1:10,000 MORPHOLOGIC MAP OF TYCHO CRATER CENTRAL PEAK. T. A. Roseborough[1], M. R. Henriksen[1], H. Bernhardt[1], and M. S. Robinson[1], [1]School of Earth and Space Exploration, Arizona State University, P.O. Box 873603, Tempe, AZ 85287 (vroseborough@ser.asu.edu)

Introduction: Tycho crater (43.31°S, 348.78°E, 85 km diameter) is one of the youngest (85 my [1]) and best-preserved complex craters on the Moon. The crater floor is ~4400 meters below the rim and the central peak rises ~2.5 km above the crater floor. The central peak exhibits a variety of landforms.

Prior mapping of the Tycho crater interior [2,3] largely focused on impact melt deposits on the crater floor, with only generalized mapping of the central peak. One study [2] classified the central peak as one unit, while another [3] identified four central peak units.

Slopes, optical maturity, composition, and rock abundance were examined by [4] for the units defined in [3] above and below the angle of repose (which they defined as 32°). For the slope analysis, the SLDEM2015 was used, a 60 m pixel digital terrain model (DTM) with slope baselines of 180 m [5].

Prior mapping of Tycho crater relied largely on lower-resolution images: Kaguya Terrain Camera (TC) images (10 m/px) [3], Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) mosaics (100 m/px) [2], though [2] used 14 high-resolution LROC Narrow Angle Camera (NAC) images, all at ~0.5 m/px. Topographic data sources for past studies include LOLA tracks (20 m spacing) [2] and digital terrain model (DTM) (512 px/degree) [3], LROC WAC DTM (100 m/px) [2,3], and SELENE DTM (10 m/px) [2].

We derived a 2 m/px DTM of the central peak from 32 NAC images (NAC_DTM_TYCHOPK; available on Quickmap) [6,7]. From this new DTM and orthophotos, we mapped geomorphic features and investigated slopes on 6-m baselines.

Methods: *Mapping.* We created our morphologic map using the 80 cm pixel scale orthomosaic basemap (scale of ~1:10,000). Mapping was confined to the central peak, and units were identified based on texture.

Slopes. Slope was calculated per pixel using Horn's algorithm with a 3x3 neighborhood for a 6 m baseline [8]. This calculation is comparable to the method used in [4]. Slopes in each mapped unit were isolated using shapefiles to generate histograms and summary statistics. The LROC NAC DTMs pixel scale noise results in uncertainty (<0.5°) in slope calculations [6]; a 7x7 pixel low pass filter was applied to the DTM and histograms of the smoothed data were compared with the original data with no significant difference.

Mapping: We identified five central peak units (Fig. 3): 1) a smooth mantling (Sm) material exhibiting fracturing, 2) blocky outcrops (Bo), 3) highly blocky slopes (Hbs), 4) smooth slopes (Ss), and 5) basal deposits (Bd). We also identified gullies on the slopes.

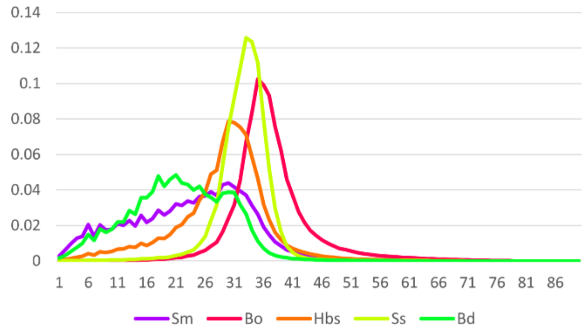

Fig. 1 Tycho central peak slope (°) histograms, normalized by the number of pixels per unit.

Unit Interpretations: The Sm unit covers the uppermost areas of the peak, and is characterized by a smooth appearance and tendency to form polygonal fractures. We interpret this unit as impact melt rock, material which melted in the crater-forming event and covered the peaks during rebound. This interpretation is consistent with the mapping in [3], which identified these areas as "central peak unconfined perch deposits," interpreted as impact melt.

The Bo unit, which appears directly downslope of Sm in almost all instances, is characterized by prominent outcrops. Because of its relationship with Sm and its rocky cliffs, we interpret this unit as Sm material which has been subjected to mass wasting. These areas largely coincide with the "central peak boulder regions" unit of [3]; however, with our high-resolution images, we feel confident interpreting these features as outcrops rather than blocks.

The Hbs unit comprises slopes with a high density of blocks. They occur downslope of Sm and/or Bo and sometimes coincide with the larger mapped gullies. We classify Hbs as eroded Sm material.

Ss consists of smooth, non-rocky slopes. These areas are generally downslope of the Sm and Bo units and are associated with gullies. We interpret this unit as granular comminuted central peak material.

The final mapped unit is the Bd unit that consists of unconsolidated rocky material found at the base of slopes, which we interpret as mass wasting deposits.

Results: Many of the slopes on Tycho central peak are within the range of angle of repose for dry granular material (28°-35°), which is consistent with its young age [9]. Sm is associated with areas of high elevation, though it does occur downslope of these areas, particularly in areas where slumping of large blocks has occurred. This unit has a mean slope of 22.9°.

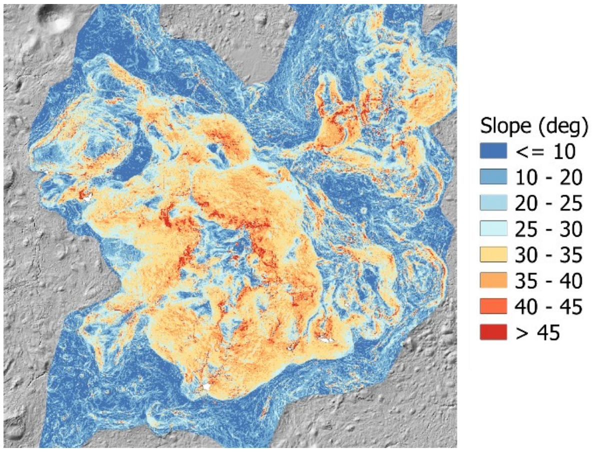

Fig. 2 Slope map of the Tycho central peak area.

Bo, the unit typically adjacent to Sm, has an average slope of 36.8°, likely greater than the angle of repose, indicating that these outcrops are largely coherent material. In addition, the substantial increase from the average Sm slope supports our interpretation that Bo is Sm material that has undergone mass wasting.

Two units are associated with the central peak slopes, Hbs and Ss. Both have mean slopes within the range of the angle of repose (28.5° and 32.1°, respectively). The higher average slope for Ss is consistent with fewer blocks on the slope- blocks on higher slopes are more likely to roll down and deposit downslope. Indeed, Bd (mean slope of 21.0°) is more often associated with Ss.

Summary: Meter-scale stereo images and a new DTM product have allowed for geomorphic mapping and quantitative analysis of the Tycho central peak.

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References: [1] Hiesinger et al. (2012) *J. Geophys. Res., 117*. [2] Krüger et al. (2016) *Icarus, 273,* 164-181. [3] Dhingra et al. (2017) *Icarus, 283,* 268-281. [4] Lemelin et al. (2020), *Icarus 351*. [5] Barker (2015), *Icarus, Volume 273*, 346-355. [6] Henriksen et al. (2017) *Icarus, 283*, 122-137. [7] https://quickmap.lroc.asu.edu [8] Horn (1981). *Proc. IEEE 69*: 14-47. [9] Jaeger et al. (1988), *Phys. Rev. Lett., 62*, *40*.

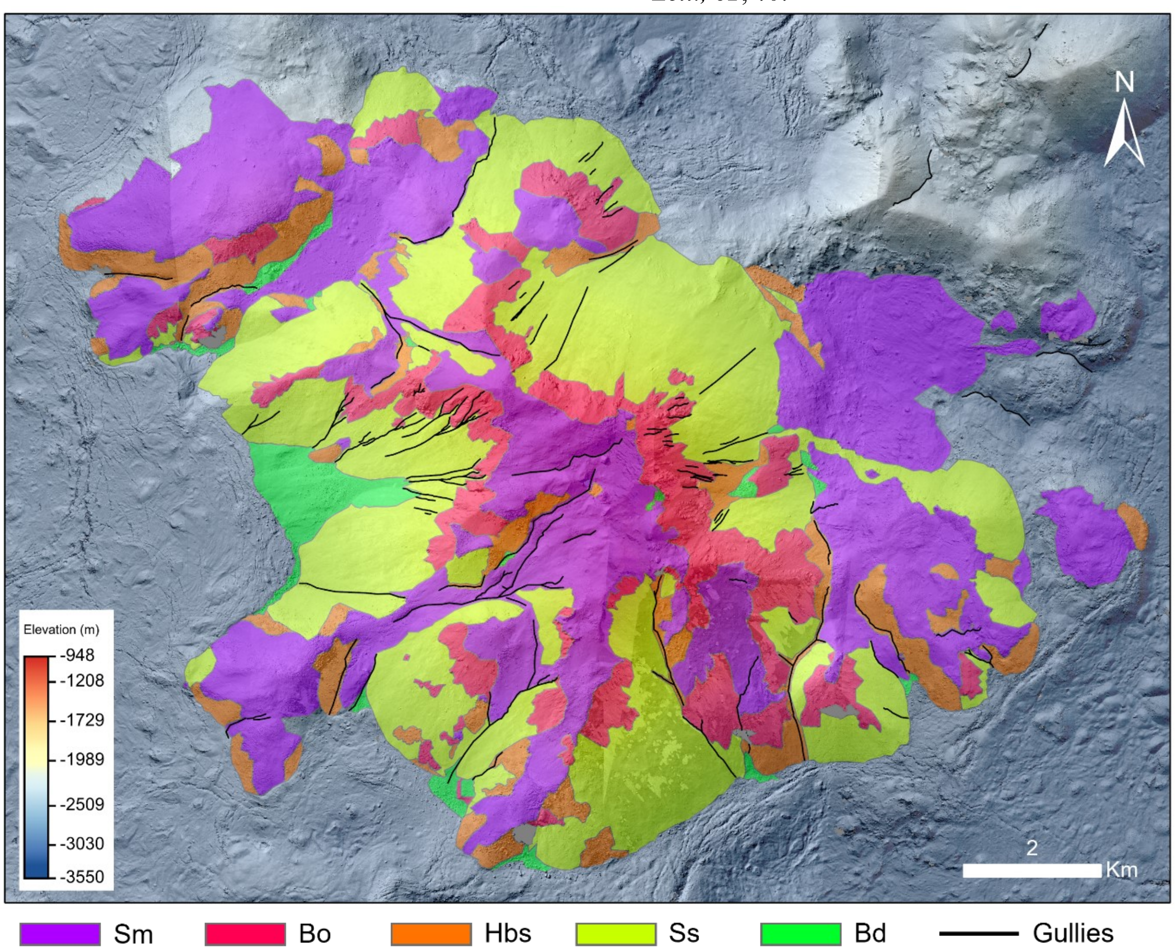

Fig. 3 Morphologic map of the central peak of Tycho crater, on the DTM 80 cm orthomosaic and colorshade.