Lava tubes formation and extensive flow field development during the 1858 eruption of Mount Vesuvius

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TUBES

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1. Introduction

Lava tubes are an important transport mechanism in lava flows [1,2]:

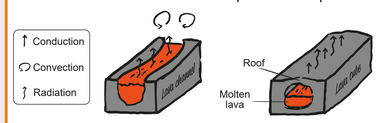


Figure 1. Thermal transfer comparison between lava channels and lava tubes

- Insulation of the molten lava by the overlying cooled crust
- Keeps the molten lava hot for a longer time
- Can greatly increase the distance of emplacement of a lava flow

2. Geological setting

Somma-Vesuvius complex:

- Southern Italy, 15 km east of Naples
- Composite stratovolcano[3]:
  - Monte Somma, a pre-existing edifice that collapsed repeatedly
  - Vesuvius, the new edifice
- Four major Plinian eruptions[4]
- Last eruptive cycle (1631-1944)[5]:
  - Open conduit condition
  - Hawaiian and Strombolian eruptions
  - Over 120 lava flows
  - Alkali-rich and crystal-rich lavas[6,7]

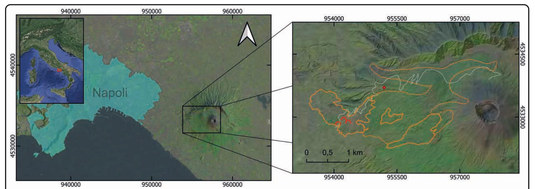


Figure 2. Location of Vesuvius b) Location of the complete and surfacing 1858 lava flow field and its lava tubes.

3. Methods

Collection of historical documents to describe the 1858 eruptive activity:

- Descriptions of the eruption
- Paintings
- Geological maps
- Description of the lava tube

Figure 3. 1858 eruption. a) Unknown artist; b) Giovan di Battista Gatti

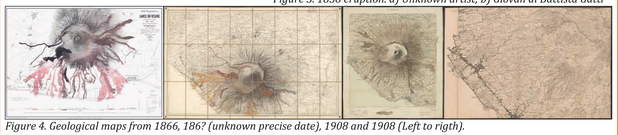


Figure 4. Geological maps from 1866, 186? (unknown precise date), 1908 and 1908 (Left to rigth).

Morphology analysis using a complete 3D model composed of:

- An internal scan produced using a time-of-fligth terrestrial laser scanner
- A surface scan (DEM) realized using an optical camera equipped UAV
- Photogrammetry scans produced with an optical camera

Figure 5. Scanning devices. a) UAV equipped with an optical camera; b) Riegl VZ-400 terrestrial laser scanner

4. The 1858 lava flow field

Temporal and spatial evolution

The 1858 eruption and its lava flow field[8]:

- 659 days of eruption (27/05/1858 - 15/03/1860)
- 6 eruptive fissures
- 2 deep valleys inundated
- Estimated erupted volume of 147 million m³

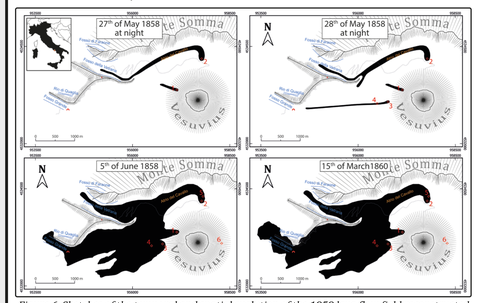


Figure 6. Sketches of the temporal and spatial evolution of the 1858 lava flow field reconstructed using historical documents. Fissures or vents are red circles. Flow field is solid black. Blue lines are boundaries of main valleus. Red diamonds is the former observatory.

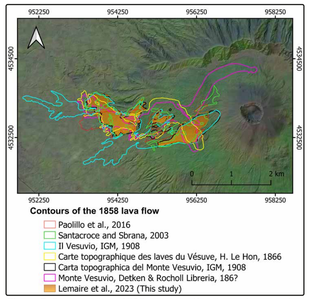


Figure 7. Contour of the 1858 lava flow field from six geological maps (coloured lines) and from the resthis study (solid orange)

Contours of the exposed surface

Six different geological maps show the contour of the 1858 lava flow field, but many discrepancies appear. We then defined:

- A complete lava flow field contour
- An exposed lava flow field contour

Exposed surface analysis

Using a 1-meter resolution Lidar DSM:

- Average slope over the exposed flow field ~16°
- Lava flow field surface full of fine scale features
  - Tilted slabs of pahoehoe lava
  - Small tumuli
- Presence of large scale features
  - Large tumuli
  - Dome-like features

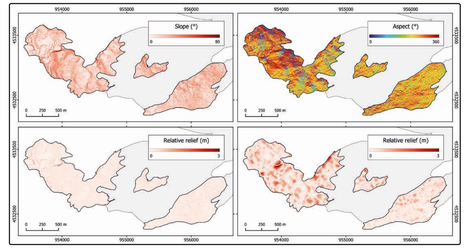


Figure 8. Surface parameters of the exposed 1858 lava flow field. Top left, slope. Top rigth, aspect. Down left, relative relief with a radius of 5 meters. Down rigth, relative reliefwith a radius of 100 meters.

5. Lava tube morphology

Surface of the lava tube

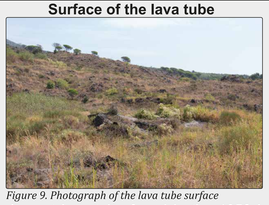


Figure 9. Photograph of the lava tube surface

The largest lava tube found in the 1858 lava flow field:

- 2 meters high relief on the flow surface
- Oriented north south
- Triangular shape
- Uplifted and tilted slabs of pahoehoe lava

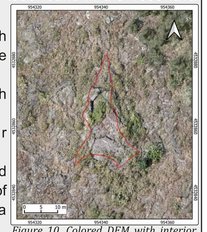


Figure 10. Colored DEM with interior contours of the lava tube (red line)

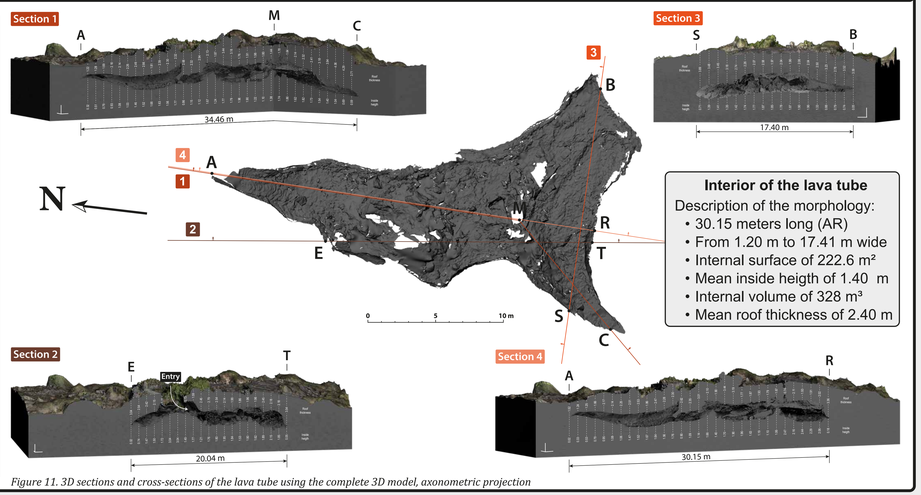


Figure 11. 3D sections and cross-sections of the lava tube using the complete 3D model, axonometric projection

Interior of the lava tube

Description of the morphology:

- 30.15 meters long (AR)
- From 1.20 m to 17.41 m wide
- Internal surface of 222.6 m²
- Mean inside heigth of 1.40 m
- Internal volume of 328 m³
- Mean roof thickness of 2.40 m

6. Internal features

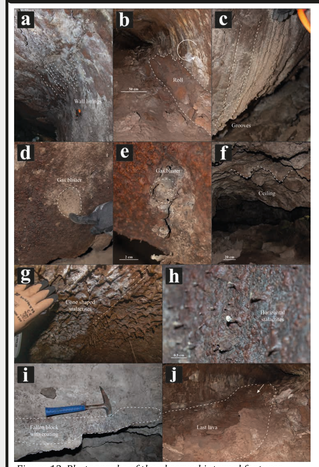


Figure 12. Photographs of the observed internal features

a) Wall linings
- Repeated coatings of lava on the walls and ceiling due to drainage and refill cycles of the lava tube[9]

b) Rolls
- Wall lining rolled down on itself while still being plastic when the lava tube drained

c) Vertical grooves
- Caused by solidified lava on the edges of the flow surface during a drop in lava level

d) Imprint of a gas blister
- Accumulation of gas in between two linings

e) Gas blister
- Surrounded by melted lava

f) Bulbous in shape ceiling
- Welded blocks of lava

g) Cone shaped stalactites
- Formed by remelting of the ceiling by accumulating hot gases[10,11]

h) Horizontal stalactites

i) Possible degassing tubes in the wall lining

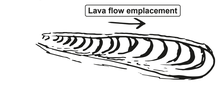
j) Coating on a fallen block
- Fracturation of the wall during the activity of the tube, the block collapsed after

k) Last lava
- Solidified lava that last entered the tube

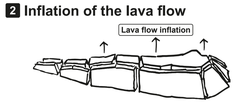
7. Lava tube formation

Step evolution of the formation mechanism based on inflation processes that formed the largest lava tube present in the 1858 lava flow field of Vesuvius:

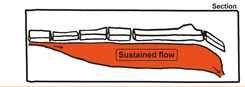
1 Emplacement of a small lava flow



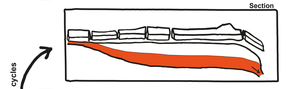
2 Inflation of the lava flow



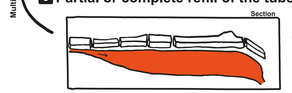
3 Sustained flow of lava within the tube



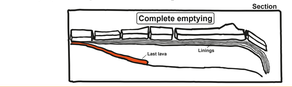
4 Partial or complete drainage of the tube



5 Partial or complete refill of the tube



6 Complete drainage of the tube



8. Conclusion

- Reconstruction of the evolution of the emplacement of the 1858 lava flow field
- Morphological analysis of the largest lava tube found in the 1858 lava flow field
  - Description of the internal features observed inside the lava tube
  - Model of the formation mechanism based on an inflation process

References

[1] SWANSON, D.A. Pahoehoe Flows from the 1969–1971 Mauna Ulu Eruption, Kilauea Volcano, Hawaii. GSA Bulletin. 1973 Feb 1;84(2): 615–626.
[2] Greeley, R. THE ROLE OF LAVA TUBES IN HAWAIIAN VOLCANOES. U.S. Geological Survey Professional Paper 1350, 1589–1602 (1987).
[3] Cioni, R. et al. Pyroclastic deposits as a guide for reconstructing the multi-stage evolution of the Somma-Vesuvius Caldera. *Bulletin of Volcanology* 61, 207-222 (1999).
[4] Cioni, R. et al. Explosive activity and eruption scenarios at Somma-Vesuvius (Italy): Towards a new classification scheme. *Journal of Volcanology and Geothermal Research* 178, 331-346 (2008).
[5] Arno, V. et al. Eruptive history. *Quademi de 'La ricerca scientifica'* vol. 8 (1987).
[6] Belkin, H. E. et al. Sampling and major element chemistry of the recent (A.D. 1631-1944) Vesuvius activity. *Journal of Volcanology and Geothermal Research* 58, 273-290 (1993).
[7] Trigila, R. & De Benedetti, A. Petrogenesis of Vesuvius historical lavas constrained by Pearce element ratios analysis and experimental phase equilibria. *Journal of Volcanology and Geothermal Research* 58, 315-343 (1993).
[8] Palmieri, L. Cronaca del Vesuvio dal 1855 al 1859. *Annali dell'Osservatorio Vesuviano* 46-80 (1859).
[9] Calvari, S. & Pinkerton, H. Lava tube morphology on Etna and evidence for lava flow emplacement mechanisms. *Journal of Volcanology and Geothermal Research* 90, 263-280 (1999).
[10] Kauahikaua, J. et al. Observations on basaltic lava streams in tubes from Kilauea Volcano, island of Hawaii. *Journal of Geophysical Research* 103, 27303-27323 (1998).
[11] Peterson, D. W. et al. Development of lava tubes in the light of observations at Mauna Ulu, Kilauea Volcano, Hawaii. *Bulletin of Volcanology* 56, 343-360 (1994).

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