NEAR-SURFACE VERTICAL STRUCTURE OF LUNAR VOLCANIC TERRAINS FROM RADAR AND INFRARED DATA. L. M. Carter[1] , R. R. Ghent[2], J. L. Bandfield[3] and B. A. Campbell[4], [1]NASA Goddard Space Flight Center (lynn.m.carter@nasa.gov), [2]University of Toronto/Planetary Science Institute, [3]Space Science Institute, [4]Smithsonian Institution.

Introduction: Lunar volcanism creates a wide variety of features such as domes, rilles, and large pyroclastic deposits. Mapping the subsurface column structure of the upper part of these deposits can provide key information about how they were formed and how the surface regolith developed through subsequent weathering. In addition, many possible lunar landing sites (e.g., the Constellation sites) are in volcanic areas, and it is critical to determine the surface and subsurface rock populations prior to landing, roving, or remote sampling. Data collected by Lunar Reconnaissance Orbiter (LRO) enable a new comparison of radar and thermal infrared data at a spatial scale (tens of meters) relevant both to understanding local geology and analyses of human and robotic landing sites.

Prior radar data have revealed buried flows and rocks within some pyroclastics deposits (e.g., Aristarchus) [1], while other deposits have radar polarimetry values that suggest very thick mounds of fine (centimeter-or-less sized) material [2]. Thermal infrared data also reveal changes in surface properties across large pyroclastic deposits [3]. Our goal is to use data from multiple wavelength regions to derive vertical structure maps that provide an improved estimate of the thickness and degree of regolith mixing in different types of volcanic settings. In cases where the thermal data reveal differences in surface structure, we can also use thermal models to investigate the burial depth of the rocks sensed by the LRO Diviner radiometer [4,5].

Measuring the subsurface at multiple depths: A multi-wavelength approach provides information about the vertical structure of the upper surface. Radar can penetrate up to ~10 times the wavelength (depending on the dielectric properties) and is sensitive to buried rocks, while thermal infrared data probes the upper few centimeters of the surface where embedded rocks influence the thermal signature. Radar is sensitive to rocks with sizes at least 10-20% of the radar wavelength, while thermal infrared data is sensitive to rocks with a size and burial depth that can influence the surface diurnal heating. We use radar data at 70 and 12.6 cm wavelengths from LRO and ground-based sources, thermal infrared cooling curves and derived products (e.g., rock abundance and regolith temperature) from LRO Diviner, and optical imaging, to map changes in the size, depth, and abundance of rocks across volcanic terrains.

Aristarchus (large pyroclastic deposit): Well-studied Aristarchus is the largest, and possibly thickest, pyroclastic deposit, and is often considered a leading landing site for future missions. Ground-based radar images acquired at 70-cm wavelength show an area of increased brightness that likely corresponds to lava flows that have been buried by subsequent pyroclastic deposits [1]. Shorter wavelength S-band (12.6 cm) data only shows a small portion of these flows. If the mantling pyroclastics above the flows are thin, small impacts are more likely to excavate buried rocks and alter the thermal signature compared to surrounding thick pyroclastics. However, the buried flows are not visible in Diviner rock abundance or regolith temperature data [3], and cooling curves do not reveal temperature differences between the units. These buried flows are therefore likely buried several centimeters to several tens of centimeters at their shallowest depth of burial.

Tranquillitatis Domes (small pyroclastic deposits; hollow terrain): Small domes are particularly interesting due to their wide range of surface types. The Cauchy 5 dome in Mare Tranquillitatis (Fig. 1) has been shown to have low S-band radar circular polarization ratio (CPR) values similar to those of large pyroclastics like Aristarchus. Optical images reveal that the dome has an unusual "lunar hollows" texture with mul-

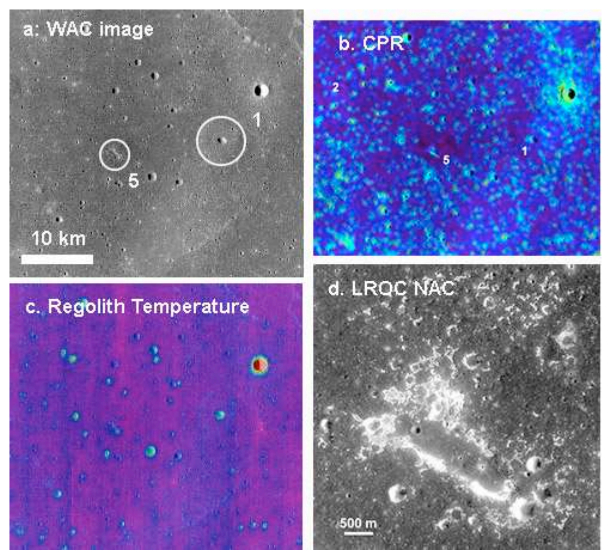

Fig. 1: The surface of the Cauchy 5 dome has a low CPR that indicates a rock poor surface (b), but the Diviner regolith temperature is not significantly different from the surroundings (c). The central vent structure at the dome center is rough with multiple pits (d) that appear rough to both Diviner and the radar. The CPR data is from ground-based Arecibo/Green Bank telescope observations [7] and is stretched from 0 (purple) to 1.0 (red). Diviner data is stretched from 2K(purple) to 30K (red).

tiple rugged pits surrounding a central vent (Fig. 1d) [6]. The central vent has enhanced Diviner-derived rock abundance and regolith temperature values, but the surrounding surface of the dome is similar in thermal properties to nearby mare. One possible subsurface structure that could produce this effect is a relatively rock-poor or low-density upper meter that still has some surface rocks.

Rima Hyginus/Rima Birt (rilles with pyroclastics): Some lunar rilles have evidence for pyroclastic deposits, including optically dark mantled terrain and low radar circular polarization ratios. In two cases, Rima Hyginus and Rima Birt, radar data at S-band (12.6 cm wavelength) reveal a somewhat greater spatial extent of pyroclastics than is visible in optical data. This could occur because thin deposits (several cm to tens of cm) will not appear as significant mantling layers in optical images, but the decrease in the near-surface cm-sized rock population could still be evident in radar imagery. Thermal infrared data provides additional information on how the thickness of rille pyroclastics drops off with distance from their sources.

In the case of Rima Hyginus, low CPR pyroclastics are visible in S-band data [2], but the Diviner derived rock abundance and regolith temperature data show only slightly different thermal properties in parts of the low-CPR area (Fig. 2a,b). In contrast, Rima Birt has clear evidence for rock-poor deposits in the Diviner regolith temperature maps. This rille has low CPR values and radar-dark terrain near a vent structure identified in optical and Clementine color ratio data [8]. To the south, the CPR values gradually increase, which may indicate an area of thinner pyroclastics (Fig. 2d). The low temperature region detected with Diviner extends farther south than the optically dark mantled region [8], but it does not extend north as far as the radar dark, low CPR areas (arrows, Fig. 2c, d). The low temperature area also does not extend as far north as the optical and spectral boundaries [8]. The Rima Birt pyroclastics therefore change in depth and have significant differences in subsurface rock abundance along the rille.

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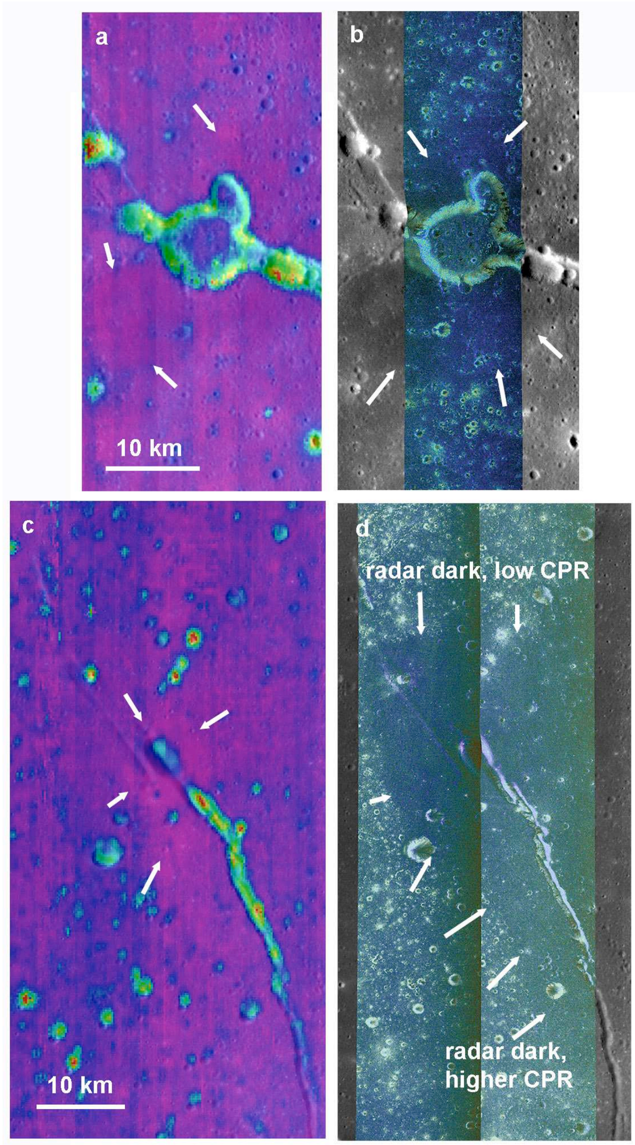

Fig. 2: Lunar rilles show a variety of thermal and radar signatures, likely reflecting changes in the depth and/or embedded rock population of the deposits. The left images are Diviner regolith temperature images of Hyginus crater (a_ and Rima Birt (c) stretched between 2 K (purple) and 30 K (red) and overlaid on WAC data. On the right are the corresponding S-band radar images from Mini-RF on LRO. The CPR is stretched from 0 (blue) to 1.0 (red) and overlaid on the total radar power. LRO WAC data fill in at the edges. Arrows point out tow temperature (a,c) and radar-dark, low CPR (b,d) pyroclastics. Note the Mini-RF images mosaicked in (d) have different look angles.