MINI-RF OBSERVATIONS OF A SAMPLE OF LARGE LUNAR PYROCLASTIC DEPOSITS. L. M. Carter[1], J. J. Gillis-Davis[2], D. B. J. Bussey[3], P. D. Spudis[4], C. D. Neish[3], B. J. Thompson[3], G. W. Patterson[3], R. K. Raney[3], and the Mini-RF Science Team, [1]Smithsonian Institution (MRC 315), PO Box 37012, Washington, DC 20013 (carterl@si.edu), [2]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI, 96822 [3]The Johns Hopkins Applied Physics Laboratory, Laurel, MD, 20723, [4]Lunar and Planetary Institute, Houston, TX, 77058.

Introduction: Lunar pyroclastic deposits are fine-grained, optically dark deposits that are typically associated with mare boundaries, volcanic centers within mare, and fractured crater floors (e.g. [1]). They are of interest both because they formed early in the Moon's history and because they contain mineral resources that could be of future use. The pyroclastic deposits appear dark at radar wavelengths ranging from 3-70 cm [2, 3, 4, 5]. They also have low circular polarization (CPR) ratios, probably because they are fine-grained, easily penetrable by radar, and have fewer embedded blocks then surrounding terrains [5,6].

Radar is a useful remote sensing tool for characterizing lunar pyroclastics, in part because radar waves can penetrate into the surface and reveal lava flows and distal crater ejecta buried within the deposits [5]. Radar can also be used to assess the locations of the thickest parts of pyroclastic deposits and to distinguish fine-grained pyroclastic material from optically dark mare [6]. New observations of pyroclastic deposits by two orbital radar instruments will be useful for discerning the extent and physical properties of pyroclastic deposits, particularly the lunar far-side pyroclastics that cannot be observed using radar from Earth-based telescopes.

Summary of Mini-RF data: The Mini-RF radar on Lunar Reconnaissance Orbiter (LRO) is a side-looking, synthetic aperture radar (SAR) that operates at both S-band and C-band (12 cm and 4 cm wavelength, respectibely) [7]. For each wavelength, data can be collected in two modes: a baseline mode with a resolution of 150 km, and a zoom mode with a resolution of 15x30 m [7]. Data are collected using an incidence angle of ~48°.

There was also a version of the Mini-RF radar on the Chandrayaan-1 spacecraft (Forerunner). That instrument operated only at S-band (12 cm wavelength) and acquired images at 150 m resolution. The incidence angle was ~35° for most images [8].

Both radars measure two orthogonal received polarizations, and the data can therefore be used to generate the four Stokes polarization parameters as well as daughter products such as the circular polarization ratio and the degree of linear polarization [7, 9]. To date, these two radars have observed several pyroclastic deposits. Here, we show two examples: Chandrayaan-1 data of Orientale, and LRO data of the Tacquet Formation.

Orientale Pyroclastic: The Orientale pyroclastic is one of 15 non-polar tracks aquired by Forerunner (Fig. 1). This deposit is an optically dark ring, about 160 km across, on the southwest side of Orientale basin. It has a higher albedo at 750 nm than most other pyroclastics and is probably mixed with highland materials [1]. Modeling of the eruption process using measured deposit properties suggests that the deposit is very thin (of order 2 m) [10]. The ring shape, lack of associated mare deposits, and a visible central source vent make this deposit unique.

If the Orientale deposit were thin and mixed into highlands material, then the S-band radar would not detect the deposit. For example, at Rima Bode, low S-band CPR values are confined to a region in the west. The radar-dark, low-CPR signature of the pyroclastic materials disappears across the highlands to the east, where the pyroclastic deposit thins and mixes with highland materials [6].

The Forerunner image of the Orientale pyroclastic deposit cuts through the eastern half of the ring (Fig. 1). A larger image of the SAR strip with a color overlay of the CPR values is shown in Fig. 2. In the two areas where the SAR strip crosses the pyroclastic, both the radar backcatter and the CPR values are lower than surrounding regions. At the northern crossing in particular, the CPR has an average of 0.2, which is lower than averages over smooth areas to the north (0.4), and it is consistent with prior observations of pyroclasctics at this incidence angle [6].

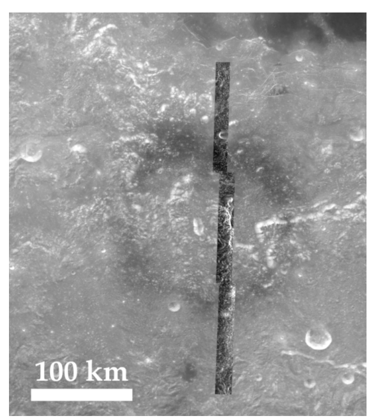

Fig. 1: Forerunner radar SAR strip of the Orientale pyroclastic deposit (SC polarization) overlaid on a Clementine 750 nm image. The pyroclastic deposit is centered at 30.3° S, 97.5° W.

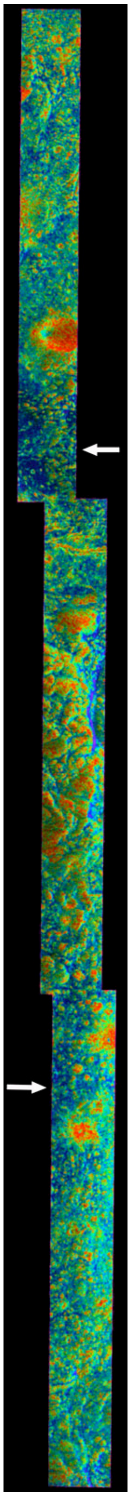

Fig 2: A Forerunner image of the Orientale CPR values, stretched to a color scale and overlaid on the total power (S1) image. The color scale runs from purple (CPR of 0) to red (CPR of 1.0). The latitudes where the radar strip crosses the pyroclastic deposit are shown with white arrows. The image was acquired at 150 m resolution.

Future LRO data across will be used to confirm that these low CPR values are caused by pyroclastic materials. If the S-band radar does detect the pyroclastics, it would suggest that this deposit is not a thin surficial covering or a minor regolith component. Instead, the deposit may be similar to other pyroclastic deposits where the radar observes low CPR values; in most cases, these deposits are thought to be several meters to tens of meters thick [1,5,6].

Tacquet Formation: At the present time, LRO has imaged only a few pyroclastic deposits and the polarimetry has not yet been processed with the calbration values. However, LRO data still provide a high-resolution view of these deposits. The Taquet Formation on the southern edge of Mare Serenitatis, which prior radar observations suggest is covered in pyroclastic material [6], appears radar dark and has fewer small impact craters than the mare deposits to the north (Fig. 3). The new imaging provides a clear view of the interior of the deposit, south of the rilles, which looks smooth and mantled.

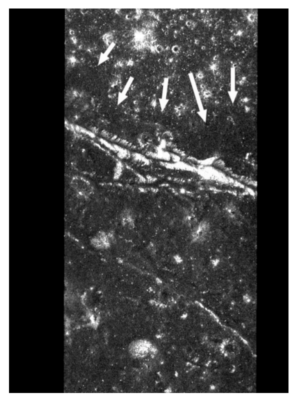

Fig 3: An LRO Mini-RF S-band zoom mode total power (S1) image of the Tacquet formation. The boundary between the deposit and Mare Serenitatis to the north is marked with arrows. The image is centered at 17° N, 18° E. The SAR strip is ~12 km wide.

References: [1] Gaddis et al., *Icarus, 161*, 262, 2003. [2] Zisk et al., *Moon, 10*, 17, 1974. [3] Gaddis et al., *Icarus, 61,* 461, 1985. [4] Thompson et al., Apollo 17 Prelim. Sci. Rep., *NASA SP-330*, 1973. [5] Campbell, B. A. et al., *Geology, 36*, 135, 2006. [6] Carter, L. M. et al., *JGR, 114,* E11004, doi:10.1029/2009 JE003406, 2009. [7] Chin et al., *Space Sci. Rev.,* doi:10.1007/s11214-007-9153-y, 2007. [8] Spudis et al. *LPSC 41*, 2010. [9] Raney, K., *IEEE Geosci. Rem. Sens. Lett., 3*, 317, 2006. [10] Head, J. W. et al., *JGR,* doi:10.1029/2000JE001438, 2002.

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