

EARTH-BASED RADAR STUDIES OF POSSIBLE FUTURE LUNAR LANDING SITES

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Introduction: Over the past three years we have carried out high resolution 13 cm and 70 cm multi-polarization radar studies of high-interest terrain on the Moon using the Arecibo/GBT radar systems [1], [2], [3] [4]. Major targets have been the area around the South Pole and regional pyroclastic deposits such as those on the Aristarchus plateau and within Mare Serenitatis. These studies support planning for future robotic and human landings, in situ resource utilization, and a number of lunar mapping and geologic investigations.

Radar Observations: The Arecibo Observatory/Green Bank Telescope (GBT) bistatic radar system can be used to obtain multi-polarization images of the Moon at 13 cm and 70 cm wavelengths. The resolution of the 13 cm images is as fine as 20 m per pixel, and is 200-500 m/pixel for the 70 cm images. The 13 cm system has similar characteristics and capabilities to the 13-cm radar system on the LRO, and can image large areas (~300x600 km) of the lunar surface in each one-hour observation. One of the advantages of radar is its sensitivity to both surface and near-surface properties. This is especially true for the Moon, with a dry regolith that has low enough microwave losses to allow penetration of the radar signal to depths of ten wavelengths or more. The reflected signal is modulated by the abundance of rocks and blocky material, both on the surface and suspended within the probing distance of the radar. The circular polarization ratio (CPR), the ratio of the echo power in the same sense of circular polarization as that transmitted to the power in the opposite sense, is a useful indicator of the presence of surface or sub-surface wavelength scale roughness, while the degree of linear polarization derived from analysis of the Stokes' polarization parameters of the reflected echo can help to distinguish between the two.

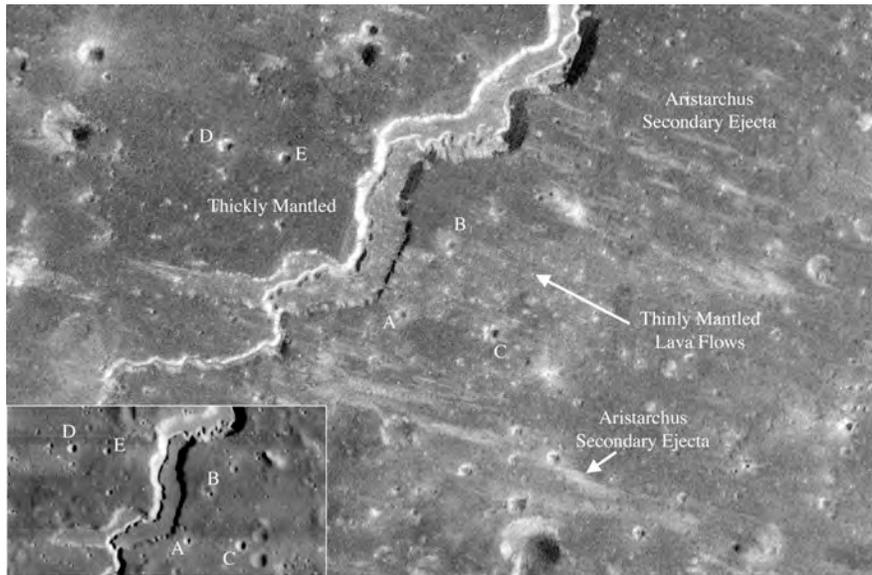


Fig. 1. Radar image at 12.6-cm wavelength of the distal end of Vallis Schröteri, where thick (radar-dark) and thin (radar-bright areas with numerous small, bright craters and streaks) mantling materials flank the rille. Inset shows LO-IV photo of the rille end, with small craters labeled to match on both images. Note the lack of optical albedo features associated with the radar-bright secondary ejecta streaks across this area.

Looking Inside Regional Pyroclastic Deposits: Fig. 1 shows a high-resolution 13 cm image of part of the Aristarchus plateau, which has been used in conjunction with 70-cm data to characterize variations in pyroclastic thickness, mare flooding from Vallis Schroteri, the abundance of impact-derived rocks, and to identify the best sites for excavation and resource extraction. What shows up clearly in this image are areas with high concentrations of sub-surface scatterers due to a probable lava flow feature near the image center, which is covered by a thin veneer of

pyroclastic deposits, and secondary ejecta related to the impact that formed the nearby Aristarchus crater [5]. Such data are important for characterizing landing sites and identifying areas that are suitable for resource extraction.

Illuminating the South Pole: The radar observations of the South Pole [2], [3], [4] (Fig. 2) have concentrated on high resolution imaging at 13 cm for landing site analysis, studies of those parts of the permanently shaded terrain that can be viewed from Earth to search for evidence of thick water ice deposits, synoptic imagery at 70 cm wavelength to identify deposits of impact melt likely associated with the formation of the Orientale basin, and measurements of the CPR to identify areas with a high degree of surface/sub-surface roughness. We have also carried out some initial studies of the linearly polarized properties of the reflected echo to study the relative importance of surface versus sub-surface scattering.

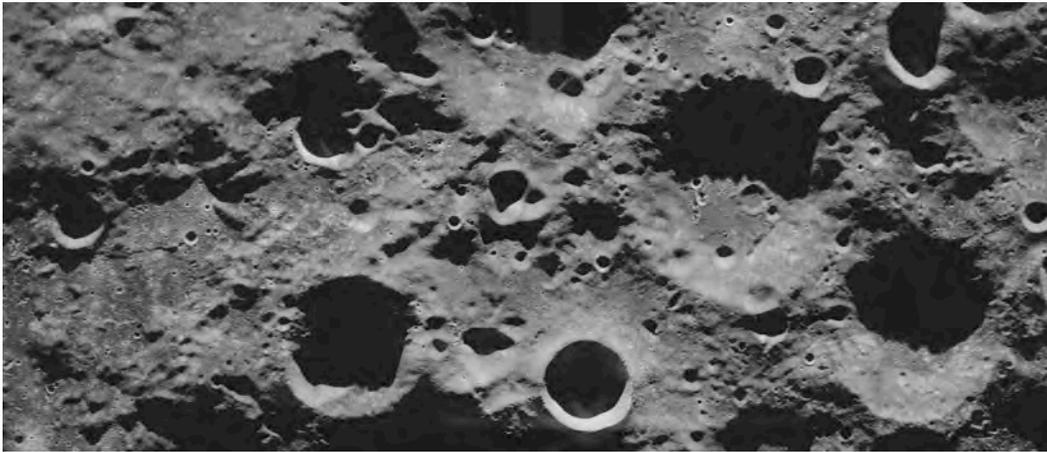


Fig. 2. Radar image at 12.6-cm wavelength of the South Pole of the Moon. Shackleton crater at bottom center.

A New View of Deep Regolith Properties: We recently released a radar map of much of the lunar near side at 70-cm wavelength through the PDS (Fig 3). These data represent a complementary view to those from UV-VIS-IR remote sensing. In particular, the 70-cm signals penetrate up to 40 m in the low-loss highland regolith, revealing differences in the depth-integrated loss properties and rock abundance that often dramatically highlight changes in geologic setting. In the area between the outer ring of Orientale basin and Oceanus Procellarum, this penetration capability reveals a large area of basalt lava flows that now lie covered by ejecta from the basin [6]. The 70-cm data also show the ubiquitous nature of radar-dark “haloes” around younger impact craters (such as Aristoteles, Petavius, and Plato), which indicate that the crater-forming process has effectively reduced the population of rocks, 10 cm and larger, in a large fraction of the ejected debris [1]. The new 70-cm and 12.6-cm radar data should be of considerable interest in support of a renewed program of geologic mapping of the Moon.

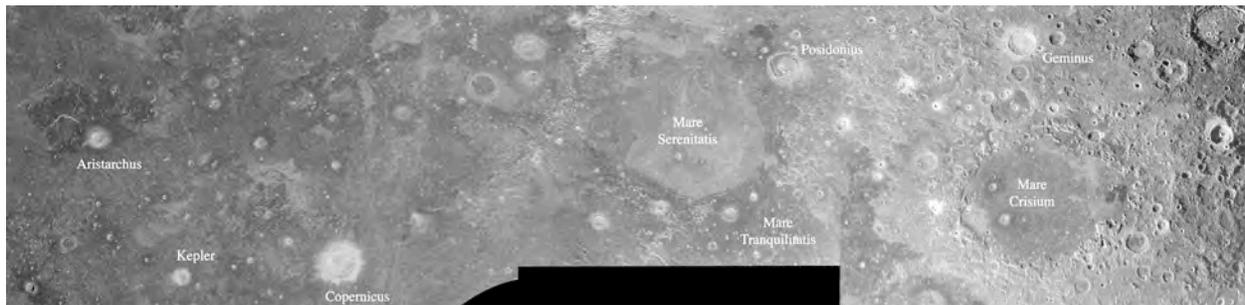


Fig. 3. Radar map at 70-cm wavelength showing a portion of the northern mid-latitude near side.

References: [1] R.R. Ghent, D.W. Leverington, B.A. Campbell, B.R. Hawke and D.B. Campbell, *J. Geophys. Res.*, September 2004; [2] B. A. Campbell, D. B. Campbell, J.F. Chandler, A. A. Hine, M.C. Nolan and P. J. Perillat, *Nature*, 426, 137, 13 Nov, 2003; [3] B.A. Campbell and D.B. Campbell, *Icarus*, 180, 1-7, Jan. 2006; [4] D. B. Campbell, B. A. Campbell, L. M. Carter, J. L. Margot and N. J. S. Stacy, *Nature*, 443, 835-837, 2006; [5] B. A. Campbell, L. M. Carter, B. R. Hawke, D. B. Campbell and R. R. Ghent, in press, *Geology*. [6] Campbell, B.A., and B.R. Hawke, *JGR*, doi:10.1029/2005JE002425, 2005.