REVISITING THE "WEIRD TERRAIN" ON THE MOON. H. Meyer[1], J. Clark[2], M. S. Robinson[2], and B. Denevi[1], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD (Heather.Meyer@jhuapl.edu), [2]Arizona State University

Introduction and Background: The "weird terrain" has been referred to by many names, but collectively it has been used to describe two defining morphologies: radially grooved crater walls with visible knobs or hills (Fig. 1a), and rough, pockmarked intercrater regions (Fig. 1b) [1–3]. First observed in Lunar Orbiter images [1, 2], the type region for this complex terrain resides in the region in and around the Ingenii basin (33.4°S 163.8°E). Similar morphologies were identified in the northern Apollo [4], Hubble, Sirsalis, and Descartes [2] regions on the Moon and at the Caloris antipode on Mercury [5]. Further, all four lunar terrains of this type are also associated with magnetic anomalies, and most research that has been done to-date has focused on explaining the magnetic anomalies through modeling and large scale geomorphic observations [3, 4, 6–12]. Here, we focus on the characteristics of the type region, which we refer to as the Ingenii terrain, to provide a robust point of comparison for all other instances of the weird terrain.

The Ingenii terrain is located at the approximate antipode of the Imbrium basin, which led to two hypotheses regarding its formation: (1) ejecta/secondary impacts clustered at the basin antipode [12, 13], and (2) mass wasting induced by seismic waves (specifically those caused by the Imbrium basin-forming event) [1–3]. Conflicting morphologic indicators have hindered efforts to determine which process or to what degree each process is responsible for the terrain we see today. With the arrival of the LRO and Kaguya spacecraft, higher resolution images and consistent mosaics with a variety of illumination conditions, as well as topography are available, which make it possible to characterize the morphology and stratigraphy of the weird terrain at the scale of its characteristic features. Here, we begin by assessing the overall distribution of the grooved component of the weird terrain in the Ingenii/Apollo region and report crater measurements on the associated intercrater terrain as a first step in a detailed morphologic and stratigraphic analysis.

Data and Methods: *Distribution.* LROC WAC mosaics [14], topography [15], and newly created hillshades depicting four perpendicular solar azimuths (minimize lighting bias) were used to identify the extent of the grooved terrain.

Stratigraphy & Age Dating. LROC WAC images were processed using ISIS3 [16, 17]. If the Ingenii terrain is collectively due to a single event, we expect to see similar surface or resurfacing ages in their crater size-frequency distributions (CSFDs). As such, the first

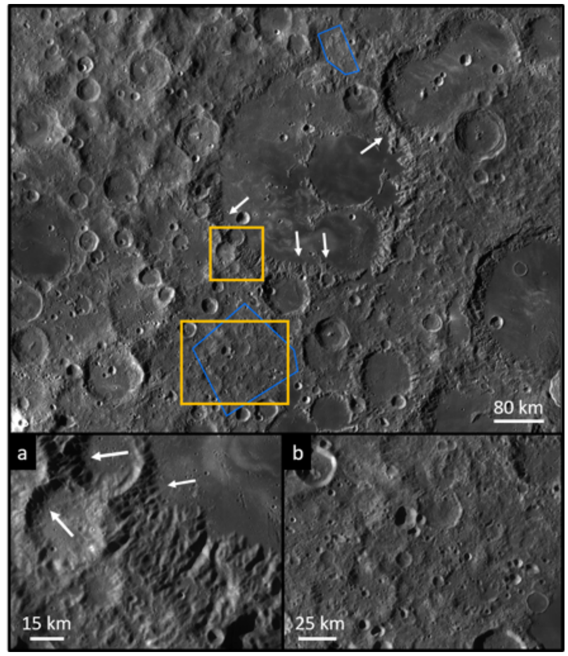

Figure 1: LROC WAC morphology basemap [14], orthographic projection centered at 164°E 32°S. White arrows denote examples of the grooved high-standing rim of the Ingenii basin. Blue lines denote count areas for CSFDs in Fig. 3 (Ingenii A to the south; Ingenii B to the north). Yellow boxes denote the locations of a and b. (a) WAC mosaic zoomed in on the walls of Ingenii. Arrows demonstrate that the grooves are not limited to Ingenii but present in nearly all large craters in this region. (b) An example of the pitted intercrater terrain, e.g., [3].

CSFD measurements for the Ingenii terrain were conducted to the north and south of the Ingenii basin, both within the pitted intercrater terrain [3] (Fig. 1), which is the second defining feature of the terrain in question. The count areas and CSFD measurements were defined using the CraterTools extension in ArcGIS [18]. The resulting CSFDs were then plotted and fit in Craterstats using the methods described in [19]. These preliminary CSFD measurements only included primary craters ≥ 1 km in diameter omitting smaller craters that are likely at saturation equilibrium. Derived absolute model ages (AMAs) are based on the production and chronology function of [20], which is valid for lunar craters >10 m and <100 km in diameter.

Discussion: Our preliminary mapping focused on the extent of the grooved terrain associated with the Ingenii region alone, revealing areas of grooved terrain distributed over 2 million km^2, or about twice the area of the Imbrium basin itself. As previously observed [6, 12], the affected region is wedge-shaped, and the grooves are oriented perpendicular to high-standing topography with no other observable trend in directionality. The bulk of the craters exhibiting grooves are >50 km in diameter except for basin secondaries (likely from the Imbrium basin). The terrain previously identified at the Serenitatis antipode north of Apollo basin does exhibit the same grooved morphology found at Ingenii and Hubble, but it is limited to approx. 25,700 km^2 (Fig. 2). This region is superposed by secondary craters and light plains materials from the nearby Orientale basin. There are subtle features nearby to the west that may be extensions of this terrain that subsequent large impacts have obscured. Interestingly, the grooves in this region exhibit overwhelmingly SW-NE or NW-SE orientations limited to the highly degraded, parallel, and roughly E-W rim sections of SPA. The limited range of groove orientations is likely due to the lack of high-standing terrain in general in this region, particularly terrain as ancient as the basins that are thought to have led to the formation of the Ingenii terrain.

The preliminary CSFD measurements for the count areas adjacent to Ingenii basin produced ages of $4.0 \pm 0.02 Ga$ and $3.9 \pm 0.05/0.06 Ga$ (Fig. 3). Although the ages are similar, they are statistically separable. We postulate that the 4 Ga AMA reflects the age of the Ingenii basin. The slightly younger age suggests the timing of the Van de Graaff impact or perhaps the formation age of the Ingenii terrain itself if it is indeed related to the Imbrium basin-forming event. The CSFD of the Ingenii A count area appeared to be in equilibrium, but upon closer inspection, it is actually in production (Fig. 3). More work is needed to determine if there are recurring patterns in the AMAs for this region, which is ongoing.

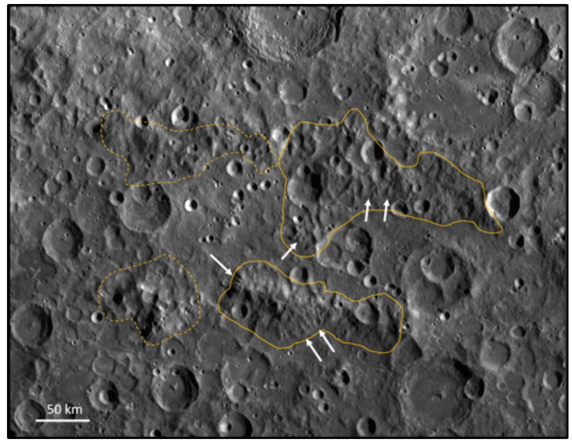

Figure 2: LROC WAC morphology basemap [14], orthographic projection centered at 200°E 19°S, the proposed Serenitatis antipode. White arrows denote examples of the grooved high-standing terrain characteristic of the weird terrain. Solid yellow outlines denote clear examples of this grooved terrain (approx. 25,700 km^2), while dashed yellow lines denote subtle features that may constitute an extension of the groove-bearing terrain in this area.

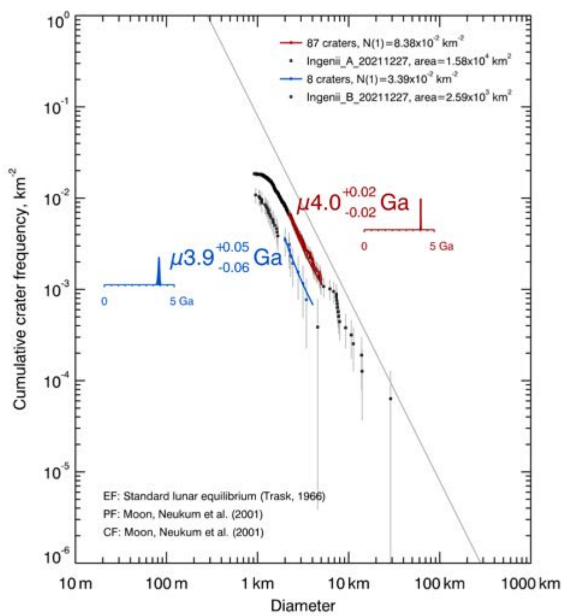

Figure 3: CSFDs for two pitted and furrowed intercrater areas around the Ingenii basin. Red denotes the count area south of the Ingenii basin (Ingenii A), and blue denotes the count area to the west of Van de Graaff (Ingenii B).

References: [1] Schultz P. (1972) *A Preliminary Morphologic Study of the Lunar Surface* University of Texas Press, Austin. [2] Schultz P. (1974) *Moon Morphology* University of Texas Press, Austin. [3] Schultz P. H. et al. (1975) *The Moon* 12(2):159. [4] Hood L. L. et al. (1989) in *Proceedings of the 19th Lunar and Planetary Science Conference* 99–113. [5] Murray B. C. et al. (1974) *Science* 185(4146):169. [6] Wieczorek M. A. et al. (2001) *Journal of Geophysical Research: Planets* 106(E11):27853. [7] Richmond N. C. et al. (2005) *Journal of Geophysical Research: Planets* 110(E5). [8] Hood L. L. et al. (2006) in *American Geophysical Union Fall Meeting 2006*. [9] Hood L. L. et al. (2007) in *Lunar and Planetary Science Conference*. [10] Hood L. L. et al. (2008) *Icarus* 193(2):485 ISSN 0019-1035 doi saturn's Icy Satellites from Cassini. [11] Kreslavsky M. A. et al. (2012) *Journal of Geophysical Research: Planets* 117(E12). [12] Hood L. L. et al. (2013) *Journal of Geophysical Research: Planets* 118(6):1265. [13] Moore. H. J. C. A. et al. (1974) in *Proceedings of the Fifth Lunar Science Conf.* vol. 1 71–100. [14] Speyerer E. J. et al. (2016) *Space Science Reviews* 200:357. [15] Scholten F. et al. (2012) *Journal of Geophysical Research: Planets (1991–2012)* 117(E12). [16] Robinson M. et al. (2010) *Space Science Reviews* 150(1):81. [17] Anderson J. et al. (2004) in *35 th Lunar and Planetary Science Conference; Abstracts of the Papers*. [18] Kneissl T. et al. (2011) *Planetary and Space Science* 59(11-12):1243. [19] Neukum G. (1983) . [20] Neukum G. et al. (2001) in *Chronology and evolution of Mars* 55–86 Springer.