Long-term patterns of unrest before eruption at large calderas

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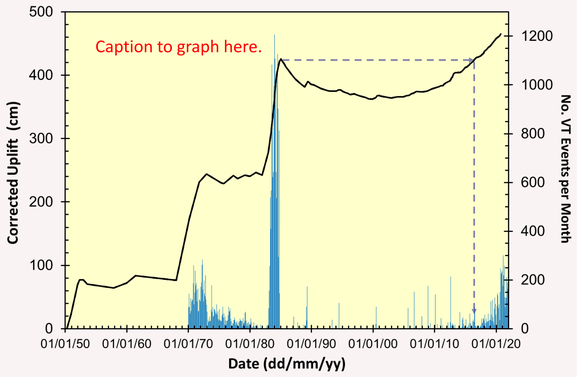
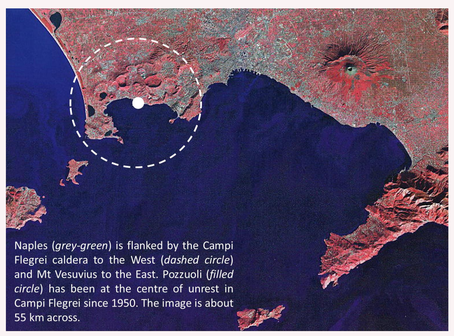
The last 70 years of unrest at Campi Flegrei, in southern Italy, provides an excellent opportunity for investigating the evolution of cascading precursors to crustal rupture at large calderas.

A restless caldera

Campi Flegrei is a sinking caldera. Subsidence has been interrupted in four episodes since 1950. When secular subsidence is removed, the first three episodes triggered corrected uplifts of 75-175 cm in about two years at intervals of 10-20 years (Kilburn et al., 2017). The current episode has continued with a previously unseen style of behaviour: twenty years of additional subsidence until 2000, followed by slow uplift that by 2017 had returned the corrected uplift to its 1984 level.

The amounts and timescales of the first three episodes are consistent with the intrusion of magmatic sills (Woo & Kilburn, 2010); those of the ongoing episode are consistent with the permeable flow of magmatic gas and meteoric water (Kilburn et al., 2017; Troise et al., 2019; Chiodini et al., 2021).

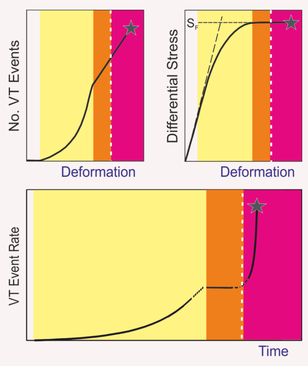


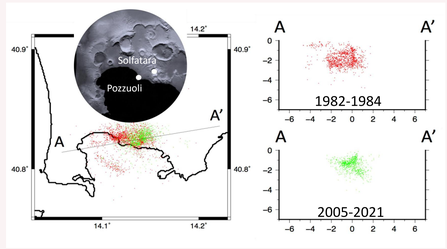


VT trends expected before eruptions

Long-quiescent volcanoes must stretch and break the crust before magma can erupt. Sesimicity and deformation can be related directly to changes in stress [Kilburn, 2018].

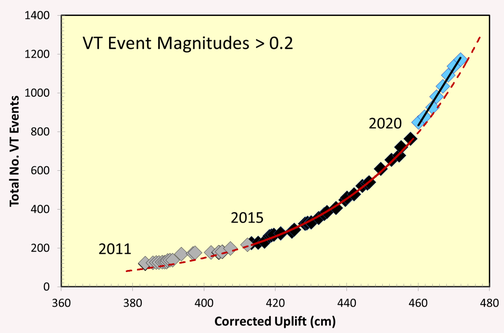
Common trends are an **exponential** and then **linear** increase in the number of VT events with deformation (*right, near top*). This reflects an evolution from *quasi-elastic* (*yellow*; elastic deformation with subordinate fault movement) to *inelastic* (*orange & magenta*; faulting alone) behaviour. It correlates with changes from deformation under an increasing and then constant stress (*right, far top*) and, also, from exponential to steady-hyprbolic VT event rates with time (*right,bottom*).

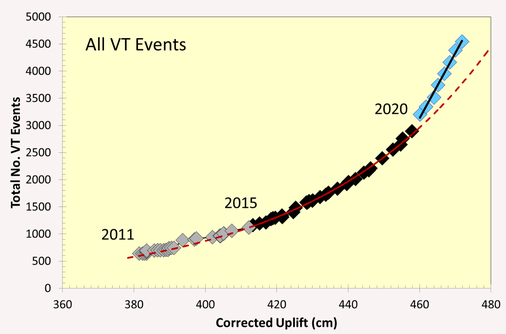




Left. VT seismicity began again at Campi Flegrei after the onset of slow unrest. The earthquakes have been confined to a smaller volume than observed during the previous crisis in 1982-1984. The change suggests a concentration of stress around a potential rupture.

Below. After re-establishing equilibrium in 2011-2015, the number of VT events increased exponentially and then linearly with deformation. The change in trend occurred in late 2020. The crust is now deforming inelastically at a steady rate of about 250 events per month. If the trend continues, we expect the rate of seismicity will finally accelerate towards rupture along a hyperbolic trend.





Conclusions

- Unrest since 1950 describes the progressive stretching of the crust by repeated intrusions until its permeability had increased sufficiently for a major change in the flow of pore fluids.
- The change marks an evolution towards crustal rupture and has been observed at several volcanoes, including large calderas (Robertson & Kilburn, 2016; Kilburn, 2018).
- The presence of a new rupture increases the possibility that magma reaching shallow depth in the future will erupt, rather than intrude as had occurred between 1950 and 1984.
- Future unrest will not replicate behaviour seen during the past 70 years and new scenarios for emergency response are needed to take account of Campi Flegrei's dynamical and structural evolution.

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Chiodini G et al. (2021) J Volcanol Geotherm Res, 414: 10.1016/j.jvolgeores.2021.107245. **D'Auria L et al. (2015)**. Sci Rep, 5: 1-11. **Del Gaudio C et al. (2010).** J Volcanol Geotherm Res, 195: 48-56. **Kilburn CRJ** (2018) Front Earth Sci, 6: 103389/feart.2018.00133. **Kilburn CRJ et al.(2017)** Italy. Nature Communications, 8: 1-8. **Robertson RM, Kilburn CRJ (2016)** Earth Planet Sci Lett, 438: 86-94. **Troise C et al.(2019).** Earth Sci Rev, 188: 108-122. **Woo JYL, Kilburn CRJ (2010)** J Geophys Res, 115: 10.1029/2009JB006913.

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