

**GEOLOGICAL MAPPING OF THE ENCOUNTER HEMISPHERE ON PLUTO.** O. L. White<sup>1</sup>, J. M. Moore<sup>1</sup>, S. A. Stern<sup>2</sup>, H. A. Weaver<sup>3</sup>, C. B. Olkin<sup>2</sup>, K. Ennico<sup>1,3</sup>, L. A. Young<sup>2</sup>, A. F. Cheng<sup>2</sup>, and the New Horizons Geology, Geophysics and Imaging Theme Team. <sup>1</sup>NASA Ames Research Center, Moffett Field, CA, 94035-1000 ([oliver.l.white@nasa.gov](mailto:oliver.l.white@nasa.gov)), <sup>2</sup>Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO, 80302, <sup>3</sup>The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD, 20723.

**Introduction:** Nine months after its flyby of Pluto in July 2015, New Horizons has returned high quality images (achieving ~80 m/pixel in resolution) covering the encounter hemisphere of the planet, which reveal it to have a highly diverse range of terrains, implying a complex geological history. The highest resolution images that were initially received on the ground covered most of the prominent Plutonian feature informally named Sputnik Planum, and its surroundings, allowing detailed geological mapping of this area to commence (Fig. 1) [1]. All feature names used here are informal.

**Geological Mapping To Date:** Sputnik Planum, with an area of ~870,000 km<sup>2</sup>, is notable for its smooth appearance and apparent total lack of impact craters at ~320 m/pixel resolution [2], and consists of N<sub>2</sub> ice with smaller concentrations of CH<sub>4</sub> and CO ice [3]. The Planum displays a variety of textures across its expanse, including smooth and pitted plains in the south; high-albedo cellular terrain in the center (the cells are bounded by troughs with medial ridges); and, in the north, lower-albedo cellular terrain (perhaps due to entrained dark material), which displays lobate patterns indicative of glacial flow into the rugged, hilly, cratered terrain north of Sputnik Planum. The cells likely form as a result of solid-state convection occurring within the N<sub>2</sub> ice [2]. 200 individual cells have been mapped, with a mean diameter (assuming a circular planform) of 33.4 km ( $\sigma = \pm 18.9$  km). The network of troughs defining the edges of the cells becomes less interconnected in central Sputnik Planum, perhaps indicating thicker N<sub>2</sub> ice at this location. Separating Sputnik Planum from the cratered highlands to the west are ranges of chaotically-oriented mountains that stretch all the way along its western margin, and which may represent fragments of Pluto's H<sub>2</sub>O ice crust that have been disrupted and reoriented by the N<sub>2</sub> ice [2]. Bright, rugged, pitted uplands to the east may currently be experiencing resurfacing by deposition of N<sub>2</sub> ice that sublimated from Sputnik Planum, and which is reintroduced back into the Planum via glacial flow from the uplands [2]. To the south of Sputnik Planum is a ~150 km-diameter edifice (Wright Mons) that shows a rough, undulating surface and which features a very wide and deep summit depression. The bulk morphology of Wright Mons, (and that of Piccard Mons,

an even larger edifice to the south), has caused it to tentatively be interpreted as a cryovolcanic edifice [2].

A comprehensive relative chronology for the units mapped to date has not yet been assembled, but terrain immediately to the west of Sputnik Planum in Cthulhu Regio appears to be the oldest on Pluto, with the highest spatial density of large, unmodified impact craters. Terrain to the north of Sputnik Planum also displays a high spatial density of impact craters, but they generally appear more modified than those in Cthulhu Regio. The bright pitted uplands to the east appear younger still, displaying very few identifiable impact craters. Wright Mons displays one impact crater at ~230 m/pixel resolution, and may be less than 1 billion years old [4]. Sputnik Planum's total lack of impact craters at ~320 m/pixel resolution implies that it has a crater retention age no greater than ~10 million years [2], making its units the youngest observed on Pluto.

**Continued Geological Mapping:** Mapping performed to date is presented in Fig. 1. Forthcoming mapping will expand to terrain to the east and west of the current mapping area, including the terrains discussed below.

The bright pitted uplands to the east of Sputnik Planum eventually transition to the 'bladed terrain' of Tartarus Dorsa. The stratigraphic relationship of the bladed terrain to the pitted uplands is a subject of interest. Tartarus Dorsa consists of several broad (~100 km-wide), ~NE-SW-aligned swells that are covered in ~N-S-aligned blade-like ridges. Individual ridges are typically several hundred meters high, and are spaced 5 to 10 km crest to crest. Both the pitted uplands and bladed terrain may be remnants of a formerly continuous deposit degraded either by sublimation (forming features analogous to those of degraded terrestrial snow or ice fields - penitentes and sun-cups - but much larger), or through undermining and collapse, possibly through melting at depth. However, whether both types of terrain did indeed form in the same way, with one merely being a more modified version of the other, or if the pitted and bladed textures formed through independent means, remains to be determined.

To the north of the pitted uplands and the bladed terrain is the 'eroded mantle terrain', i.e. material is draping underlying topography. The density of craters here is low except for a few degraded examples that are >50 km across. The mantle appears smooth with con-

vex rounded edges. This terrain is also characterized by erosion via steep-sided pitting that reaches 3-4 km deep and tens of km across. The larger pits display elongate and irregularly-shaped planforms and may indicate that material is being sapped from the subsurface at these locations. The smaller pits are sometimes interjoined and aligned in chains, which may indicate formation via collapse through tectonic extension.

Cthulhu Regio, located to the west of Sputnik Planum, covers a swath from  $\sim 15^\circ\text{N}$  to  $\sim 20^\circ\text{S}$ , and stretches westward almost half way around the planet to  $20^\circ\text{E}$ . Cthulhu Regio appears not to be a distinct physiographic province, but instead a region of dark mantling thin enough to preserve underlying topography, superimposed upon various geological terrains, including dendritic valleys, craters, faults, and retreating scarps.

Terrain to the west of Sputnik Planum appears more heavily tectonized than that to the east, featuring numerous extensional fractures (graben and normal faults) in various stages of degradation. At  $\sim 30^\circ\text{N}$ , there exists a region of mottled plains that is bounded by an arcuate scarp (Piri Rupes, see Fig. 1) along part of its southern and western borders. These plains appear to have been exhumed through degradation of an overlying layer (perhaps through sublimation of material forming plateaus that surround the plains), and

scarp retreat may be occurring at edges of the plains.

To the northwest of Sputnik Planum, smooth, flat and bright cratered plains are encountered. In some locations, these plains show a fretted appearance, whereby they are separated into polygons by a network of darker troughs reaching 3 to 4 km wide. This morphology may indicate tectonic disruption of the crust.

This mapping project is revealing the remarkable extent of Pluto's geological diversity. Several units seem to be encountered only in a particular location (as far as we can tell), and are not obviously replicated in other parts of Pluto, indicating that unique sets of landscape modification conditions may occur on Pluto.

**References:** [1] White O. L. et al. (2016) *LPSC XLVII*, Abstract #2479. [2] Moore J. M. et al. (2016) *Science*, 351, aae0030 [3] Grundy W. M. et al. (2016) *Science*, 351, aad9189. [4] Singer K. N. et al. (2016) *LPSC XLVII*, Abstract #2276.

Fig. 1. Simple cylindrical projection of most of Pluto's encounter hemisphere. Geological mapping performed to date is located in the center of the map. Thin black lines indicate cell boundaries and troughs in Sputnik Planum. Ellipses mark the locations of regions outside the currently mapped area that will be the subject of forthcoming mapping.

