Mantle heterogeneity controls on small-volume basaltic volcanism

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We thank Brenna and Cronin (2015) for their Comment on our recent publication (McGee et al., 2015), and welcome the opportunity to further elaborate on the clear correlation between erupted volumes and chemical composition of primitive volcanic products in the Auckland Volcanic Field (AVF). After postulating that P2O5 content can be used as a proxy for La and rare earth element (REE) ratios in AVF basalts, Brenna and Cronin claim that the relationships we observe between erupted volumes and chemical signature of AVF basalts are, in fact, nonexistent when looking at the P2O5 content of most MgO-rich sample of 41 out of the 53 eruptions in the AVF. Here we show that there are several significant flaws in their argument, and furthermore suggest that the whole rock data they recommend we use, if in fact scrutinized correctly, actually validates our original observations.

First, the use of samples with the highest MgO content is fraught with difficulty, as it does not take into account the effect of crystal accumulation (MgO content in AVF lavas can reach up to 15 wt%), and moreover, it biases the data set by neglecting the significant compositional variability observed in primitive eruptive products from monogenetic centers (e.g., Brenna et al., 2011; Smith et al., 2008; Strong and Wolf, 2003). In our original contribution, we used data from 14 centers that have standard data associated with major and trace element analyses that could be rigorously scrutinized, that are represented by ≥10 samples (black circles in Fig. 1), and importantly, that span the volume and composition spectrum observed within our wider AVF database. For detailed inspection of melting and ascent processes, we focused on the 5 out of these 14 centers for which published U-series isotopes are available. Nevertheless, when reviewing all primitive samples from all 40 centers available for study (i.e., 7 < MgO wt% ≤ 13), the clear correlations between erupted volumes and SiO2 and CaO/Al2O3 that we initially reported are still apparent (Fig. 1). Furthermore, there is, in fact, a strong negative correlation between volume and P2O5 (Fig. 1C) contrary to the claim of Brenna and Cronin.

Second, we question the use of P2O5 as a proxy for La and REE ratios, which forms the basis of the argument of Brenna and Cronin. Bulk partition coefficients (D) for La and P in garnet peridotite are more than an order of magnitude different (DLa = 0.08, DP = 0.0039, using the Kp in P of Brunet and Chazot [2001] in OI, Cpx and Gt, and Ulmer [1998] in Opx, and Kp in La, and mineral modes from Beier et al. [2013]). The similarity in Kp for La and K (DK = 0.0041; Beier et al., 2013) indicates that variation in the K/La ratio (Kp/KpLa = 1) in AVF samples is due to variation in mantle source composition (supported by other features such as Sr and Nd-Hf anomalies, and Pb and U-Th isotopic data). Kp/P2O5 ratio (Kp/KpP ≤ 0.05), on the other hand, will be mainly controlled by partial melting degree, and thus cannot be used to test our observations.

Finally, Brenna and Cronin claim that our interpretations are inconsistent with the lack of correlation between eruption age and chemical composition in the AVF. This is a misunderstanding of our interpretation, as our model does not predict such a correlation. Instead, we proposed that the involvement of carbonated peridotite and the dilution of its chemical signature occur over the course of each melting event, not continuously over the lifetime of the field. In fact, a key finding of this study is that in order to preserve the spectrum of compositions in major and trace elements, and its clear correlation with eruptive volume, extraction of melt must be almost instantaneous in each melting event.

We conclude by suggesting that our study exemplifies the use of well-constrained, detailed analyses to highlight important features that may be missed when data are plotted indiscriminately; it also shows the importance of understanding the behavior of individual elements when applied to melting models.

REFERENCES CITED


