THE THORIUM ABUNDANCE DISTRIBUTION OF THE HUMORUM PYROCLASTIC DEPOSIT J. J. Hagerty[1], B. R. Hawke[2], T. A. Giguere[2], L. R. Gaddis[1] and D. J. Lawrence[3], [1]U.S.G.S. Astrogeology Science Center, Flagstaff, AZ 86001, [2]University of Hawai'i, Hawai'i Institute of Geophysics and Planetology, Honolulu, HI, [3]Johns Hopkins University, Applied Physics Laboratory, Laurel, MD email: jhagerty@usgs.gov.

Introduction: A very large pyroclastic deposit of regional extent has been identified in the southwestern portion of Mare Humorum [1,2]. The elongate deposit extends from Liebig F in the NW to Doppelmayer G in the SE and has an area of ~1475 km^2 [3]. The SW Humorum (SWH) pyroclastics largely overlie older mare basalt deposits. The eastern portion of the SWH unit is embayed by younger mare basalts. Earth-based 12.6-cm and 70-cm radar data indicate that the pyroclastics are thickest (> 10 m) in an area that extends ~15 km to each side of Rima Doppelmayer. To the west, the SWH deposit becomes much thinner. The thick portion of the SWH unit exhibits a low-albedo, high FeO values (16-18 wt%), and very low optical maturity values. The thinner SWH deposits have slightly higher albedo values and lower FeO abundances.

The SWH deposits exhibit steep infrared continua, low albedoes, and very broad absorption bands (> 0.4 μm) centered longward of 1 μm [4]. Similar parameters were observed in spectra measured for the pyroclastic deposits on the Aristarchus Plateau [5,6,7], attributed by numerous workers to the presence of Fe^{2+}-bearing pyroclastic glass [3,5,6,7]. We also attribute these spectral characteristics to the presence of Fe^{2+}-bearing glass in the SW Humorum pyroclastics.

Laboratory analyses of pyroclastic glasses from the lunar sample suite show that this volcanic material has a greater depth of origin and lesser fractional crystallization than mare basalts [e.g., 8,9]. These data indicate that pyroclastic glasses are the best examples of primitive materials on the Moon, and they are of critical importance both in characterizing the lunar interior and as a starting place for understanding the origin and evolution of lunar basaltic magmatism [3]. Additional remote sensing and geologic studies are therefore needed to assess the full resource potential of regional pyroclastic deposits and to address key scientific and resource utilization issues [10].

While thorium (Th) data from the Lunar Prospector Gamma Ray Spectrometer (LP-GRS) indicate that the Humorum pyroclastic deposit is associated with a regional Th anomaly (Figure 1), it is possible that a low-Th signature at Humorum is being overwhelmed by adjacent high-Th sources. In an attempt to better understand the Th distribution at Humorum, we used Th data from the LP-GRS, along with a variety of other remote sensing data, to construct a forward model that allows us to estimate the Th abundances of portions of the deposit. The new Th distribution map not only places compositional constraints on the Humorum pyroclasitc deposit, but also provides information about the magmatic evolution of this region of the Moon.

Forward Modeling: As part of our forward modeling process, we model a portion of the lunar surface in which we can control the Th abundances of specific geologic features [e.g., 11]. We select our regions of interest using a combination of existing geologic maps, orbital photography, spectral reflectance data, and gamma-ray and neutron data [e.g., 11,12]. We use these data to define specific geologic features and lithology types. We are aided in this effort by previous investigations of the Humorum deposit [e.g., 1,2,4] that defined major geologic units in the region. These studies show that the thickest, darkest part of the pyroclastic deposit does not appear to have been affected by contamination from other materials [4]. Perhaps more importantly, the sharpness of observed contacts between the various volcanic units within Mare Humorum suggests that little horizontal mixing has occurred in this region [4].

After identifying major geologic units in our model, we assign Th abundances to each of those units using the procedures outlined in our previous work [e.g., 11,12]. We propagate the expected gamma ray flux from these geologic features through the LP-GRS spatial response, which produces a simulated Th 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. Once a match is achieved, we can use the modeled Th distribution to determine the Th abundance of any given feature of interest. Although this procedure gives a non-unique result we can obtain quantitative estimates and uncertainties of surface abundances using a chi-square (χ^2) minimization technique [e.g., 13] that compares the measured and modeled Th abundances.

Results and Conclusions: A comparison of the LP-GRS Th map (Figure 1) with our forward modeling results (Figure 2) shows that our modeled abundance distribution closely matches the measured Th distribution. Figure 3 shows that Th abundances lower than 1.80 ppm are not consistent with the measured data (i.e., Humorum must have ≥ 1.80 ppm). A χ^2 analysis of our modeled results shows that the uncontaminated portion of the deposit (black outline in Figures 1 and 2), is consistent with a Th content of 1.80 ± 0.30 ppm.

A complementary deconvolution method (i.e., the Pixon method [14]), shows that the uncontaminated portion of the deposit is consistent with a Th abundance of ~1.80 ppm. In total, our results show that the elevated Th abundances at Humorum are inherent to the pyroclastic deposit and are not the result of being co-located with other Th-rich sources. We can use this robust Th estimate, in conjunction with other remote sensing data, to place additional constraints on the composition and petrogenesis of this volcanic deposit.

Examination of other LP and Clementine data sets shows that the average titanium (TiO_2) abundance at Humorum is ~4.0 wt.% (Clementine), while the average iron (FeO) abundance is ~20 wt.% (Clementine). These TiO_2 and FeO values are consistent with measured abundances in yellow glasses from the lunar sample suite [8]. Additional support for this assertion can be derived from a comparison of our modeled Th values with Th values in the lunar sample suite. For instance, the modeled Th abundance of 1.80 ppm is consistent with Th abundances in Apollo 15 yellow glasses, which have as much as 1.70 ppm Th [15].

In summary, results from this study suggest that the Humorum pyroclastic glass deposit contains only slightly elevated Th abundances and that the glasses in the deposit are compositionally similar to the Apollo 15 yellow glasses from the lunar sample suite. As is the case for glasses in the sample suite, it is likely that the Th abundances in this deposit reflect the composition of the source region from which the parental magmas were derived. The rapid ascent of pyroclastic magmas on the Moon [16] suggest that the Th component was not added via assimilation but was inherent to the source region, as was indicated in the petrogenetic models for the Apollo pyroclastic glasses [8,15]. While the Th values in the Humorum deposit are not as high as those seen in the Aristarchus and Rima Bode deposits, the Th abundances at Humorum are high enough to indicate that the thermal driver for extended volcanism at Humorum was the decay of heat-producing elements in the underlying lunar mantle.

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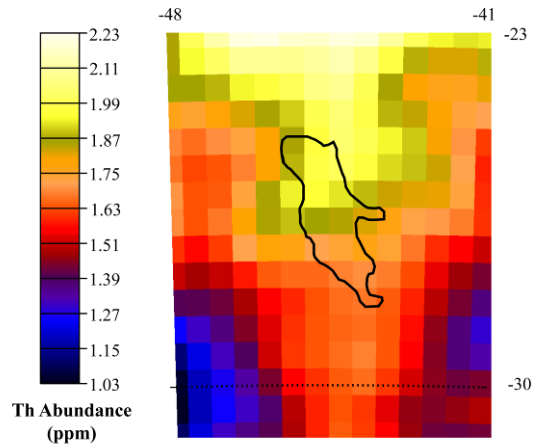

Figure 1. LP-GRS Th abundance map for Humorum. The area outlined in black represents the thickest portion of the pyroclastic deposit.

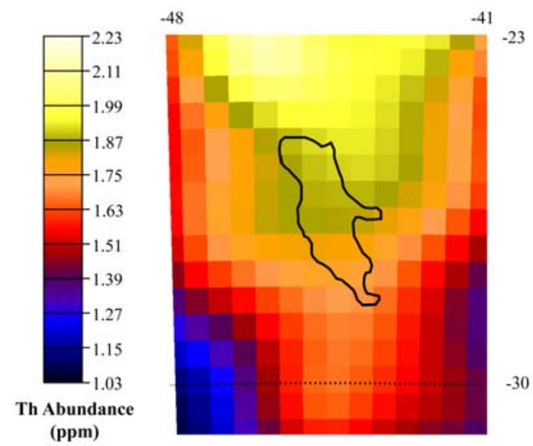

Figure 2. Forward modeling results for Humorum. The selected region has 1.80 ppm Th.

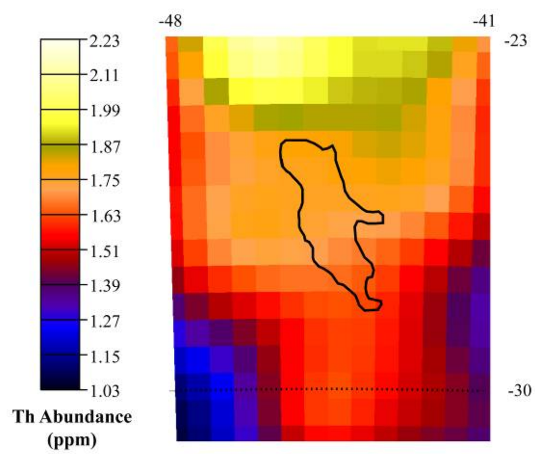

Figure 3. Forward modeling result if the uncontaminated portion of Humorum has 1.0 ppm Th instead of 1.80 ppm.