REVISED THORIUM ABUNDANCES FOR LUNAR RED SPOTS.

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Introduction: Lunar red spots are features on the nearside of the Moon that are characterized by high albedo and by a strong absorption in the ultraviolet [1]. These red spots include the Gruithuisen domes, the Mairan domes, Hansteen Alpha, the southern portion of Montes Riphaeus, Darney Chi and Tau, Helmet, and an area near the Lassell crater [2]. It has been suggested that many of the red spots are extrusive, nonmare, volcanic features that could be composed of an evolved lithlogy enriched in thorium [2,3]. In fact, Hawke et al. [2,3] used morphological characteristics to show that Hansteen Alpha is a non-mare volcanic construct. However, because the apparent Th abundances (6 – 7 ppm) were lower than that expected for evolved rock types, Hawke et al. [3] concluded that Hansteen Alpha was composed of an unknown rock type. Subsequent studies by Lawrence et al. [4,5] used improved knowledge of the Th spatial distribution for small area features on the lunar surface to revisit the interpretation of Th abundances at the Hansteen Alpha red spot. As part of their study, Lawrence et al. [4,5] used a forward modeling technique to show that the Th abundance at Hansteen Alpha is not 6 ppm, but is more likely closer to 25 ppm, a value consistent with evolved lithologies. This positive correlation between the morphology and composition of Hansteen Alpha provides support for the presence of evolved lithologies on the lunar surface. It is possible, however, that Hansteen Alpha represents an isolated occurrence of non-mare volcanism. That is why we have chosen to use the forward modeling technique of Lawrence et al. [4,5] to investigate the Th abundances at other lunar red spots, starting with the Gruithuisen domes.

The Gruithuisen domes are relatively high albedo features located near the northwestern border of Mare Imbrium (36°10′N; 39°20′W) [6]. Previous studies of the Gruithuisen region have suggested that the domes have morphologies that are consistent with evolved volcanic constructs [1,6,7]. Nevertheless, the Lunar Prospector Gamma-ray Spectrometer (LP-GRS) data indicate that the Th abundance for this region is approximately 6-7 ppm, which is not consistent with an evolved composition. This apparent contradiction can be addressed by using the forward modeling technique of Lawrence et al. [4,5].

Forward Modeling: Forward modeling of planetary gamma-ray data is a process whereby surface abundances are first estimated using data from measured abundance distributions, geologic maps, and high resolution data from Clementine [8]. The expected gamma-ray flux from the estimated abundances is propagated through the entire instrument response to get simulated data. The simulated data are then compared to the measured data and, if needed, the modeled abundance distribution is iteratively modified until a match is achieved. This type of forward modeling has been successfully carried out for both gamma-ray measurements of the Moon [4,5] and neutron measurements of Mars [9].

The forward modeling technique uses information from the LP-GRS Th maps and Clementine Spectral Reflectance (CSR) FeO maps (Figs. 1 and 2). When the two maps are compared, it is apparent that there is an Fe/Th anticorrelation, similar to what was documented for other nearside locations of the Moon [10]. If we assume that the Fe/Th anticorrelation exists on CSR spatial scales, at least for the portion of the map discussed here, we can use the CSR data to delineate regions of high and low Th abundances, as shown in Fig. 3.

Region 1 in Fig. 3 represents cratered, highlands material. LP-GRS data show that this region has ~10 µg/g Th. Regions 2 and 3 represent the Gruithuisen Domes, which appear to have 6-8 µg/g Th. Region 4 represents the Gruithuisen-B crater, which has ~3 µg/g Th. Regions 5 and 6 correspond to a string of unnamed topographic highs that have apparent Th values of 5 - 6 µg/g. Region 7 represents a very small topographic feature southwest of Mons Delisle that has a measured Th value of ~5 µg/g. Region 8 corresponds to Mons Delisle, an intriguing feature that has an apparent Th value of ~5 µg/g. Region 9 is similar to region 1, but has a Th abundance of 2.5µg/g. As part of the forward modeling process, the Th values of regions 2, 3, 5, 6, 7, and 8 were iteratively adjusted until a match with the measured data was achieved. It should be noted, however, that the Th values of regions 1, 4, and 9 remained constant during the modeling process.

Results: Fig. 4 shows the Th distribution that is produced when regions 2, 3, 5, 6, 7, and 8 are given the following Th values: Region 2 = 25 µg/g, region 3 = 20µg/g, region 5 = 16 µg/g, region 6 = 25 µg/g, region 7 = 60 µg/g, and region 8 = 35 µg/g. Conversely, Fig. 5 shows how the same regions look if they are all assigned a Th value of ~10 µg/g (i.e., average Th value for highlands). When these results are compared with the measured data in Fig. 2, it is clear that the results from the Fig. 4 closely match the data in Fig. 2.

Discussion: The results from the forward modeling provide a way to more accurately estimate the true Th abundances of the small features in the Gruithuisen region. These results do not prove that the features in the Gruithuisen region have the specific Th abundances cited above; however, the results suggest that the Th values are much higher than previously indicated. These relatively high Th values are important because they provide support for an evolved composition of the Gruithuisen domes. We note that the Th "tail" that extends down to and includes Mons Delisle does not necessarily indicate the presence of evolved lithologies within the "tail." Nevertheless, we hope that the results from this study provide the impetus to re-examine the morphology of this region. Now that the forward modeling technique has been used to successfully model two red spots (Hansteen Alpha and the Gruithuisen domes), we can use the technique to better understand the Th abundances around other locations of identified nonmare volcanism. Specifically, we plan study the Th abundances around other candidate locations of non-mare volcanism given by Hawke et al. [3], to see if they share similar characteristics.

References: [1] Wagner R. et al. (2002) *JGR, 107,* 5104; [2] Hawke B. R. et al. (2001) *LPS XXXII,* Abstract #1249; [3] Hawke B.R. et al. (2003) *JGR, 108,* 5069; [4] Lawrence D.J. et al. (2004a) *LPS XXXV,* Abstract #1727; [5] Lawrence D.J. et al. (2004b) submitted *GRL*; [6] Chevrel S.D. et al. (1999) *JGR, 104,* 16515; [7] Head J.W. and McCord T.B. (1978) *Science, 199,* 1433; [8] Lucey P.G. et al. (2000) *JGR, 105,* 20297; [9] Prettyman T.H. et al. (2004) *JGR, 109,* 5011; [10] Lawrence D.J. et al. (2003) *JGR, 108,* 5103.

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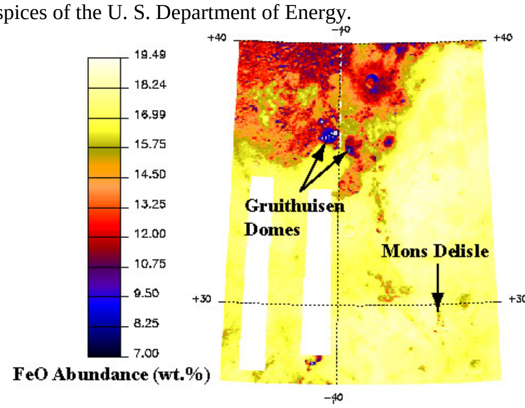

Fig. 1. Map of CSR FeO abundances in the Gruithuisen region.

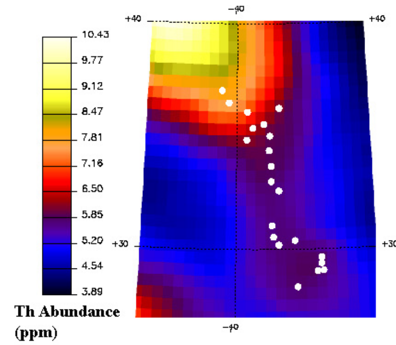

Fig. 2. Map of LP-GRS Th data for the Gruithuisen region. The white dots correspond to the features modeled in Fig. 3.

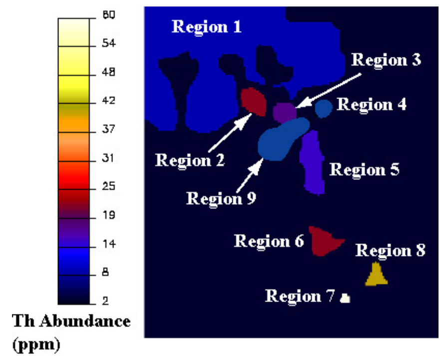

Fig. 3. Map of assumed Th compositions for the forward model. See text for assumed abundances.

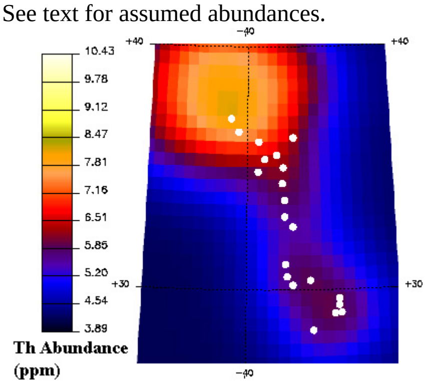

Fig. 4. Simulated Th map when regions 2, 3, 5, 6, 7, and 8 have high Th abundances.

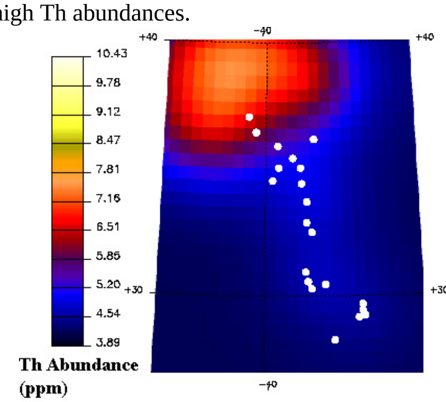

Fig. 5. Simulated Th map when regions 2, 3, 5, 6, 7, and 8 have Th abundances of 10 μg/g.