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Magma degassing as a source of long-term seismicity at volcanoes: the Ischia Island (Italy) case

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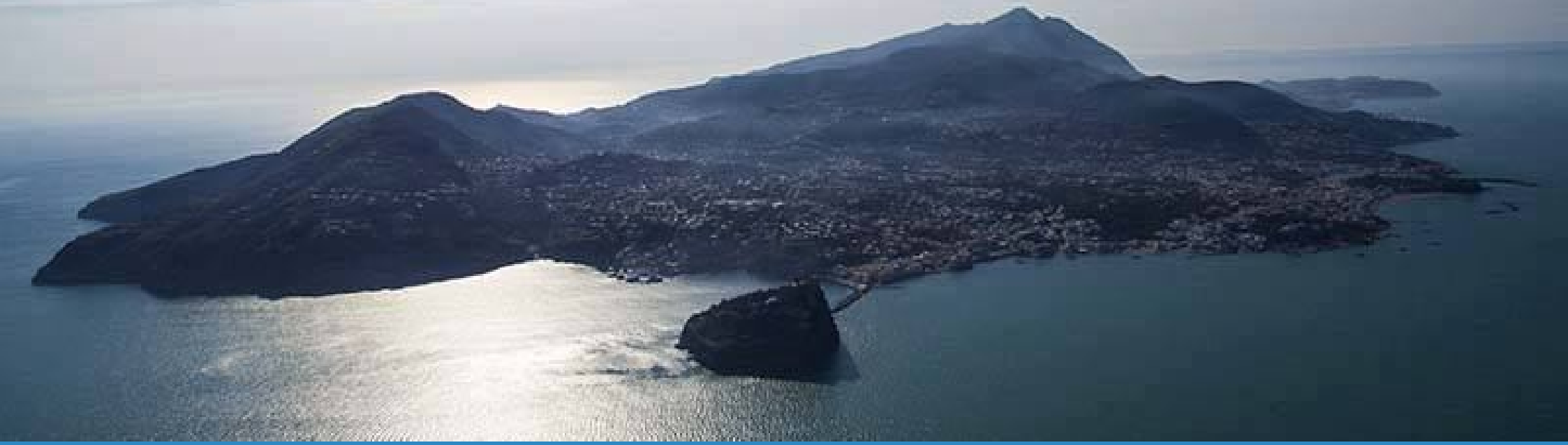
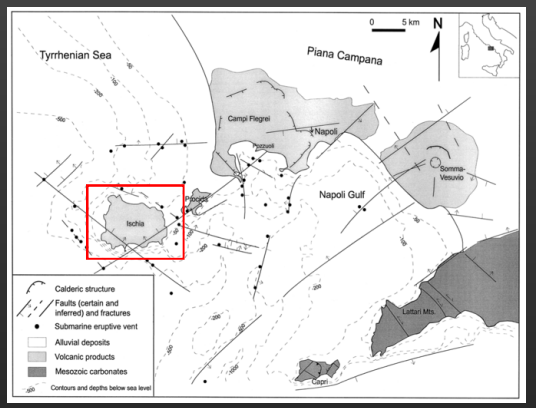
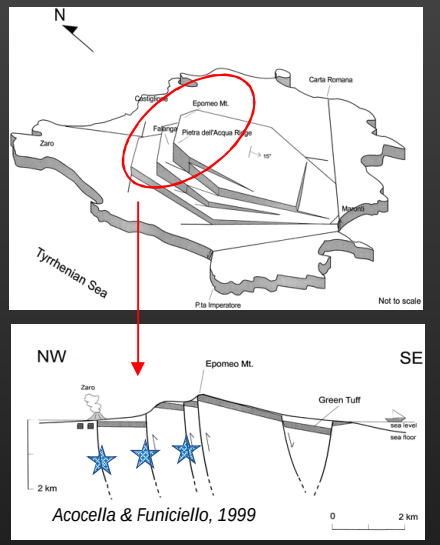


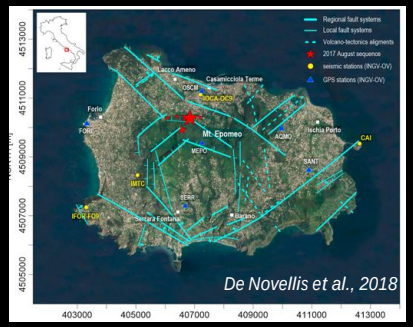
Ischia volcanic island (Italy)

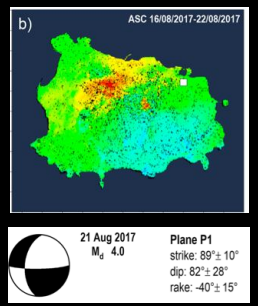
- Resurgence > 800 m in 35-55 ka
- Fault-bounded block with topmost uplift at NW and tilt downward SE
- Last activity 10 ka ago with peak in the last 6 ka (last eruption in 1302 AD)
- Northern boundary experiences destructive seismic activity (1228, 1796, 1881, 1883 and 2017)
- Similarities among these events in terms of:
  - fault location
  - shallow depth (< 2km)
  - subvertical geometry
  - 4<M<5
  - dip-slip motion

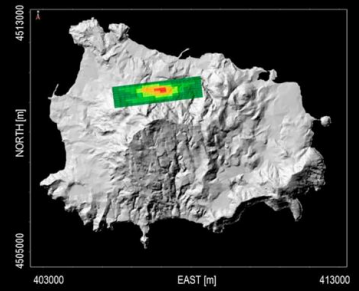




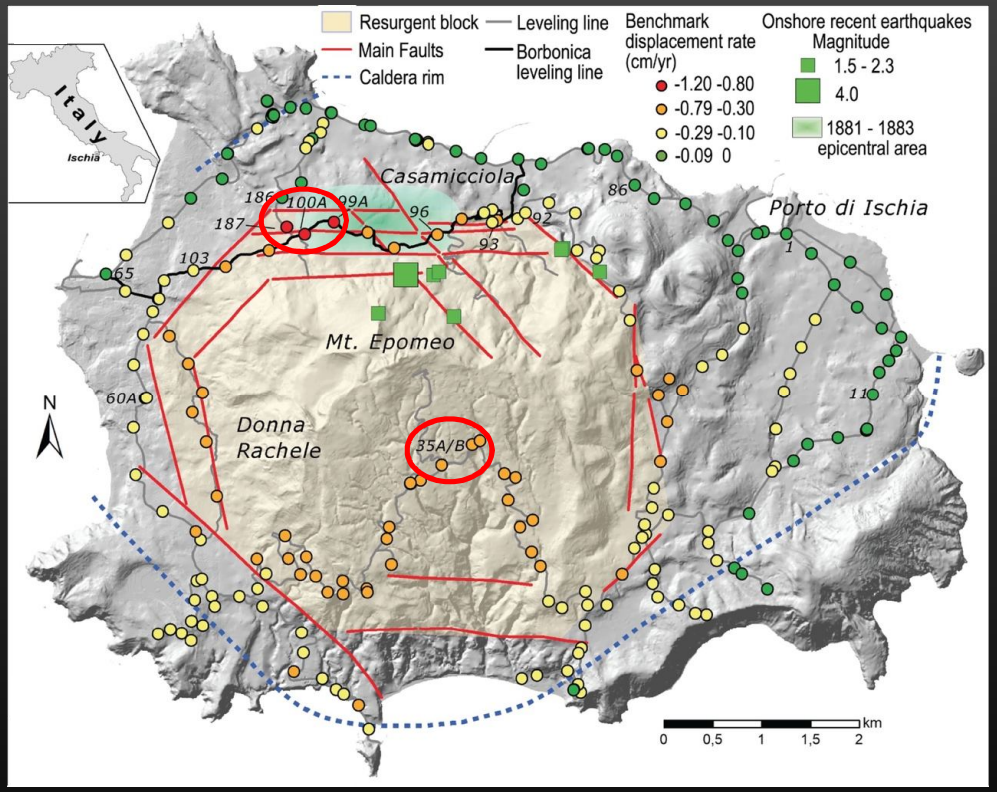
The M 4.0 earthquake of 21 August 2017

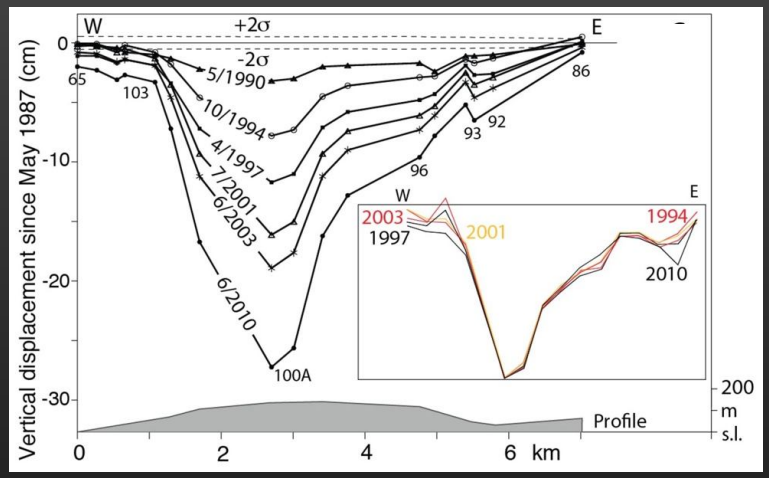


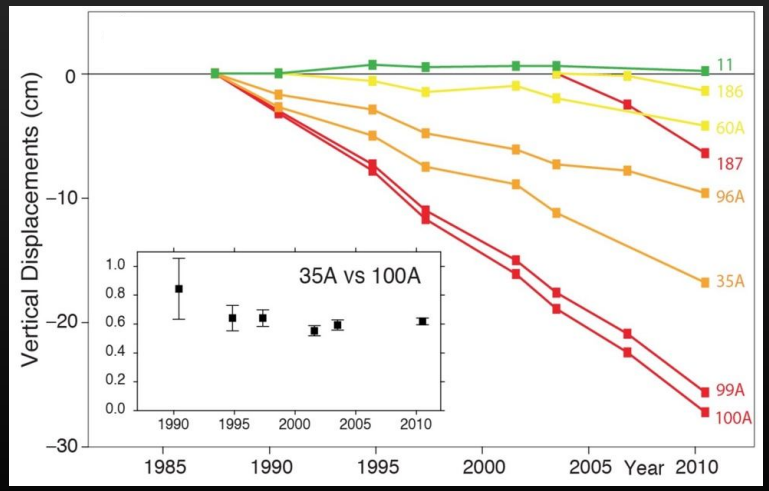




Deformation at Ischia during 1987-2010





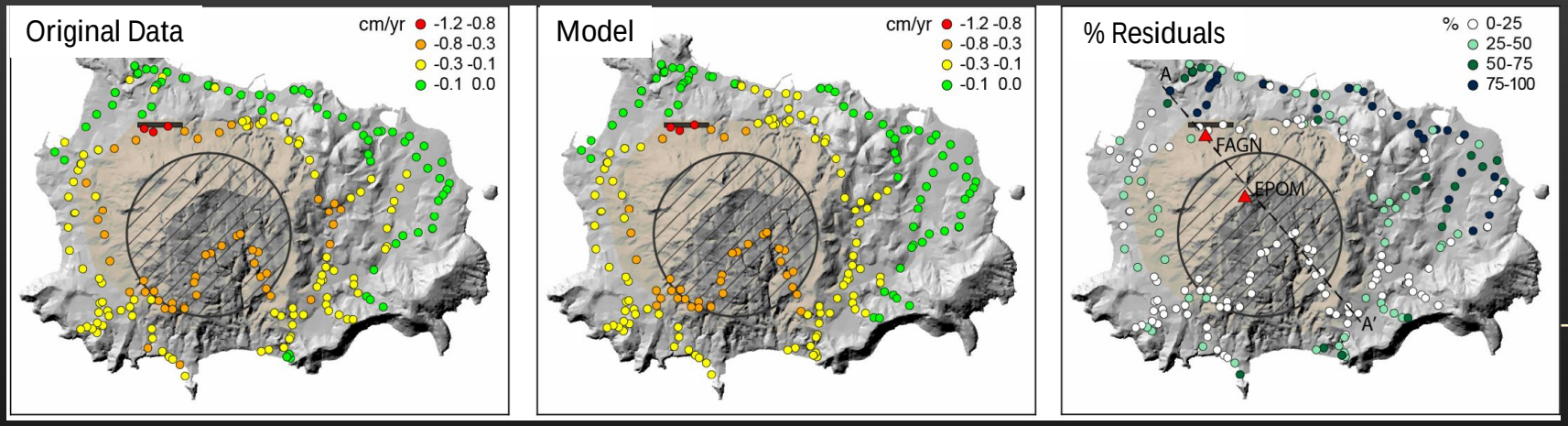


The self-similarity of the normalized patterns and the constant ratio between 35A and 100A benchmarks suggest the activity of the same source/s and interdependence in the process/es controlling the deformation at Ischia

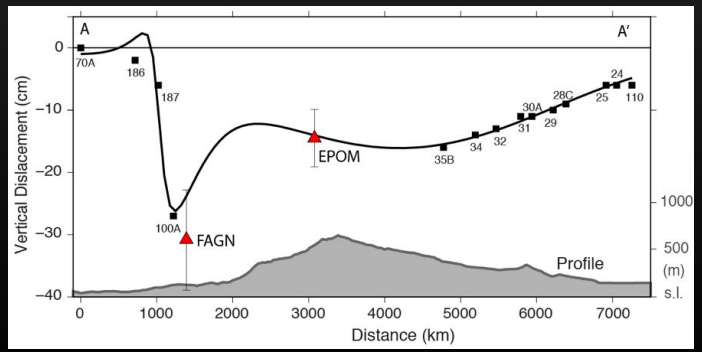
Results – Comparison between data & model

Geodetic inversions by means of VSM (Volcanic and Seismic source Modeling)

- Sill-like source to mimic the island-scale subsidence
- Fault to match the small-scale deformation of the NW margin of the block



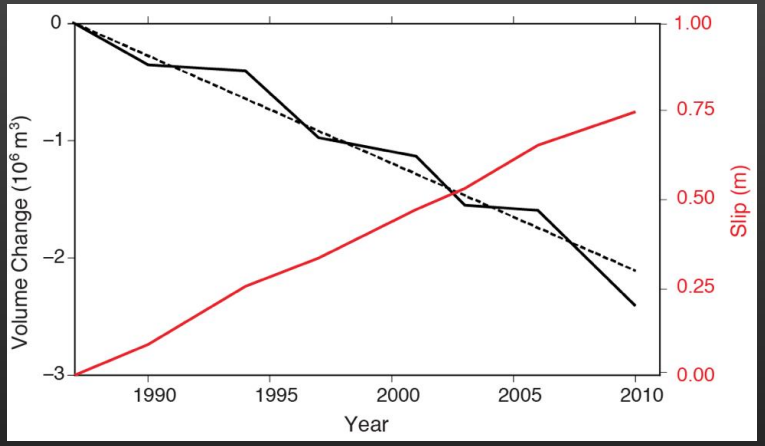
NW-SE Profile



Results

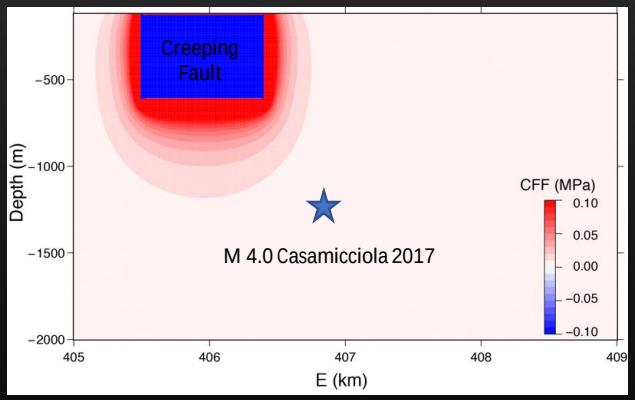
- **Sill source**
  d=2.2 km and ΔV=-10^5 m^3/yr
- **Fault** (fixed dip=80°, E-W orientation)
  aseismic slip rate 3.1 cm/yr

Results – Volume change and dip-slip



- Inversions considering each campaign 1987-2010
- Sill deflation and aseismic slip rates are constant
- Total volume change of sill $\Delta V = -2.4\ 10^6\ m^3$
- Total slip at fault Δu=75 cm
- Equivalent magnitude in 23 yr M_w 4.6

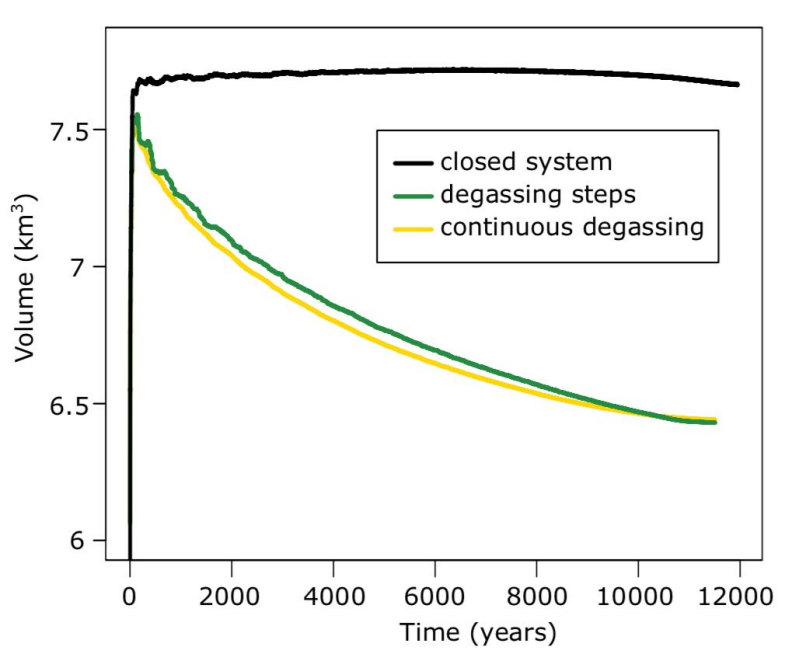
- Slip on the shallowest part of the bordering faults – down to 500 m depth
- From CFF computations there is evidence of changes of 0.1 MPa at the fault base
- Fault has been creeping for longer



The normal mechanism of the 2017 Casamicciola earthquake suggests seismicity is consistent with a deflationary forcing process

Results of thermo-petrological simulations

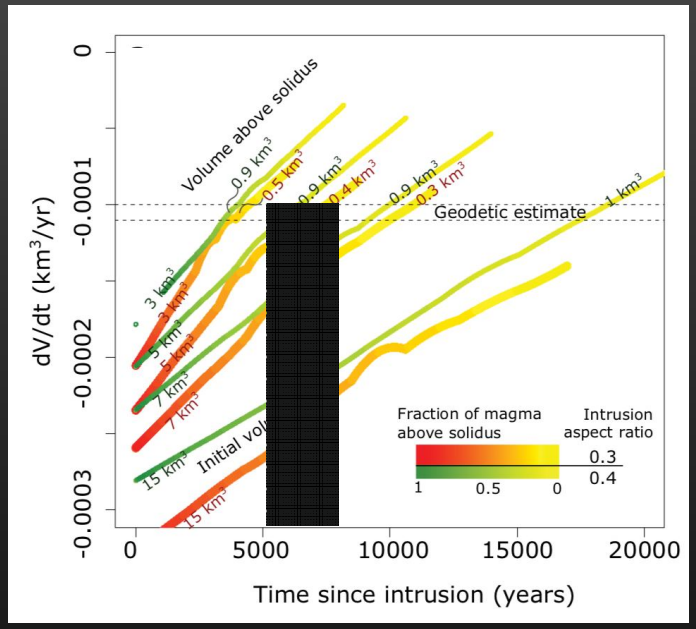
Temporal evolution of volume for different conditions of system and intrusion

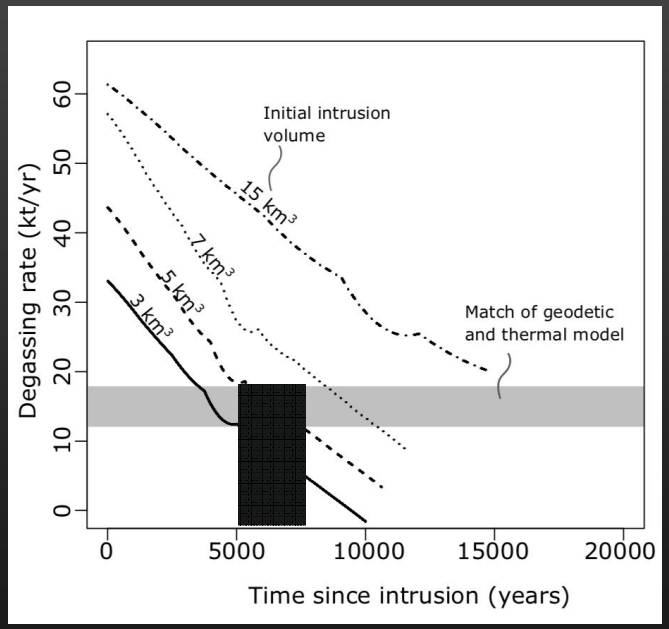


- Thermo-petrological simulations by rhyolite-MELTS for ΔV from crystallization, cooling and degassing
- Coupled with models of temporal evolution of cooling of a cylindrical magma body at 2-4 km depth, aspect ratio 0.2-0.4 and initial volume of 3-25 km^3
- Closed system shows intense crystallization and limited degassing, resulting in limited volume variation → not compatible with observed rates
- Open system scenarios lead to considerable volume contraction, with rate higher during young history

Results of thermo-petrological simulations

Temporal evolution of volume for different conditions of intrusion





Degassing rates 12-18 kt/yr

- Negligible amount w.r.t. emissions at Ischia (e.g., at Donna Rachele)
- Intrusion has degassed most of the fluids

Combined effect of cooling and crystallization leads to accumulation of excess fluids

- Volumetric contraction decreases with time for a wide range of initial intrusion volumes
- The deflation rates match the geodetic value at increasing times since the onset of the injection

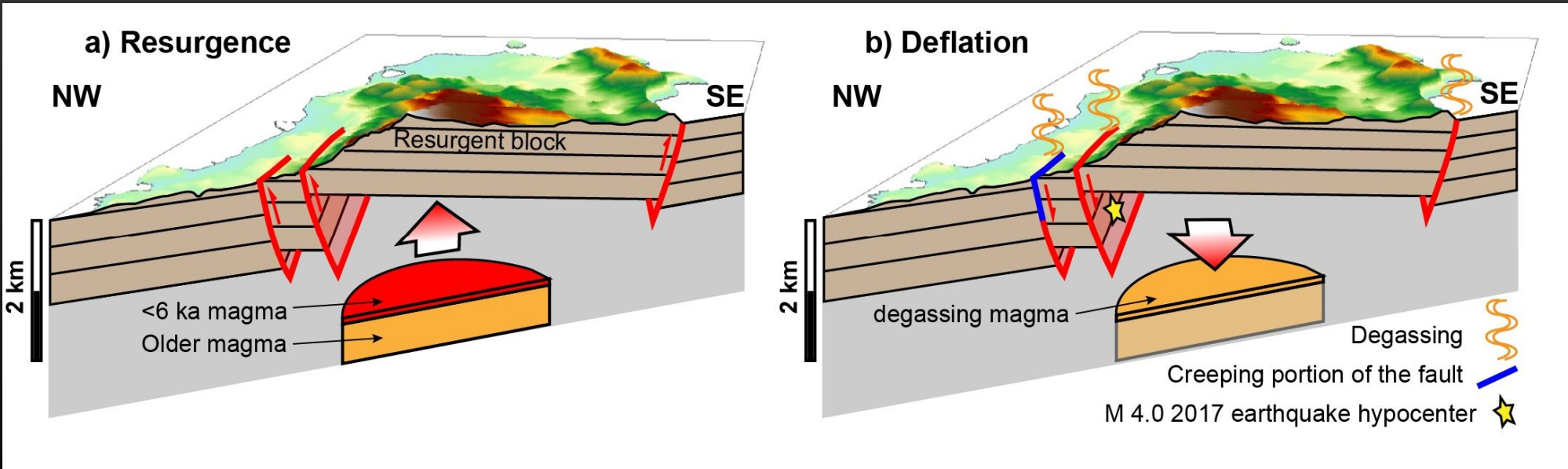
The eruptive records suggest the current magmatic cycle started 6 ka ago

- Best match for initial volume ~5 km^3
- At least 0.4-0.9 km^3 of eruptible magma is still cooling and degassing for the next hundreds/thousands years

The proposed model

Magma degassing from a cooling magma body is responsible of subsidence at Ischia

a) Resurgence produces a tilted uplifted block, activating inward dipping reverse faults
b) Degassing of the injection of 6 ka ago deflates the uplifted block, reactivating faults to the NW in normal motion, supporting the magmatic nature of the source



Ischia is a unique case of deflating resurgence accompanied by recurrent seismicity!
(degassing, subsidence and seismicity will continue in the future)

Conclusions

- About 30 years of leveling data show constant-rate subsidence of the resurgent block at Ischia.
- Mechanical and thermo-petrological simulations indicate degassing as main cause of the observed subsidence of the resurgent block.
- Seismicity marks an acceleration of decades-long subsidence, driven by degassing that will continue for hundreds/thousands years.

Trasatti, E., V. Acocella, M. De Vito, C. Del Gaudio, G. Weber, I. Aquino, S. Caliro, G. Chiodini, S. de Vita, C. Ricco & L. Caricchi
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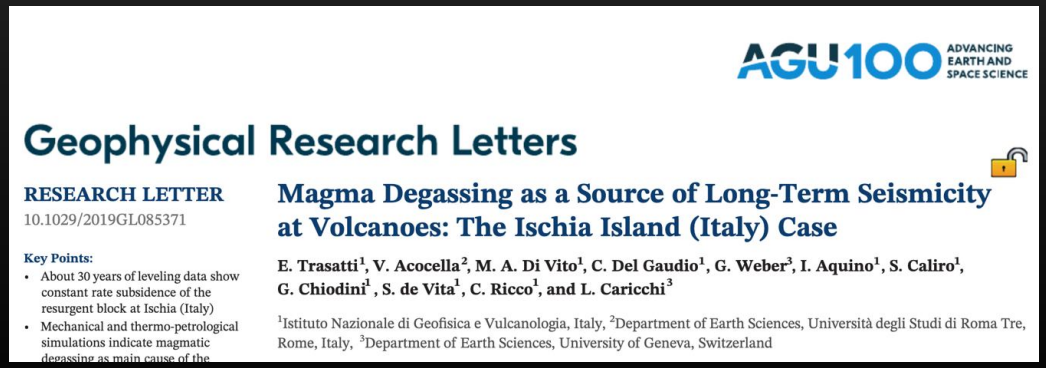
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085371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Key Points:
- About 30 years of leveling data show constant rate subsidence of the resurgent block at Ischia (Italy)
- Mechanical and thermo-petrological simulations indicate magmatic degassing as main cause of the

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