Forum Reply

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 P_2O_5 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 P_2O_5 content of the most MgO-rich sample of 41 out of the 53 eruptions in the AVF. Here we show that there are three 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 (white and gray circles in Fig. 1). 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 SiO_2 and CaO/Al_2O_3 that we initially reported are still apparent (Fig. 1). Furthermore, there is, in fact, a strong negative correlation between volume and P_2O_5

Figure 1. Correlations between volume (from Kereszturi et al., 2013) and (A) SiO_2, (B) CaO/Al_2O_3, and (C) P_2O_5 for 510 data points (MgO varies from 7 to 13 wt%) covering 40 volcanic centers in the AVF, all from our consolidated database. Filled black circles are the data from McGee et al. (2015), white circles are all other data from the wider AVF database. Gray filled circles are the most primitive samples from each center. Gray stars represent 7 centers for which only one sample is available.

(Fig. 1C) contrary to the claim of Brenna and Cronin.

Second, we question the use of P_2O_5 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 ($D_P = 0.08$, $D_{La} = 0.0039$, using the K_{DS} for P of Brunet and Chazot [2001] in Ol, Cpx and Gt, and Ulmer [1998] in Opx, and K_{DS} for La, and mineral modes from Beier et al. [2013]). The similarity in K_D for La and K ($D_K = 0.0041$; Beier et al., 2013) indicates that variation in the K/La ratio ($K_DK/K_DLa \approx 1$) 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). The K/P_2O_5 ratio ($K_DK/K_DP \approx 0.05$), 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

Beier, C., Mata, J., Stöckhert, F., Mattielli, N., Brandl, P., Madureira, P., Genske, F., Martins, S., Madeira, J., and Haase, K., 2013, Geochemical evidence for melting of carbonated peridotite on Santa Maria Island, Azores: Contributions to Mineralogy and Petrology, v. 165, p. 823-841.

Brenna, M. and Cronin, S. J. 2015, Mantle heterogeneity controls on small-volume basaltic volcanism: Comment: Geology, v. 43, doi: 10.1130/G37023C.1

Brenna, M., Cronin, S.J., Németh, K., Smith, I.E.M., and Sohn, Y.K., 2011, The influence of magma plumbing complexity on monogenetic eruptions, Jeju Island, Korea: Terra Nova, v. 23, p. 70-75, doi:10.1111/j.1365-3121.2010.00985.x.

Brunet, F., and Chazot, G., 2001, Partitioning of phosphorus between olivine, clinopyroxene and silicate glass in a spinel lherzolite xenolith from Yemen: Chemical Geology, v. 176, p. 51-72, doi:10.1016/S0009-2541(00)00351-x.

Kereszturi, G., Németh, K., Cronin, S.J., Agustín-Flores, J., Smith, I.E.M., and Lindsay, J., 2013, A model for calculating eruptive volumes for monogenetic volcanoes—Implication for the Quaternary Auckland Volcanic Field, New Zealand: Journal of Volcanology and Geothermal Research, v. 266, p. 16–33, doi:10.1016/j.jvolgeores.2013.09.003.

McGee, L.E., Millet, M.-A., Beier, C., Smith, I.E.M., and Lindsay, J.M., 2015, Mantle heterogeneity controls on small-volume basaltic volcanism: Geology, v. 43, p. 551–554, doi:10.1130/G36590.1.

Smith, I.E.M., Blake, S., Wilson, C.J.N., and Houghton, B.F., 2008, Deep-seated fractionation during the rise of a small-volume basalt magma batch: Crater Hill, Auckland, New Zealand: Contributions to Mineralogy and Petrology, v. 155, p. 511–527, doi:10.1007/s00410-007-0255-z.

Strong, M., and Wolff, J., 2003, Compositional variations within scoria cones: Geology, v. 31, p. 143-146, doi:10.1130/0091-7613(2003)031<0143:CVWSC>2.0.CO;2.

Ulmer, P., 1989, Partitioning of high field strength elements among olivine, pyroxenes, garnet and calcalkaline picrobasalt: Experimental results and an application: International Journal of Mass Spectr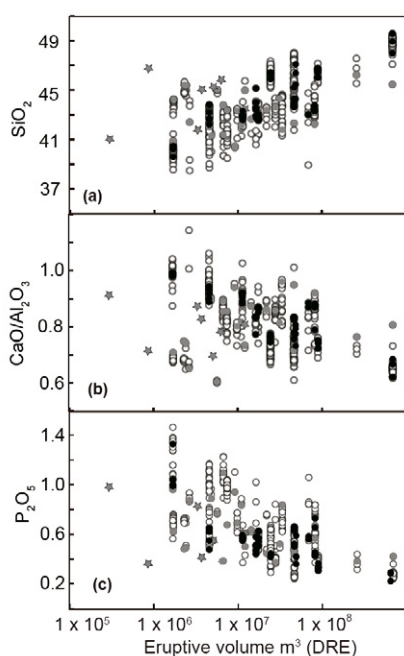ometry and Ion Physics, v. 89, p. 42-47.