbrite are in good agreement with coexisting matrix glass compositions, lending support for our analysis. The compositionally variable cores of the amphiboles give predicted melt compositions with large compositional variations from andesitic (63 wt% SiO_2) to high-Si rhyolite. These compositional variations in the predicted melt compositions suggest that there may be a range of heterogeneous melts undergoing progressive differentiation within a major crustal magma storage region underneath the volcano. The results support the existence of genuine intermediate composition melts within the storage region. Interaction between these stored melts, disaggregating mush fragments and replenishing magmas gives rise to the chemical complexity observed in erupted magmas. We also used our multiple regression model to predict the compositions of melts that were in equilibrium with amphiboles in plutonic nodules from Grenada lavas. The predicted melts cover a wide range of compositions, perhaps as a result of in situ fractionation, but are consistent with melt inclusions hosted in those cumulates, as reported by Stamper et al. (2014). Overall, our new pressure- and temperature-independent equations resolve issues associated with previous pressure-dependent studies and represent a useful tool for further investigation of crustal processes at subduction zones.

Keywords: Calcic amphibole, chemometrics, melt compositions, multiple regression, Ongatiti ignimbrite, plutonic xenoliths, Grenada