THE GEOLOGY OF THE PLATO REGION OF THE MOON. D. Trang[1], J.J. Gillis-Davis[1], B.R. Hawke[1], P.J. Issacson[1], and P.D. Spudis[2], [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu, HI 96822 (dtrang@higp.hawaii.edu), [2]Lunar and Planetary Institute, Houston, TX 77058

Introduction: The Plato region is anomalous in three remote sensing data sets: 1) it exhibits a radar dark halo in 3.8-cm and 70-cm radar, 2) the rim of Plato reveals a more mature regolith than nearby highlands and maria, and 3) it is a spectral red spot. The geologic processes that coherently explain these anomalies are debated. Thus, the goal of this study is to determine the sequence of events that formed the radar dark halo, the red spot, and mature regolith observed at Plato.

Previous remote sensing data sets point to various geologic processes. Radar dark halos are associated with the presence of rock-poor materials [1,2], which could be related to ejecta deposits, or pyroclastic materials [3]. Red spots are regions on the Moon that exhibit a steep spectral continuum slope in the ultraviolet to near-infrared [4]. Studies have associated red spots, such as the Gruithuisen domes, Lassell massif, and Hansteen Alpha, with regions of exposed silicic material [5] and pyroclastic deposits such as the Aristarchus Plateau [6].

In this study, we characterized Plato's radar dark halo and anomalously red material with many new remote sensing data sets provided by Chandrayaan-1, Kaguya, and the Lunar Reconnaissance Orbiter (LRO) missions. Additionally, principal component analysis on the M^3 hyperspectral data permitted identification of spectral endmembers. Integrating these data sets allowed us to produce a map of the Plato region based on various physical and compositional aspects of the regolith. With a fresh perspective gleaned from these new data, we re-investigate the two hypotheses previously cited to explain the origin of the radar dark halo, the mature regolith, and the anomalously red material surrounding Plato.

Data & Methods: We prepared multiple maps of the Plato region that emphasize different compositional and physical properties of the regolith. Data sets that contain compositional information come from instruments such as the UVVIS camera on Clementine, the Moon Mineralogy Mapper (M^3) on Chandrayaan-1, and the Diviner Lunar Radiometer Experiment (DLRE). We produced maps of FeO, TiO_2, and the optical maturity (OMAT) using the algorithms from [7,8] and Clementine UVVIS data. The FeO and TiO_2 maps measure elemental abundances and OMAT estimates the degree of space weathering. Another derived product used is the Christiansen Frequency (CF) feature map from DLRE. Here the position of the CF in wavelength is indicative of Si abundance [9]. And the last compositionally related product was produced from a principal component analysis (PCA) of the 85 band M^3 hyperspectral data in order to determine spectral endmembers [e.g., 10].

The physical properties of the regolith were mapped using Aricebo 70-cm radar, the LRO's Wide Angle Camera (WAC), the LRO's Miniature Radio-Frequency (Mini-RF), and the Kaguya's Terrain Camera (TC). We derived the circular polarization ratio product with both radar data sets, Arecibo 70-cm and Mini-RF 12.6-cm radar because of the sensitivity of CPR to surface and subsurface block populations [11]. Also, we acquired monochromatic high-incidence angle WAC data, which is similar to a shaded relief map because the data set emphasizes topography [12]. Another map that emphasizes topography is the Kaguya's digital elevation model (DEM) data, which was derived from the Terrain Camera [11]. DEMs data can reveal structures and depressions that are not easily recognized in shaded relief maps. Also, we derived other maps with Kaguya's DEM, such as the slope map.

Geology of Plato: Mapping landforms and geologic units that surround Plato may provide insights into the origin of the three remote sensing anomalies. Plato is an Imbrian-aged, 101 km in diameter crater located in the highlands between Mare Frigoris and Mare Imbrium [14]. The interior of Plato crater is mare-filled and dated at ~2.8 Ga [15].

The highlands region immediately surrounding Plato includes sinuous rilles, secondary craters, and crater chains [14]. There are three major sinuous rilles located at the 2, 3, and 9 o'clock positions relative to Plato crater (Fig. 1). Two of the rilles exhibit a "cobra-head" type feature at their origin. In addition, two possible volcanic chains are found to the east and south of Plato.

Our map of the Plato region revealed nine major units (Fig. 1). Five of the nine major units are mare units subdivided on the basis of titanium content. The highlands region was split into four units based on 70-cm radar data and the PCA analysis: undivided highlands, radar dark halo, radar bright rim, and spectrally red rim material.

The two units we are most interested in are the red rim material and the radar dark halo unit, since they are poorly understood. Spatially, the red rim material is discontinuous around the rim of Plato and extends from the contact between the wall of the crater and the mare flooded floor to about the contact between the radar bright rim and the radar dark halo. However, the red rim material is not detected on the mare in Plato, and the red rim material is rarely found on wall slopes greater than 25°. The OMAT reveals the red rim material to be more mature than the surrounding area.

Discussion: We explored two different mechanisms that attempt to explain the radar dark halo and the red spot anomaly: Silicic material and pyroclastic deposits.

Silicic Material: Generally red spots, such as the Gruithesien domes and Hansteen Alpha, are associated with silicic material. We investigated whether Plato is made of the same material. However, upon observing the Christiansen Frequency feature map from DLRE, we do not observe any consistency between Christiansen Frequency feature values below 8-μm with any major units, signifying that the red rim material likely is not silicic.

Glass-Bearing Pyroclastic Deposits: Some red spots, such as the Aristarchus Plateau, are likely to be pyroclastic deposits, therefore we explored the possibility that Plato's rim material is dominated by pyroclastics. One supporting argument for this unit being composed of pyroclastics is that the optical maturity of the red rim material is different than the surrounding area, which is expected from glass since OMAT calculates the degree of space weathering assuming the material started with a crystalline structure. In addition, pyroclastic material tends to drape the local region with a thickness up to 10's of meters [16]. Therefore, on steep slopes, the material should have mass wasted, whereas on shallow slopes, the pryoclastic material would still exist. However, the iron content of this proposed pyroclastic material is ~5%, which is much lower than typical lunar pyroclastic material. Hence, a counterarguement to highlands pyroclastic material is that there is no highlands pyroclastic material identified in current samples.

Conclusion and Future Work: The goal of this study was to produce a hypothesis that incorporates an explanation for both the radar dark halo and the red rim material. Our observations show that the red rim material existed before the mare inside Plato, is spatially discontinuous around the rim, and typically found on shallow slopes on Plato's walls. We concluded that the most likely origin of both anomalies is a highland-type pyroclastic volcanic event.

The investigation of the three Plato anomalies is far from complete. To further characterize the region, we plan to examine Lunar Prospector data and investigate other elements, such as Th. Thorium is associated with KREEP, the final products of magmatic differentaition. Additionally, we want to test the UVVIS model of the FeO and TiO_2 elemental abundances because Clementine elemental abundance maps assumes the material obeys the Hapke regolith reflectance model [5], which the red rim and radar dark halo material may violate. Additionally, we plan to synthesize highland pyroclastics in the laboratory, then space weather the material and to examine the spectrum. Laboratory experiments allow us to see if we can reproduce the spectral character of M^3. Also, This project will be expanded to the Apollo and Moscoviense regions; both regions exhibit similar properties to the Plato region.

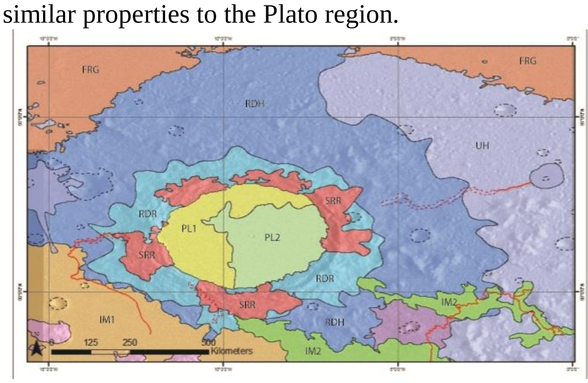

Fig. 1: Map of the Plato region. FRG=Mare Frigoris; Im1=Mare Imbrium (Lo-Ti); Im2=Mare Imbrium (Hi-Ti); PL1=Mare in Plato (Lo-Ti); PL2=Mare in Plato (Hi-Ti); UH=Undivided Highlands; RDH=Radar Dark Halo; RDR=Radar Bright Rim; SRR=Spectrally Red Rim

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