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LOCAL MIGRATION OF SMOOTH TERRAIN MATERIAL IN IMHOTEP ON COMET 67P.

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Abstract: The smooth terrains of comet 67P/Churyumov-Gerasimenko (67P) were highly active during the Rosetta mission. We provide a model that fully captures the observed mass loss from the largest smooth terrain basin, located within the Imhotep region. We also generate high-resolution (cm-scale vertical accuracy) digital terrain models of dozens of boulders and cliff margins across the entire Imhotep region to measure both the erosion and subsequent restoration of the smooth terrains. These measurements provide the first direct measure of fallback on 67P, and lay the groundwork for future measurements of fallback on all other smooth terrains across 67P.

Introduction: Formed predominantly by airfalling debris liberated during erosion of the consolidated nucleus, the smooth terrains of comet 67P/Churyumov-Gerasimenko (67P) represent sedimentary basins of ice-rich regolith materials [1]. The smooth terrains also exhibited the most drastic changes as observed by Rosetta, where large depressions formed and then grew via scarp retreat across the smooth plains [2,3,4]. Understanding their evolution is therefore paramount to understanding the evolution of 67P's surface.

The largest smooth terrain deposit resides in the Imhotep region, a large basin around the equator of 67P. This basin receives insolation throughout the comet's orbit, with a strong peak around perihelion. In the months leading up to perihelion, a large depression formed within the smooth terrain deposit, and migrated at a rate of 18-28 cm/hr, presumably by sublimation of subsurface water-ice [2]. The detailed physics of this process, however, remained unclear.

Mass Loss Via Scarp Retreat: To investigate the origin and evolution of the changes observed within Imhotep we applied a model that we developed for similar depressions observed in Hapi [4]. We assume that the smooth terrains are composed of granular particles with a fraction of volatile ice embedded within a non-volatile matrix. We then estimate diurnally averaged rates of sublimation of water ice from those particles, which is directly related to the scarp migration rate. This simple model successfully captured the physics that was driving the migration of the scarps in Hapi [4], and was also recently applied by Hobley et al. [5] to measure ablation rates on the surface of Europa.

We therefore applied our analytical model to the Imhotep changes, with the only input to the model being the daily peak temperature (~250-260 K in July 2015, when the changes were occurring). We will discuss the details of how our model successfully reproduces both the migration rate and observed morphologic evolution.

Fallback Measurements: To measure the volume of fallback, instead of measuring the topographic evolution of a flat surface, we instead use known landmarks that have a measurable relief. If the observed exposed height of boulders/cliff margins increases between any given topographic measurement, then the features are getting excavated, and the smooth terrains are eroding. If the exposed boulder/cliff height is decreasing, then the feature is getting buried by deposition.

The DTMs we generated use a pipeline that we have developed, which has been shown to generate very high precision DTMs of 67P's surface, particularly the smooth terrains [4,6]. Depending on the image scale, we attain vertical precisions up to a few centimeters.

In Figure 1, we show two of three DTMs we generated of 2 boulders (and their immediate vicinity) within Imhotep. These DTMs were made from images acquired near the start and end of the mission (2014-09-02 and 2016-01-23), and shortly before perihelion (2015-03-25). For each boulder in each DTM, we calculate the exposure height as the difference between the average elevation of the boulder (pink regions in *Fig. 5c/d*), and the average elevation within an annulus ~10 pixels wide around the boulder (cyan regions in Figure 1). This initial analysis shows that for the September 2014 DTM, the exposure of the boulders is 5.4±1.0 m. In March 2015, the exposure heights increase to 7.0±1.1 m (Figure 1), and then decrease after perihelion to 1.6±0.3 m in January 2016 (Figure 1). This conforms with the expected pattern, where erosion of the smooth terrains dominated prior to perihelion, followed by deposition during/after perihelion.

These measurements provide the first direct measure of fallback on 67P, and lay the groundwork for future measurements of fallback across the remainder of the Imhotep basin. We will discuss these measurements and resulting implications.

References: [1] Thomas, N., et al.: A&A, 583, A17, 2015; [2] Groussin, O. et al.: A&A, 583, A36, 2015; [3] El-Maarry, R.M.: Science, 355, 1392-1395, 2017; [4] Birch, S.P.D.: Nature Geoscience, in review, 2019; [5] Hobley, D.E.J. et al.: Nature Astronomy, 11, 901-904, 2018; [6] Tang, Y. et al.: A&A, accepted, 2019.

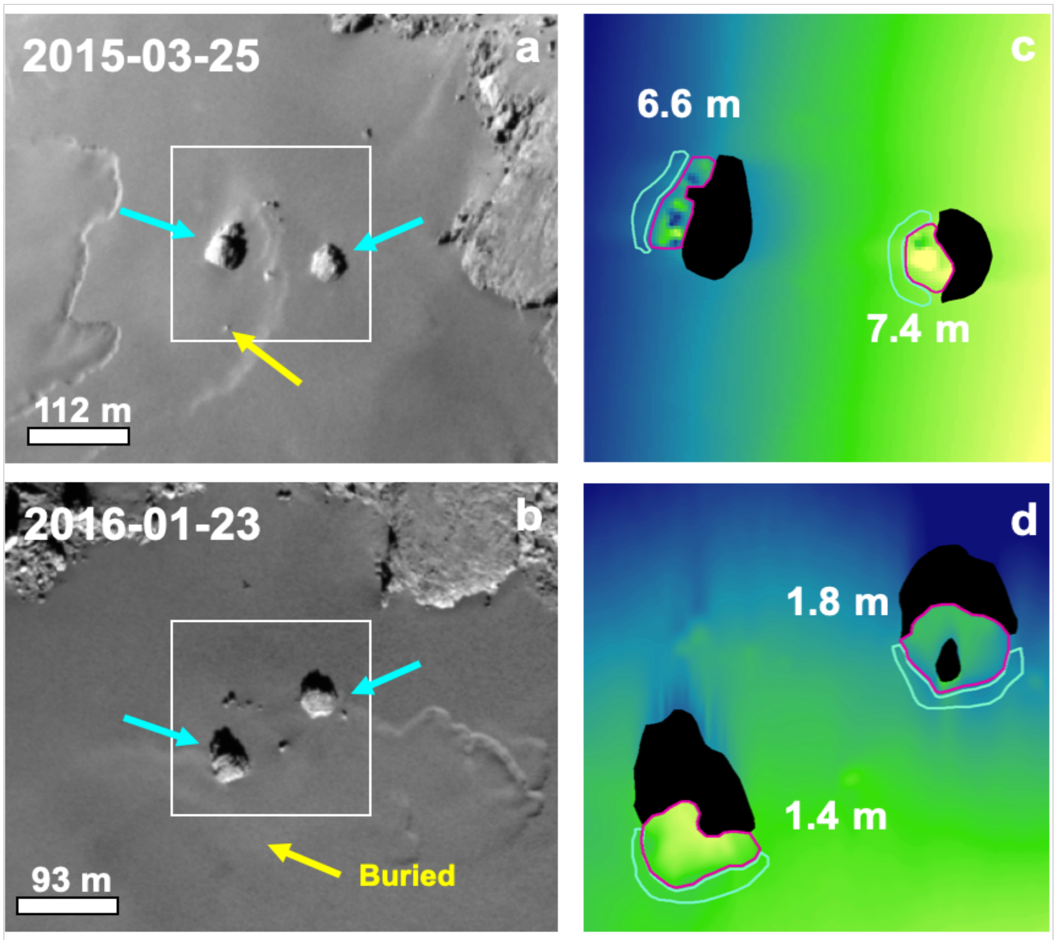

Figure 1: a/b: OSIRIS NAC images of the region we used in our initial study. The boulders are marked by cyan arrows in both panels; c/d: Example DTMs derived from the insets in panels a/b. Boulder exposure heights are listed for each boulder. Regions in black were excluded due to shadows and/or albedo contrasts.