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Cliff Collapses on Comet 67P/Churyumov-Gerasimenko Following Outbursts as Observed by the Rosetta Mission

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Abstract

We are undergoing an intensive search for surface changes on comet 67P/Churyumov-Gerasimenko making use of the wealth of data that was collected by the Rosetta mission over more than two years, which could help constrain the processes that drive surface evolution in comets on a seasonal, and possibly longer term, scales. Focusing on regions that have been subjected to strong outbursts gives us the highest chance of detecting surface changes and better understanding the effect of sublimation-driven outgassing on cometary surfaces. Here, we focus on the detection of a previously unobserved cliff collapse event near the sharp boundary of the comet's northern and southern hemispheres in the small lobe. This collapse is one of the largest such events observed on the comet. Furthermore, its talus suggests heterogeneities in surface materials strength on the comet or varying mechanisms of cliff collapse.

1. Introduction

Comets display evidence for nearly all fundamental geological processes, which include impact cratering, tectonics, and erosion [e.g., 1]. In addition, they also display sublimation-driven outgassing, which is comparable to volcanism on larger planetary bodies in that it provides a conduit for delivering materials from the interior to the surface. Outgassing through sublimation has been shown to occur on comet 67P/Churyumov-Gerasimenko (hereinafter referred to as 67P) in two main modes [2]: A) a low intensity, yet long-running, activity in the form of jets or filaments that follow the insolation patterns and repeat roughly each comet rotation, and b) sudden high intensity events that resemble outbursts, which are active for a limited amount of time (minutes to hours) and then fade away. Numerous surface changes have been observed on 67P with links to different processes [3]. Given their apparent strong nature, it is probable that outbursts cause visible morphological changes on the surface at their source region. Indeed, a cliff collapse in the so-called Aswan area in the northern hemisphere reported in [3] and [4] suggests that it was associated with an outburst or a dust plume event. We are investigating the source regions of outbursts that were reported in [2] to look for surface changes that may have occurred as a result of these outbursts so we can better understand their mechanism, effect on surface evolution, and any potential controls the source region morphology may have on the morphology or scale of the outbursts themselves. We focus here on an outburst that occurred in mid September 2015 (Figure 1), roughly one month following perihelion.

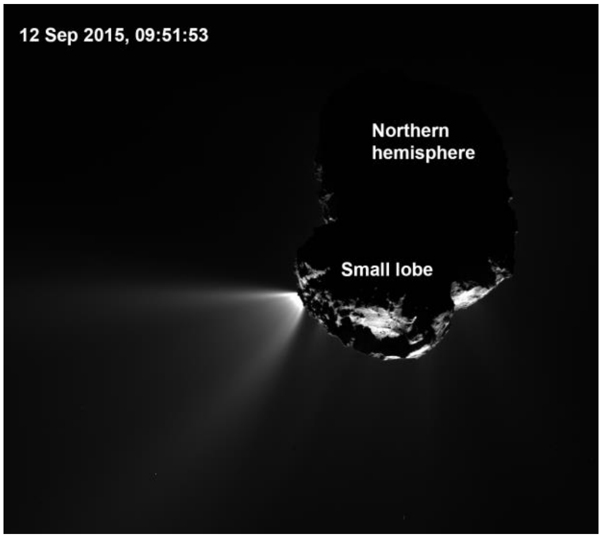

Figure 1. Comet 67P/Churyumov-Gerasimenko and an observed outburst that occurred on 12th of September 2015. The event can be traced roughly to the northern-southern hemisphere boundary on the small lobe.

2. Methods

A list of observed outbursts have been catalogued by [2] including their time, morphology, and approximate source location. We use this data to retrieve images from the cameras onboard Rosetta prior to, and after the outburst events. The Rosetta orbiter carried a scientific camera, OSIRIS [5], as well as a navigational camera, NavCam. We use both datasets since these cameras were usually operating at different times from each other. We inspect the images at a given outburst location prior and after the event to look for morphological changes.

Results

Two cliff collapses in the northern hemisphere were reported earlier in literature. [3] gave an overview of surface changes and included two examples in the Ash and Seth regions in the comet's large lobe [6]. The second of these, also dubbed the "Aswan Cliff" was the focus of a dedicated study reported in [4] because it was observed to be associated with a an outburst or plume event [4], whereas a similar relation could not be easily established for the collapse in the Ash region. We report here on a third cliff collapse that occurred at the boundary between Maftet (northern hemisphere) and Wosret (southern hemisphere) regions [7]. High resolution images (Figure 2) from OSIRIS show that an ~2000 m^2 area has collapsed making it one of the largest cliff collapses that have probably occurred during the Rosetta mission's lifetime. Inspection of images close to the outburst event (at low resolution because Rosetta was pushed to larger distances from the comet for safety during the highly active perihelion period) allow us to ascertain that the scarp was intact up to May 2015.

Due to the close alignment of 67P's southern summer solstice with perihelion passage, the southern hemisphere is subjected to higher solar input, resulting in higher levels of activity and more intensive erosion [8]. The scarp's location and the fact that it appears to have been intact until May 2015 (at least) increases the likelihood that the collapsing event is linked to the outburst that occurred in September 2015. We plan to continue our investigation to further constrain the timing of the collapse. Furthermore, inspection of the talus near the collapsed region indicates that the location has witnessed other mas wasting events in the past. In addition, the talus encompasses blocks of variable size ranging up to tens of meters in size, which is substantially larger than the talus boulder population at the Aswan cliff, which is mainly comprised of boulders a few meters in width [see 4]. This variability in the talus size distribution suggests heterogeneities in surface materials strength on the comet, or varying mechanisms of cliff collapse.

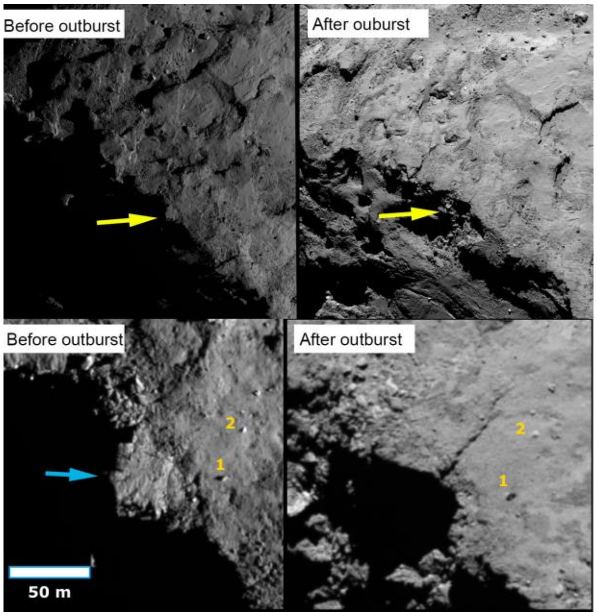

Figure 2. Upper panels: Yellow arrows show the location of a scarp at the boundary between the illuminated northern hemisphere and the dark southern hemisphere of the small lobe at times before and after the outburst event (September 2014 and June 2016, respectively). Lower panels: Close-ups of the upper panel show the scarp (blue arrow) that appears to have collapsed in the image after the outburst. A couple of boulders (1, and 2) are marked for orientation.

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