The summit activity at Mt. Etna from 1995 to 2001: A multidisciplinary approach to investigate the long-term processes of the magmatic plumbing system

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The integration of volcanologic observations, petrologic data, microgravity and ground deformation acquired at Etna from 1995 to 2001, provided the opportunity to investigate the long-term dynamics of Mt. Etna during a period when the activity was restricted to the summit craters.

Temporal patterns of major and trace elements indicate that the variability of bulk rocks composition is due to fractional crystallization and mixing between residing and new intruding magmas. Microgravity data show that from late-1996 to mid-1999 and from late-2000 to mid-2001, strong gravity decrease occurred, centered on the upper southeastern sector of the volcano. The gravity decreases coincide with an increase in the rate of the seismic strain release. Ground deformation show, from 1994 to the onset of the 2001 eruption, an almost continuous expansion of the volcano mainly due to magma accumulation into the western sector of the volcano. Therefore, the anti-correlation between gravity and seismicity in the eastern flank is not strictly connected to movements of magma and/or change of its chemical and physical properties. Conversely, these data suggest an increase of micro-fracturing along the NNW–SSE structural trend, implying a local density (gravity) decrease coupled with an increase in the release of seismic energy.

From 1996 to 1999 the inferred increase in the rate of fracturing and acceleration of deformation in the volcano eastern flank led to the ascent of conspicuous magma volumes that promoted the reactivation of the South-East and Voragine summit craters, with sustained an intense explosive and effusive activity until the end of 1999. The increase of rate of fracturing from late-2000 to mid-2001 enhanced the formation of a preferential path for magma ascent to the surface and the onset of the July 2001 flank eruption.

Control of magma recharge and buoyancy on the frequency and magnitude of volcanic eruptions

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The frequency at which volcanic eruptions occur is inversely proportional to the volume of magma released in a single event. The basic requirements for a volcanic eruption to occur are that enough heat is supplied to the crust to assemble a body of eruptible magma and that overpressure is sufficient for the magma to reach the surface without solidifying. Starting from these basic principles we used thermo-mechanical calculations and Monte Carlo simulations to quantify the relative contribution of magma fluxes and the physical properties of the crust on likelihood and volume of volcanic eruptions. The calculations were performed considering the periodic input of magma in pulses of different size and shape injected at various frequencies The average rate of magma supplied to the upper crust over hundreds of thousands of years appears to control the volume of magma that can potentially be released during a single eruption, whereas the time interval between short-lived pulses of magmatism, affects the total duration of magma injection preceding an eruption. Our calculations reconcile the relationship between erupted volume and upper crustal magma residence times, and replicate the correlation between erupted volumes and caldera dimensions. Our modelling shows that relatively small and frequent eruptions are triggered by magma injection while buoyancy is important to trigger large eruptions. These calculations permit to identify the physical processes controlling the relationship between frequency and magnitude of volcanic eruptions and increase our capability of determining the temporal evolution of volcanic activity in different volcanic systems.

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