TOPOGRAPHY OF PLUTO AND CHARON: IMPACT CRATERING.

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Introduction: The geology of the Pluto system as revealed by *New Horizons* in July 2015 proved to be surprisingly diverse [1]. The encounter also provided the first survey of impact craters on Kuiper Belt objects. For both Pluto and Charon, questions relating to mean impact velocity (~2 km/s) and the importance of lower viscosity volatile ices in the outer layers were considered [1,2]. Here we survey the impact morphologies based on imaging and topographic mapping and compare with those on other icy bodies. **(All feature names are informal.)**

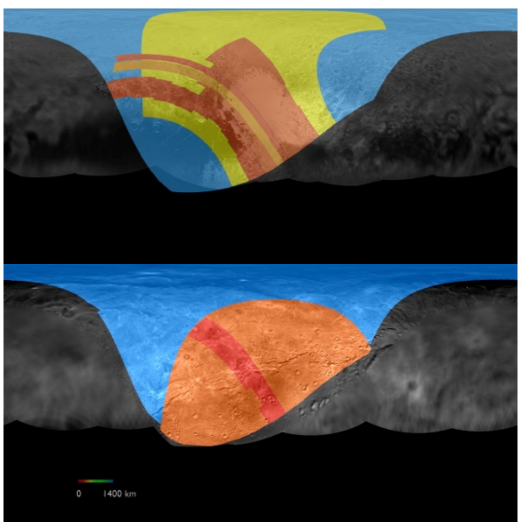

Figure 1. Cartographic and topographic coverage maps of Pluto (top) and Charon (bottom). Color coding indicates stereo DEM quality in vertical resolution, from ~100 m (red) to ~1000 m (blue).

Cartographic and Topographic Mapping: New Horizons observed ~35% of the surfaces of Pluto and Charon in panchromatic and four broadband wavelengths at resolutions sufficient to resolve impact crater morphologies (Fig. 1). These overlapping data sets were designed to produce stereogrammetric digital elevation maps (DEMs) over most of the encounter hemispheres. Stereo mapping coverage over the anti-Charon encounter hemisphere of Pluto was achieved using MVIC scans at 600, 475, and 315 m/pixel scales, producing DEM coverage with vertical sensitivity of ~850 m. Additional regional coverage was provided by combining LORRI framing camera images at ~80 to 400 m/pixel, and combining LORRI and MVIC mosaics. Vertical resolutions as good as 100 m were obtained in some areas (Fig. 1). For Charon, similar stereo mapping coverage was obtained (Fig. 1), with best vertical resolutions also down to ~100 m along the LORRI high-resolution scans.

Pluto: As most of the two highest resolution LORRI scan mosaics fall within the craterless Sputnik Planum, the best stereo mapping coverage for craters on Pluto is the ~230-m LORRI LEISA ride-along scan which falls along the western margin of the 800-km-wide, ~3-km deep ovoid depression associated with Sputnik Planum (SP). Although relatively ancient, this structure has characteristics of a highly degraded (and likely low-velocity) impact basin (Fig. 2). Most of this depression is flanked by rugged eroded highlands. The western margin is also ringed by prominent isolated massifs up to 5 km high (al-Idris, Norgay, and Hillary Montes). Overall, the SP regional structure bears some resemblance to the degraded Caloris basin on Mercury [e.g., 3].

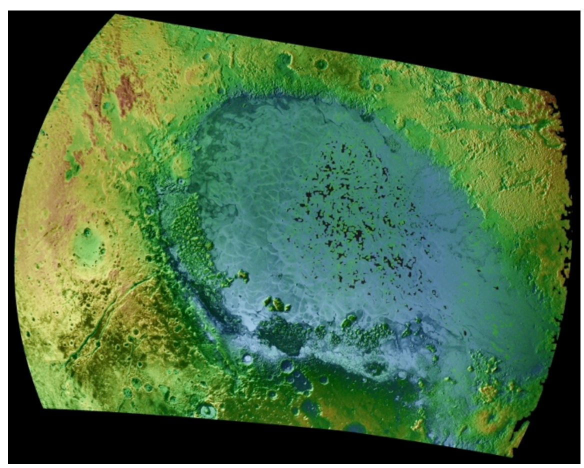

Figure 2. Preliminary DEM across anti-Charon hemisphere of Pluto, showing huge depression associated with SP region. Burney is the small depression just left of SP. A N-S trending degraded fracture system extends from middle bottom to upper left. North is to upper left, 6 km of relief are displayed.

A prominent system of degraded troughs runs tangent to the rim of the SP structure. The trough trends N-S and extends to the north pole across the illuminated disk and is likely ancient as well. The topographic depression of Sputnik Planum likely has had a profound influence on Pluto's geologic and rotational history [4].

The next largest unambiguous impact structure on Pluto is 250-km-wide Burney crater (45°N 135°E). This circular depression is also degraded but still retains ~3-km of relief (Fig. 2). A discrete rim scarp is not obvious but the likely rim site is suggested by a ring of low hills at the 250-km diameter. Topography reveals the presence of 3-5 topographic rings surrounding Burney, possible evidence of extensional failure analogous to the multiring structures on the Galilean satellites [5].

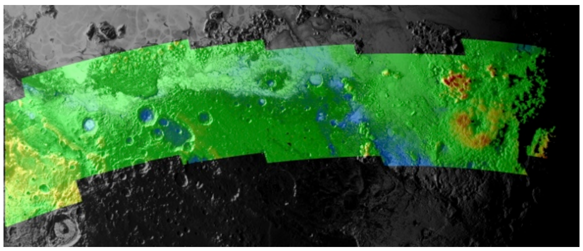

Figure 3. High-resolution DEM across western margin of Sputnik Planum. Spatial resolution ~235 m, vertical resolution ~200 m. Note numerous craters and the odd large mound to right [7]. North is to left. Topographic relief displayed is ~6 km.

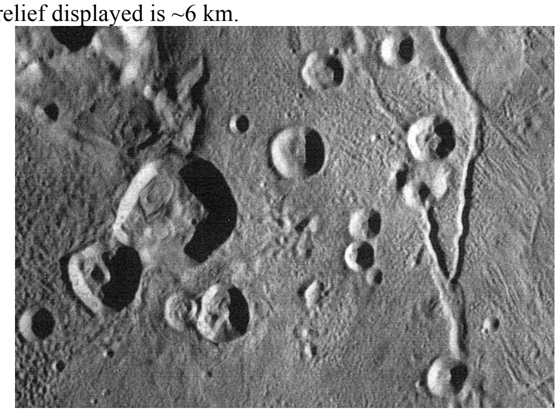

Figure 4. Typical simple and complex craters on Charon. Largest crater is 30 km across.

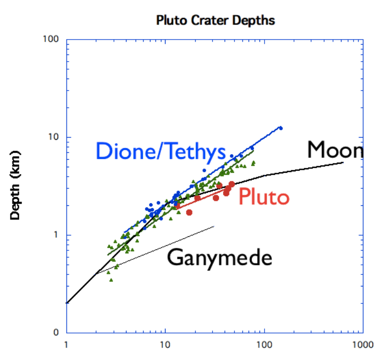

Figure 5. Initial crater depth/diameter values for relatively pristine craters on Pluto.

Simple extrapolation from other icy bodies suggested that complex craters would form at ~10 km diameters, and central pit craters at ~50 km on Pluto [REF]. While the formation of complex craters appears to be consistent with this prediction (Fig. 3), only one crater >50 km can be considered consistent with a central pit morphology. New Horizons data have revealed that Plutonian craters have been subject to varying degrees of erosional degradation (Fig. 3), resulting in morphologies from nearly pristine to barely recognizable. Thus, recognition of original morphologies, including ejecta and secondaries (which have not yet been identified), is often difficult. Craters in northern regions commonly feature dark deposits at different levels along the rimwall, suggesting compositional layering.

Charon: Craters on Charon have not been subject to similar erosional/depositional processes and are easier to classify. Complex crater morphologies (ridged and hummocky floors) are observed at >10 km and central peaks at D greater than ~15 km, consistent with other icy bodies (Fig. 4). Pancake and possibly lobate ejecta deposits are also observed in a few craters, which bear some resemblance to those on Dione and other icy moons. Ray patterns (not seen on Pluto) are observed on Charon and usually have dark inner and bright outer deposits. The largest crater recognized on Charon (Dorothy Gale, $D \approx 230$ km) is seen at high solar illumination but is resolved to be ~6 km deep central peak crater.

Depths on the most pristine craters on Pluto are intermediate between Ganymede and the icy Saturnian satellites (Fig. 5), consistent with gravity scaling and consistent with other topographic evidence (e.g., unmodified normal and extensional faulting) that the outer layers of Pluto are cold and able to retain topography long-term. Charon's craters, however, appear to be shallower than those on the Saturnian satellites.

Conclusions: Pluto and Charon feature a rich variety of impact crater landforms. Complex craters, including a few candidate central pit craters, are common. We observe no direct evidence of viscous relaxation, suggesting that heat flows in both bodies have not been high enough over their histories to deform the surface. Large impact events have been rare in the Pluto system since its formation. Erosional and depositional degradation has been significant over most of Pluto's history [1,6] but not sufficient to wipe out its cratering history, placing limits on erosional efficiency.

References: [1] Moore, J., et al., (2015), Science, in press. [2] Bray, V. and P. Schenk (2015) Icarus, 246, 156. [3] Fassett, C., et al., (2009) Icarus, 285, 297. [4] Nimmo, F. et al. (2016) LPSC, 2207. [5] Schenk, P., et al. (2004) in *Jupiter*, Cambr. Univ. Press. [6] Singer, K. (2016a) this conference; Robbins, S. et al. (2016) this conference. [7] Singer, K. (2016b) this conference.