THORIUM ABUNDANCES ON THE ARISTARCHUS PLATEAU: INSIGHTS INTO THE COMPOSITION OF THE ARISTARCHUS PYROCLASTIC GLASS DEPOSITS J. J. Hagerty[1], D. J. Lawrence[2], B. R. Hawke[3], R. C. Elphic[4], and L. R. Gaddis[1], [1]U.S.G.S. Astrogeology Research Program, Flagstaff, AZ 86001, email: jhagerty@usgs.gov. [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD. [3]University of Hawai'i, Hawai'i Institute of Geophysics and Planetology, Honolulu, HI. [4]Los Alamos National Laboratory, Space Science and Applications, Los Alamos, NM.

Introduction: The Aristarchus region of the Moon is one of the most complex and geologically interesting areas on the lunar surface because it retains a record of both impact and volcanic processes [1]. Previous studies of the Aristarchus Plateau (AP) have shown that the concentration of thorium (Th) across the plateau is not constant (ranging from 4.9 to 9.3 ppm) and that it is difficult to determine if the high-Th values on the plateau are strictly associated with Th-rich ejecta from Aristarchus crater [1].

In an attempt to understand better the Th abundance distribution across the plateau, we have used Th data from the Lunar Prospector Gamma Ray Spectrometer (LP-GRS), along with a variety of other remote sensing data, to construct a forward model that will allow us to estimate the Th abundances of specific portions of the plateau [e.g., 2]. The new Th abundance distribution map provides additional constraints on the composition of pyroclasitc deposits on the plateau, which in turn has implications for the composition of the underlying lunar crust and mantle.

Aristarchus Background: The Imbrian-aged Aristarchus Plateau is an elevated, rectangular crustal block (220x170x2 km) that is embayed by mare basalts [3]. The plateau has low ultraviolet albedo, low radar reflectivity, high concentrations of radioactive elements, and high radon emanations [3]. Evidence for volcanism at the plateau is demonstrated by the unique abundance of sinuous rilles, cobra head craters, and dark mantling material of pyroclastic origin [4]. The pyroclastic material on the plateau is 10-30 m thick [5] and consists of fine-grained, block-free material containing a large fraction of volcanic glass [4].

The composition of the pyroclastic deposits on AP remains poorly characterized due to the unusual physical and optical properties of the region [6]. In fact, there is still some debate about what type of glass makes up the pyroclastic deposits. In a recent study, Pieters and Tompkins [6] suggest that the 1 µm band of the Clementine UVVIS data for AP is not distorted, indicating that there is little titanium (Ti) in the deposit. The low-Ti assertion is supported by recent radiative transfer modeling of reflectance data that was used to suggest that AP contains very low-Ti abundances [7]. Conversely, early studies of the plateau suggested that the pyroclastic deposits contain orange/red glass [4], a glass typified by high TiO_2 concentrations in the lunar sample suite [see 8]. Note that all of the pyroclastic glasses in the lunar sample suite show a direct correlation between color and Ti content, with green glasses having the lowest Ti content, yellow glasses having intermediate Ti content, and red-black glasses having the highest Ti content [see 8]. Elevated Ti contents for the Aristarchus pyroclastics are supported by the Ti estimates of Gaddis et al. [9] who used Clementine UVVIS data to suggest that Aristarchus pyroclastics may resemble the Apollo 17 orange glasses, which contain 7 wt.% TiO_2. These different data provide conflicting results, leading to widely different interpretations about the composition of the pyroclastic deposits on AP. As part of this study, we use forward modeling of Th data from the LP-GRS, in conjunction with Th data from ion-probe analyses of lunar pyroclastic glasses [10], to provide additional information about the composition of the pyroclastic deposits on AP.

Forward Modeling: As part of the forward modeling process, we re-create a specific portion of the lunar surface in which we can control the Th abundances of specific geologic features [see 2 for more details]. We select our regions of interest by using a combination of existing geologic maps, orbital photography, spectral reflectance data, and gamma-ray and neutron data [e.g., 2]. We used these data to define lithology types and to identify areas on AP that contain little or no contamination from Th-rich ejecta from Aristarchus Crater. Uncontaminated areas on the plateau provide the clearest compositional information about pyroclastic deposits on the plateau.

Once we have reconstructed a specific geologic environment, we propagate the expected gamma ray flux from this geologic environment through the LP-GRS spatial response, which produces a simulated Th abundance distribution. We then compare the simulated Th distribution to the measured Th data and iteratively adjust the simulated distribution until we achieve a match with the measured data. We recognize that this procedure gives a non-unique result; however, we can obtain quantitative estimates and uncertainties of surface abundances using a chi-square (χ^2) minimization technique [e.g., 11] that compares the measured and modeled Th abundances. The optimum Th value for a given geologic feature is the one that minimizes the chi-squared value.

Results and conclusions: A comparison of the LP-GRS Th map (Figure 1) with our forward modeling results (Figure 2) shows that our Th abundance distribution closely matches the measured Th abundance distribution. Figure 3 shows that Th abundances lower than 6 ppm are not consistent with the measured data. A chi-squared analysis of our modeled results shows that the uncontaminated pyroclastic deposits on the northwestern portion of the plateau (see area outlined in black in Figures 1 and 2), is consistent with a Th content of 6.7 ± 0.18 ppm. A complementary deconvolution method (i.e., the Pixon method), described by [12], also shows that the uncontaminated portion of the pyroclastic deposit is consistent with a Th abundance of approximately 6.6 ppm.

Analyses of pyroclastic glasses from the lunar sample suite [e.g., 10] show that the Apollo 14 (A14) red glasses are the only pristine volcanic glasses that have Th abundances as high as 6 ppm [10]. Because these are not impact glasses, the high Th abundances signify the incorporation of a KREEP component [8, 10]. Based solely on the Th content, the AP pyroclastic glasses are most similar to A14 red glasses, which have TiO_2 contents of > 15 wt.% [see 8].

Conversely, a re-analysis of LP gamma-ray and neutron spectrometer data suggests that the AP pyroclastics contain between 5 wt.% (LP-NS) and 9 wt.% (LP-GRS) TiO_2 [i.e., 13]. Additionally, data from the Hubble Space Telescope (HST), while controversial, have been used to suggest that AP contains between 7 and 8 wt.% TiO_2 [14]. These values are consistent with the previously mentioned estimates of 7 wt.% TiO_2 from Clementine UVVIS data [9]. The TiO_2 values from LP, HST, and Clementine are all consistent with the TiO_2 contents of intermediate-Ti yellow glasses from the lunar sample suite [e.g., 8].

The results from this study can be used to suggest that the pyroclastic glasses on AP are compositionally different from glasses in the lunar sample suite. The AP glasses have TiO_2 abundances similar to the A15 yellow glasses but have Th abundances similar to the A14 red glasses. It is likely that the elevated Th abundances in the AP glasses represent the incorporation of a KREEP component into the parental magmas and not contamination from Th-rich ejecta. The mechanism by which a KREEP component was incorporated is debatable, however, the rapid ascent of pyroclastic magmas on the Moon [15], tend to indicate that the KREEP component was not added via assimilation but was inherent to the source region, as was suggested in the petrogenetic models for the A14 glasses [8,10].

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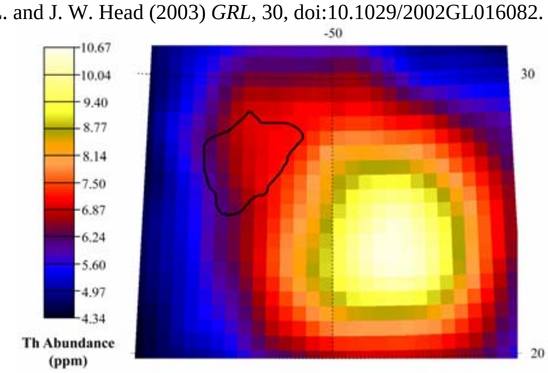

Figure 1. Th abundance map for AP as derived from the LP-GRS. The area outlined in black represents the portion of the pyroclastic deposits on AP that contains little or no Th-rich ejecta from Aristarchus crater.

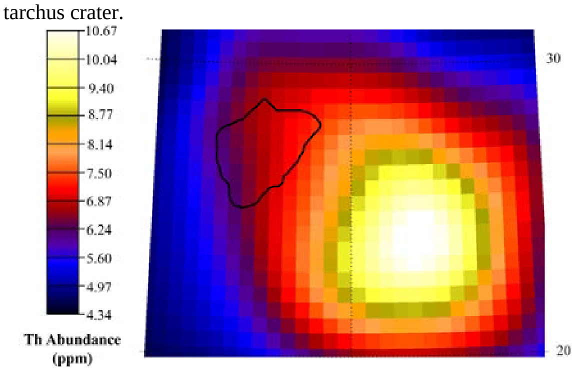

Figure 2. Th map for AP as derived from our forward modeling. The area outlined in black represents the portion of the pyroclastic deposits on AP that contains little or no Th-rich ejecta from Aristarchus crater.

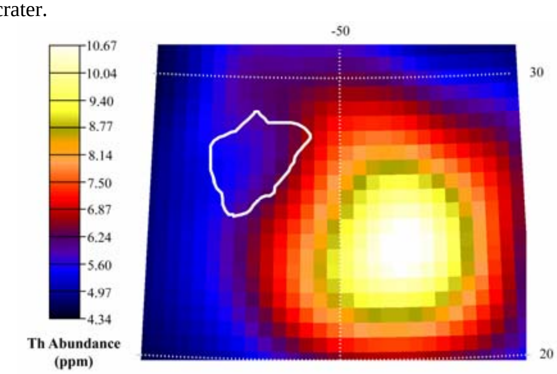

Figure 3. Forward modeling result if the uncontaminated portion of AP (outlined in white) has 5.0 ppm Th instead of 6.7 ppm.