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Relationship between thermal-contraction polygons and substrate properties on Mars

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On Earth, sharp drops in negative temperatures can cause ice-cemented ground to crack and form polygonal patterns. Over time, water and/or sand can infill cracks (Péwé, 1959; Lachenbruch, 1962; Black, 1976). This material can freeze into ice or sand wedges, uplifting polygon margins and forming low-centred polygons (LCPs). When wedges degrade, elevation of margins decreases which forms high-centred polygons (HCPs). On Mars, similar polygonally-patterned ground is observed (with LCPs and HCPs) and also thought to be formed by thermal contraction of the ground (Mellon, 1997), but the type of wedge is unknown. Liquid water is thought to have been unstable on Mars's surface for 3 billion years, but a recent study in Utopia Planitia suggested an ice-wedge origin for the studied polygons (Soare et al., 2021). This implies near-surface liquid water on Mars in the recent past, and presence of massive ice in the subsurface – an interesting source of water for future manned missions.

Here, we investigate the relationship between polygon density & type and the properties of the substrate that bears them (e.g. grain size or porosity). We focus on polygons in Utopia Planitia and use the same grid-based mapping technique as Soare et al. (2021). This technique consists in gridding the study area in squares of given dimensions (500 x 500 m), and in each square noting the presence of each polygon type. We mapped three geomorphological units in our study area: the "sinuous unit" (sinuous shape, polygon-rich), the "boulder unit" (covered in decametric boulders, polygon-poor), and the craters. For each unit we calculated parameters (e.g. percentage of squares containing polygons) which we expect to act as proxies for different substrate properties (e.g. capacity for the ground to form polygonally-patterned ground). We found that:

- the boulder unit is an ice-poor massive material hindering ground cracking / polygon formation;
- the sinuous unit is an ice-rich material favouring ground cracking, but not ice wedge formation or preservation;
- crater floors host ice-rich material favouring ground cracking, and are environments favourable to ice wedge formation and preservation.

Our study area is located at the terminus of Hrad Vallis, a valley system originating from a nearby volcano (Elysium Mons) and thought to have conveyed both lava and mudflows (Hamilton et al., 2018). Therefore, we suggest that the boulder unit could be a low-viscosity lava flow, which would have been topped by a later viscous mudflow that formed the sinuous unit, both originating from Hrad Vallis. The low elevation of crater floors compared to their surroundings leads to higher

atmospheric pressure and lower temperatures at their bottom. This could favour ground ice formation and preservation – a “cold trap effect” already discussed by Conway et al. (2018) and Soare et al. (2021).

In summary, we show that polygon density and type can provide insights into the geological properties of a substrate, and here it allowed us to suggest origins for the units of our study zone that are consistent with the geological context of the area.