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An Investigation of Araneiform Terrain in Angustus Labyrinthus, Mars.

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1. Introduction

Seasonal condensations and sublimations of CO_2 in the south pole not only drive energy exchange between the pole and atmosphere, but also have created a host of enigmatic phenomena exhibiting intriguing patterns. Araneiform terrain is one striking example (informally called "spider") which is observed exclusively in the southern polar area and characterized by radially organized troughs usually with central depressions [1-3] (Fig.1). Their formation is suggested to involve with gas jetting activities invoked by basal sublimation of translucent CO_2 ice slabs [1-3]. However, its detailed formation mechanism as well as thorough schematic of erosion process is still incompletely understood. The objective of this work is to address these issues.

Angustus Labyrinthus (81ºS, 296ºE, dubbed "Inca City") hosts a considerable number of spiders [2] and has been repeatedly covered by the High Resolution Imaging Science Experiment (HiRISE) with image scale as high as 0.25 m/pix [4]. Thus, it offers a prime site for us to conduct an in-depth study.

2. Results

In this work, we (1) reported two new spider species (elongated half and spiders) based on the detailed geomorphological investigation; (2) proposed a new formation mechanism for spiders, indicating the existence of an inhibited zone around a newly formed spider which is consistent with the non-random distribution characteristics confirmed by the spatial randomness analysis; (3) explained effects of local topography (e.g., ridges) and pre-existing linear depressions in the formation process of half and elongated spiders.

We mapped spatial disruption of spiders in the Inca City region based on HiRISE images (Fig.1a). Two newly-reported spider types (half and elongated spiders) are identified.

Elongated spiders: Located in one region with current available observations and characterized by short sinuous troughs emanating from straight linear depressions (Fig.1c).

Half spiders: Located along ridge boundaries with one-half observable (Fig.1d).

Through spatial randomness analysis (Fig.2, details of this method see [5]) of one spider population (Fig.2a), we can see the spatial distribution of spiders is non-random or more separated than random (Fig.2b).

3. Discussions and conclusions

In this work, we suggest that seasonal CO_2 ice slab layer remains in contact with the substrate during basal sublimation thus the gas is trapped inside the substrate (Fig.3a), in contrast with general understanding that the sublimating gas is trapped between the substrate and the CO_2 ice slab layer [1-3]. Then released gas disperses into the porous substrate, building pressure. The ice layer cracks at certain threshold pressure leading to gas-jetting and consequent erosion (for more detail see Fig.3 and 4). Therefore, substrate porosity and degree of cohesion are crucial parameters for spider formation.

When the extremities approach those of a neighboring spider, pressure accumulation becomes shared, weakening the carving force, and thus causing the spider growth to slow down. We expect that in the vicinity of one spider, the dispersed pressure should inhibit the initiation of a new spider. In other words, an inhibited zone exists in which another spider is less likely to occur.

The spatial randomness analysis in our sample population (Fig.2a) confirmed that spatial distribution of spiders is non-random and yields a value which is 55 m. We suggest it indicates the minimal size of the inhibited zone in this spider population. We expect this value is closely associated with the substrate porosity and varies from region to region.

The linear depressions in the elongated spider distribution region are likely pre-existing features produced by different geological processes and offer a ready-made path for gas migration towards a vent. Some linear depressions with sparse troughs could express an early stage of elongated spider formation (Fig.1c). For half spiders, more consolidated material with lower porosity on the slope area than the flat region results in a faster pressure-rising which leads to gas flows towards the neighboring flat region. This may enhance the initiation of jetting near the boundary. The sun-facing slopes may reinforce this trend for receiving more solar insolation. In addition, the more consolidated material of slope area also likely prevents the growth of spider “legs” up the slopes.

Our case study in the Inca City region provides new understanding in the formation process of basal sublimation-driven features and thus offers new insights into polar surface processes.

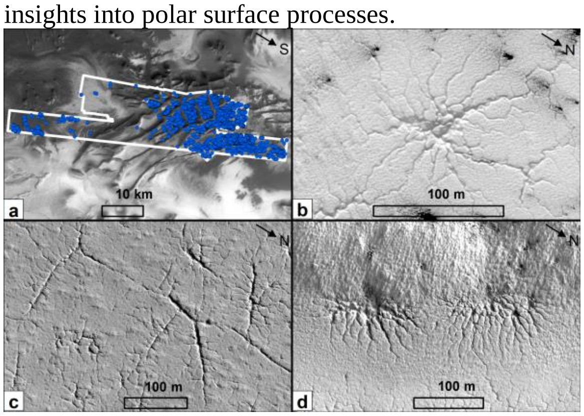

Figure 1. (a) Spatial distribution mapping of spiders in the Inca City region. White polygon indicates the HiRISE coverage; blue points indicate the locations of spiders. (b) An example of spiders. (c) Elongated spiders. (d) Half spiders.

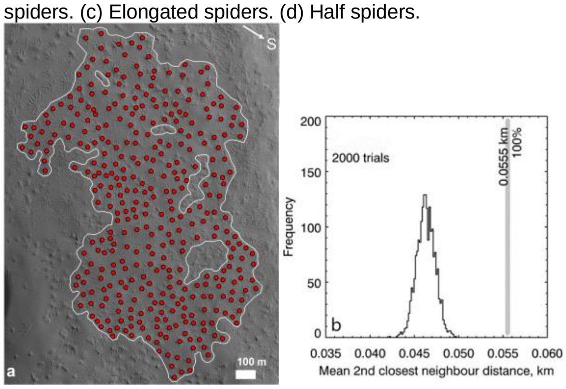

Figure 2. Spatial randomness analysis. (a) The spider population chosen for this analysis. The white polygon delineates the extent of mapped area. Red points show positions of spider centers. (b) Histogram showing the mean 2nd-closest neighbor distances (M2CNDs) for 2000 random configurations relative to the M2CND value (grey bar) of observed spider population (details see [5]).

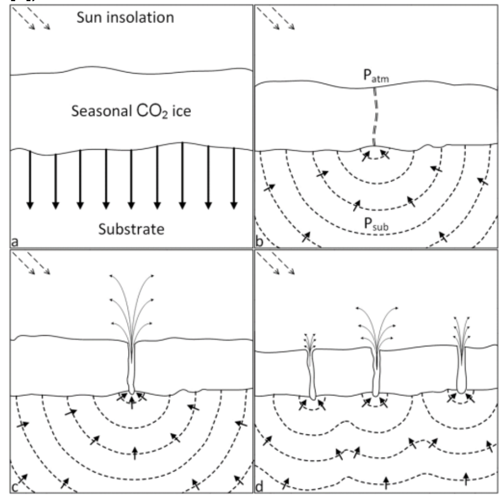

Figure 3. (a, b) In the spring, with sunlight penetrates to the substrate, basal sublimation occurs. The sublimating gas disperses into the porous substrate and migrates towards the rupture along the pressure gradient. (c) The pressure gradient leads to gas eruption at certain value, which results in rapid escape of gas entraining sand and dust, forming cavities or holes. (d) Beyond a certain range, the rate of lateral flow becomes lower than the local rate of accumulation from basal sublimation. A new rupture occurs. Below this range, the lateral flows act to inhibit accumulation of sufficient pressure to cause a rupture.

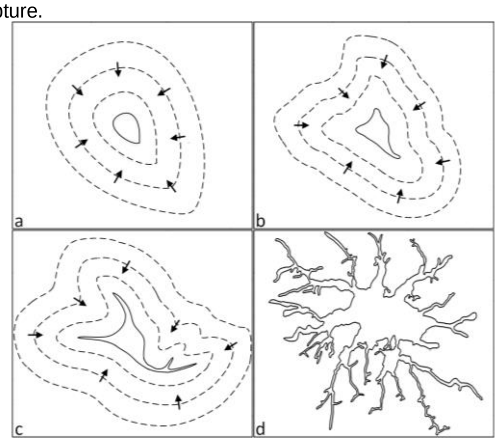

Figure 4. The schematic of spider erosion. Collapses at substrate-atmosphere boundary may initiate irregular prominence in pit. Pressure gradient diverts gas flow preferentially towards any prominences of a pit, enhancing irregularity, and leading to growth of troughs. (d) shows a mapping of a real spider in our study area.

References

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