RADAR REMOTE SENSING STUDIES OF LUNAR PYROCLASTIC DEPOSITS. Lynn M. Carter[1], Bruce A. Campbell[1], B. Ray Hawke[2] and Donald B. Campbell[3], [1]Center for Earth and Planetary Studies, Smithsonian Institution, P.O. Box 37012, Washington DC 20013, [2]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu HI 96822, [3]Department of Astronomy, Cornell University, Ithaca NY 14853.

Introduction: Lunar pyroclastic deposits record the early history of volcanism on the Moon and contain mineral resources (metal oxides and volatiles) of potential future use [1]. Earth-based radar provides a unique way to study the physical properties of the Moon's surface. The received radar echo is sensitive to the composition of the surface (through the dielectric constant and loss tangent), to the presence of subsurface scatterers, and to the surface and subsurface roughness. Using radar imaging, we are working to complete a survey of the large lunar pyroclastic deposits in order to study their distribution and physical properties. We will also use high-resolution images of specific targets to investigate detailed unit boundaries and variations within deposits.

We use the Arecibo 12.6 cm wavelength (S-band) radar and the Green Bank Telescope (GBT) in West Virginia to image the Moon at resolutions as high as 20 m/pixel. Similar observations were used to study the radar scattering and polarization properties of the lunar south pole, especially with regards to the hypothesized polar ice deposits [2]. These radar data are among the highest resolution images ever acquired for the Moon, and are comparable in resolution to some of the Apollo Lunar Orbiter, Apollo panoramic camera, and Clementine high-resolution camera images.

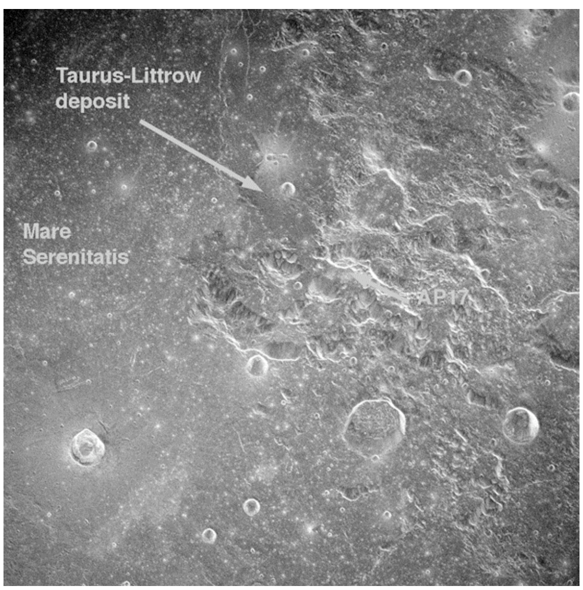

Fig. 1. An S-band radar image of the Taurus-Littrow pyroclastic deposit and Mare Serenitatis to the west. Resolution is 60 m/pixel.

At the distance of the Moon, the 305 m diameter Arecibo telescope produces a beam 230 km across at S-band. For the high-resolution imaging, we use a coded wave with a time resolution of 0.1 μs and a 50 minute coherent integration on the source to create delay-Doppler images with resolutions of ~20-30 m. We can also generate "survey" images with ~60-80 m resolution using an integration time of 20 minutes. The delay-Doppler images are then mapped to a lunar coordinate system.

At present, we have acquired survey-mode images of most of the Southern boundary of Mare Serenitatis, including the Apollo 15 and Apollo 17 landing sites and the Sulpicius Gallus pyroclastic deposits. We also have ~30 m/pixel images of the Aristarchus pyroclastic deposit and the Apollo 17 landing site. Processing and analysis of these data is still ongoing and so far we have focused on the Taurus-Littrow and Aristarchus deposits.

Taurus-Littrow and Apollo 17 landing site: Apollo 17 landed in the Littrow Valley, about 30 km east of the main section of the Taurus-Littrow pyroclastic deposit. In both optical and radar images, the deposit appears thickest near its western margin, where it is embayed by mare basalt [3]. An overview image at S-band (Fig. 1) shows the pyroclastics as darker terrain in the central part of the image. Moving away from the central part of the deposit, the terrain bright-

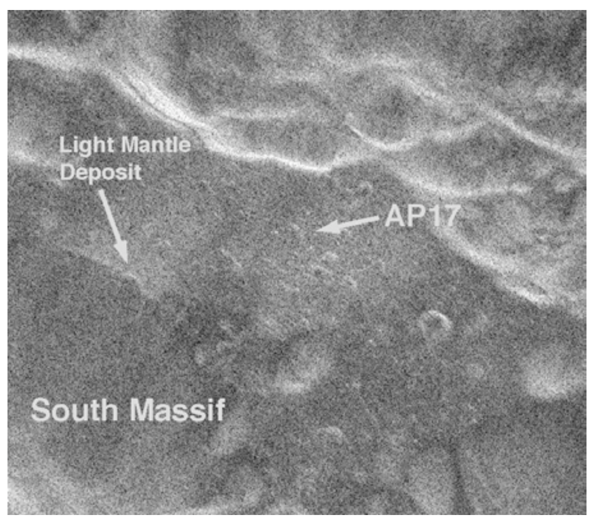

Fig. 2. S-band radar image of the Taurus-Littrow Valley. The position of the Apollo 17 landing site is marked with an arrow. Resolution is 30 m/pixel.

ens and more craters are evident, most likely indicating a change in deposit thickness. In particular, some areas mapped as pyroclastics by [4] show no appreciable darkening compared to the surrounding mare basalts at 12.6 cm wavelength.

We also have high-resolution images of the Apollo 17 landing site (Fig. 2), which can be used to investigate the extent of the pyroclastic deposit on a more localized scale and to compare the radar analysis with ground-truth observations. Fig. 2 shows the spray of Tycho secondary crater ejecta near the landing site, as well as the light mantle deposit near South Massif visited by the astronauts.

Aristarchus Plateau: The Aristarchus pyroclastic deposit mantles a plateau near the crater Aristarchus, and is the largest such deposit, with an area of ~49,000 km [5]. A mapping and remote sensing study [6] showed that the mantling material is likely several meters to perhaps a few tens of meters in thickness across the Plateau, based on analysis of partially infilled craters. The detailed variations in thickness, and the degree to which Aristarchus crater ejecta “contaminates” the pyroclastic material, are significant outstanding questions for any future resource exploitation on the Plateau.

We collected 70-cm (~500 m resolution) and 12.6-cm wavelength (~30 m resolution) dual-polarization radar images of the Plateau in 2005-2006. Preliminary analysis of these new data shows that: (1) the area W and SW of the “Cobra Head” vent is likely underlain by mare basalts over a greater area than mapped by Zisk et al. [1977], with a thinner cover of pyroclastic debris than elsewhere on the Plateau; (2) there are many occurrences of Aristarchus rough ejecta within the upper meter or so of the mantling material that are not evident in visible and infrared spectra of the upper surface.

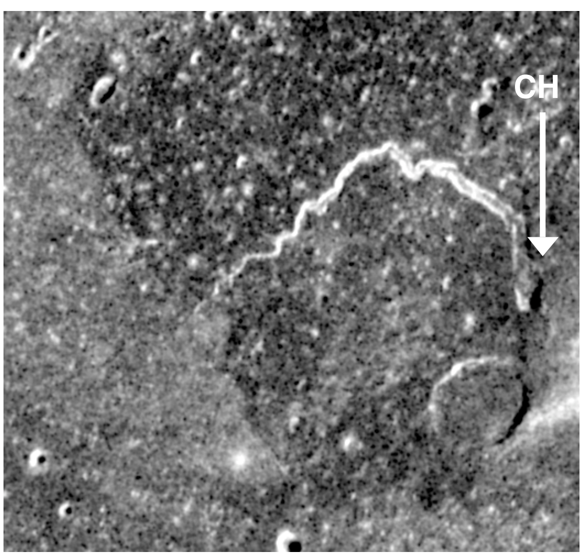

Fig. 3. 70-cm wavelength same-sense radar image of portion of the Aristarchus Plateau. Resolution 500 m. Note the areas of higher radar return W and SW of the Cobra Head (CH).

The presence of an extensive basalt flow complex beneath part of the mantling material is inferred from the 70-cm same-sense backscatter map, which shows a region, flanking the rille and extending SW to Oceanus Procellarum, with mare-like echo strength (Fig. 3). We suggest that this area represents lava flows erupted prior to or contemporaneous with the pyroclastics.

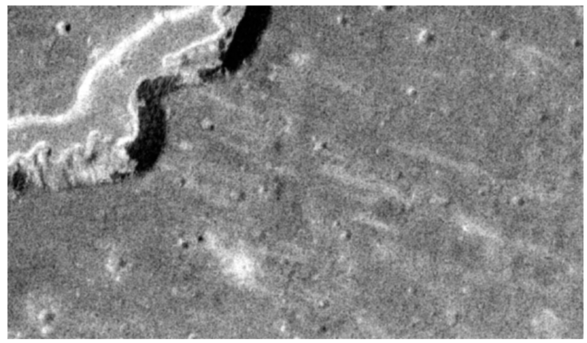

Fig. 4. 12.6-cm radar image of a part of the Plateau and Vallis Schroteri. 30-m resolution, showing bright streaks radial to Aristarchus that likely represent decimeter-scale debris incorporated within the mantling deposit.

Distal Aristarchus ejecta forms distinctive streaks or “herringbone” patterns in the 12.6-cm radar image (Fig. 4), many of which are not associated with any change in VIS-IR reflectance properties. This suggests that the 10-cm and larger-scale debris is within the upper meter or two of the mantle, rather than at the surface. Conversely, many high-albedo patches associated with secondary crater clusters on the Plateau have no radar enhancement, suggesting that they are primarily compositional or optical maturity differences among fine-grained materials.

References: [1] Hawke *et al.* (1990), *Proc. LPSC XX*, 380. [2] Campbell *et al.* (2006), *Nature*, *443*, 832. [3] Weitz *et al.* (1998), *JGR*, 103, 22725. [4] Wolfe and Scott (1981), Geologic Map of the Taurus-Littrow area, *USGS Prof. Paper 1080*. [5] Gaddis *et al.* (2003), *Icarus*, *161*, 262. [6] Zisk *et al.* (1977), *Moon*, *17*, 59.