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Magma fluxes and storage beneath Grímsvötn volcano, Iceland, estimated from ice-kept historical tephra

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Compositional time-series can unravel the dynamics of magma systems beneath active volcanoes. In ideal cases, parameters such as magma flux, reservoir geometry, its lifetime and the transfer time of magma can be inferred from the compositional variations. Quantification of these parameters will improve the understanding of volcano behaviour and, thus, the predictions of their future activity. From the Grímsvötn volcano, Iceland, ice-kept historical tephra has been precisely analysed for trace element concentrations and Sr-, Nd- and Pb isotope ratios. Most of the tephra have uniform isotope ratios suggesting co-genetic magma evolution. Temporal variations of the tephra compositions over the last eight centuries reveal linear decrease and increase in compatible and incompatible trace element concentrations, respectively, caused by eruptions of increasingly differentiated basaltic magma with time. The trace element systematic is readily explained by polybaric fractional crystallization suggesting a magma system composed of multiple storage zones beneath Grímsvötn volcano.

The simple mechanism of magma differentiation and the temporal variations allow estimation of diminishing melt fraction (F) in the magma system as a function of time. Increasing concentrations of incompatible elements in the basalts suggest that F decreased by 35% over the last 800 years. This corresponds to a slow magma differentiation rate, or ∼4 x10-4 yr-1. Magma production rate for the 20th century suggests that approximately 8 km3 of basalts have erupted since AD 1200, whereas the volume of the magma system has decreased from approximately 100 km3 to 70±20 km3. Assuming a similar future behaviour, Grímsvötn volcano will produce for the next 500-1000 yrs basalts of increasingly evolved composition with higher volatile contents. Consequently, Plinian basaltic eruptions such as that of 2011 are likely to become more frequent.