Geophysical Research Abstracts
Vol. 21, EGU2019-4083, 2019
EGU General Assembly 2019

Phonolite phenocrysts, Cumulates and Syenites: different eruption products from the Laacher See volcano (Germany) constrain the pre-eruptive magmatic history

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Time-scales extracted from chemically zoned minerals provide insights into crystal residence time, magma storage and compositional evolution of magmas and allow better constraints on pre-eruptive history of large and potentially dangerous magma chambers. We studied chemical diffusion across zoning and exsolution patterns of alkali feldspars (1) in carbonatite-bearing cognate syenites, (2) as phenocrysts in phonolite, and (3) from cumulates: all these are different products from the 6.3 km^3 (D.R.E) phonolitic Laacher See Tephra (LST) deposit in western Germany (12.9 ka).

Diffusion chronometry was applied to zoned alkali feldspars from each of the eruption products separately. (1) Modelling of K-Na interdiffusion in sanidines from syenites of known pre-eruptive age gives 630-670 ^oC as the range of effective storage temperature. These values along with a conduction model constrain the radial growth rate of the syenite carapace at $\sim$8 cm/year. Diffusion across the exsolution boundaries constrain the maximum time between the destabilisation of the system prior to eruption to be only 40-50 days. (2) Similar diffusion modelling was applied to Ba-diffusion across zonations in sanidine phenocrysts from the phonolite melt. The phenocrysts in the felsic samples (the top of the magma chamber), being very similar to those of the syenites and not being in equilibrium with the surrounding matrix, are interpreted to be xenocrysts that were entrained from the syenites into the phonolite during the unrest before the eruption. The phenocrysts in the mafic phonolites (the base of the magma chamber) have Ba-rich outermost rims of 2-10 μm which represents a late overgrowth after heating and destabilisation of the magma system. Diffusion modelling on the corresponding boundary gives a time scale of 4-7 years, which is interpreted to be the maximum duration between the most recent recharge event by basanite magma and eruption. However similar time-scales are not obtained from the phonolite of intermediate composition (middle of the magma chamber) suggesting that the effects of the basanite intrusion were limited only to the base of the magma reservoir. Diffusion time-scales obtained from the inner zones of the sanidine phenocrysts from both mafic and intermediate phonolites suggest another similar recharge event 1500-3000 years before the last basanite recharge. The cumulates (3), are entirely devoid of zoned crystals. Only crystals with resorbed boundaries or very thin overgrowths (a few microns) with very sharp compositional changes imply the activation of cumulates only months before eruption. Based on the diffusion time-scales and storage temperatures obtained from the zonation and exsolution in feldspars from different products of the same magma system, we present a genetic model for the process and timing of storage and activation of the system prior to the eruption of Laacher See.