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Experimental simulation of cometary surfaces using volatile-rich analogue materials

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Introduction

Cometary surfaces are shaped through the process of activity when the comet approaches the sun and the sublimation of volatiles removes dust and gases. Recently, the ESA Rosetta mission showed the geomorphologic diversity of comet 67P/Churyumov-Gerasimenko in great detail (Fig. 1), giving us the opportunity to investigate the sublimation processes on small Solar System bodies by means of geomorphologic analyses of the surface. In order to understand how these processes alter the surface appearance, we investigate the morphologic evolution of sublimating cometary surfaces in the laboratory of the IGEP department at TU Braunschweig. The focus lies on the evolution of different morphologies that were found on comet 67P/ Churyumov-Gerasimenko, such as fractures and debris deposits [1, 2]. We consider the composition and initial geometry of the samples and variable insolation flux. Different sample compositions and geometries are prepared to model the interaction of volatile-dust mixtures with vacuum conditions. The results will not only provide information on the material properties and parameters (e.g. cohesion, tensile strength) of comets, but will also enable us to analyse the morphologic evolution of cometary surfaces.

Figure 1: Image of comet 67P. It shows a diverse surface with various boulders and fractures. We want to reproduce these patterns in the laboratory. The image measures 1 km across. Copyright: ESA/Rosetta /NAVCAM

Scientific objectives and questions:

-Under which insolation and compositional conditions do fractures form in the sample material?

-Under which insolation and compositional conditions do cliffs collapse form and larger blocks of debris?

-Under given environmental conditions, how stable are morphologic features and do they remain on the surface?

-How do sublimating volatiles support the process of dust transport?

-What are the time scales of activity under given environmental conditions?

Methods

Initial investigations were conducted using cometary analogue materials. These materials are mixtures of water-ice and siliceous particles with a diameter of a few microns and in different mixing ratios. The water-ice particles are produced by freezing mist with liquid nitrogen and the siliceous material consists of spherical particles of comparable size.

In our experiments we use sample mixtures of variable particle sizes and water-ice/siliceous dust ratios [3, 4]. The samples are shaped into various morphologies, such as cubes or cylinders representing cliffs or boulders and placed into the vacuum sublimation chamber provided by the CoPhyLab project. A solar simulator is installed above the chamber and insolates the sample through a window with about 1.1 solar constants. During insolation, water-ice sublimates and the altering sample morphology is observed with cameras for several hours and subsequently analysed.

Results

After the cometary analogue material had been shaped in morphologic forms, they were placed into the cooled vacuum chamber and monitored for 16 hours. During the sublimation time we observed the following morphologic changes:

1. The insolated top surface of the samples was stable.

2. Individual particles broke off steep (90°) walls as fine grained deposits.

3. The sample broke up into larger blocks.

The experiments with constant insolation show a dependency of the cohesion of the remains on volatile-dust ratio. Volatile rich samples decay completely to loose and fine-grained deposits, while samples rich in dust form larger and more stable fragments (Fig. 2).

Discussion

The experiments can be divided into three phases. After a first and short period of inactivity, the volatile ice begins to sublimate from the surface of the sample. The resulting volatile-free material reduces sublimation in underlying areas, depending on the initial volatile content of the sample. In the third phase occasional sample collapses expose fresh material to the surface and briefly increases the sublimation rate.

Outlook

It has been shown that active cooling of the sample with liquid nitrogen is absolutely necessary to achieve meaningful results because the experiments at room temperature lead to sublimation patterns incomparable to those on 67P. This will be implemented in upcoming experiments. Upcoming experiments will include CO_2-ice as volatile and additional monitored processes will be:

-variability of mass loss during different phases of insolation

-lateral extent of mass movements

-evolution of temperature inside the sample material

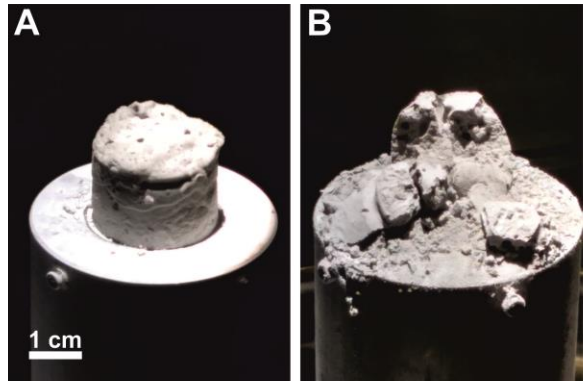

Figure 2: Stages of a sample during the sublimation process. The samples are 2.5 cm in diameter. **A:** A sample at the beginning of the experiment. It consists of water ice and siliceous material in a mass ratio of 1:2. Insolation comes from the top. **B:** The same sample at the end of the experiment decayed into numerous fragments. The remains range from fine particles to angular boulders in a broad particle size distribution.

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