Geophysical Research Abstracts
Vol. 19, EGU2017-16023, 2017
EGU General Assembly 2017

Petrological insights on the effusive-explosive transitions of the Nisyros-Yali Volcanic Center, South Aegean Sea

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Volcanoes erupting silicic, volatile-rich magmas can exhibit both effusive and explosive eruptions, even during closely spaced eruptive episodes. Understanding the effusive-explosive transition is fundamental in order to assess the hazards involved. Magma properties strongly influence the processes during magma ascent that determine the eruptive style. Here, we investigate the link between changing conditions in the magma reservoir and the eruptive style. The Quaternary Nisyros-Yali volcanic center, from the South Aegean Sea, provides an excellent natural laboratory to study this process. Over the last 60-100 kyrs, it produced a series of dacitic to rhyolitic eruptions that emplaced alternating effusive and explosive deposits (with explosive eruptions likely shortly following effusive ones). For this study, nine fresh and well-preserved units (five effusive and four explosive) were sampled and analyzed for whole-rock, groundmass glass and mineral compositions, in order to draw insights into the magma chamber processes and thermodynamic conditions that preceded both types of eruptions.

Silicic magmas in Nisyros-Yali record a complex, open-system evolution, dominated by fractionation in mushy reservoirs at mid to upper crustal depths, frequently recharged by warmer input from below. Storage temperatures recorded by the amphibole-plagioclase thermometer span a wide range, and they are always cooler than the pre-eruptive temperatures yielded by Fe-Ti oxide thermometry for the same unit, whether it is effusive or explosive. However, magmas feeding effusive eruptions typically reached cooler conditions (expressed by the presence of low-Al, low-Ti amphiboles) than in the explosive cases. The difference between the pre-eruptive and the lowest storing temperatures in the Nisyros series are in the order of 10-30°C for explosive units, while the difference is of about 40-110°C for the effusive units. The Yali series does not perfectly fit this pattern, where explosive units have also been heated for 50-100°C.

During crystallization and storage in subvolcanic magma reservoirs, relatively cold conditions and higher H_2O contents would favor volatile saturation, allowing reservoirs to become more compressible. Hence, a higher fraction of magma recharge would be needed to reach the necessary chamber overpressure to trigger an eruption. In turn, this higher fraction of recharge would allow more mixing and heating of the resident silicic magma, lowering melt viscosity. This facilitates the formation of a permeable foam by growth and expansion of the already nucleated gas bubbles, inducing early syn-eruptive degassing in the conduit and favoring effusive outpouring of magma. In contrast, slightly warmer conditions (and/or slightly lower H_2O concentrations) in the mush would lead to reservoirs with less exsolved volatiles, hence less compressible. Thus, eruptions would be triggered faster and pre-eruptive warming would be more limited, reducing magma viscosity less than in the previous case. Bubble nucleation would mostly be confined to the conduit with syn-eruptive degassing starting at shallower depths and being less efficient, thus favoring an explosive eruption.