SIMULATING THE EFFECTS OF THERMAL FATIGUE ON THE FORMATION OF REGOLITH IN A THERMAL VACUUM CHAMBER

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Introduction: Precious space is a research group funded by the Alexander von Humboldt foundation that aims at determining the presence, preservation and characteristics of planetary materials, especially with regard to the understanding and characterization of regolith since it is ubiquitous on all solar system bodies. Regolith and rocks on the surface of asteroids and the moon are subject to diurnal temperature variations that are able to damage the structural integrity of this material [e.g., 1,2] and thus, in-depth understanding of this process is crucial.

Diurnal temperature effects: Different types of stresses can be distinguished based on the spatial scale on which they occur: Grain-scale stresses can develop between grains with different thermal expansion coefficients e.g. metal and olivine, and are driven by the amplitude of the temperature excursion. Additional stresses can also develop at a macroscopic scale due to strong spatial temperature gradients, e.g., stresses within a rock due to daytime surface heating on the surface of a planetary body [e.g., 3]. Simplified, crack propagation due to these stresses leads to block erosion and, in combination with meteoroid impacts [e.g., 4], are able to degrade intact rocks and transform a blocky surface into finer regolith. Recent observations have shown how surfaces of small bodies thought to be covered by cm-scale particles [e.g., 5] are blocky in nature [6,7] and the blocks have unexpectedly low thermal inertia, high porosity and low tensile strength [8] asking for additional in-depth studies.

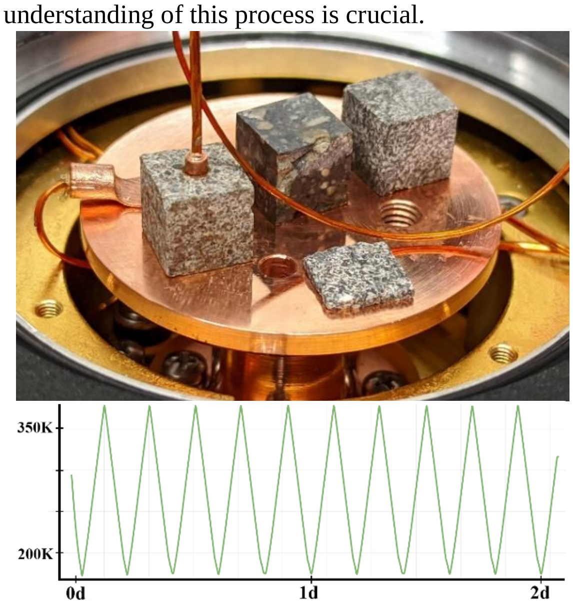

Figure 1: (picture) Cu-coldfinger inside the vacuum chamber with the monitor sample (left) and the attached thermocouples to monitor the temperatures. Crack monitoring is performed on the two additional cubic samples. The thin sample is a reference for thermography. (plot) Measured temperature of a test sample during 10 cycles between 170K and 370K showing the reproducibility of the system (d: Earth days).

Sample Selection: Meteorites allow us to study the mineralogy and petrology of the asteroids they derive from. Since each meteorite group and their respective parent bodies have their unique mineralogy and thermal properties (e.g. Fig. 1c and d), their structural changes as they respond to temperature excursions need to be evaluated individually. For this study, we selected meteorite samples covering different achondrite (Northwest Africa (NWA) 11273, lunar; NWA 11050, eucrite) and chondrite groups including carbonaceous (Allende, CV3; Murchison, CM2; Jbilet Winselwan, CM2; Tagish Lake, C2) and ordinary chondrites (Chelyabinsk, LL5; El Hammami, H5). Because certain minerals in meteorites can be altered on Earth within short timescales, the original mineralogy and texture will be rapidly lost and physical properties may change due to the weathering of e.g. metal and sulfide grains. Thus, meteorite falls have been chosen for the experiments where ever possible.

Experimental Setup: To understand the effect of diurnal temperature variations on the selected meteorite samples, we set up an experimental chamber that is based on an evacuated (~5×10^{-6} mbar) cryostat. A custom-made Cu-coldfinger can be cooled by liquid nitrogen to 100K and cyclically heated with a 100W cartridge heater to up to 475K covering the naturally observed surface temperatures of Near Earth Asteroids (NEAs) or the Moon (e.g. Fig. 1a, [e.g., 2]). Temperatures measured on various locations in the chamber and within a monitor sample show a well reproducible experimental setup (e.g. Fig 1b). Combining the observations of the thermal cycling experiments obtained by scanning electron microscopy and micro computed tomography (µ-CT) scans allows for in-depth understanding of crack growth and crack formation in a variety of different meteorite samples in vacuum conditions.

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