Using structure from motion and high-resolution digital elevation models to investigate the relationships between emplacement history and lava surface roughness: Hawaii, California and Mars

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Introduction

We can infer eruption conditions using variations in roughness at different scales on a lava flow. Mauna Ulu, Hawaii and Amboy, California were used as analogues for a range of martian lava flow surfaces.

- Hawaii offers an opportunity to observe young flows, but the weathering and erosional processes are significantly different from those on Mars[1].
- Lava flows at Amboy are older than those produced by Mauna Ulu, and display varying levels of mantling by wind-blown sand similar to expectations for Mars.

This research aims to answer several questions about lava surface roughness and geologic history. The one presented here is:

- How do roughness values of mantled lava flows on Mars compare to values at Amboy?

Methods

- We selected sites located on and off the wind streak at Amboy (1m/pixel, airborne LiDAR) to compare the effect of mantling on lava surface roughness there with surfaces on Mars (2m/pixel, HiRISE)
- Roughness Doughnut (RD) method displays roughness values relative to the focus point, based on neighborhood elevation statistics.
- RD considers cells along the circumference of a circle, unlike the Topographic Position Index which averages the full area of the circle, thereby dampening roughness signals. RD values and related elevation products should highlight partially mantled surfaces
- Neighborhood size was adjusted to change the scale of roughness being observed.
  - The outer radius or 'doughnut thickness' remained constant at 2 cells.
- RD rasters were calculated by:

$$\frac{mean\ raster - original\ DEM}{range\ raster} = RD$$

- The larger the RD value, the lower the topographic variation at the selected scale. A small value represents the inverse of this – a wider variety of elevations at the scale.
- A Principal Component Analysis (PCA) was used to identify patterns in the data.

Figure 1: TPI (left) and RD (right) roughness comparison using a Mauna Ulu Structure from Motion DEM, 0.14 mm/pixel

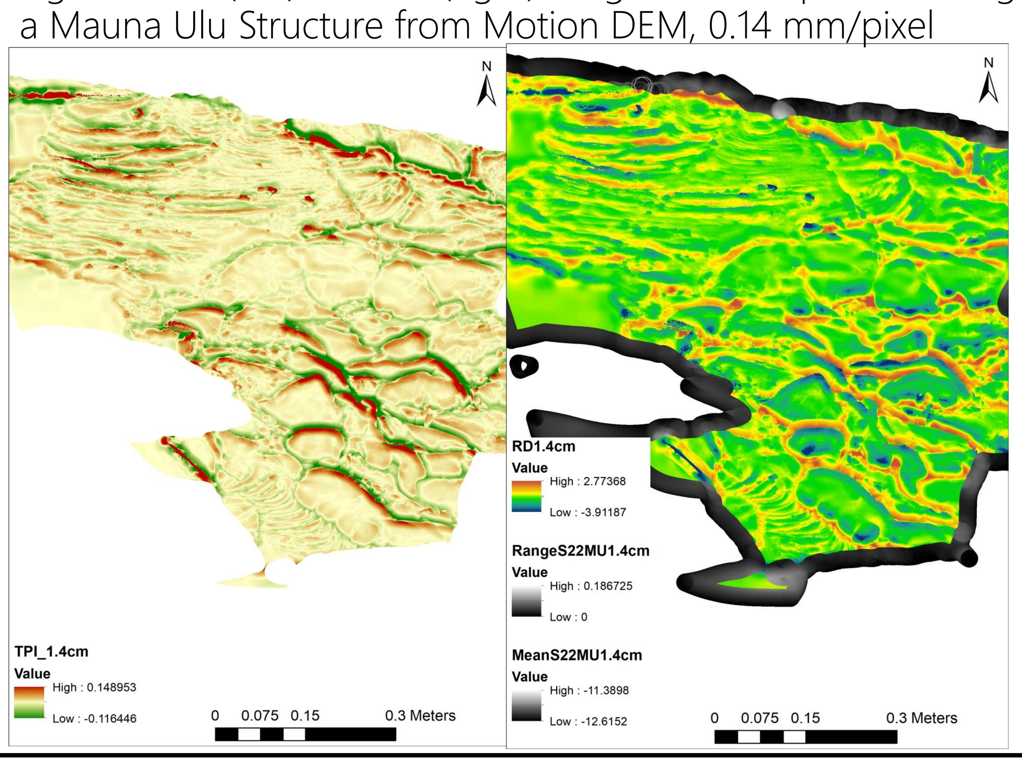


Figure 2: Location of sites relative to the crater and wind streak at Amboy, California

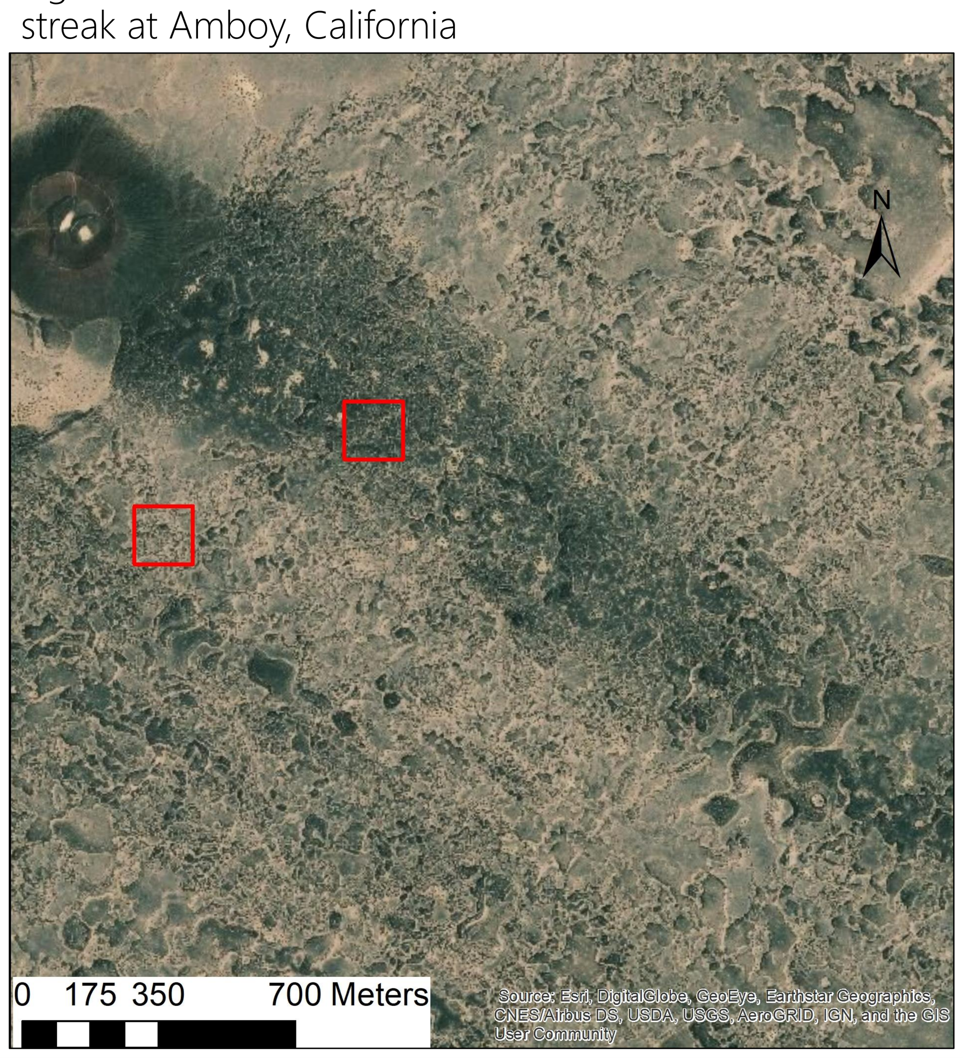


Figure 3: mantled lavas in the Tharsis region of Mars. Location of selected sites marked by yellow pin (HiRISE)

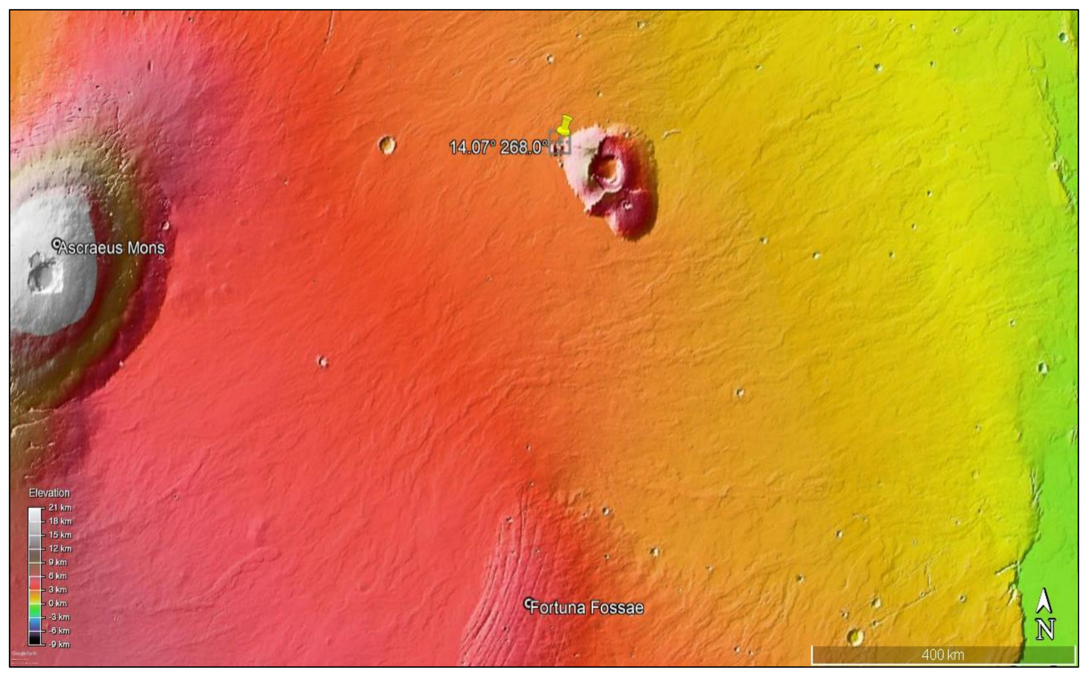
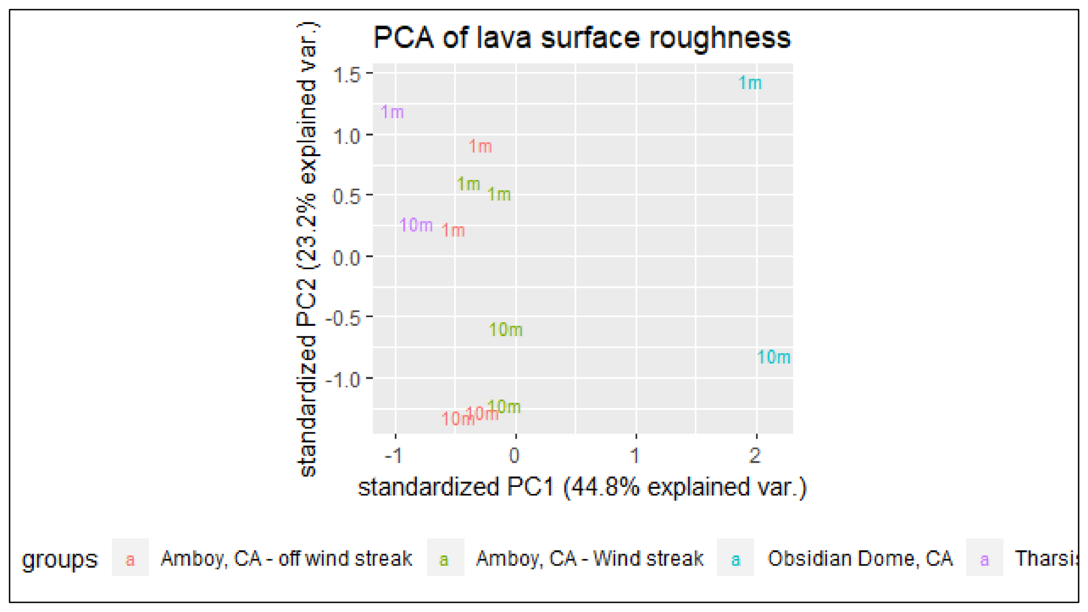


Figure 4: Principal Component Analysis of roughness data from Amboy, and Tharsis. Obsidian Dome was included to show that this method can be used to distinguish between mafic and silicic flows



Conclusions

- RD values increase with the rate of mantling, though this trend is not robust
- As sand settles preferentially in the lowest regions, the elevation range as well as the final SDD value increase.
  - This is true for both comparison sites at Amboy, at both the 1-meter and 10-meter scales, as well as Tharsis
- Trends and patterns of roughness values are similar between locations, though the features on Mars are significantly larger than those in California.

Results

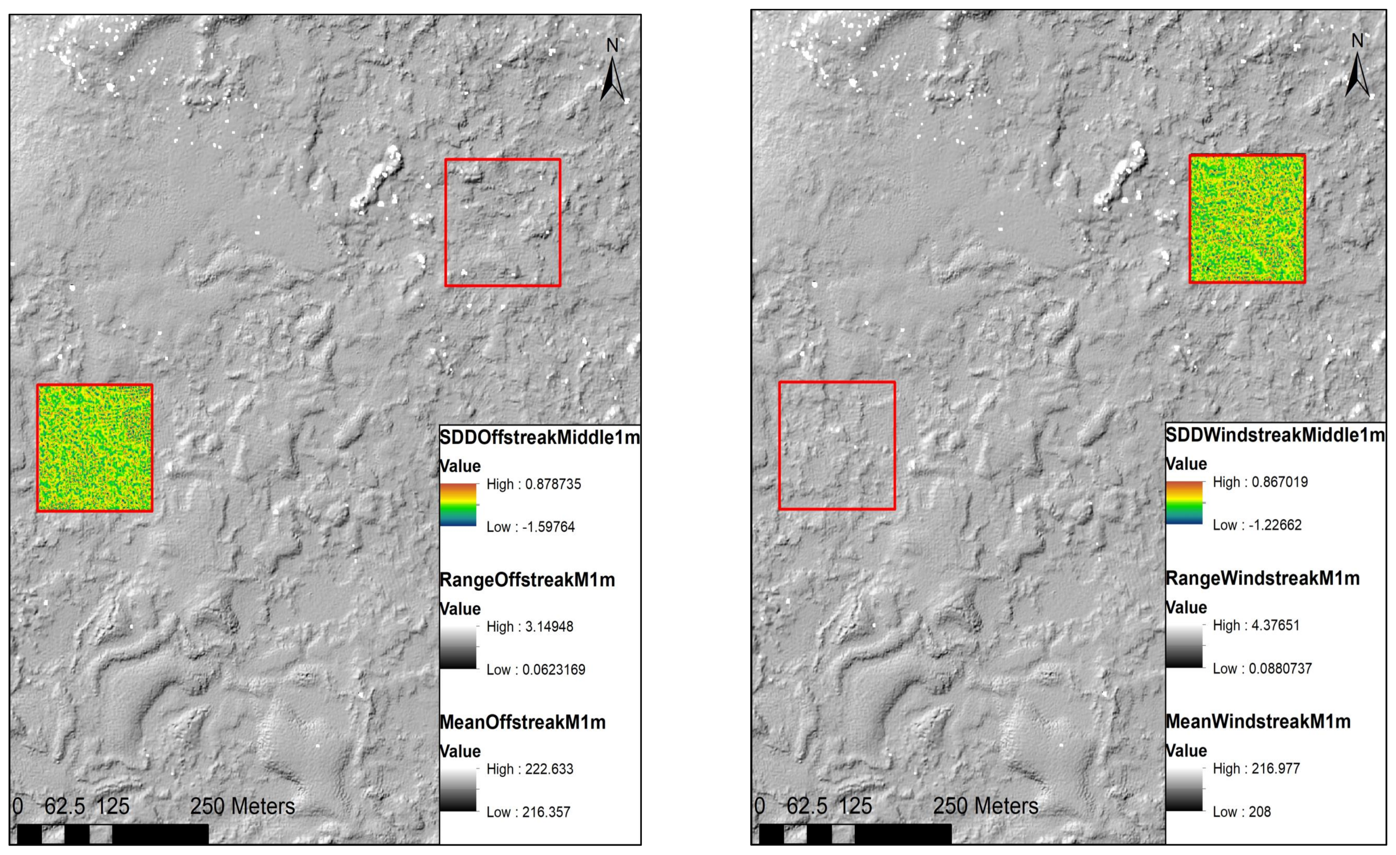


Figure 5a (left): Surface roughness at the 1 meter scale on an area outside of the wind streak at Amboy.
Figure 5b (right): Surface roughness at the 1 meter scale on the wind streak at Amboy

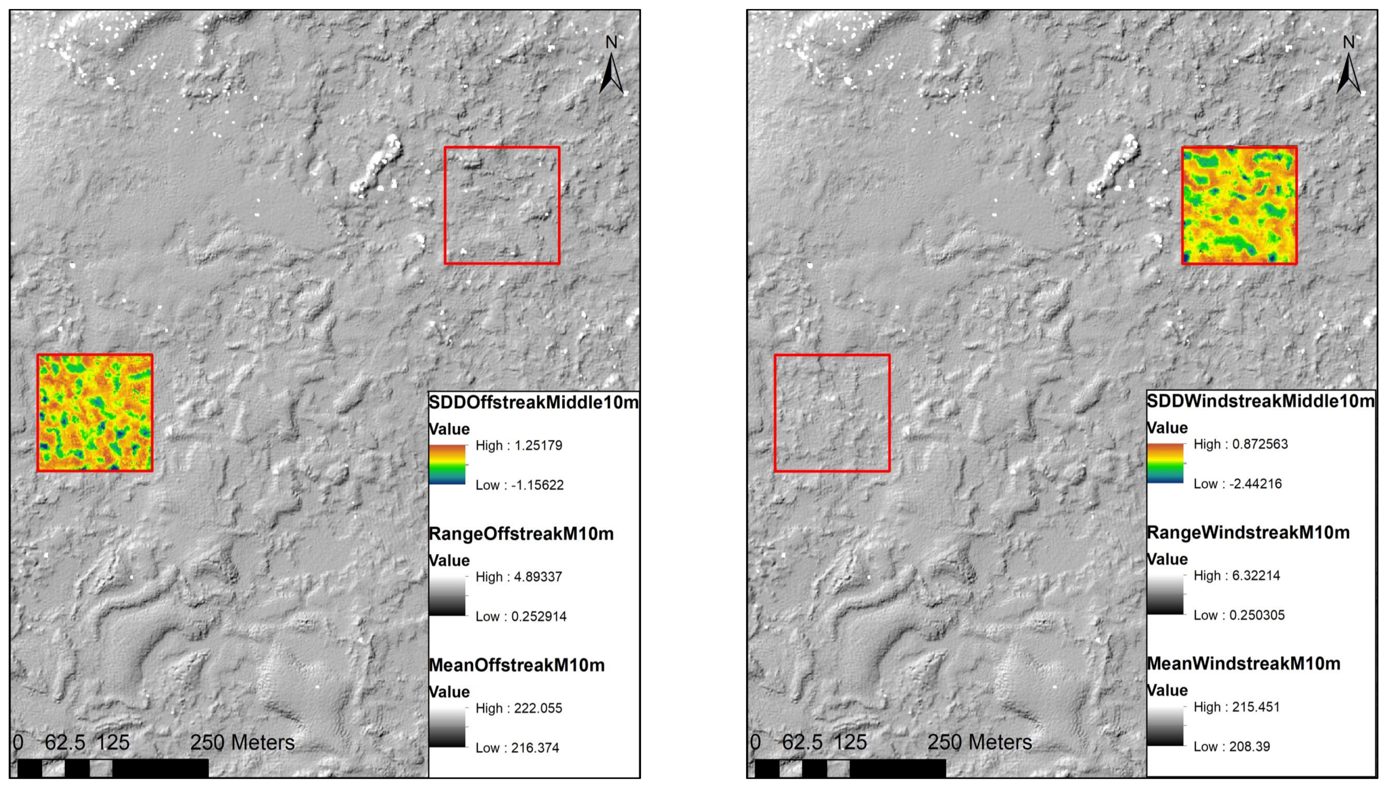


Figure 6a (left): Surface roughness at the 10 meter scale on an area outside of the wind streak at Amboy.
Figure 6b (right): Surface roughness at the 10 meter scale on the wind streak at Amboy

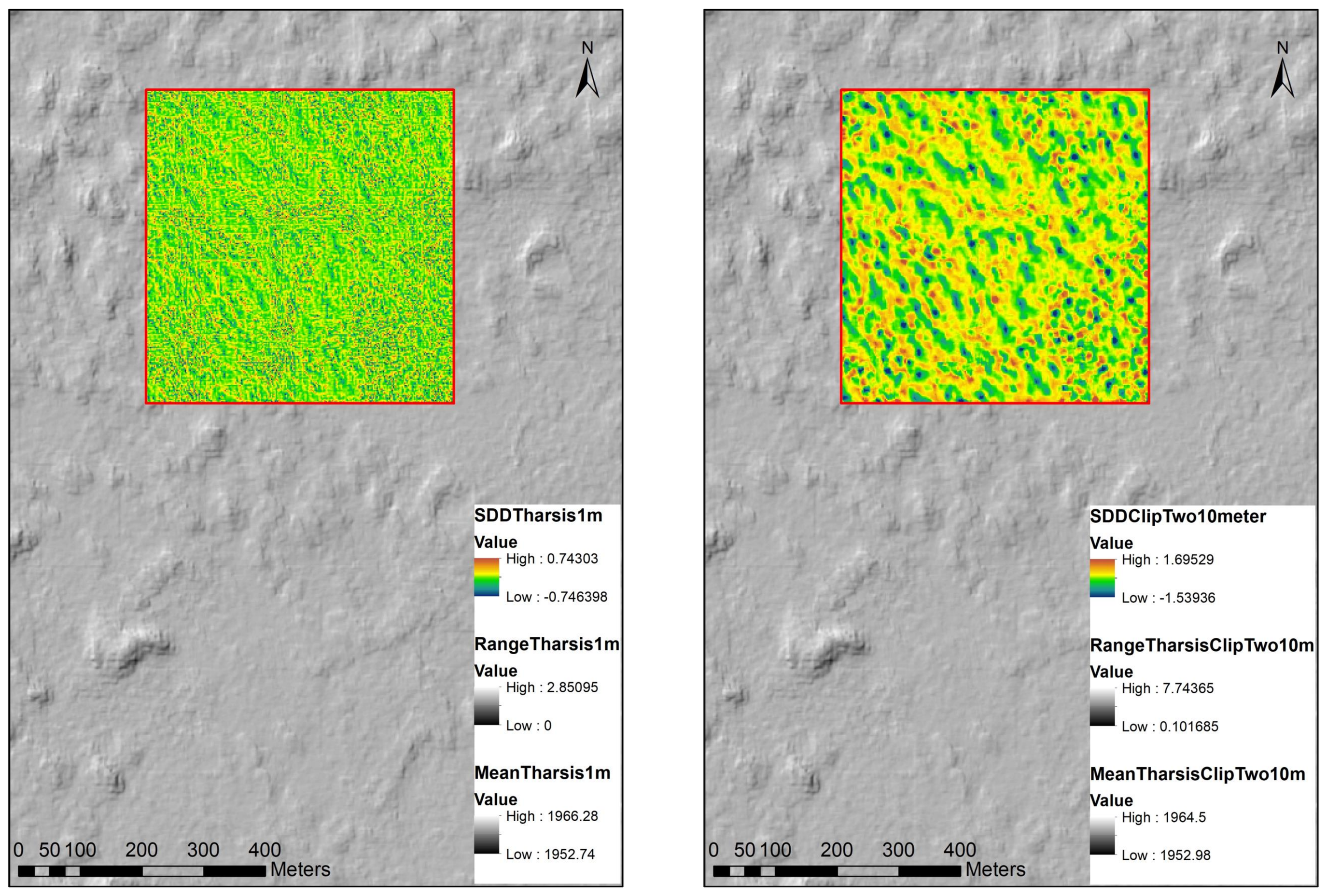


Figure 7a(left): Surface roughness at the 1 meter scale on an area in the Tharsis region.
Figure 7b (right): Surface roughness at the 10 meter scale on an area in the Tharsis region

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