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Magma transfer at Campi Flegrei caldera (Italy) before the 1538 AD eruption

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Defining and understanding the shallow transfer of magma at volcanoes is crucial to forecast eruptions, possibly the ultimate goal of volcanology. This is particularly challenging at felsic calderas experiencing unrest, which typically includes significant changes in seismicity, deformation and degassing rates. Caldera unrest is particularly frequent, affects wide areas and often does not culminate in an eruption. Moreover its evidence is usually complicated by the presence of a hydrothermal system. As a result, forecasting any eruption and vent-opening sites within a caldera is very difficult.

The Campi Flegrei caldera (CFc), in the densely inhabited area of Naples (Italy), is commonly considered one of the most dangerous active volcanic systems. CFc is a ∼12 km wide depression hosting two nested calderas formed during the eruptions of the Campanian Ignimbrite (∼39 ka) and the Neapolitan Yellow Tuff (∼15 ka). In the last ∼5 ka, resurgence, with uplift >60 m close to the central part of the caldera, was accompanied by volcanism between ∼4.8 and ∼3.8 ka. After ∼3 ka of quiescence, increasing seismicity and uplift preceded the last eruption at Monte Nuovo in 1538 for several decades. The most recent activity culminated in four unrest episodes between 1950-1952, 1969-1972, 1982-1984 and 2005-Present, with a cumulative uplift at Pozzuoli of ∼4.5 m; the present unrest episode has been interpreted as being magma-driven. These unrest episodes are considered the most evident expression of a longer-term (centuries or more) restless activity. The post-1980 deformation largely results from a magmatic oblate or sill-like source at ∼4 km depth below Pozzuoli.

Despite the restless activity of CFc, the recent unrest episodes did not culminate in eruption, so that any possibility to define the pre-eruptive shallow transfer of magma remains elusive. Indeed, this definition is a crucial step in order to identify and understand pre-eruptive processes, and thus to make any forecast. To fill this gap, we focused on the last eruption of 1538, reconstructing its pre-eruptive deformation pattern. For this, we exploited the unique historical, archaeological, geological and long-term geodetic record of the caldera to carefully determine the height variations (and related errors) of 20 selected sites along its coastline. The integration of this large dataset permitted the first reconstruction of pre-eruptive short- and long-term ground deformation of the CFc and to model the magma transfer before the eruption. Our data suggest a progressive magma accumulation from ∼1251 to 1536 in a 4.6±0.9 km deep source below the caldera centre, and its transfer, between 1536 and 1538, to a 3.8±0.6 km deep magmatic source ∼4 km NW of the caldera centre, below Monte Nuovo; this peripheral source fed the eruption through a shallower source, 0.4±0.3 km deep. This reconstruction corroborates the existence of a stationary oblate source, below the caldera centre, that was feeding lateral eruptions for the last ∼5 ka, and suggests: repeated emplacement of magma through intrusions below the caldera centre; occasional lateral transfer of magma feeding non-central eruptions within the caldera. Comparison with historical unrest at calderas worldwide suggests that this behavior is common.