USING MINI-RF TO INVESTIGATE THE ANOMALOUS UVVIS SPECTRUM IN THE APOLLO AND PLATO REGION.

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Introduction: Lunar pyroclastic eruptions occur as regional deposits on the lunar nearside, and as localized deposits globally on the Moon [1]. In particular, they are found in association with basin margins, craters, volcanic vents, and sinuous rilles [2]. Most pyroclastic deposits are easily identified with optical remote sensing based on their low albedo, 0.079-0.096 [1]. For instance, the Apollo 17 sampled the dark mantle in Taurus-Littrow and found orange and black glass beads associated with fire-fountaining [3]. However, not all pyroclastic deposits have low albedo. Green and yellow volcanic glasses have a higher albedo than the dark black beads; thus making it difficult to identify them optically [1]. On the other hand, radar backscatter and spectral reflectance data can identify these high albedo pyroclastics [1]. Pyroclastic deposits yield low radar returns at 3.8-cm, 12-cm, and 70-cm wavelengths [4,5,6]. In addition, UVVIS spectral reflectance data have shown pyroclastic deposits to have moderate to high FeO content [7].

We examine two study areas because of an apparent contradiction between UVVIS spectral characteristics and radar backscatter for typical highland materials. The first study area is around the crater Plato (9ºW, 51ºN) Fig. 1, a mare-filled crater north of Mare Imbrium. The second area of interest is inside the basin of Apollo (152ºW, 36ºS) on the lunar far side. Both locations are radar dark, yet they have reflectance values and FeO compostions similar to average highlands. Furthermore, Clementine data show the materials surrounding these two study areas to be spectrally red (i.e. have a steep UVVIS continuum) and have a low optical maturity index (OMAT), which suggests the material is glassy. We study the backscatter properties of these two anomalous areas using new radar data from the Mini-RF instrument on the Lunar Reconnaissance Orbiter (LRO) spacecraft [8,9]. Studying these areas is intended to help develop criteria for indentifying bright pyroclastic deposits, which would be important for understanding the thermal history of the Moon.

Mini-RF: Mini-RF is a side-looking, synthetic aperture radar (SAR) designed to map the permanently dark areas of the lunar poles and characterize the nature of the deposits there. However, Mini-RF has acquired non-polar, circularly polarized data (CPR) to aid in global analyses of pyroclastic deposits and mare composition. Mini-RF has two bands X-band (5-cm) and S-band (12.6-cm), with an illumination incidence angle of 45º [9]. Radar images are acquired in strips with two possible resolutions: a baseline mode with a resolution of 150-m (S-band) or 75-m (X-band), and a zoom mode with a resolution of 50-m (S-band) or 15-m (X-band) [9]. Image strips are 4-6 km wide depending on the mode. In addition to providing higher resolution data than Earth-based radar for the lunar near side, Mini-RF data will provide new and invaluable observations of pyroclastic deposits in the lunar farside.

Data Description: Radar data are used to describe the chemical and physical properties of both Apollo and Plato regions. A low backscatter indicate a paucity wavelength-sized or larger rocks and/or increased FeO and TiO_2 (e.g., radar loss tangent is affected by FeO and TiO_2 in lunar materials) [4].

Clementine-based FeO and TiO_2 maps [10] can estimate the geochemistry of pyroclastic deposits. However, the algorithms were not calibrated using pyroclastic glasses and therefore exhibit greater uncertainty than they do for typical regolith . These FeO and TiO_2 maps are compared to reurn samples of pyroclastic glasses. Pristine pyroclastic glasses have FeO range from about 16 wt.% to 25 wt.%; the TiO_2 range from <1 wt.% to 16 wt.% [11].

OMAT is a maps illustrate lunar surface maturity. Space weathering (e.g. impacts, solar wind, cosmic rays) changes the physical properties and chemical composition of the regolith [12]. The longer a materials's exposure to the space weathering environment, the more mature it becomes (e.g., higher abundance of submicroscopic iron and agglutinitic glass [12]). Mature surfaces have low OMAT values while fresh craters have high OMAT values [10]. Pyroclastics, because they are glassy, also have low OMAT values [10].

Clemetine UVVIS spectral data characterizes the composition and physical properties of the lunar regolith. The UVVIS continuum, like the OMAT algorithm, is sensitive the maturity and glass content within the regolith. Thus, the continuum becomes steeper or spectrally redder as the abundance of pyroclastic glass or submicroscopic iron increases.

In our effort to understand the formation of the Apollo and Plato region, we integrate each of these data sets because they are sensitive to different physical and/or chemical properties. Combining Mini-RF radar data with Clementine UVVIS ratio, albedo, optical maturity (OMAT), FeO, and TiO_2 data can guide interpretations of lunar surface materials in the absence of samples.

Results: The spectrally red character of the material proximal to Plato and inside Apollo basin is anomalous compared with typical highlands values. Compositional maps of both Apollo and Plato reveal that both locations exhibit FeO and TiO_2 compositions similar to highlands. Mini-RF data of these two areas show the materials to be radar dark relative to surrounding highlands. OMAT maps of the two study areas display low OMAT values; OMAT values for Apollo are lower than Plato

Discussion: There are three possible processes that could produce the radar dark anomalies, cryptomare, rock-poor ejecta, and/or pyroclastic deposits [4].

Cryptomare Cryptomare are basalt deposits covered by highlands materials. The highlands material was emplaced over the basalt during basin and crater formation. The mare materials are then exposed in the ejecta of highlands craters and appear as optically dark materials with a 1-micron mafic absorption [13]. Cryptomare are associated with higher FeO and TiO_2 than highlands. This hypothesis is considered because the basalt mixed with highlands elevates the materials FeO and TiO_2 composition and can contribute to lower radar backscatter [4]. However, both the Apollo and Plato region have low FeO and TiO_2 compositions.

Rock-Poor Ejecta Radar dark haloes have been observed around impact craters [7]. The haloes are composed of fine ejecta lacking meter-sized blocks. Overtime, the haloes fade because of the gardening effect [7]. Futhermore, the halo size to crater size correlation agrees with other radar dark halo craters. One this basis Thompson et al. (2006) concluded that the region around Plato is from fine eject.

Pyroclastic Deposits Thompson et al. (2006) deduced pyroclastics deposits were not the source of the radar dark halo around Plato because of its low FeO and TiO_2, but does not conclusively rule the possibility out. The region around Plato has several sinuous rilles and crater chains [1]. Furthermore, the region around Plato appears spectrally red and anomalously low OMAT values, which is consistent with pyroclastic deposits [10]. However, using the Lucey method of calculating iron [14] with a green glass spectrum yields a value of 17 wt.% FeO, which is slightly lower than the average green glass composition of 19.5 wt.% FeO. The FeO composition around Plato and Apollo are much lower than the Lucey algorithm would predict for a relatively pure deposit of green glass.

Conclusion: Apollo basin and Plato are similar in UVVIS, OMAT, FeO, TiO_2, and radar data, which suggest they share a common origin. Much of the data is consistent with a pyroclastic origin but the evidence is not yet conclusive. The radar data is consistent with both models of formation, however, the anomalously low OMAT values and sinuous rilles found around Plato favor a pyroclastic origin. In contrast, the highlands-like albedo, and low FeO and TiO_2 compositions favor radar dark haloes do to rock-poor ejecta [7]. Traditionally, pyroclastic deposits are thought to be optically dark and have elevated FeO and TiO_2 compositions. While lunar green and yellow glasses have been found to be optically bright, our calculations of FeO using a green glass spectrum does yield values close to measured iron values. If regions around Plato and inside Apollo basin are pyroclastic deposits, they might represent a new type of low-FeO pyroclastic volcansim.

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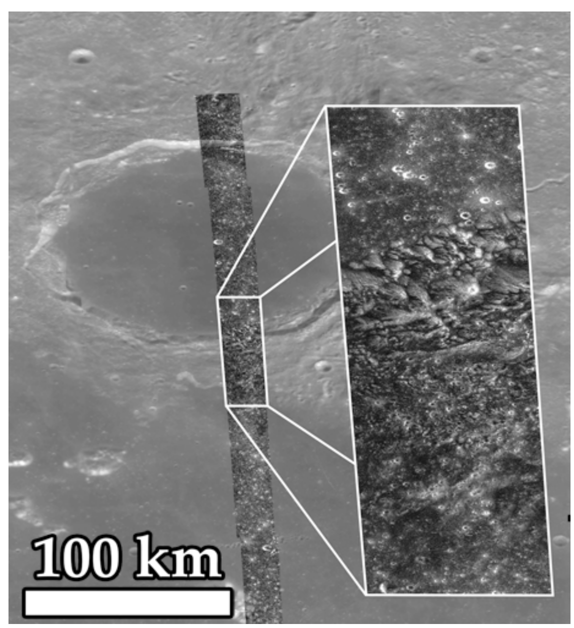

Fig. 1 Mini-RF S-band zoom image of the crater Plato with a Clementine 750 nm albedo image for context.