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Towards a better understanding of desiccation processes on Mars and its implication to Martian hydrology: numerical modelling, global mapping, and field studies

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Abstract

Recent global mapping efforts using high resolution images have shown that polygonal cracks likely formed by desiccation are widespread throughout Mars, usually in geologically and/or mineralogically specific settings. We briefly describe here our recent finds and ongoing efforts into understanding desiccation processes on Mars using geological mapping, numerical modeling, and field studies.

1. Introduction

Polygons on Mars range in size from 2 meters all the way up to 10 kilometers in diameter. Consequently, different formation mechanisms have been proposed depending on their size scales. A global study of Intermediate-spaced (70-300 m crack spacing) polygonal cracks (ISPs) inside impact craters was carried out by [1] (Fig. 1). Using an analytical model, desiccation was suggested as a (main) mechanism for the formation of intermediate-size polygons, while not ruling out contributions from thermal stresses (see [1] for detailed analysis).

Incidentally, [2] used thermal infrared remote sensing data to identify and characterize global distribution of distinct materials interpreted to contain chloride salts on the Martian surface located in ~640 distinct sites (Fig. 1c) dispersed throughout Noachian- and Hesperian-aged (more than 3 Gyr old) terrains. Their survey also shows that the materials occur in local topographical lows and occasionally display cracking with a morphology and size distribution similar, at times, to ISPs that were mapped by [1]. In addition, various workers studying clay-rich terrains on Mars have reported that the deposits occasionally display polygonal cracking [e.g., 3,4] which is common for clays undergoing dehydration. Assuming that all of these occurrences of polygonal cracks in specific geological settings are more indicative of desiccation rather than periglacial processes, we can infer that further in-depth studying of these cracks should yield important information on Mars' ancient climate and hydrology. To that end, a multidisciplinary approach is being taken to understand how desiccation may work in a Martian climatic setting. We briefly report here on the highlights of our ongoing work.

2. Results

2.2. Numerical Modelling

A pre-fracture incrementally non-linear elastic–hydric model was developed and reported in [5] that shows that tensile stresses rise monotonically with desiccation. The model clearly shows that for typical diffusivity values of clayey soils with a considerable amount of smectites enough stress can build up to stimulate cracking of various spatial scales. These results corroborate earlier assumptions that giant desiccation polygons on Earth occur through lowering of the water table rather than surface evaporation. Extending the model to Mars shows that soils would crack within similar diffusivity limits but in slightly longer periods of time owing to the lower gravity. Form that, it can be deduced that two main conditions need to be fulfilled for desiccation cracks to occur under current martian climatic conditions, namely, that the thermal and soil diffusivity conditions 1) allow for the formation of an unsaturated zone with a considerable thickness while at the same time 2) limiting the growth of the permafrost downward which would disrupt the cracking process (see [5] for detailed analysis and model description).

2.1. Survey of putative chloride-rich terrains

An ongoing campaign of mapping the putative chloride-rich terrains shows that cracking is nearly ubiquitous in the putative chloride-rich deposits that are imaged by high resolution cameras (less than 3 m/pixel resolution) with a range of crack spacing that varies from 2 meters up to 70 meters. The chlorides are usually found within basins and natural depressions, and interestingly, are occasionally associated with clay-rich signatures as the presented numerical model in [5] predicts.

2.3. Field studies

In Jan 2012, we conducted a field trip to two dried up lakes in California, US that were reported [6] to display large desiccation polygons. Soil samples from various depths and locations were collected for lab analysis coupled with an on-site survey with ground-penetrating radar to investigate the physical properties of the subsurface and possibly the depth to the water table. The analysis of the acquired data will be reported in the meeting.

3. Conclusions and future work

The current project which combines mapping, modelling, and fieldwork is yielding significant results that should help in understanding the process of desiccation in a Martian climatic setting. Future work involves: 1) Building up the numerical models to incorporate temperature fluctuations and freezing. 2) Careful lab studies and physical experiments on the field samples and other analogue soils in a Mars simulation chamber. 3) Further mapping and characterization of terrains on Mars exhibiting putative desiccation cracks using high resolution images in addition to spectral data.

4. References

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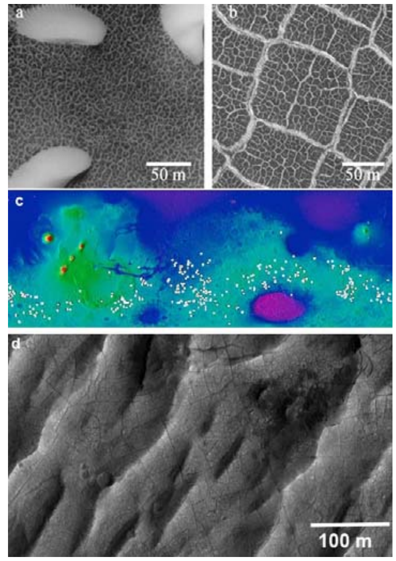

Fig. 1. (a) Typical thermal contraction polygons (TCPs) on Mars and comparison to ISPs (b) with high resolution orbiter images from the HiRISE camera (resolution 25 cm/pixel). TCPs on Mars are typically 5-10 meters wide and are ubiquitous in the high latitudes (a). ISPs on the other hand are usually associated with impact craters and range in size from 15 to 350m. In the higher latitudes the fractures, usually 1-10 meters wide, are occasionally filled with frost or permanent ice and usually display two distinct size groups: Large 70 to 350 meter-sized polygons with an average polygon diameter of 120 meters, and a smaller group, not always present, ranging in size from 5 to 20 meters which are most likely TCPs. (c) Distribution of putative chloride-rich material on Mars as reported by [3]. (d) Typical cracking patterns associated with chlorides as seen with high resolution images.