TOPOGRAPHY OF ULTIMA THULE (2014 MU69) AT LOCAL SCALES: SURFACE EVOLUTION OF A SMALL PRIMITIVE BODY. P. Schenk[1], R. Beyer[2,3], C. Beddingfield[2,3], C.J. Bierson [4], J.M. Moore[2], O. Umurhan[2,3], M.R. El-Maarry[5], O. White[2], K.N. Singer[6], W.B. McKinnon[7], S. Robbins[6], H. Weaver[8], C. Olkin[6], J. Parker[6], J. Spencer[6], S.A. Stern[6]; [1]LPI, Houston, TX, USA (schenk@lpi.usra.edu), [2]NASA ARC, MS 245-3, Moffett Field, CA, 94035, [3]The SETI Institute, CA, [4]Univ. of California, Santa Cruz, CA, [5]Birkbeck, Univ. of London,UK, [6]SwRI, Boulder, CO, [7]Washington Univ. in Saint Louis, Saint Louis, MO, [8]JHU-APL, Laurel, MD.

INTRODUCTION: The New Horizons encounter with a small Kuiper Belt object, 2014 MU69 (nick-named Ultima Thule) presents the first opportunity to examine the geology and topography of a small, bilobate, nearly pristine, icy cold classical KBO [1]. Data returned as of this writing clearly indicate that Ultima Thule (UT) is constructed of two nearly spheroidal bodies, with diameters of 14 and 19 km, and in contact with each other along a narrow "neck" that has yet to be resolved [2, 3]. This geometry suggests a gentle collision between two similar sized bodies that retained much of their original shape, resulting in two joined spheroidal collisional remnants. Issues that can be addressed with mapping and topography at higher resolution and higher phase data, to be returned in February 2019, is whether the collision resulted in damage to the original bodies, in the form of fractures, compressional ridges, or other forms, like interpenetrational welding of weak porous fractal dust-ice balls.

Post-merger processes could have altered the surface. These include migration of volatile frosts which could leave deposits in frost traps, or sublimation scarps or pits produced by heating from early Al^{26} , passing OB stars, or nearby supernovae. ISM dust scouring over the 4.5 Gyr age of the solar system could also have altered UT's surface texture. Topographic mapping will be key to mapping out such features and constraining their depth, thickness or other properties.

Another objective will be the search for impact craters derived from collisions with smaller Kuiper Belt objects, many of which will have occurred at ~300 m/s and may have resulted in unusual crater morphologies [4,5].

Data and Observations: New Horizons observations of UT were designed in part to maximize stereo opportunities. These include observations of the encounter side at nominal (slightly smeared) pixel scales of ~30-35 m/pixel at 30-40° phase angles (depending on final encounter geometry), and approach images at several resolutions. Stereogrammetry will result in digital elevation models (DEMs) of variable vertical height accuracy.

Existing observations (at the time of this writing) include two encounter-side images at pixel scales of 300 and 140 m and phase angles of 11-13° (Fig. 1), providing very weak stereo. The search for small scale features such as ridges, scarps and pits must await additional imaging. Due to the low phase angle, observed features are dominated by albedo variations, some of which may be topographically controlled [6]. Some bright-dark arcuate features appear to be topographic ridges, suggesting that brighter material has migrated downslope into topographic lows [6], though a reliable assessment of topographic variability and their association with compositional units awaits additional imaging. The low contrast due to high sun illumination and small convergence angle of the two images did not permit any topographic reconstruction, though "blinking" of the two images (Fig. 1) permits some apparent topography to become visible.

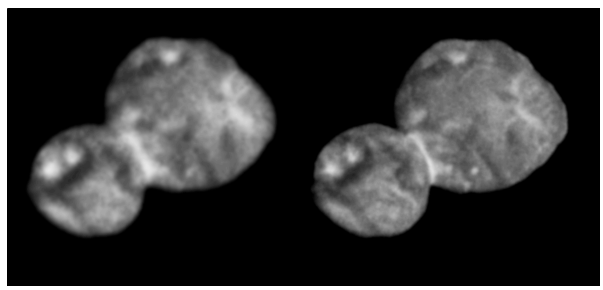

Figure 1. Side-by-side stereo view of Ultima Thule at pixel scales of 300 and 140 m/pixel. The two spheroids are 14 and 19 km across, which have been informally named Ultima (L) and Thule (R) respectively. Dark arcuate feature on Thule surrounding two bright spots may be a 7-8 km diameter impact crater.

Compositional segregation of ices and non-ice materials often results in cryptic brightness rings on images of other icy satellites at low phase angles, such as on Ganymede or the lumpy irregular Saturnian moons Prometheus or Janus (Fig. 2). Even with the low phase angle of the current images of UT, large >1 km circular albedo features appear to be essentially absent. The arcuate 'ridge' patterns also appear to be uninterrupted by circular scars. Limb profiles [3] also show no evidence of large impact-induced divots in the shape of UT, at least where we can sample such topography. These observations imply that impact craters do not evolve to form consistent albedo rings, or that few if any "large" impact craters formed on the observed side of UT.

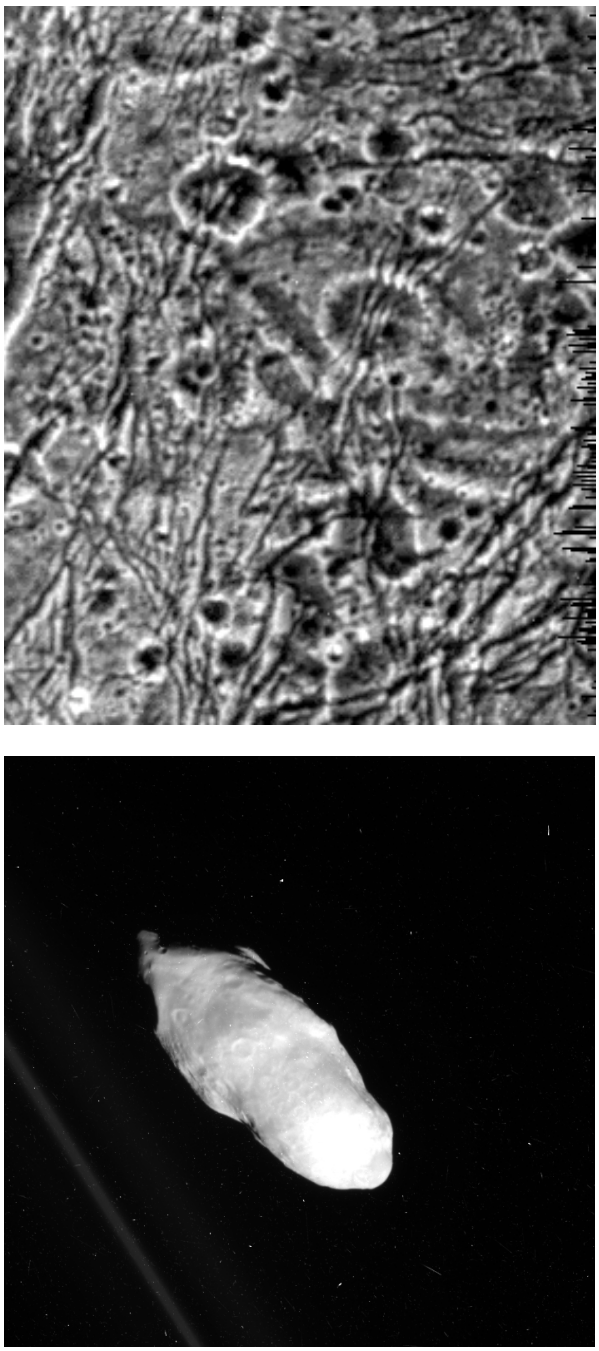

Figure 2. Low phase angle images (<20°) of Ganymede (top) and Prometheus at resolutions comparable to UT (Figure 1). Larger craters on Ganymede are ~10 km across; Prometheus itself is 60x135 km. Images highlight circular albedo features due to compositional segregation (e.g., Ganymede) or surface coatings associated with impact craters, in some cases degraded.

One possible exception is the formation of two bright spots surrounded by a dark arcuate feature on the distal side of the Thule lobe (Fig. 1). This feature is ~7-8 km across and could be a relatively large impact crater in which bright material has moved downslope [4]. Whether these patterns reflect an impact feature or its true size is to be determined.

Knobby relief is evident along the limb at the distal end of the Ultima lobe (Fig. 1). Whether this is related to a large impact crater or remnant accretional debris or other processes is unknown but the area is expected to be more visible in the higher resolution encounter imaging. There are also features at the distal ends of UT that may be due to exposed layering in the body, similar to the layering seen in some short period comets, which should be much more evident in subsequent imaging.

Conclusions: The apparent lack of large craters in the observed areas suggests that we may be able to map out any structures related to the formation and evolution of these two joined bodies. Indeed, ridge-like structures are evident in the limited stereo available (Fig. 1). Possible effects include those related to the accretion of the original bodies, their (slow) collision, and any deformation related to post-contact adjustments of the two spheroids. Morphologies in the neck region will be key to understanding the nature of the contact and how it deformed the two bodies (if at all).

References: [1] Stern, S.A. et al. (2019) *LPSC 50, this volume*. [2] Moore, J. et al., *LPSC 50, this volume*. [3] Bierson, C. et al., *LPSC 50, this volume*. [4] Bray, V. J., et al., *LPSC 50, this volume*. [5] Singer, K., et al., *LPSC 50, this volume*. [6] Dhingra, R. D., et al., *LPSC 50, this volume*.