Survey of sublimation Landforms at the South Pole of Mars - A Case Study of Angustus Labyrinthus.

J. Hao[1], G. Michael[1], S. Adeli[2], R. Jauman[1,2], [1]Planetary Sciences and Remote Sensing, Institute of Geological Sciences, Freie Universität Berlin (Malteserstrasse 74, 12249 Berlin, Germany; J.Hao@fu-berlin.de), [2]Institute of Planetary Research, Deutsche Zentrum für Luft- und Raumfahrt (DLR) (Rutherfordstrasse 2, 12489 Berlin, Germany).

Introduction: CO_2 condenses and sublimates each year at poles of Mars [1]. This seasonal process not only drives energy exchange between the poles and atmosphere, but also leads to a variety of sublimation landforms. One prominent example are araneiforms or spiders [2-5]. They are observed exclusively in the southern polar area and are characterized by radial or dendritic troughs usually with central depressions [2-5] (Fig.1). Gas jetting models were proposed to explain their formation process which involves basal sublimation of a seasonal translucent CO_2 slab ice layer and subsequent gas jetting [2-7]. However, the detailed formation mechanism still remains incompletely explored. We try to address this issue in this work.

Angustus Labyrinthus or the Inca City region (81ºS, 296ºE) hosts an abundance of spiders [4] and has been intensively monitored by the High Resolution Imaging Science Experiment (HiRISE) with a spatial scale up to 0.25 m/pix [8]. Hence, it is a promising target for us to conduct an in-depth study of araneiforms.

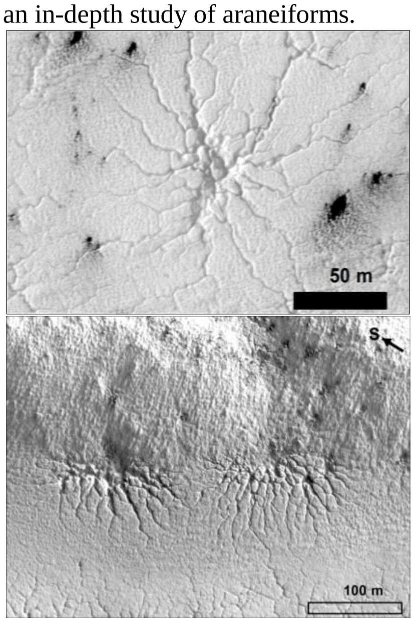

Fig.1 Upper: Spider in Angustus Labyrinthus; Bottom: Half spider located at a ridge boundary.

Results: We mapped spatial distribution of spiders in the Inca City region based on HiRISE images (Fig.1a), and observed one new spider type (half spiders) based on detailed geomorphological investigation. They are located only along ridge boundaries with one-half observable (Fig.1).

We proposed a new formation mechanism for spiders, inferring the existence of an inhibited zone around a newly formed spider which is consistent with the non-random distribution characteristics indicated by the spatial randomness analysis (Fig.2).

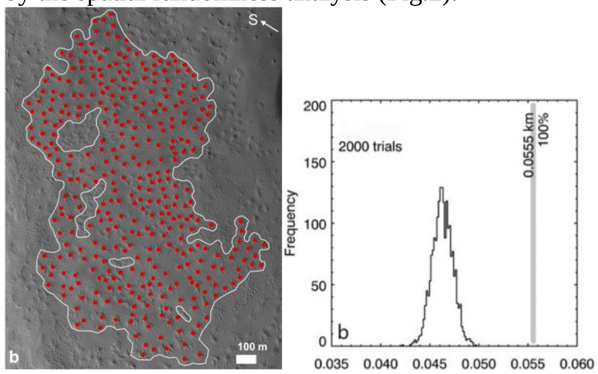

Fig.2 Spatial randomness analysis for a spider population. (a) spatial mapping for the spider population; (b) result of spatial randomness analysis. The histogram was generated for random configurations. The gray bar indicates mean 2nd-closest neighbor distance (M2CND) of the spider population. This M2CND is larger than the majority of random configurations, it shows that the spatial distribution is non-random or 'more separated than random'. The unit of X axis is km.

We explained the effect of local topography (e.g., ridges) in the formation process of half spiders.

Discussion and conclusions: In this work, we suggest that the seasonal CO_2 ice slab layer remains in contact with the substrate during basal sublimation and thus that 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 [1-4]. The released gas disperses into the porous substrate, building pressure [5]. The ice layer cracks at certain pressure leading to gas-jetting and consequent erosion (for more detail, see Fig.3 and 4). Therefore, substrate permeability, porosity, and degree of cohesion are crucial parameters for spider formation.

When the spider extremities approach those of a neighboring spider, the pressure accumulation becomes split, weakening the erosive force, and thus causing the spider growth to slow . We expect that in the vicinity of one spider, the released 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.2) confirmed that the spatial distribution of spiders is non-random and yields a value which is 55 m. We expect this value is closely associated with the substrate permeability and varies from region to region.

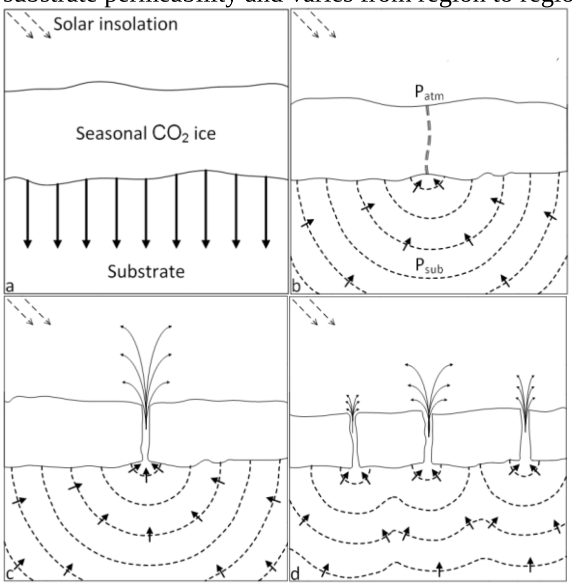

Fig.3 Spider formation. (a) solar insolation warms surface beneath ice layer triggering basal sublimation; (b) ice cracks at certain pressure; (c) gas erupts, entraining soil material above the surface, forming cavities; (d) the formation of one spider influences the vicinity such that another spider is less likely to occur inside the inhibited zone.

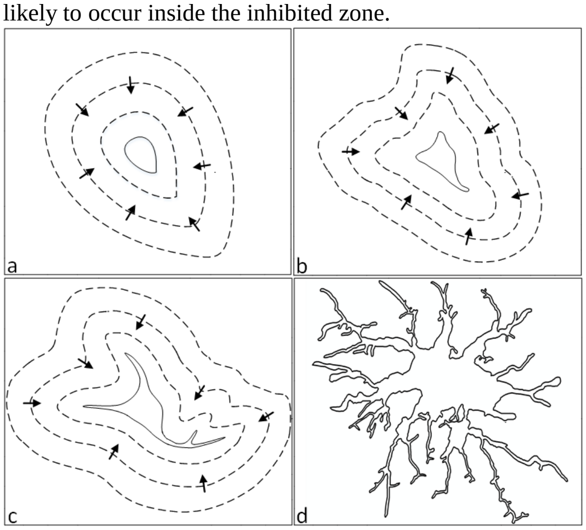

Fig.4 The schematic of spider growth. (a) Gas eruption produces a pit in the substrate. (b and c) Collapse at substrate-atmosphere interface may initiate irregular prominence in pit. Pressure gradient diverts gas flow preferentially towards any prominences of a pit, enhancing irregularity, and leading to growth of a trough. (d) Seasonal repetitions of the above processes lead to dendritic troughs. (d) shows a mapping of a real spider in our study area.

For half spiders, more consolidated material with lower permeability on the slope area than the flat region results in a faster pressure-rise 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 [5].

Summary: (1) We suggest a spider formation mechanism, detailing the mechanism of growth of central depressions and dendritic troughs. We propose the sublimating CO_2 gas enters and pressurizes the porous substrate. (2) The permeability and degree of cohesion of the substrate are significant parameters controlling the mechanism of the spider growth. (3) The presence of a spider structure restrains the initiation of a new spider in its vicinity by diminishing the local pressure beneath the overlying seasonal CO_2 ice layer, producing an inhibited zone. (4) Spatial randomness analysis reveals that initiation locations of spiders are more separated than a random distribution which is consistent with our proposed spider formation mechanism. (5) Our finding on half spiders indicates that the topography and substrate characterization play an important role in spider formation.

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

References: [1] Leighton and Murray (1966) Science 153. [2] Kieffer et al. (2007) Nature 442. [3] Piqueux et al. (2003) JGR, 108 (E8), 5084. [4] Hansen et al. (2010) Icarus 205(1). [5] Hao et al. (2019) Icarus 317. [6] Pilorget et al. (2011) Icarus 213. [7] Portyankina et al. (2010) Icarus 205, 311–320. [8] McEwen et al. (2007a) JGR, 112, E05S02. [9] Michael et al. (2012) Icarus 218, 169–177.