USING A TWO-LAYERED THERMAL MODEL TO EXPLAIN THE ORIGIN OF DYNAMIC CHANGES ON COMET 67P/CHURYUMOV-GERASIMENKO. A.S. Jindal[1], S.P.D. Birch[2], A.G. Hayes[1], O.M. Umurhan[3], J.B. Vincent[4], R. Marschall[5], and D. Bodewits[6], [1]Cornell University (asj59@cornell.edu), [2]Massachusetts Institute of Technology, [3]NASA Ames, [4]DLR Institute of Planetary Research, [5]CNRS, Observatoire de la Côte d'Azur, Laboratoire J.-L. Lagrange, [6]Auburn University.

Introduction: Comets are among the most primitive bodies in our solar system, acting as time capsules from the birth of the Solar System. Materials on their surfaces record presolar history and the initial states of planet formation, and also contain key volatiles (e.g., water) and prebiotic organics that were likely delivered to the early Earth. As a result, returning a sample from a comet for detailed study has been a priority for NASA's last two Planetary Science Decadal Surveys.

However, even cometary surfaces (especially the surfaces of Jupiter Family Comets (JFCs)) are undergoing constant evolution driven by processes including sublimation, outbursts and impacts. Large portions of comet 67P/Churyumov-Gerasimenko's northern hemisphere, for example, are blanketed by fallback material consisting of centimeter-sized particles that have been transported across the comet. These large deposits of centimeter-sized particles are termed the smooth terrains and observations from ESA's Rosetta mission showed that the most drastic transient changes that occurred throughout 67P's 2015 perihelion passage took place within a subset of these deposits [1,2,3,4,5]. However, we still do not understand the processes driving these changes within the smooth terrains which is crucial to decipher the overall evolution of cometary surfaces and provide context for any samples we may bring back to Earth in the future.

Motivated by this, our work explores the evolution of the largest smooth terrain deposit on 67P, within the Imhotep region, a highly active, and the southernmost of all smooth terrain basins on 67P [6]. Using image data from the Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) narrow angle camera (NAC) onboard the Rosetta spacecraft, we have tracked decameter-scale changes across the smooth terrains of Imhotep for a period of almost two years between September 2014 and August 2016, bracketing 67P's perihelion passage in August 2015. Changes within the Imhotep region are mostly driven by uniform scarp migration - scarp activity is observed across the entirety of the smooth terrains at different points along the orbit when the comet is close to perihelion. We have tracked the position and migration rates for these scarps, and present a thermal model which provides a mass-loss rate and explains our observations.

Observations of Scarp Driven Activity: Scarp activity in the Imhotep region began on June 5th, 2015, with the initial activity localized between 2.5°N and 13.5°S until June 27th. This is followed by deposition of sediment north of 14°S in the weeks leading up to perihelion (August 13th), as evidenced by the partial or complete burial of scarps. Simultaneously, activity continues to spread in the more southern parts of the basin, with several new scarps mobilizing as far as 35°S. After perihelion, scarp-driven erosion spreads across the entire basin while at the same time deposition of material is also observed with scarps in both the northern and southern extents of the basin disappearing under sediment. This complicated behavior of portions of smooth terrains eroding and portions receiving new material is not seen on other smooth terrains of 67P and is unique to the Imhotep region. Scarp-driven activity finally comes to an end by December 6th, 2015, when no more changes are observed until the end of the Rosetta Mission in September, 2016. All scarps observed during the period of activity originate from topographic discontinuities such as boulders, cliffs or even pre-existing scarps. The final appearance of the smooth terrains is not dissimilar from the initial appearance, with a few large scarps interrupting an otherwise smooth surface, suggesting minimal activity throughout the rest of 67P's orbit.

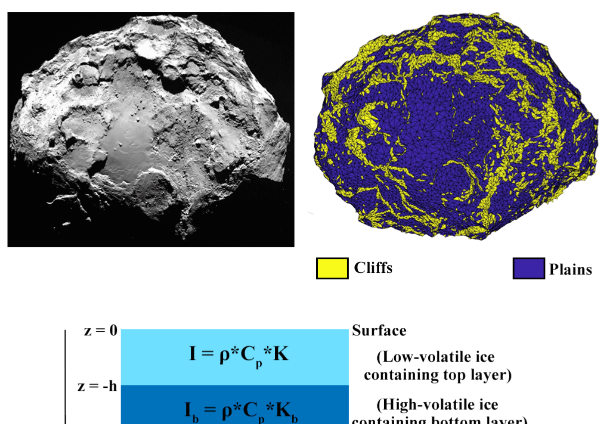

Figure 1: (top left) Rosetta OSIRIS Wide Angle Camera image - W20140905T062922570ID30F13 - cropped, showing the Imhotep region. (top right) Facets in the SHAP7 model [7] - referenced to the image - classified into cliffs and plains. (bottom) Two layers of the thermal model with a volatile rich layer blanketed by a more ice-depleted (though not zero) top layer

Thermal Model: To explain our observed changes, we have set up a two-layer thermal model where a volatile rich layer is blanketed by a more ice-depleted top layer (the depth of which is determined from the diurnal skin depth). The surface is divided into "cliffs" and "plains" based on their gravitational slopes [8] where the cliffs have a thermal inertia slightly greater than the plains (Figure 1). Apart from this, the composition is assumed to be uniform across the entire region.

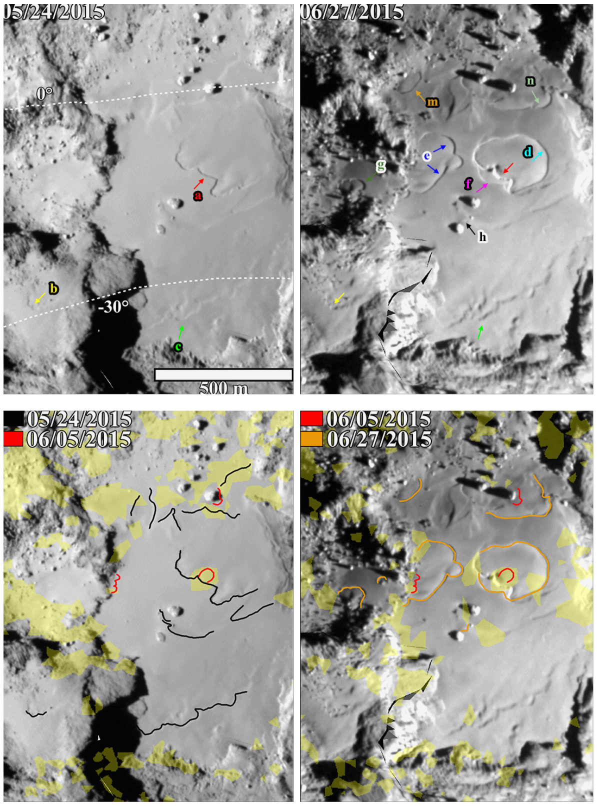

Figure 2: (top) Images showing location of scarps at two different dates. Images are obtained by georeferencing two OSIRIS Near Angle Camera Images to a base image using the shapeViewer software. Scarps are highlighted by the arrows. (bottom) Same images as the upper panels, with scarp boundaries for two different dates highlighted. The regions highlighted in yellow in the lower panels indicate regions of the highest calculated mass flux between the dates for which scarp boundaries are marked in each image. Our highest calculated mass fluxes correspond well to locations where scarps originate.

Using the SHAP4S shape model for 67P [9], we calculate the amount of energy available for sublimation at a given time and use it to derive a mass loss rate from each facet. We are able to show a strong correlation between regions where scarp activity initiates during a given period of time and the regions with the highest mass flux during the same period (Figure 2). We have not assumed any ice-enhanced locations on the surface while setting up the model, rather we have a surface of uniform composition. This suggests that the formation of scarps is controlled by the local topography, with any differences in the composition of the surface due to activity post migration of the scarps.

While our model accurately predicts where scarps form, more work is being done to explain the overall dynamic evolution of the scarps. Furthermore, smooth terrains have been observed on several other JFCs like 19P/Borrelly [10,11], 9P/Tempel 1 [12,13], 103P/Hartley 2 [14,15] and are not unique to 67P. Our work thus has implications for not only understanding the evolution of smooth terrains of 67P, but the evolution of cometary surfaces (especially JFCs) in general.

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