COLORS OF ENCELADUS: PLUME REDEPOSITION AND LESSONS FOR EUROPA.
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Introduction: Global mapping of icy Enceladus has revealed complex color and photometric patterns related to the redeposition of plume material back on the surface [1,2]. Data acquisition is now essentially complete and here we describe the patterns observed and apply some of these lessons to Europa, where the search for active plume deposition is in its infancy (and stymied by limited data acquisition). Multispectral mapping coverage was acquired in 3 Cassini Imaging Science Subsystem (ISS) narrow-angle camera (NAC) broadband color filters:CL1:IR3 (930nm), CL1:GRN (568nm), and UV3 (338nm) [with supplemental filters in some areas] and at phase angles from ~3° to ~155°. Three major aspects are discussed: global patterns, local deposition, and phase angle effects.

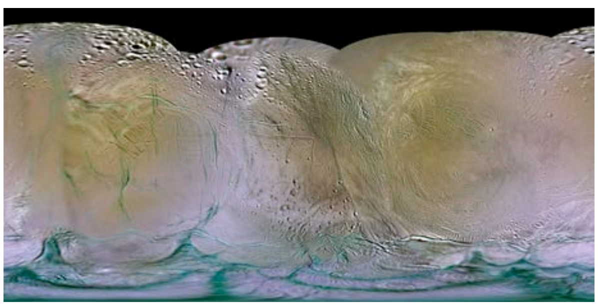

Figure 1. Global IR3-GRN-UV3 map of Enceladus.

Global Patterns: Cassini ISS mapping coverage allows for the production of detailed color maps of Enceladus (Fig. 1). Color mapping (Fig. 1) confirms that the global-scale IR/UV ratio map [1] correlates well with modeled plume fallout distribution maps [2]. The pattern forms two lobate extensions northward form the South Polar Region along longitudes 40° and 220°W, each of which narrows as it extends northward. The color pattern is consistent with the centers of these lobes being dominated by larger particles with higher salt content. Recently acquired north polar coverage (>70° N) (Fig. 2) confirms an eastward deflection in the two predicted lobes and in a simple pattern more consistent with curtains being the dominant source of plume fallback material (yet allowing jets to contribute significantly) [3].

Local Deposition: The crenulated or funicular terrains between the four 'tiger stripe' ridges from which the plumes erupt exhibit a different color than do terrains external to this rhombohedral shaped area (Fig. 3). In the color mosaic they have a more magenta hue indicating that green is suppressed. This zone is also characterized by a rolling highly tectonized texture and elevated heat flow [4], and is also remarkably free of smooth "snow"-like deposits that form in areas further to the north. The supposition is that this terrain is tectonically active today and is overturning in the solid-state at such a rate as to prevent significant accumulation of plume fallout despite close proximity to multiple vent sources.

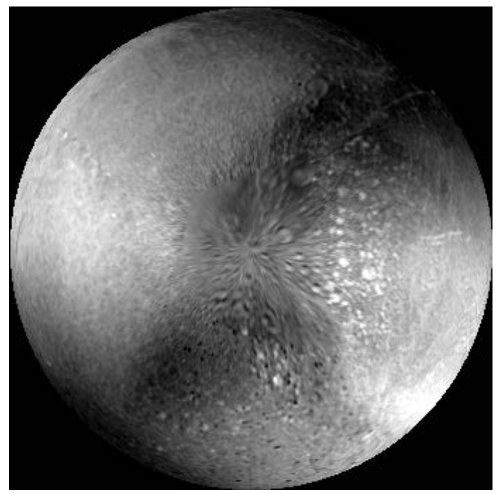

Figure 2. IR3/UV3 ratio map of the northern hemisphere of Enceladus, showing the convergence of the two lobes of plume material near the pole. Orthographic projection of northern hemisphere.

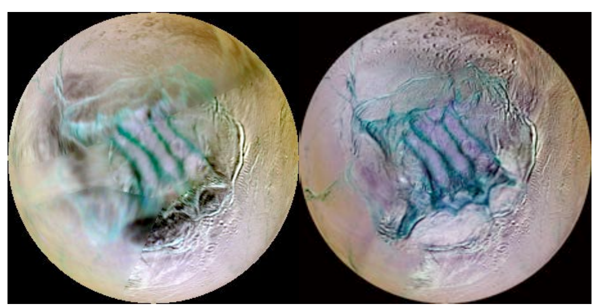

Figure 3. IR3-GRN-UV3 color maps of the southern hemisphere of Enceladus. Left) <25° phase angle, (right) 40-75° phase angle. Note dark regions in left mosaic becoming brighter in right mosaic.

Another region of interest is high-resolution color mapping in the far north (Fig 4). Coverage is limited but is centered at ~60°N, 210°W and at resolutions of 40 to 100 m/pixel. These surfaces, which lie close to the center of one of the northward-extending lobes of plume fallout, are mottled and have occasional discrete patches of different color embedded within the global pattern, particularly on the steep rim walls of some craters. Tests are underway to determine if topography has any control, and whether they represent some type of local bedrock or soil properties.

Phase Angle Effects: Examination of the image library shows that not all terrains exhibit similar phase behavior. Two regions stand out. These form an incomplete diffuse ring between 30 and 70°S latitude (Fig. 3). At phase angles <40° these terrains are darker than the rest of the surface, but at phase angles >50° they are brighter (Fig. 3), indicating that the surface materials regionally differ in some aspect of their mechanical structure that affects the directional scattering of light. All colors are affected.

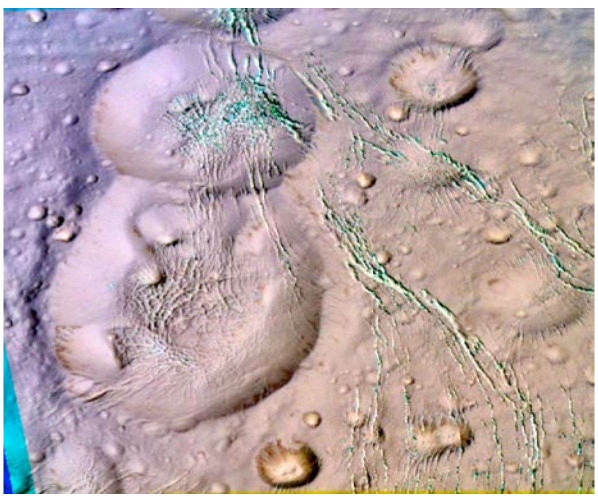

Figure 4. High-resolution (~50 m/pixel) view of Dunyazad crater (D~31 km), showing dark brown coloration on crater rims and bluish coloration on steep fracture walls.

Photometric modeling is in progress but such anomalous phase behavior could be consistent with differences in regolith compaction or grain sorting due to mass wasting and exposure of solid or lithified materials along unresolved topographic slopes. The anomalous dark areas coincide with some highly fractured reticulated terrains and Y-shaped discontinuities that are topographically and morphologically distinct from active SPT terrains. They are also located in the region of largest grain deposition in the fallout map [2]. Other factors that may cause or enhance the differences observed include the degree of crystallinity of the ice or the sizes of ice grains [5], and macroscopic roughness in the region of the tiger stripes.

Lessons for Europa: Although the exact patterns observed on Enceladus are unlikely to be repeated at Europa (especially the South Polar locations), we might expect to observe plume fallout patterns that can be identified in close proximity to their source. Color patterns and phase angle effects due to compaction are both plausible and will require extensive global coverage acquired and analyzed iteratively. Efforts are further complicated by likely damage to and alteration of nonactive plume deposits by the Jovian radiation environment.

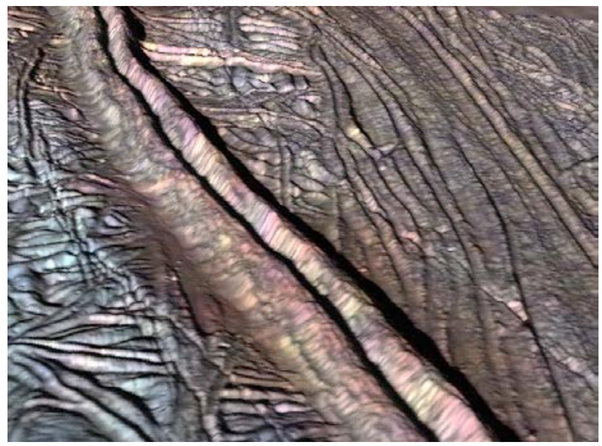

Figure 5. Perspective rendering of double ridge Androgeos Linea, Europa, showing red-stained ridges and flanking depressions. Ridge width is ~3 km, height ~250 m.

To date no similar patterns have been identified on Europa but Voyager and Galileo mapping coverage were very limited and analysis is not quite complete. One candidate plume source is the large global-scale double ridges, once known as triple bands, which are flanked by diffuse depressed reddish zones a few km across (Fig. 5). These could be localized plume deposits [6] formed in association with polar wander on Europa [7].

References: [1] Schenk, P., and 5 others, (2011) *Icarus,* **211**, 740; [2] Kempf, S., U. Beckmann, and J. Schmidt (2010) *Icarus,* **206**, 446; [3] Spitale, J. et al. (2015) *Nature*, **521**, 57; [4] Bland, M., W. McKinnon, and P. Schenk (2015) *Icarus* **260**, 232. [5] Brown, R. H. et al. (2006). *Science* **311**, 1425; [6] Fagents, S. (2003) *J. Geophys. Res.,* **108**, 10.1029/2003JE002128; [7] Schenk, P., I. Matsuyama, and F.Nimmo (2008) *Nature*, **453**, 368.