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The Unusual Atlas/Hercules Region of the Moon

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Abstract

NASA's Lunar Reconnaissance Orbiter carries the Mini-RF and Diviner Lunar Radiometer payloads. Recently, Diviner-derived H-parameter maps provided an unusual thermophysical measure near the craters Atlas and Hercules. Here, we utilize Mini-RF and Earth-based radar observations to investigate this region and its unusual thermophysical properties more thoroughly.

1. Introduction

Additional enigmatic deposits have emerged since the Lunar Reconnaissance Orbiter (LRO) entered orbit that contrast with the lunar regolith at large. Unlike optical anomalies, such as swirls, this new class of deposits are unusual for their thermophysical characteristics. One ubiquitous class consists of lunar cold-spot craters, so named because they are characterized with extensive regions, relative to their cavity diameter and depth, of anomalously cold temperatures in nighttime Diviner data [2]. These extensive cold regions are not easily explained by conventional impact mechanics. Hayne et al., [1] further characterized these ejecta features with high H-parameter values suggesting their thermophysical properties are consistent with a 'fluffed up' regolith in the upper 10 to 30 cm created by some aspect of the impact process.

However, also reported by Hayne et al., [1] were cold spots associated with pyroclastics as well as the thermophysically unique Atlas crater region (~45N, ~45E). With thermophysical similarities to cold-spot regoliths initially it seems to fit the definition of a cold-spot. But, the Atlas region is without similar geomorphological characteristics and bears dramatic differences in spatial scale. The 'Atlas thermophysical anomaly' also consists of high H-parameter values relative to its surroundings, similar to lunar cold-spots, and suggests it consists of finer regolith materials, with higher porosities, and with lower thermal inertias than typical regolith. But,

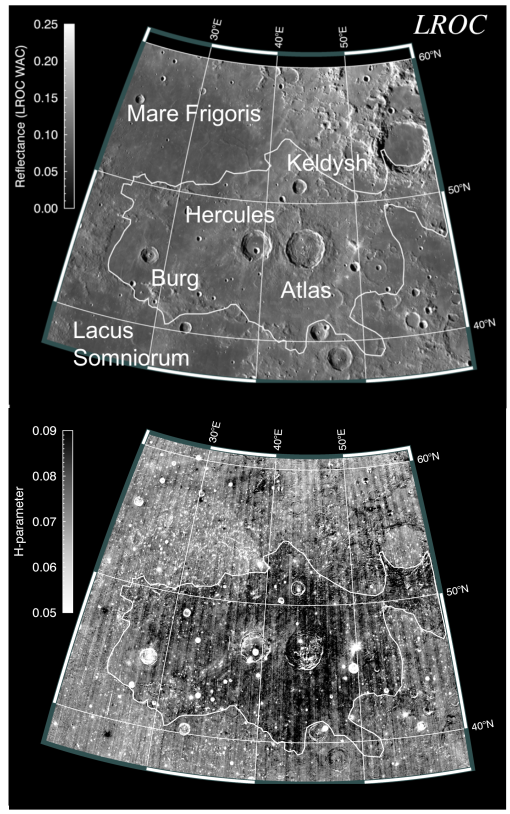

__Figure 1__: The Atlas crater region in LROC WAC monochrome and Diviner derived H-parameter maps (color bar inverted) of Hayne et al., [1].

unlike typical cold-spots, the mechanism for formation is even less clear.

2. Objectives

The Atlas region may provide a unique insight into how the lunar regolith is being mechanically and chemically weathered that contrasts with cold-spots in general. For example, unlike Atlas, cold-spots are not typically observed in radar wavelengths. Here we focus our investigation on the physical properties of the Atlas region and how they may or may not be synergistic with its thermophysical properties with increasing depth. And we do this with a combination of monostatic and bistatic observations at multiple wavelengths of the region. We also begin to postulate potential formation mechanisms of this region relative to lunar cold-spots and radar-dark halo craters (e.g., new craters, pyroclastic deposits, etc.). Questions we aim to answer include: How does this mechanism that formed the Atlas thermophysical anomaly contrast with that of typical cold spots and radar dark halo craters? Does its signature manifest Why don't all radar dark halo craters form thermal anomalies similar to the Atlas region?

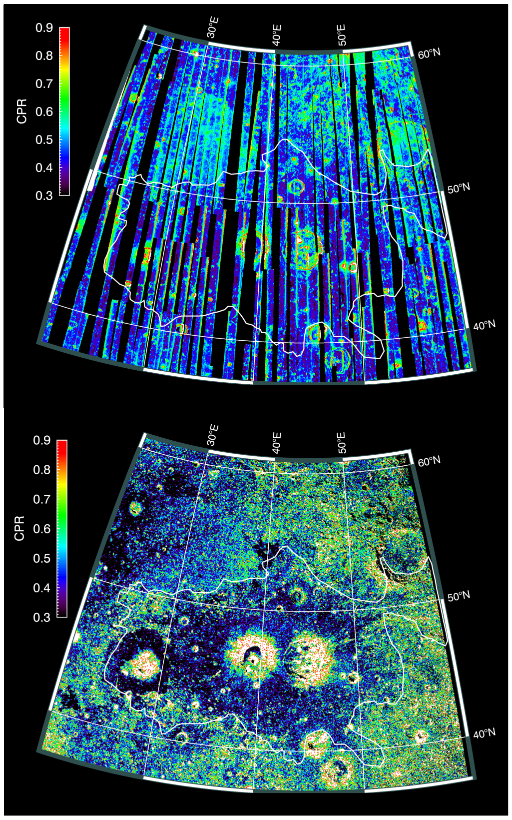

***Figure 2**: CPR observations of the Atlas crater region in (Left) Mini-RF 12.6 cm monostatic and (Right) P-band 70.3 cm bistatic configurations.*

3. Methods

Most of the initial study of this region starts with the analysis of LRO Mini-RF monostatic S-band (12.6 cm) and Earth-based Arecibo Observatory-Greenbank Observatory (AO/GO) bistatic P-band (70.3 cm) observations. The contrast in physical sensitivity be-tween circular polarization ratio of these two data sets is very informative regarding surface and subsurface scatterer sizes and depth.

We are also utilizing Arecibo-Mini-RF bistatic observations which are more targeted towards boundaries of the thermophysical region. Collecting bistatic radar data involves AO and/or DSS-13 illuminating the lunar surface at S-band (12.6 cm) or X-band (4.2 cm) wavelength, respectively, with a circularly polarized, chirped signal and tracking the Mini-RF antenna boresight intercept on the surface of the Moon. Transmitted pulses from AO and/or DSS-13 are 100 to 400 µs in length and the Mini-RF receiver operates continuously, separately receiving the horizontal and vertical polarization components of the signal backscattered from the lunar surface. The resolution of the data is ~100 m in range and ~2.5 m in azimuth but can vary from observation to observation, as a function of the viewing geometry. For analysis, the data are averaged in azimuth to provide a spatial resolution of 100 m. This yields an ~40-look average for each sampled location in an observation and an average $1/N^{1/2}$ uncertainty in the backscattered signal of ±16%. In theory, this should also enable a modest improvement in along track resolution, but processing for that effort has not yet been attempted.

4. Discussions and Observations

In radar wavelengths, 12.6 and 70 cm, the Atlas region shows distinctive low backscatter characteristics far more consistent with radar-dark halo craters than lunar cold-spots (Figure 2) [2, 3]. In fact, multiple radar-dark halo craters are apparent including Burg, Atlas, and Hercules. These backscatter properties are consistent with lunar regolith devoid of scatterers (boulders, fractures, and other corner reflectors) to at least ~10 meter depths, significantly greater depths than suggested by Diviner. The peculiar aspect of this region is its thermophysical properties relative to other radar-dark halo craters. Unlike Atlas, most other radar-dark halo craters show no significant contrast in the Diviner H-parameter relative to their surroundings. This suggests something about this region is unique or differential to other radar-dark halo craters. However, there are a few exceptions which we will examine in further detail during this study. Hayne et al., [3] also noticed some interesting similarities with certain cold-spots associated with pyroclastic deposits, particularly Aristarchus, which we will also examine.

References

[1] Stickle A. et al. (2016) LPSC. [2] Ghent R.R. et al. (2005) JGR, 110, doi:10.1029/2004JE002366.
[3] Hayne P.O. et al. (2017) JGR, 122, 2371-2400.