THE SHAPES AND DISTRIBUTIONS OF DUNES ON PLUTO. J. Radebaugh[1], M.W. Telfer[2], E.J.R. Parteli[3], R.A. Beyer[4] and R.L. Kirk[5]. [1]Department of Geological Sciences, Brigham Young University, Provo, UT (janirad@byu.edu), [2]School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, UK, [3]Department of Geosciences, University of Cologne, Pohligstraße 3, 50969 Cologne, Germany, [4]NASA Ames Research Center and SETI, Mountain View, CA, [5]USGS Astrogeology Division, Flagstaff, AZ.

Introduction: The surface of Pluto as revealed by New Horizons has many geological features similar to other bodies in the solar system, including mountains, craters, tectonic fractures, cryovolcanic constructs and even a convecting glacier [1,2,3]. Included among the geological landforms are hundreds of sand dunes, stretched across the Sputnik Planitia glacier (Fig. 1) [4]. These features have many morphological similarities to dunes on Earth, Mars, Venus and Titan, such as bifurcations or "y-junctions", an increase in size towards the center of a given dune patch (or "pattern coarsening"), alignment with wind streaks, and deviation around topography [4]. New Horizons MVIC (Multispectral Visible Imaging Camera) images revealed a concentration of methane ice associated with the dunes, meaning they are made of methane sand (where "sand" means a loose, subround, small particle of any composition) [4,5]. Here we describe their shapes and relative heights, the variations in their patterns, and their distribution across the underlying glacier.

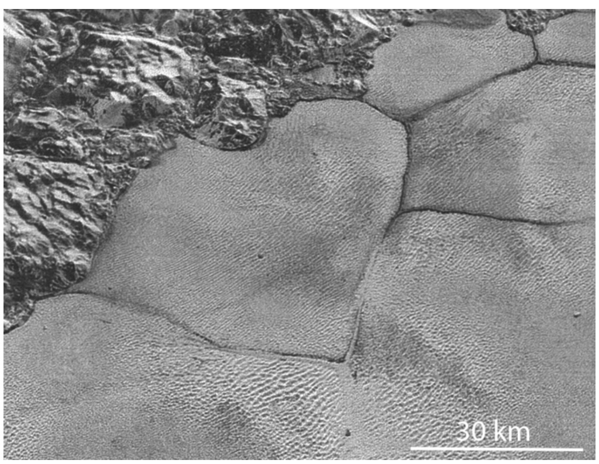

Fig. 1. Dunes on Sputnik Planitia at the base of the Al Idrisi Montes. NASA/New Horizons

Shapes and Heights of Pluto's Dunes: The features initially described as dunes on Pluto are concentrated in the NW corner of the Sputnik Planitia glacier, near the 5-km-high Al-Idrisi Montes. They have regularly spaced [4], elevated and ridge-like morphologies that vary in height and spacing across the terrain. Features in the middle of the heart-shaped feature in Fig. 1 (a convection cell, typical of other cells across Sputnik Planitia, [6]) are straight over distances of several tens of kilometers, are relatively closely spaced (~400 m) and are highly parallel (upper left, Fig. 2) [4]. They have some y-junctions, indicating excursions from the regular pattern, but defects like these are comparatively rare. In many ways, their morphologies are like ripples; in fact, they were modeled as "elementary" transverse dunes, which are the smallest dunes that can be formed by wind on a flat surface [supplemental material in 4]. Features at the bottom of Fig. 1 (upper right, Fig. 2) are generally larger, more widely spaced (~700 m) [4], and based on their shading appear to be taller than those in the north.

Features far to the left in Fig. 1 (bottom of Fig. 2) are more laterally discontinuous and have almost a boxed pattern in planview. These features also appear to have slightly flatter tops than the other dunes (Fig. 3). This may result from a gradual flattening of the crestlines, either through wind- or sublimation-related erosion [7]. That the dunes of Pluto are relatively small is consistent with them being elementary forms, and also makes them analogous to snow dunes on Earth, which tend to have smaller heights.

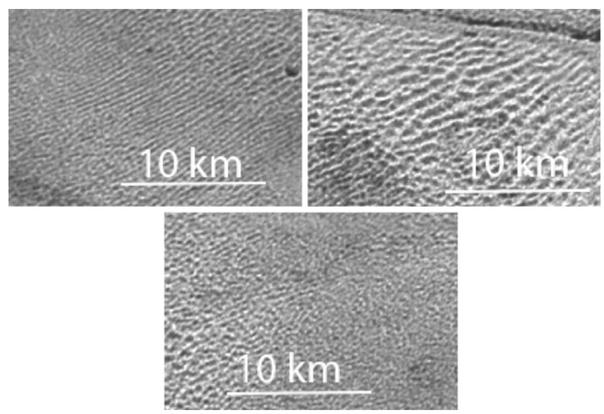

Fig. 2. Dune shapes discussed from Fig. 1.

Distributions of Pluto's Dunes: Away from the base of the Al-Idrisi Montes, there are many regularly spaced linear ridges across Sputnik Planitia that have patterns consistent with being dunes [4]. The ridges are perpendicular to wind streaks, appropriate for dunes that form transverse to the winds [4]. Most ridged forms on Sputnik Planitia are oriented roughly NNE-SSW, consistent with a regional wind blowing from Al-Idrisi across Sputnik [4]. Ridged forms at first glance are randomly distributed across Sputnik, covering perhaps 40% of the surface (Fig. 3). They do not favor an upwind or downwind portion of a convection cell; however, they are preferentially found away from the convection cell centers (Fig. 4). No one reason stands out for why this concentration occurs, but potential reasons include: 1 – the convection cell centers are the most active regions on the glacier, acting to erase all landforms on the surface, 2 – the dunes have not yet formed on the active centers or 3 – the convection cell centers are warm and act to sublimate the methane snow or ice sand that makes up the dunes.

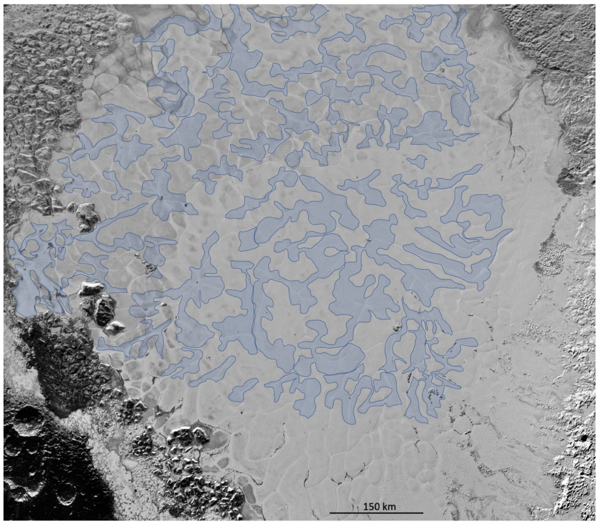

Fig. 3. Rough distribution of dune-like linear ridges (blue) across Sputnik Planitia. Map is made from 32ppd mosaic; small features are not visible or mapped.

Linear ridges away from Al-Idrisi have much less lateral continuity. The box-like morphology of the features in the SW of Fig. 1 (bottom of Fig. 2) is seen in many locations, and progresses to the point of demonstrating an enclosed, sometimes circular, depression morphology (Fig. 4). In these locations, the patterned forms are sublimation-dominated, probably even caused by sublimation [7]. These features are distributed more commonly on the southern and eastern margins of Sputnik Planitia.

So what is it that defines features as being depositional (dunes) vs. erosional (sublimation pits)? Features that appear to stand proud of an originally flat surface are most likely depositional, originating as dunes. Features that are the reverse, clearly being pits in an originally flat surface, are instead erosional, or from sublimation [4,7]. But there are features that almost appear to be transitional between the two endmembers (Fig. 4). It is possible there is a close relationship between the two forms that depends on materials. Perhaps the dune sands sinter together from solar heating and the saltation impact process. This then means that the dunes become immobile, solid forms that can only undergo transport in the form of erosion through sublimation or wind-stripping [4]. Depending on the times required for alteration of the dunes, this may indicate some dunes are young and fresh, perhaps currently forming, while others have formed and undergone sintering and are now eroding by sublimation [4]. In general, Pluto's dunes must be fairly young, given the rate of the convection thought to be occurring on Sputnik Planitia [6]; however, it is uncertain if they are forming today or when winds were stronger in the past [4,8].

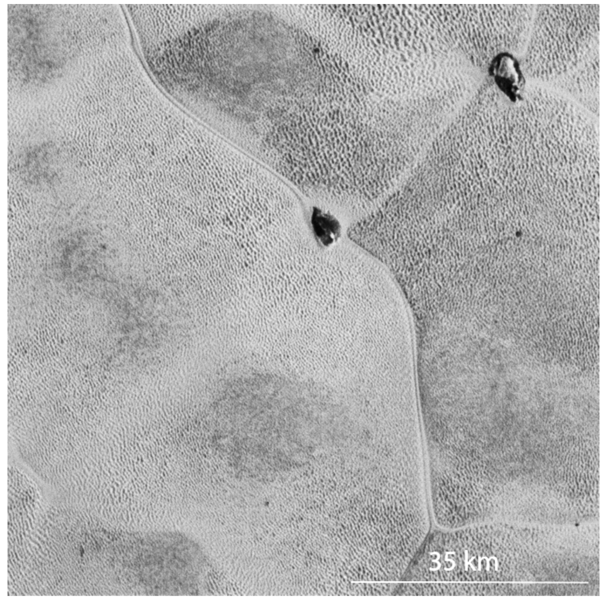

Fig. 4. Centers of convection cells (dark) are free of linear or cell-like forms. The shapes of the ridges are discontinuous and may be transitional between depositional and erosional. Image located 200 km E of the S margin of Al-Idrisi.

Conclusions: The dunes of Pluto have forms that vary in size and shape across Sputnik Planitia. They display shapes, spacings and heights consistent with shapes of dunes seen on other planets, especially elementary forms and snow dunes on Earth. While stereogrammetry of New Horizons data is insufficient to resolve the morphology of these features, photoclinometry algorithms [9,10] may be able to derive their shape. Paired with regional mapping of their locations and models for wind effects on Pluto's sands [11], will provide a more conclusive picture of the differences and relative ages of the features and the state of activity on Pluto today.

References: [1] Stern, S.A., et al. 2015. *Science 350*(6258). [2] Moore, J.M., et al. 2016. *Science 351*, 1284-1293. [3] Schenk, P.M., et al. 2018. *Icarus 314*, 400-433. [4] Telfer, M.W., et al. 2018. *Science 360*, 992-997. [5] Earle, A.M., et al. 2018. *Icarus 314*,195-209. [6] McKinnon, W.B., et al. 2016. *Nature 534* p.82. [7] Moore, J.M., et al., 2017. *Icarus 287*, 320-333. [8] Stern, S.A., et al. 2017. *Icarus 287*, 47-53. [9] Soderblom, L.A. and R.L. Kirk 2003. *Lun. Planet. Scie. XXXIV*, Abst. 1730. [10] Radebaugh, J., et al. 2007. *Icarus 192*, 77-91. [11] Lenhart, E. M. et al. 2019, *this meeting*.