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Activity as a driver for cliff collapse on comet 67P/Churyumov-Gerasimenko

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Abstract

ESA's Rosetta spacecraft is orbiting its target comet 67P/Churyumov-Gerasimenko since August 2014. OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) [1], the scientific camera system onboard, has since then been acquiring images of the comet's nucleus revealing a large variety of surface features and geomorphologically diverse regions [2, 3, 4]. Among these features are cliff structures that show fractures and an accumulation of debris at the bottom, suggestive of continuous mass wasting [5]. Vincent *et al.* [6, 7] suggest that continuous cracking and subsequent removal of volatiles through activity destabelize the cliff to a point where the front of the cliff breaks off. We present here a model aiming to derive physical parameters from the observed collapse features.

1. Introduction

The OSIRIS images allow us to analyze the structure of the surface of 67P in high resolution of up to 10 cm/px. Figures 1 and 2 shows a cliff with an accumulation of debris at its foot. In addition to a fractured wall and accumulated debris, the blanket of dust covering the upper table of the cliff shows indications of mass wasting towards the cliff edge. The OSIRIS images serve to constrain parameters that help to understand the cliff's condition:

- the degree of fracturing constrains the mechanical stability of the wall
- the amount of debris that is accumulating at the foot gives a lower limit for the former volume of the cliff
- the mass wasting at the top edge constrains the thickness of the dust layer and its mechanical properties

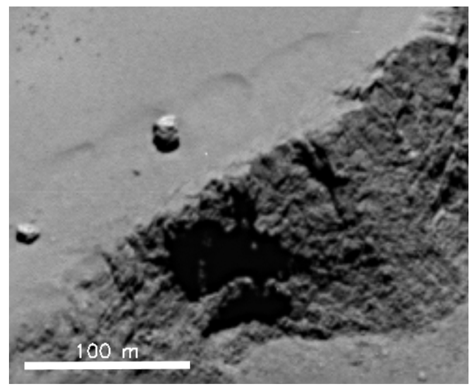

Figure 1: An example of a cliff with fractures and debris accumulated at the foot.

2. Mapping cliffs

Using images taken in September and October 2014 we map the global distribution of cliffs over the entire nucleus and compare the spatial distribution of cliffs with the maps of active sources by Vincent *et al.*

3. Modeling of cliff collapse

Assuming that volatiles act to strengthen the cliffs through their larger cohesiveness, their removal by activity should subsequently lead to structural weakening of the cliff wall resulting in a collapse of parts of the cliff. We aim to estimated the depth to which the volatiles have to receed before the wall becomes instable through a simple two-dimensional model that describes the cliff as a dust-ice-mixture with different dust-to-ice ratios. Fractures are introduced to additionally weaken the material locally. We assume material strengths as deduced by Groussin *et al.* [8].

Additionally, we conduct some descrete element modelling computer simulations using the open source code ESyS-Particle [9] to corroborate the findings from the theoretical modelling. We simulated a small slice of a cliff (50x15x25 meters; height, width, depth)

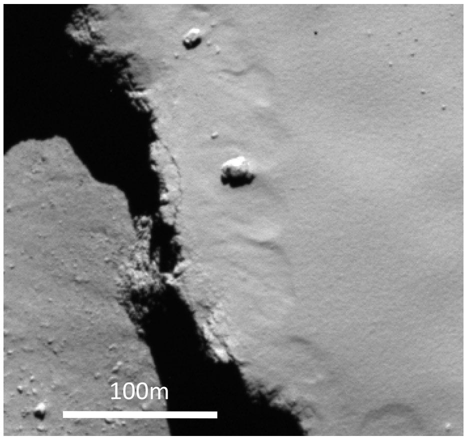

Figure 2: A top view of the same cliff as in figure 1 emphasizing the mass wasting present near the edge of the cliff.

made up of spherical boulders. The size distribution of the boulders was varied in the centimeter to meter range constrained by the size of the fragments found at the foot of the cliffs. Each individual simulated boulder consists of either a dust-ice mixture or pure dust. The strength of the cohesive bonds between boulders is stronger for those boulders containing ice, thus giving these parts of the cliff a higher strength. Starting from the front of the slice, the dust-ice boulders are replaced by pure dust one until such a point where the cliff becomes unstable. Additionally, the influence of cracks (both their number and their depth) is investigated by selectively removing boulders from the cliff in a predefined cross cut.

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