Geomorphologic Evolution of Smooth Terrains of Comet 67P/Churyumov-Gerasimenko. M. N. Barrington¹ and S. P. D. Birch², A. Jindal¹, A. Hayes¹, P. Corlies², Vincent, J.-B.³Cornell University, Ithaca, New York, 14850, mne8@cornell.edu. ²Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139. ³DLR Institute for Planetary Research Berlin, Germany.

Background: Comets represent time capsules which contain the most primitive, unprocessed material from the birth of the solar system. These primordial materials can inform us about both presolar history and the initial states of planet formation. For these reasons, comets are very desirable targets for scientific study, by ground-based observations, spacecraft missions, and even through sample return. Of particular interest are Jupiter Family Comets (JFCs), several of which travel within 1 AU of the sun at perihelion. Six JFCs have been resolved to-date, with the highest resolution images taken of comet 67P/Churyumov-Gerasimenko (67P).

ESA’s Rosetta mission co-orbited with comet 67P from 2014-2016 [1] and imaged the surface and coma using its Optical, Spectroscopic, and Infrared Remote Sensing Imaging System (OSIRIS) [2], which incorporates a Near Angle Camera (NAC) and a Wide Angle Camera (WAC). Thousands of NAC images were collected during Rosetta’s mission, providing unprecedented and high resolution spatial and temporal coverage of the comet nucleus, predominantly in the northern hemisphere.

This high-resolution view of a comet surface enabled the study of processes acting on the surface of 67P, many of which are likely applicable to the surfaces of other comets. The analysis of these processes can also inform us about the relative importance of local and global scale processes on evolving comet surfaces.

The northern half of 67P is coated in centimeter to decimeter scale airfall deposits. These particles are liberated from the consolidated nucleus in the southern hemisphere, then follow ballistic trajectories until they either escape 67P’s gravitational pull, or fall back to the surface in topographical lows located mostly in the northern hemisphere [3]. Regions covered in airfall materials are known as smooth terrains.

Once the airfall reaches the surface, the unconsolidated regolith is redistributed via several sublimation-driven processes, a process which depletes the surface of volatiles which are key to the interpretation of 67P’s initial formation conditions. Although highly detailed analyses of smooth terrain regions have been performed, a high-cadence study of the evolution of regional activity in 67P’s smooth terrains, and a global synthesis of this smooth terrain activity has not yet been studied. This type of study can shed light on dust transportation, surface evolution, and can indicate the locations and phases at which sample collection of the smooth terrains would yield less-depleted surface materials for future sample return missions. Herein, we present a survey of meter to decameter-scale changes in the 67P’s smooth terrains.

Methods: To conduct our survey, we divided the existing smooth terrain regions [4], [5] into 25 smaller sub-regions which were individually analyzed. For each region, we selected a reference image taken before 67P’s perihelion approach. We manually collected images starting from this date (unique to each region) at a cadence of once a month, increasing the cadence as necessary when changes were occurring in each region. Each of the selected images were projected and co-registered with their reference image using a combination of ShapeViewer (REF), NAIF SPICE (REF) and custom matlab software. Each of the over 600 projected images were then analyzed for changes using ArcGIS (REF).

We searched for six classes of surface change, identified by a pre-survey of the smooth terrains: boulder burial, boulder exposure, boulder migration, honeycomb evolution, plains migration, and scarp migration. Several other types of activity, detected less frequently, include pit formation, migrating smooth terrain boundaries, and bright patch exposure.

Results:

Activity Onset and Cessation.

The general trends in activity observed in each region (both deposition and erosion) are indicated in Fig. 1. Generally, the neck and comet-facing regions were the first to undergo observable changes, followed by mid-latitude regions in the northern hemisphere (sky-facing regions), then finally the equatorial and southern hemispheric regions. This is consistent with the southward migration of the subsolar latitude as the comet approached perihelion. After the comet’s perihelion passage, external regions of the comet tended to cease activity before internal regions, although exceptions exist at mid-latitudes. This trend is also consistent with the northward migration of the subsolar latitude after the comet’s perihelion passage.
Fig. 1 – An equirectangular projection of 67P, with the onset of regional activity color coded by start dates. Regions in shades of red activated before perihelion, regions in shades of green activated near perihelion, and regions in blue activated after perihelion.

**Global Dust Transport.**

Although it is clear that there are instances of topographic and geometric influences in the activity observed in several regions, our results are temporally and spatially consistent with existing dust transport models [3]. Fourteen of the 25 defined sub-regions experienced deposition between December 2014 and June 2015, suggesting a hemispheric scale deposition event occurred as 67P approached perihelion. Eight of these regions, all located in the northern hemisphere, show patterns of receiving dust deposition before experiencing local erosion (Fig. 2), while another eight regions primarily in the southern hemisphere and neck showed evidence for simultaneous deposition and erosion activity, although two of these regions which only displayed evidence of erosion could be the result of their position on local topography (Babi 2), or shielding from nearby topography (Seth 2 and Hapi 3).

**Trends of deposition followed by erosion in the sky-facing mid latitudes support this hypothesis, however limitations in our dataset prevent the confirmation of simultaneous deposition and erosion occurring in lower latitudes.** Our observations, while limited, are still not inconsistent with this concept. Simultaneous deposition and erosion in the neck region may be the result of extended windows of erosion activity from local self-heating, while the three internal regions which only displayed evidence of erosion could be the result of their position on local topography.

**Potential for Future Sample Return.**

Our results indicate that there are five sub-regions which yield the highest scientific value for future sample return missions [6]. Each of these locations experienced deposition before the onset of erosion, and is proximal to honeycomb features which can be used to detect changes in surface roughness indicative of the onset of deposition. These areas include three sub-regions of Ma’at, one sub-region of Babi, and Serquet.

**References:**


**Acknowledgements:** This research was supported by a Rosetta Data Analysis Program grant #80NSSC19K1307. We would also like to acknowledge the Principal Investigator of the OSIRIS camera on ESA’s Rosetta spacecraft, Holger Sierks, and the ESA Planetary Science Archive for the data used in this study. This research has made use of the scientific software ShapeViewer (www.comet-toolbox.com).