A HIGHLY UNUSUAL SERIES OF YOUNG IMPACT MELTS AND ROCKY EXPOSURES ANTIPODAL TO TYCHO CRATER J.L. Bandfield[1], J.T.S. Cahill[2], L.M. Carter[3], B.T. Greenhagen[4], C.D. Neish[3], G.W. Patterson[2], N.E. Petro[3], D.A. Paige[5], [1]University of Washington, Seattle, 98195-1310 (joshband@uw.edu); [2]Applied Physics Laboratory, Johns Hopkins University; [3]NASA Goddard Space Flight Center; [4]Jet Propulsion Laboratory, California Institute of Technology; [5]University of California, Los Angeles

Introduction: The Lunar Reconnaissance Orbiter (LRO) has collected a series of systematic and high quality observations that can be used to better understand the processes that lead to the current state of the lunar regolith. These observations include high resolution images collected by the LRO Camera (LROC) [*1*], thermal infrared measurements collected by the Diviner Lunar Radiometer [*2*], and backscatter observations collected by the Miniature Radio Frequency (Mini-RF) synthetic aperture radar [*3*].

These datasets can be used to detect the presence or absence of rocks with sensitivities to various details of the lunar near surface properties, such as block size, burial depth, and associated surface textures. For example, the vertical structure of the upper 10's of cm of the lunar regolith shows a distinct layering structure that develops with increasing exposure to the lunar space weathering environment [e.g., *4*]. The deviations of this vertical structure from typical mature lunar surfaces result in surface temperature, radar return, and surface morphological anomalies.

A region containing unique properties in each of these datasets has been identified near 168°E, 43°N in the northern farside highlands [*5*]. This region shows properties similar to those associated with relatively young lunar craters. However, there is no adjacent source crater and the region is otherwise typical cratered highlands. The characterization of these surfaces can be used to better identify and constrain the potential origin of these unusual features.

Results: *Diviner Lunar Radiometer:* Lunar surface rock abundance data products derived from Diviner nighttime multispectral thermal infrared measurements [*6*] have been produced at 128 pixels per degree. This data shows a ~11000 km^2 region near 168°E, 43°N (Fig. 1) containing numerous surfaces with elevated rock abundance values (up to 23% areal coverage of blocks >1m in diameter). This is distinct from the typical highland rock abundances in the region (~0.5%).

There are instances of elevated rock abundance on all surface types, including crater rims, walls, and floors as well as intercrater plains. However, rocky surfaces are not ubiquitous and there are discreet zones where elevated rock abundances are absent from steep slopes within a limited range of azimuths. These zones make up two ellipsoidal regions (Fig. 1); elevated rock abundances are absent from steep slopes with azimuths of ~70° (clockwise relative to north) in one case and slope azimuths of ~130° in the other. Other Diviner data products, such as albedo and Christiansen Feature wavelength show no associated pattern and are typical of lunar highlands surfaces.

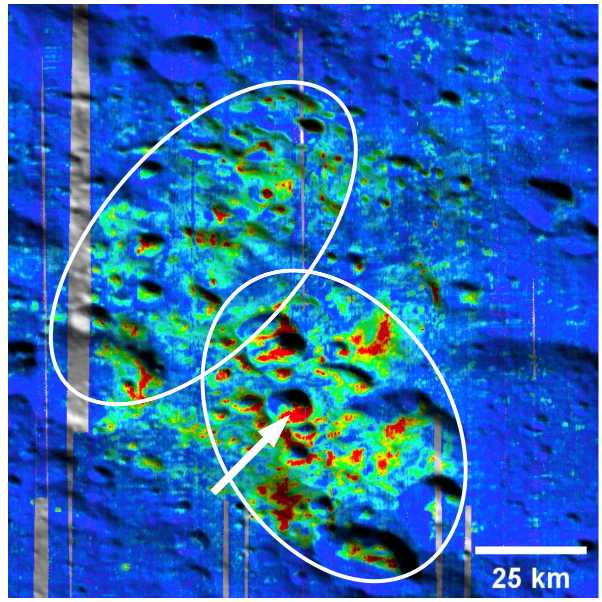

Figure 1. Diviner rock abundance [*6*] (0-5%) near 168°E, 43°N. Ovals show two distinct groups with the absence of rocks on slopes of distinct azimuths. The arrow shows the location of Fig. 2. LROC WAC DEM is used for shading.

LROC: Hundreds of ponded deposits ranging in diameter from just a few to hundreds of meters across were identified in LROC Narrow Angle Camera (NAC) images and investigated by *Robinson et al.* [*5*]. Although present over a wide range of elevations, individual ponded surfaces are flat and represent a local equipotential surface [*5*]. Flows with boulders along flow fronts, fractures, and levies are typically present on adjacent sloped surfaces. These features bear morphological similarities to impact melt surfaces near young craters elsewhere on the Moon. In areas of high rock abundances, Images show highly textured surfaces with numerous boulder piles (Fig. 2).

Mini-RF: At low spatial resolutions, the Mini-RF data are similar to other highlands surfaces. However, unique small scale features are present in the Mini-RF data in the same regions with elevated rock abundance [*7*] (Fig. 3). These high return values are associated with both the ponded surfaces visible in the LROC images and flow morphologies present on steep slopes with high rock abundances. The Mini-RF data also

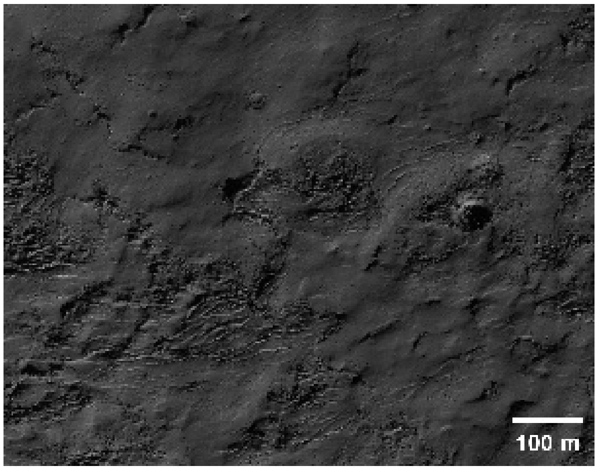

Figure 2. LROC image (M143526611L) showing rough and rocky surfaces (Fig. 1) and melt features common in the region.

bear similarities to impact melts, but individual features are smaller and more widely distributed [*7*].

Discussion and Conclusions: The exposure of blocky surfaces in the lunar environment is typically limited to young craters and their ejecta [e.g. *6*]. Over time, rocky surfaces are broken down and the presence of elevated rock abundances indicates a young formation age. Crater counts on ponded surfaces indicate ages of <1Ga and are likely significantly younger [*5*]. Exposure of extensive regions of high rock abundance requires a large and recent impact event, such as that which created Tycho or King craters.

The area of interest here has no obvious adjacent source crater or any other obvious origin, such as a volcanic source. The similarities with impact melt features in both Mini-RF and LROC images led *Robinson et al.* [*5*] and *Carter et al.* [*7*] to search for more distant sources of impact melt despite the seeming difficulty in lofting such large amounts of molten material thousands of kilometers.

Despite the difficulties involved with invoking impact melt from an unknown distant crater, there is clear evidence for flow and melt features. There is also clear evidence for surface impact of source material from two different azimuth angles across large areas. For example, a source coming from 10° above the horizon from the northwest is the only means of producing rock-free southwest facing slopes throughout the region. Impact velocities must also be low enough to preserve the pre-existing highlands landscape. Whatever the source, material fell from the sky at a high angle of incidence and from two discreet directions, causing flow features and leaving blocks exposed on the surface.

The coincidence of the rocky exposures with the antipode and age of Tycho crater makes it difficult for us to resist associating the two features. Impact events, after all, will produce a concentration of material at their antipodal location [e.g., *8-10*]. The reason for

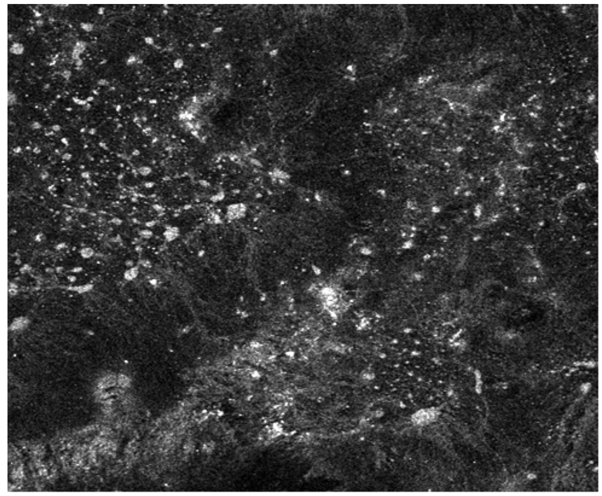

Figure 3. Mini-RF same sense image showing many individual rocky areas (circular bright spots) and flow features (thin lines) in a region of elevated rock abundance (Fig.1).

this concentration is the coincidence of great circles that intersect both the impact site and the antipode. Tycho Crater was likely formed by an oblique impact with distinct jets of material [*11*]. However, given the evidence for the limited directionality of the deposit, there is no reason that we know of for the rocky surfaces to be concentrated at the antipode.

Mini-RF data is sensitive to the presence of buried rocky surfaces that persist for much longer than exposed blocks at the surface [*12*]. It has been noted that similar flow-like features are present in Mini-RF data near Keeler Crater at 157°E, 11°S [*7*], but without corresponding elevated Diviner rock abundance values. Although the rocky surfaces near 168°E, 43°N are the clearest example, the radar data may be used to identify additional older examples (where surface rocks have been degraded), which may help us understand what caused this unusual formation.

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