Bang! Month-Scale Eruption Triggering at Santorini Volcano

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Many large silicic volcanic eruptions are thought to be triggered by intrusion of hotter, more-mafic melt into an existing magma chamber at depth, but the timing between trigger and eruption has been difficult to determine. We used diffusion profiles of olivine crystals from blebs of andesite magma to show that the 1925–28 eruption of Nea Kameni Volcano, Santorini (Greece) was triggered by a mafic magma intrusion about 1 month earlier.

The 1925–28 eruptive cycle of the Nea Kameni volcanic center produced a silicic magma (dacite) with entrained fragments (enclaves) of a more mafic magma (basaltic andesite). These enclaves represent a pre-eruptive recharge event, where hot, basaltic andesite intruded into the base of the cooler, dacitic magma chamber (*1*). As the basaltic andesite chilled, volatile saturation occurred, and the andesite overturned, rapidly distributing enclaves and heat into the overlying dacite, triggering eruption in a manner analogous to that proposed for eruptions at Thera and elsewhere (*2*, *3*).

Enclaves within the 1925–28 lava flow contain zoned olivine crystals that record a complex and intriguing history. Magnesium-rich crystal cores imply derivation from a basaltic parent melt but are hosted in andesitic enclaves, suggesting remobilization of basaltic crystallization products by a later, andesitic melt. This hybrid basaltic andesite was then intruded into the cooler dacitic magma chamber, where it quenched and solidified while transferring its heat to the overlying material (*1*). During this process, iron-rich rims formed on olivine crystals, and an adjacent crystal framework of plagioclase feldspar grew. Diffusive exchange between the Mg-rich crystal cores and their Fe-rich rims occurred during the period between input of the volcanic trigger and subsequent eruption of the volcano.

Fe-Mg diffusion rates within olivine are relatively well constrained (*4*) and both strongly temperature-dependent and anisotropic. Plagioclase-melt thermometry (*5*) constrains the maximum intrusion temperature of the Santorini basaltic andesite hybrid at 1080 ± 30°C (2σ). Oxygen fugacity (fO_2) was constrained between $10^{-9.6}$ and $10^{-9.9}$ bars, following (*6*).

Our method is similar to that used previously by (*7*), but we determined the Fe-Mg diffusion distance through back-scattered electron (BSE) compositional (*z*) contrast images (Fig. 1A), calibrating with electron microprobe point analyses. Crystallographic axis orientations were determined by electron back-scatter diffraction and U-stage (three-dimensional) petrography. We modeled diffusion profiles by using a two-dimensional, finite-difference method with composition-, orientation-, and activity-dependent diffusion parameters (Fig. 1, A to C). Further details can be found in the supporting online material.

The best fit of the forward model results to observed diffusion profiles for five crystals (Fig. 1D) implies that the basaltic andesite intruded into the magma chamber 15 to 75 days before eruption, with a >95% confidence interval of between 20 and 60 days. Understanding this recharge-to-eruption duration for previous eruptive cycles at Santorini, and potentially other volcanoes, is particularly valuable because the input of batches of recharging magma is detectable seismically. Thus, the use of previously erupted materials can, via this approach, obtain characteristic time scales that may ultimately lead to improved hazard forecasts.

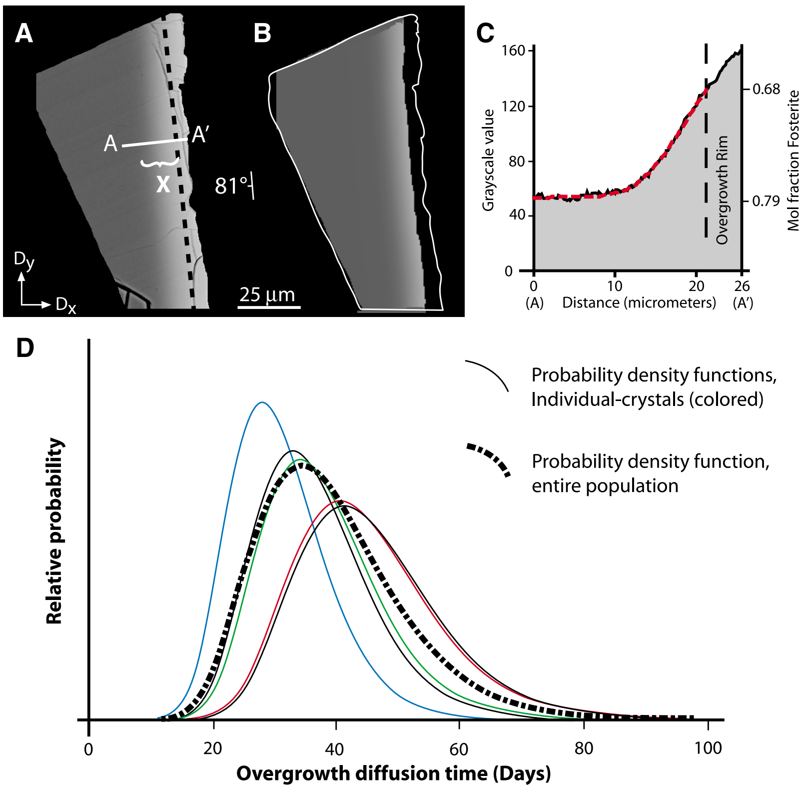

Fig. 1. Results from enclave sample K2-01. (**A**) Image of crystal Ol_08 showing diffused rim zone (**X**), overgrowth to right of dashed line, tick mark displaying dip of crystal face, and modeled components of diffusion (D_y, D_x). Fe-rich compositions appear as paler gray shades. (**B**) Result of best fit forward model, at 33 days equilibration. (**C**) Traverse A-A′ showing model (red line) and raw data (gray envelope), with gray scales and calibrated compositions. (**D**) Fine lines show intrusion-to-eruption time probability distributions for five crystals (calculated by using the combined temperature and fO_2 uncertainties); bold dash-dotted line shows the integrated probability for the entire population.

References and Notes

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Supporting Online Material

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Materials and Methods
References

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