Comets are comprised of some of the most ancient materials in the solar system, and as such, they represent the substances from which the planets were later formed. By understanding the geologic processes which have acted on cometary bodies, we better understand the context in which to analyze these primordial materials. A detailed understanding of the geomorphologic processes acting on the surfaces of comets is also essential to the future success of comet sample return missions, as it provides necessary data about possible surface evolution which will enable safe touch-and-go sample collection.

Both the surface and coma of comet 67P have been studied extensively since the Rosetta mission’s visit to the comet between 2014 and 2016. During this mission, Rosetta’s Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) captured over 8,200 near-angle camera (NAC) images of the surface of 67P [1], with a bias for the northern hemisphere, which is largely covered by unconsolidated materials called smooth terrains [2].

Smooth terrains consist of large deposits of airfall materials which blanket many regions in the northern hemisphere of 67P [3]. These terrains undergo erosion and deposition driven by the sublimation of volatile ice-rich centimeter to decimeter scale particles which have been redistributed as a result of sublimation-driven erosion of the more consolidated materials [4].

According to numerical models [3] [5] [6] [7] and observations [8] [9], the deposition of airfall materials onto the smooth terrains occur during perihelion, when the northern hemisphere experiences solar light [7]. Once deposited, these materials are redistributed as sublimation exposes new surfaces whose volatiles continue to sublimate, creating a cycle of activity as long as solar insolation is sufficient. These surface changes often occur as mass-wasting events, scarp migration [10], and depression and honeycomb formation [11].

The high spatial and temporal resolution of OSIRIS’s images provides a unique opportunity to evaluate not just the date and categorization of such changes on the comet’s surface, but the more nuanced evolution of smooth terrain geomorphologies. We therefore present the decameter scale spatial and temporal evolution of smooth terrains in the Imhotep, Ma’at, Hatmeht, Nut, Serquet, and Ash regions of comet 67P.

In order to determine the regional locations and types of changes occurring on 67P’s surface, we first selected a reference image which was collected before the comet’s perihelion approach, and before major sublimation activities had begun on the surface.

Next, we generated lists of NAC images which overlap at least 30% with the latitudes and longitudes of the reference image and projected each of these images into the same reference frame as our reference image using a RANSAC reprojection. We created a GUI which then allows the user to cycle through the list of projected images and compare each of them to the reference image. Differences detected between the projected image and reference image were then marked and classified according to the type of change which occurred. These changes include boulder migration, boulder burial, exposure, scarp migration, honeycomb formation, and pitted plains migration. Images with observed changes were sorted by date, and those representing data collection approximately one to two weeks apart were projected onto a three-dimensional model of 67P using ShapeViewer and imported into the ArcGIS software environment for further analysis.

In the case of Ash, as well as several yet-to-be-analyzed regions, an insufficient number of images were able to be reprojected using the RANSAC method due to poor image resolution over key periods of surface evolution. In these cases, images were sorted manually, and likewise projected in Shapeviewer and imported into ArcGIS software where we searched for changes without the assistance of the GUI.

The evolution of most of these smooth terrain-dominated regions begins in a short window of time, ranging from May 10-6 June 2015. While we cannot conclude that the evolution of the Nut region began any sooner than the first observed change on January 17, 2016, the observed evolution of the nearby region Serquet starting May 10, 2015 may suggest that Nut’s evolution began near the same time.

The final observed changes in the geomorphologies of each region also appear to have occurred within a short timespan, ranging from November 28, 2015 to February 27, 2016. This does not include the current final date of observed changes in the Ash region, which is a tentative upper limit and may be better constrained as the analysis of the Ash region continues.

Boulder burials and exposures are observed in almost every region observed so far, with the exception of Ma’at. Boulder migrations are only observed in two regions so far; Nut and Hatmeht, which contain bouldered terrains and talus deposits respectively, and are located adjacent to nearby cliffs. Scarp migrations are also only present in two regions, Imhotep and Hatmeht, which both span either side of the equator of 67P. Of these two regions, Imhotep is the only one to undergo scarp migrations at the hectometric scale. In the more northern regions, the migration of plains is more common, although few meter to decameter scale scarp migrations are observed in the first sub-region of Ash, which had not entirely entered into polar night during the period of heightened activity in 2015. The redistribution of fine-grained regolith is observed in both Nut and Ash, although a DTM of Ash is necessary to determine if the deposition is related to material settling into areas of low gravitational potential as in Nut, related to large-scale deposition of airfall materials, or an artifact related to changes in viewing geometry.

The data collected so far show diverse geomorphologic activity occurring on the surface of comet 67P. The changes observed on the surface appear to exhibit trends in the beginning and cessation of erosional and depositional activity which are consistent with an increase in solar insolation accompanying the comet’s perihelion approach on August 15, 2015. The similarity in start dates of evolution across multiple regions while competing in cycle length suggests the availability of high-resolution images of each region during peak activity.

Further investigation will be needed to determine if the concentration of scarp migrations near the equator is observable in other equatorial regions. A DTM is necessary to determine the scale of the deposition observed in the Ash 1 sub-region. Most importantly, the continued collection of data from the remaining smooth terrains will better inform the nature of the spatial and temporal evolution of regions which exist as distinct regions, as well as the evolution of the comet as a whole. For this region, future work will also include the creation of global maps which will detail the nature of these spatial and temporal relationships.

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References


Zoom link: https://cornell.zoom.us/j/91265261401?pwd=aWpUaHVLMBs33WB0nfWlWOb72Zbdz09