CORRELATION BETWEEN SURFACE ROUGHNESS AND SLOPE ON A LUNAR IMPACT MELT.

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Abstract: The Mini-RF synthetic aperture radar on LRO has observed a solidified impact melt flow descending from the eastern rim of Tycho crater. The melt flow changes in surface roughness as it descends from the crater rim, becoming rougher as the slope increases and smoother as the surface flattens. We observe an abrupt change in radar backscatter at the end of the Tycho impact melt flow, which may be consistent with a transition from an a'a-like to a smooth ponded or pahoehoe-like crust. An a'a flow can change into a pahoehoe flow in response to a reduction in strain rate, and is most commonly observed when flows move from steep slopes to level ground.

Observations: Tycho is a Copernican-age crater located on the lunar nearside (43°S, 349°E). Abundant impact melt is associated with Tycho, located on the floor of the crater as a large pond, on the walls as pools and flows, and on the outer rim as a veneer, flows and ponds [1]. This impact melt has been observed by the Mini-RF synthetic aperture radar (SAR) and the Lunar Orbiter Laser Altimeter (LOLA) on NASA's Lunar Reconnaissance Orbiter (LRO), as well as by the Terrain Camera (TC) on JAXA's Kaguya orbiter. Mini-RF has the ability to obtain SAR images in the S-Band (12.6 cm) and the X-Band (4.2 cm), at resolutions of 150 m (baseline) and 30 m (zoom) at both wavelengths. LOLA is capable of acquiring high-resolution topography of the lunar surface with a vertical resolution of 10 cm and a shot-to-shot spacing of 15 m within a track. Kaguya's Terrain Camera acquired images of the lunar surface with a resolution of 10 m/pixel.

In the Mini-RF and Kaguya images, a particularly striking impact melt flow is observed to descend from the eastern rim of Tycho crater (Figure 1). We have registered the Mini-RF image with three LOLA topographic profiles, and found that the melt changes in radar backscatter properties as it descends from the rim. Along the melt flow, brighter (rougher) surfaces correspond to larger slopes, while darker (smoother) surfaces correspond to smaller slopes (Figure 2). Note in particular the transition from "bright" to "dark" at the end of the flow (Figure 1a, bottom right).

Discussion: The interpretation of the emplacement of impact melt flows requires knowledge of parameters not easily obtained for the Moon (such as viscosity, composition, temperature). Therefore, it is important to compare lunar impact melts with similar images of terrestrial lava flows, whose formation is better understood. In particular, there are extensive SAR observations of pahoehoe and a'a lavas on the Earth [2]. Pahoehoe flows are characterized by surfaces smooth at the scales of decimeters to meters, while a'a surfaces are highly irregular, brecciated, and rough [3]. Mini-RF's S-Band (12.6 cm) is sensitive to the roughness of the lunar surface and near-subsurface at scales of centimeters to decimeters, so it can potentially differentiate between these two types of lava.

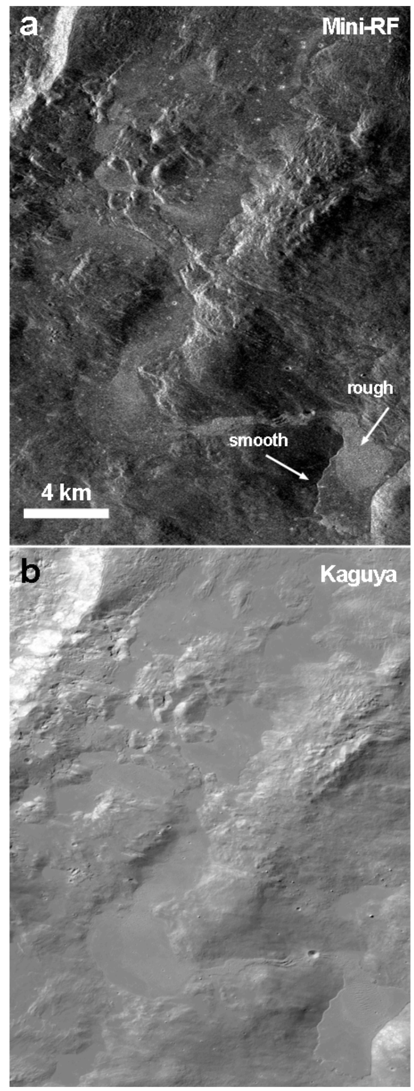

Figure 1: (a) Mini-RF S-Band total radar backscatter image of an impact melt flow southeast of Tycho crater (seen at top left). Where the flow terminates at the lower right of the image, it transitions from a rough texture to a smooth texture. (b) Kaguya TC image of the same region.

We suggest that the abrupt change in radar backscatter observed at the edge of the Tycho impact melt flow is consistent with a transition from an a'a-like to a smooth ponded or pahoehoe-like crust. The transition from pahoehoe to a'a along a single lava flow was once thought to be irreversible in volcanology [3,4]. However, recently Hon et al. [5] showed that within a restricted rheological range (T ~ 1125-1140°C, with Y ~ 100 Pa s), Hawaiian lavas can form either a pahoehoe or a'a crust, depending on the strain rate experienced by the flow. An a'a flow can transition to a pahoehoe flow in response to a reduction in strain rate; it is most commonly observed when flows move from steep slopes to level ground, such as the changes in slope seen at Tycho. Though the LOLA strip does not go directly through the transition zone observed at the end of the flow (Figure 2), the difference between the top of the flow (A) and the bottom of the flow (B) is ~ 75 m, representing a slope of 2°. The smoother, ponded melt at the base of the flow has a peak elevation of 75 m at its two edges, and grades evenly towards an elevation of 70 m at its mid-point, representing a maximum surface slope of 0.2°. At the southern edge of the flow, the elevation drops 17 m, representing the thickness of the flow.

We can use the circular polarization ratio (CPR) of the Mini-RF data to distinguish between different types of lavas. Flat surfaces tend to have low CPR values, while rough surfaces tend to have high CPR values, approaching unity. The median CPR for the "smooth" (~0.8) and "rough" (~1.1) areas are both higher than the same values seen for pahoehoe (CPR ~ 0.2) and a'a (CPR ~ 0.5) fields on Earth [2]. Indeed, they are more consistent with blocky lavas (CPR ~ 0.8 - 1.0), representative of more evolved lavas [2]. However, in a Kaguya optical image of the same region (Figure 1b), the "smooth" melt ponds do not have a particularly blocky texture, save for a few entrained blocks and small craters.

There are several expalanations that could account for the increased CPR. One explanation is that the flow is rich in centimeter- and decimeter-sized clasts, either unresolved in the optical image, or buried within the top ~1 m of the flow. Alternatively, the texture of the lava flow may be consistent with platy-ridged flows seen in Iceland and on Mars [6]. Platy-ridged flows are thought to be generated when the originally coherent upper surface of the lava flow is disrupted by a large influx of lava. In this case, an influx could be caused by the overflow of a melt pond at higher elevation. Platy-ridged lavas in Iceland consist of breccia containing 10-20 cm clasts, which would make them appear rough at the scale of the radar wavelength. Future LROC NAC images will be needed to determine the surface texture of the melt flow at the rough/smooth interface.

References: [1] Morris A.R. et al. (2000) *LPSC XXXI*, Abstract #1828. [2] Campbell B.A. and Campbell D.B. (1992) *JGR, 97*, 16,293-16,314. [3] MacDonald G.A. (1953) *American Journal of Science, 251*, 169-191. [4] Peterson D.W. and Tilling R.T. (1980) *Journal of Volcanology and Geothermal Research, 68*, 307-323. [5] Hon K.A. et al. (2003) *USGS Professional Paper 1676*, 89-104. [6] Keszthelyi L. et al. (2004) *Geochemistry Geophysics Geosystems 5*, Q11014.

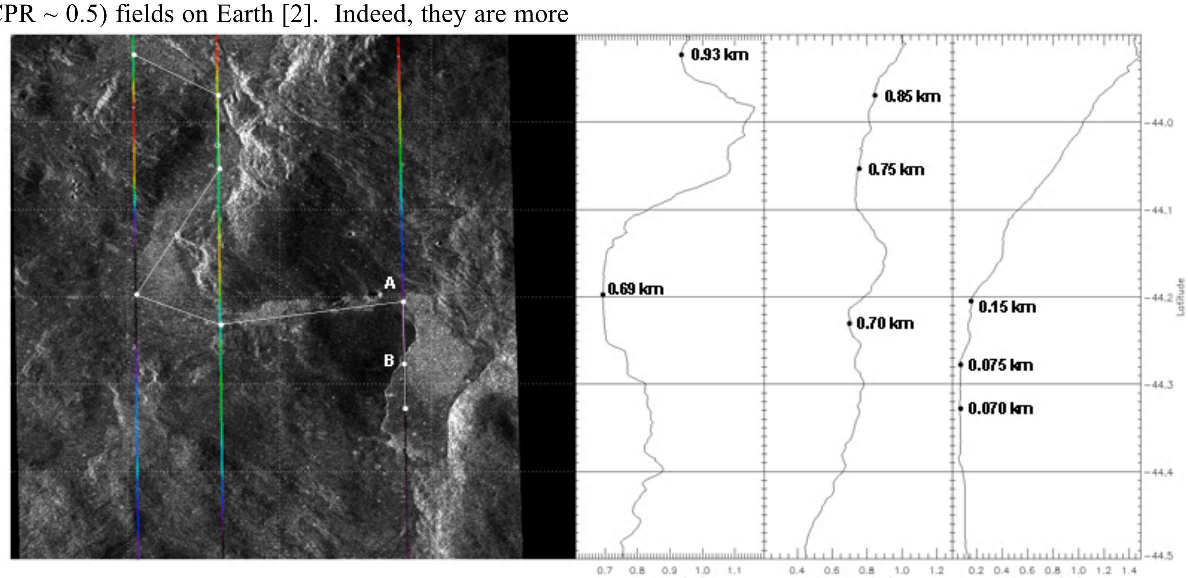

Figure 2: (left) LOLA strips overlaid on a Mini-RF S-Band image of the impact melt flow. Colors represent the relative elevation, from red (high) to purple (low). (right) LOLA topography of the impact melt flow for the three strips shown at left (from orbits 1067, 2805, and 3768), with elevations marked at specific points for reference.