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Desiccation experiments using wet clay-bearing soils as an analogue for desiccation cracks on Mars

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1. Introduction

Extensive mapping of polygonal fracture patterns on the surface of Mars suggests that polygonal desiccation crack patterns may be a common feature that is present in various size scales ranging from cm-scale up to hundreds of meters [1–4]. Therefore, it is essential to investigate the nature of soils that are capable of producing desiccation patterns at the scale seen in satellite and rover images as well as to constrain the climatic conditions that are needed for the process to take place on the Martian surface. Recent models suggest that migration of subsurface water may be needed even more than surface evaporation to account for the size-scale (10s of meters wide) of the polygonal patterns seen on Mars [5]. As such, this work has important implications for our understanding of the history of liquid water on Mars.

In this meeting, we will be reporting on the initial results from our desiccation experiments on wet soil analogues in ambient and Mars-like atmospheric conditions. These experiments represent the first step in understanding the processes involved on the cm-scale (i.e., involving only surface evaporation), which may later be extrapolated accordingly to account for larger scales.

2. Methods and experimental set-up

The soil analogues that are being used are mainly composed of Werribee clay, which is a smectite-rich clayey soil that was weathered from basaltic rocks, and has been used in many desiccation experiments [5] (table 1), and clay-rich soil samples that have been collected during fieldtrips to Coyote and Lucerne dried lakes (in California, US), which are locations of large desiccation cracks [5, 6].

The experiments are being carried out using two different setups; one for ambient laboratory conditions and the other one for conditions of reduced pressure and temperature, more representative of the surface of Mars. The experimental setup for ambient conditions consists of an accurate lab scale (resolution of 1 mg) connected to a computer to acquire and save mass measurements with the desired time resolution. A petri dish containing the sample is placed on the balance and its entire surface is observed continuously by a colour CMOS camera. The acquisition of images is synchronized with the mass measurements.

Figure 1: Picture of the simulation chamber showing a sample of clay/sodium chloride mixture through the upper window and cameras and illumination fibres fixed around the window.

The second setup consists of a nitrogen-cooled vacuum chamber in which the sample can be kept under low pressure / low temperature conditions for extended periods of time. The chamber is equipped with a large window on its upper side (figure 1). Visible and near-infrared cameras record the evolution of the surface of the sample with a user-defined time-resolution.

3. Initial results

We report here on initial results from the experiments that have been carried out using Werribee clay. The sample is initially in a slurry state (water content of ~130% by wt) left to desiccate freely at ambient conditions (~22 °C, 1 atm, 30–35% RH). The water content decreases linearly with time and continues to do so even after the onset of cracking (Figure 2). Cracks are expected to develop when the stresses that buildup within the soil because of desiccation exceed the tensile strength of the soil (typically in the order of 100s of kPa at the onset of cracking for Werribee clay).

We plan to extend these experiments by investigating the effect of various salts on the extent and time-scale of cracking as well as the properties of other soil analogs. These experiments will be reported on in more detail at the meeting.

Table 1: Properties of Werribee clay (adapted from [5]. Percentages are those of weight, not volume

Basic Properties of Werribee clay soil	
Specific gravity	2.66
Clay content (%)	62
Atterberg limits	
Liquid limit (%)	127
Plastic limit (%)	26
Plasticity index (%)	101
Linear shrinkage (%)	22
Mineralogy	
Quartz (%)	30
Feldspars (albite (%)	8
Illite (%)	10
Kaolinite (%)	10
Ca-smectite (%)	42

4. References

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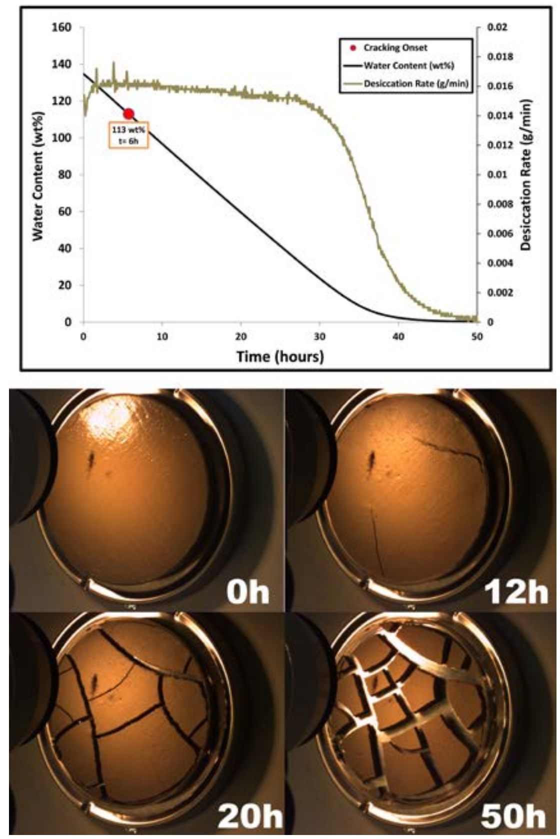

Figure 2: Plot: water content of the soil (wt %) versus time (in hours) for a Werribee clay slurry (~135 wt %) along with another plot for the desiccation rate (in g/min) versus time. Onset of cracking is shown as a red dot (at ~113 wt % after 6 hours of free desiccation) The desiccation process progresses linearly with a rather constant rate up to a certain point (~40 wt %) where it becomes more difficult to get rid of the water due to increased binding forces and the near complete desiccation of the soil's surface. Figures: Images taken of the sample at different times. Cracks initiate as pseudo-linear cracks that later on intersect in an orthogonal manner. Once enough cracks have been created, further desiccation acts to widen the pre-existing cracks.