BLOCKY REGOLITH AND RUGGED SUBSURFACE DEPOSITS ON THE MOON: CORRELATION OF DUAL-WAVELENGTH RADAR DATA AND HIGH-RESOLUTION IMAGES. B. A. Campbell[1], B. R. Hawke[2], and L. M. Carter[3], [1]Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, Washington, DC 20013-7012, campbellb@si.edu; [2]HIGP/SOEST, University of Hawaii, Honolulu, HI, 96822, hawke@higp.hawaii.edu; [3]Goddard Space Flight Center, Greenbelt, MD, lynn.m.carter@nasa.gov.

Introduction: Earth-based radar observations at 12.6-cm and 70-cm wavelengths show that some lunar volcanic domes [1] and mare flow complexes [2] have rugged surface morphology. In many instances, the 70-cm echoes and moderate-resolution photos suggest that these platy or bouldery units occur beneath meters of mantling regolith. We compare radar images at the two wavelengths with new LROC high-resolution photos to better understand the geologic properties of these surprising lunar deposits. This work also sheds new light on regional variations in regolith properties with depth.

Radar Data: The 12.6-cm (S-band) radar data have a spatial resolution of 80 m per pixel with four "looks" to reduce speckle [3]. The 70-cm (P-band) data for the Marius Hills region have 500 m per pixel resolution with six looks, and for some regions (such as Mare Serenitatis) we have collected 200-m resolution images [4]. At both wavelengths, we transmit a circular-polarized signal and measure the echo in both senses of the circular echo polarization. Careful calibration to the background thermal noise permits accurate (to a few percent) estimation of the circular polarization ratio (CPR) on spatial resolutions of ~400 m at S-band and ~2 km at P-band.

The same-sense circular (SC) echo is dominated by scattering from objects with diameters 1/10 the radar wavelength and larger, on the surface or buried within the probing depth of the radar signal (10 to ~50 wavelengths depending on the regolith loss properties). The CPR, which captures the proportion of diffuse or double-bounce scattering relative to mirror-like reflections, is most easily compared between areas due to its robust calibration.

Marius Hills Study Site: Some of the roughest volcanic deposits on the Moon are associated with domes in the Marius Hills region [1, 5]. We have studied a bouldery slope on the east side of one such dome imaged in NAC frame 111972612R. The 12.6-cm radar image (Fig. 1) highlights a dome planform primarily controlled by rectilinear scarps, presumably formed by collapse of the original edifice to form lobate fields of optically bright boulders. A NAC view of one scarp shows that the largest visible boulders are about 8 m in diameter, and in a few locales these appear to comprise intact outcrops (Fig. 2) from which emanate fans of debris.

The mesa-like area that forms the top of the dome is covered by regolith which is boulder-poor at the 50-cm NAC resolution. The thickness of this layer is sufficient to preclude excavation of rubble from the flow in craters up to ~30 m in diameter, suggesting a minimum thickness of 3 m about 100 m inward of the scarp edge. Along the scarp, some 10-15 m craters excavate blocky debris, while those within darker-toned slumped regolith fans do not. These variations along the dome flank likely represent a mixing of thick regolith present on the original surface and blocks exposed during formation of the debris fan.

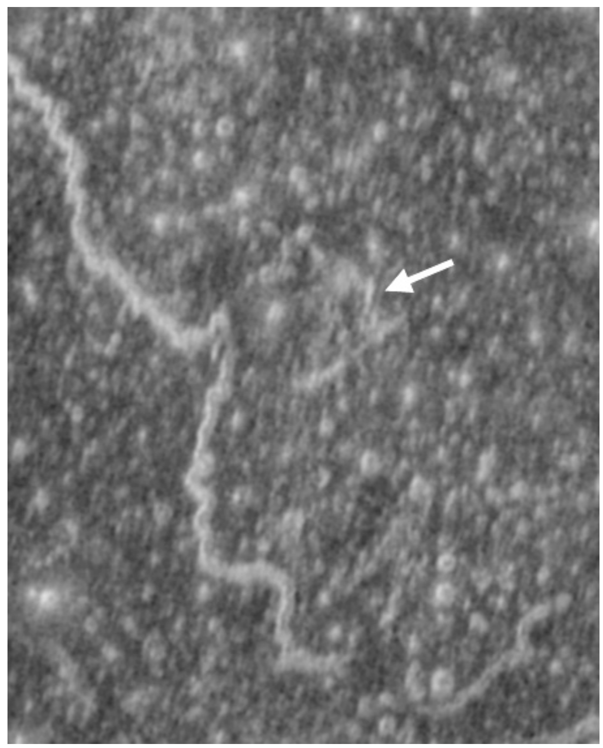

Fig. 1. 12.6-cm wavelength, SC polarization radar image of dome in the Marius Hills. Arrow notes a radar-bright linear scarp shown in the LROC-NAC frame (Fig. 2). Image resolution about 80 m/pixel.

The SC radar echoes at 12.6-cm wavelength are very high in the region of the scarp, consistent with the abundant surface boulders. The echoes drop dramatically onto the upper mesa surface, so there is evidently enough attenuation in the 3-m or thicker regolith cover to "hide" any underlying bouldery terrain, and the regolith itself must be no more rocky than typical surrounding mare units. This degree of attenuation is consistent with a basalt deposit (as opposed to much greater penetration possible in low-loss highland materials).

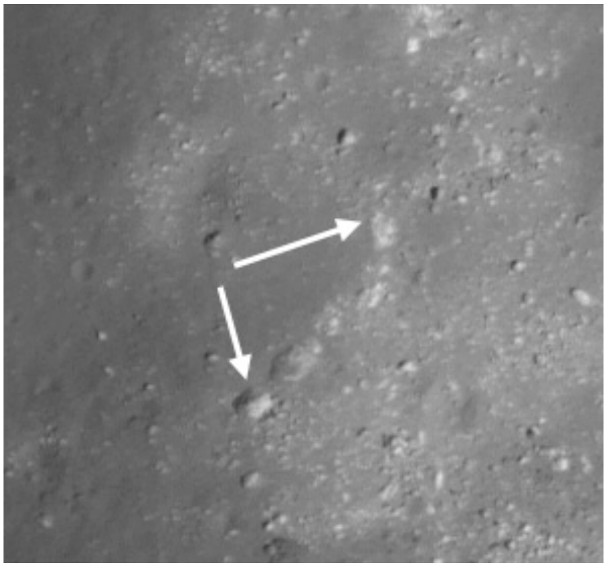

Fig. 2. Portion of LROC-NAC 111972612R. Image width 150 m, resolution 50 cm/pixel. Arrows indicate outcrop along collapsed dome margin. Regolith-covered "mesa" to left, boulder-strewn slope to right.

The 70-cm SC radar echoes are high across the entire upper surface of the dome (Fig. 3). This shows that the blocky morphology observed at the scarp face is representative of the primary flow morphology, and not simply a mechanical disruption of smoother flows during the flank collapse. If the outcrops represent dense lava core deposits, similar to the interior of terrestrial a'a or blocky flows, then the domes may be built up of numerous overlapping flow units of roughly 30 m thickness (i.e., 10 m of rubble above and below a 10-m core).

Future Work: Additional studies of sites within the Marius Hills, as LROC data become available, should increase our understanding of outcrops and the excavation of blocky debris to further constrain flow unit scales and the roughness of the original volcanic surfaces. These localized studies of a "known" rough unit will also benefit the ongoing 70-cm mapping of apparently rugged mare flows [2, 4] which lack the exposures so prevalent in the dome clusters.

A comparison of LROC images and radar echo properties (particularly the CPR at two wavelengths) among rough volcanic deposits and crater ejecta will also offer new insights into the correlation between surface and subsurface rocks. Early work at the Surveyor sites applied Rosiwal's principle, positing that the surface rocks reflect a realistic two-dimensional cut through a three-dimensional volume distribution [6]. This assumption was carried into analyses associating radar echoes with rock abundance [7, 8]. A corollary assumption is that comminution of bedrock blocks to form the regolith yields a simple power-law or exponential size-frequency distribution, such that echoes at 12.6-cm and 70-cm wavelengths should have a well-defined relationship. In the Marius Hills, Mare Serenitatis, and perhaps elsewhere, these premises are likely invalid, and it will require a combination of optical, thermal infrared, microwave emission, and radar data to fully characterize the nature of the regolith substrate and the size distribution of rocks with depth.

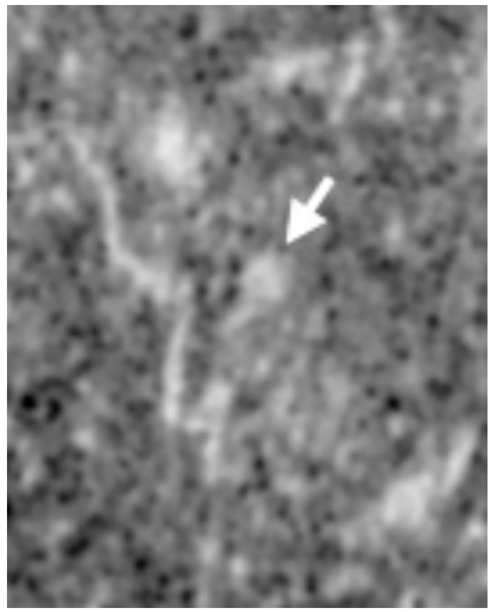

Fig. 3. 70-cm wavelength, SC-polarization radar image of the Marius dome (arrow). Resolution ~500 m/pixel.

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