SMALL-AREA THORIUM ENHANCEMENTS ON THE LUNAR SURFACE. D. J. Lawrence, R. C. Elphic, W. C. Feldman, O. Gasnault, I. Genetay, S. Maurice, and T. H. Prettyman, Los Alamos National Laboratory, Group NIS-1, MS D466, Los Alamos, NM 87545 (djlawrence@lanl.gov); Observatoire Midi-Pyrénées, Toulouse, France.

Introduction: One of the limitations of the published thorium abundances [1] from the Lunar Prospector Gamma-ray Spectrometer (LP-GRS) is that the spatial resolution is relatively broad and has not yet been precisely determined. For example, the measurements from the low-altitude portion of the LP mission were given on (60x60) km$^2$ equal-area pixels and have an estimated full-width, half-maximum (FWHM) resolution of 45 – 60 km. Since the resolution of these data is so close to the size of the equal-area pixels, it is difficult to carry out studies of abundance features that have a size comparable to the resolution limit.

There are a number of reasons why we want to study small-area (<60 km$^2$) features using the thorium data. First, if we can better identify small-area enhancements and how they may be associated with certain features on the lunar surface, we will develop a better understanding of the local geology than if we had broad regional abundances. Understanding the abundance signal from small-area features will also help us to better understand the spatial resolution limits of the LP-GRS data. This is important for studies that are limited by the broad spatial footprint of the published thorium data [2] or for studies trying to understand the true abundances under the LP-GRS footprint [3,4]. Finally, in addition to giving us a better understanding of the thorium abundances on the lunar surface, the identification and characterization of small-area features will help us to understand the LP-GRS dataset and details about the technique of planetary gamma-ray spectroscopy. In particular, the information that we learn about the LP-GRS data from studying small-area enhancements is fundamental to the development of spatial deconvolution algorithms that can substantially improve the final spatial resolution. Here we present a study where we map the thorium data using pixels (0.5°x0.5°) that are substantially smaller than the expected LP-GRS spatial footprint. We then optimize the measured spatial resolution to the limit of the orbital gamma-ray technique by smoothing the data using an empirically determined gamma-ray response function.

Measuring the LP-GRS spatial resolution: When LP-GRS thorium data are binned onto 0.5°x0.5° pixels, the intrinsic spatial resolution of the LP-GRS data is preserved because each pixel is substantially smaller than the LP-GRS footprint. However, since there is only about one minute of data collection per 0.5°x0.5° pixel, the unprocessed 0.5°x0.5° map also shows considerable scatter. This scatter can be greatly reduced by smoothing the data over the entire surface. In order to properly carry out the smoothing procedure, we need to know the gamma-ray response function (i.e., the size and angular dependence of gamma-rays from the surface that are detected by the LP-GRS).

It has been shown to a good approximation that the gamma-ray response function can be approximated as a two-dimensional gaussian function with a FWHM that scales linearly with altitude from the lunar surface [5]. We have developed a technique using both the low- and high-altitude data that exploits this approximation to measure the spatial response function. As described in [6], we have measured the FWHM of the low-altitude data to be 62 km.

Fig. 1 shows the results when low-altitude data binned on 0.5°x0.5° pixels are smoothed in an equal-area sense using a two-dimensional gaussian function having a FWHM = 62 km. For this map, we have scaled the absolute abundances to the values of [1] because we have not yet satisfactorily determined how the smoothing procedure affects the absolute abundances. Upon inspection, we find that the smoothed map is an improvement over the (60x60) km$^2$ map of [1]. In particular, the map in Fig. 1 highlights thorium enhancements and high contrast interfaces and sharpens many small-area features.

Identification of small-area thorium enhancements: One of the initial goals of this study is to identify and characterize small area thorium enhancements that have a size near the limit of the LP-GRS spatial footprint. In the smoothed data of Fig. 1, such enhancements will have a 2D gaussian distribution with a FWHM of roughly 60 km. In a preliminary survey, at least ten locations have thorium enhancements that clearly fit this characterization. It is likely that more thorium enhancements will be identified with further study. Of the identified enhancements, about half are clearly associated with geologic features such as craters and half do not show a clear association with an identified geologic feature. Below, we describe two of the enhancements.

Compton/Belkovich: In [1], a thorium enhancement was identified in the NE highlands near the cra-
SMALL-AREA THORIUM ENHANCEMENTS: D. J. Lawrence et al.

ters Compton and Belkovich. There is no association of this enhancement with any known crater, however. [1] and [7] describe this location as possibly being rich in an alkali anorthosite material. Fig. 2 shows a map of this region and Fig. 4 shows a profile through the thorium enhancement in this region. The profile in Fig. 4 is well fit by a gaussian function having a FWHM of 63 km. This indicates that the enhancement producing the signal has a diameter of ≤60 km. As described in [7], Clementine UVVIS and LWIR data have been used to identify a 20 km diameter albedo feature that is associated with the thorium enhancement. If we assume that the entire thorium signal is coming from the albedo feature, then calculations show that the thorium abundance on the surface may be as high as 20 µg/g. However, if the thorium is spread out over an area larger than the albedo feature, the surface thorium abundance will be lower.

**Timocharis:** Fig. 3 shows a map and Fig. 4 shows a profile through a thorium enhancement that is clearly associated with the 33 km diameter crater Timocharis located in the SE mare basalts of Imbrium basin. The profile of Fig. 4 is well fit by a gaussian having a FWHM of 60 km, which indicates that a small-area enrichment is producing the observed thorium signal. The impact that created Timocharis evidently landed in a location with a thin mare basalt layer and/or a thick sub-layer of high-thorium material. If we assume that the thorium is evenly distributed across the crater diameter, we calculate that the thorium abundance should be enhanced above the local background by a factor of 2. Since the measured abundance at Timocharis is 2 µg/g above a background 6 µg/g (see Fig. 4), this implies that the actual abundance at the surface may be 2x2 + 6 = 10 µg/g. This would make its abundance roughly equivalent to the thorium abundance seen at the larger Apennine Bench to the east. However, if the thorium is distributed across both the crater and ejecta blanket (50 km diameter as seen in the airbrush map of [8]), then the thorium abundance will be closer to the observed value of 8 µg/g.


**Figure 1:** Lunar thorium abundances mapped onto 0.5°x0.5° pixels and smoothed with a 62 FWHM 2D gaussian function.

**Figure 2:** The Compton/Belkovich thorium enhancement.

**Figure 3:** Thorium enhancement at the crater Timocharis (13°W, 26.7°N). The large thorium enhancement to the right is the Apennine Bench.

**Figure 4:** Profiles along the Compton/Belkovich thorium enhancement at 100°E (circles) and Timocharis crater at 12°W (diamonds).