Supplementary Materials for

Elevated magma fluxes deliver high-Cu magmas to the upper crust

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Methods

Fig. S1 – S2

Captions for Data S1 – S3

Brief explanation on calculating 'Shape Coefficients' [as per O'Neill (2016)]

Other Supplementary Materials for this manuscript include the following:

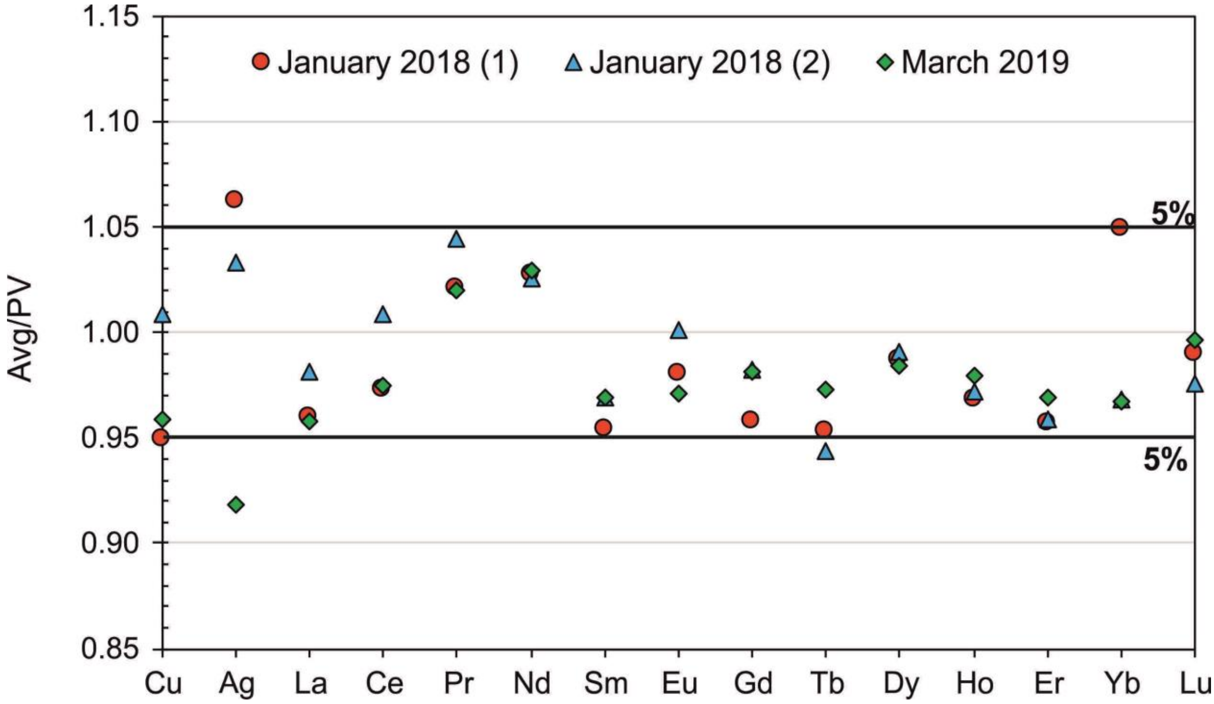
Data S1 – S3 (separate Microsoft Excel file)

METHODS

New analyses are presented here for volcanic rock (mostly lava) samples from Yate, Apagado, Hornopirén [*cf*. Watt et al. (2011, 2013)] and for samples from Villarrica, Quetrupillán, Lanín, San Pedro and Ollagüe stratovolcanoes situated within the Chilean Andes (Fig. 1). Samples were collected from separate lava or pyroclastic units, in most cases undated, with each sample believed to represent an individual eruptive event, and thus discrete batches of magma.

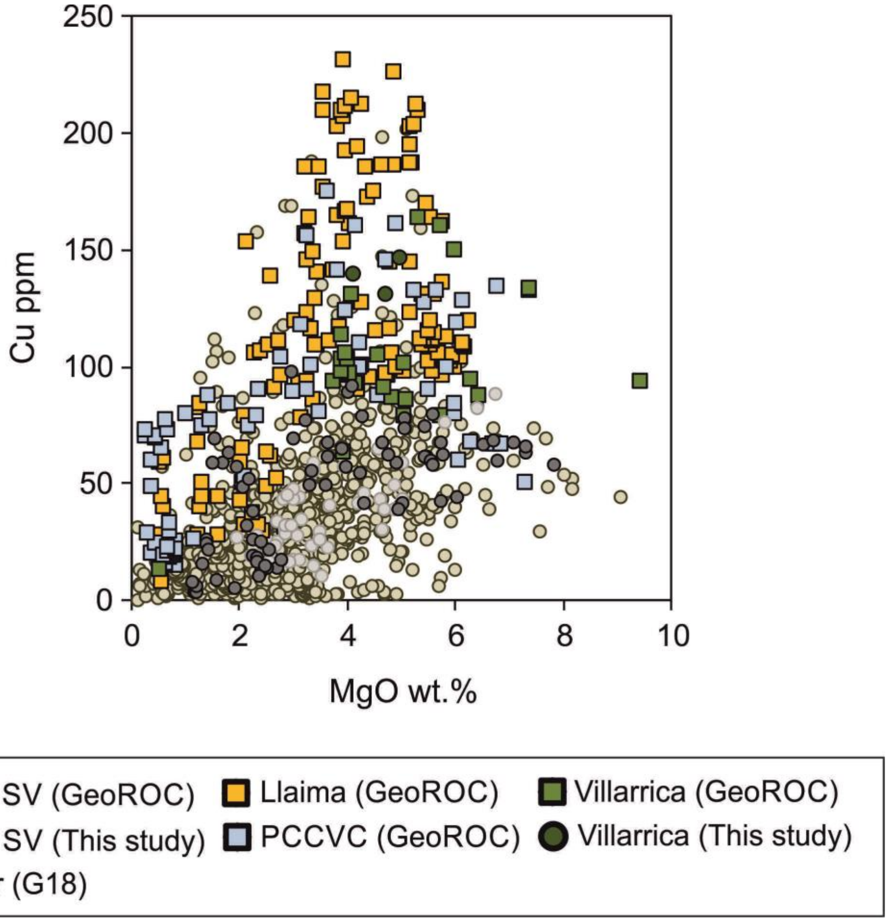
The major and trace element compositions of the stratovolcano samples presented in the current study were determined by whole rock analysis, following the analytical methods of Cox et al. (2019). Samples were analysed for their major element composition by either inductively coupled plasma – optical emission spectrometry (ICP-OES) at the School of Earth and Ocean Sciences, Cardiff University, U.K., or by X-ray fluorescence (XRF) at the School of Geology, Geography and the Environment, University of Leicester, U.K. The trace element compositions of the samples were determined by ICP-MS/MS at the School of Environment, Earth and Ecosystem Sciences, Open University, U.K. Reference material BHVO-2 was used as a monitor to track and correct for instrument drift. Data accuracy was assessed using a range of ISRMs across analytical techniques. The analyses of these ISRMs were mostly within 5% of published values for the major elements and within 7% of published values for the trace elements (Fig. S1).

Figure S1



Multi-element plot presenting the accuracy of averaged analyses of Cu, Ag and the rare earth elements of the BHVO-2 monitor for each analytical session over which data was acquired (i.e., January 2018). Accuracy is mostly better than 5%. Avg.: average; PV: preferred values for the BHVO-2 monitor housed at The Open University.

Figure S2



Copper – MgO bivariate plot comparing the Cu contents of stratovolcanoes (SV) across the Central and Southern Volcanic Zones of the Chilean Andes to those presented in the current study and from Ecuadorian stratovolcanoes [G18: data from Georgatou et al. (2018)]. Copper and MgO data for the Chilean stratovolcanoes has been compiled from the Andean Arc (parts 1 and 2) GeoROC databases [*http://georoc.mpch-mainz.gwdg.de/georoc*: accessed 25/01/20]. The Andean Arc databases were filtered to include only whole rock analyses of volcanic rocks from named stratovolcanoes. Analyses of metamorphic and sedimentary rocks, pegmatites, plutonics, veins, ores, mantle xenoliths, minerals, glass and inclusions were all removed. PCCVC: Puyehue – Cordon Caulle Volcanic Complex.

Data S1 (separate file)

Microsoft Excel file presenting raw analyses for new samples presented in the current study and International Standard Reference Materials.

Data S2 (separate file)

Microsoft Excel file presenting International Standard Reference Material data.

Data S3 (separate file)

Microsoft Excel file presenting filtered data from the Andean Arc databases of GeoROC, as presented in Fig.’s 2a and S2.

Calculating rare earth element ‘Shape Coefficients’

The ‘shape coefficients’ (λ_1, λ_2) presented in this study are based on the work of O’Neill (2016). These ‘shape coefficients’ provide a means through which the smoothness and shapes of chondrite normalised rare earth element (REE) patterns can be assessed, easily presenting large volumes of data. Such ‘shape coefficients’ take into consideration each of the REE (as opposed to specific REE) when assessing, for example, the linear slope (λ_1) and curvature (λ_2) of a chondrite normalised REE pattern.

To calculate these ‘shape coefficients’, chondrite normalised REE patterns are fitted to orthogonal polynomials. It is from these orthogonal polynomials that the ‘shape coefficients’ are determined. Full details on how to calculate each ‘shape coefficient’ can be found in O’Neill (2016), with the associated supplementary Excel spreadsheet (with embedded macros) allowing the automatic calculation of these coefficients.

Additional References

Watt, S.F.L., Pyle, D.M., Mather, T.A., and Naranjo, J.A., 2013, Arc magma compositions controlled by linked thermal and chemical gradients above the subducting slab: Geophysical Research Letters, v. 40, p. 2550–2556.

Watt, S.F.L., Pyle, D.M., Naranjo, J.A., Rosqvist, G., Mella, M., Mather, T.A., and Moreno, H., 2011, Holocene tephrochronology of the Hualaihue region (Andean southern volcanic zone, ∼42° S), southern Chile: Quaternary International, v. 246, p. 324–343.