Enhanced Thorium Abundances at Lunar Irregular Mare Patches. David J. Lawrence[1], Karen R. Stockstill-Cahill[1], Lauren M. Jozwiak[1], Patrick N. Peplowski[1], Jack T. Wilson[1]; [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD, 20723 (David.J.Lawrence@jhuapl.edu).

Introduction: Irregular mare patches (IMPs) are a class of small (< ~few km) features with irregular morphology, sharp features, and low crater densities located within the nearside maria [1–4]. Based on crater distribution ages, IMPs have been interpreted as geologically recent volcanism, forming within the past ~100 million years (100 Ma) [3–5]. Alternatively, unique physical properties or relatively recent modification may mean that the basalts within the IMPs are similar in age to typical basalts [e.g., 6 – 8]. One of the most well-known IMPs is the Ina feature located on the central nearside of the Moon.

The possibility of young (<100 Mya) volcanism stands in direct contrast to our prevailing understanding of the igneous evolution of the lunar surface. Radiometric dating of the Apollo samples indicates lunar mare volcanism was prevalent between ~3.1 – 3.9 Ga [9, 10], and remote observations further suggest lunar volcanism waned between ~ 1.2 – 2.0 Ga [11, 12]. Volcanic eruptions in the last 1 Ga, much less the last 100 Ma, would therefore challenge the established scientific models of lunar volcanism and would revolutionize our understanding of the thermal evolution of the Moon. One dataset that has yet to be investigated in relation to IMPs is remotely measured thorium abundances from the Lunar Prospector Gamma-Ray Spectrometer (LP-GRS). Thorium abundances on the Moon are linked to KREEP materials (KREEP = potassium [K], rare-earth elements [REE], phosphorus [P]) that are associated with late-stage volcanism on the lunar surface. Here, we report the results of an initial analysis where we characterize identified IMPs based on their thorium abundances from LP-GRS data.

Analysis of Thorium Data: The highest spatial resolution thorium abundances are those reported by [13], and are the result of spatial reconstruction algorithms applied to the 30-km-altitude thorium dataset from the LP mission [14]. For the locations of the IMPs, we used the compilation of [4], who listed 70 IMPs, all of which are located on the lunar nearside. For the analysis here, we identified a 20-km circular diameter around each IMP location and calculated the average thorium abundance at each location. One limitation to this analysis is that due to the spatial resolution mismatch, the measured thorium abundances represent an average abundance in the vicinity of each IMP, and not necessarily the exact abundance at each IMP location.

Results and Discussion: Figure 1A shows the nearside map of thorium abundances from [13]. The locations of IMPs are shown with black circles. The IMPs are located in two broad regions, with a western region located in western Imbrium basin, and an eastern region southeast of Imbrium basin and around western mare Tranquillitatis. Maps with closer focus for both these regions are shown in Figures 1B and 1C, respectively. In the western region, the thorium abundances of the IMPs are close to, but not at the areas of maximum thorium content (e.g., Mairan [41.6°N, 43.4°W] and Aristarchus [23.7°N, 47.4°W] craters). In the eastern region (which contains the type IMP Ina; labeled in the figure), IMPs are also located around, but not at, the locations of highest thorium content. Interestingly, a large grouping of IMPs is clustered around a previously identified moderate thorium enhancement [14, 15] near Arago crater in western mare Tranquillitatis. Prior to this study, the thorium enhancement near but not coincident with Arago crater was one of the few identified thorium enhancements that had no corresponding surface feature from other photogeologic and compositional datasets [14]. Figure 1D shows the nearside thorium abundances plotted versus longitude. The IMP thorium contents (red circles in Figure 1D) range from 3–6 ppm in the eastern region to 6–8 ppm in the western region.

In almost all cases, the IMP thorium abundances are neither at the minimum or maximum values for lunar thorium abundances (one exception is a high-thorium IMP very near Aristarchus crater). These results therefore suggest there is some linkage between the unique characteristics of IMPs and moderate expressions of KREEP-like materials. In addition, with the identification that KREEP materials are likely enhanced in hydrogen abundances [16], these results raise the question if young volcanism on the Moon might be related to late-stage radiogenic heating and enhanced volatile content. At this time, orbital data cannot easily address these questions, as in-situ measurements are needed to address the young/old nature of IMPs, as well as characterize the thorium content of the IMPs on a <1 km spatial scale. These types of measurements would be ideally suited for a future landed lunar surface investigation.

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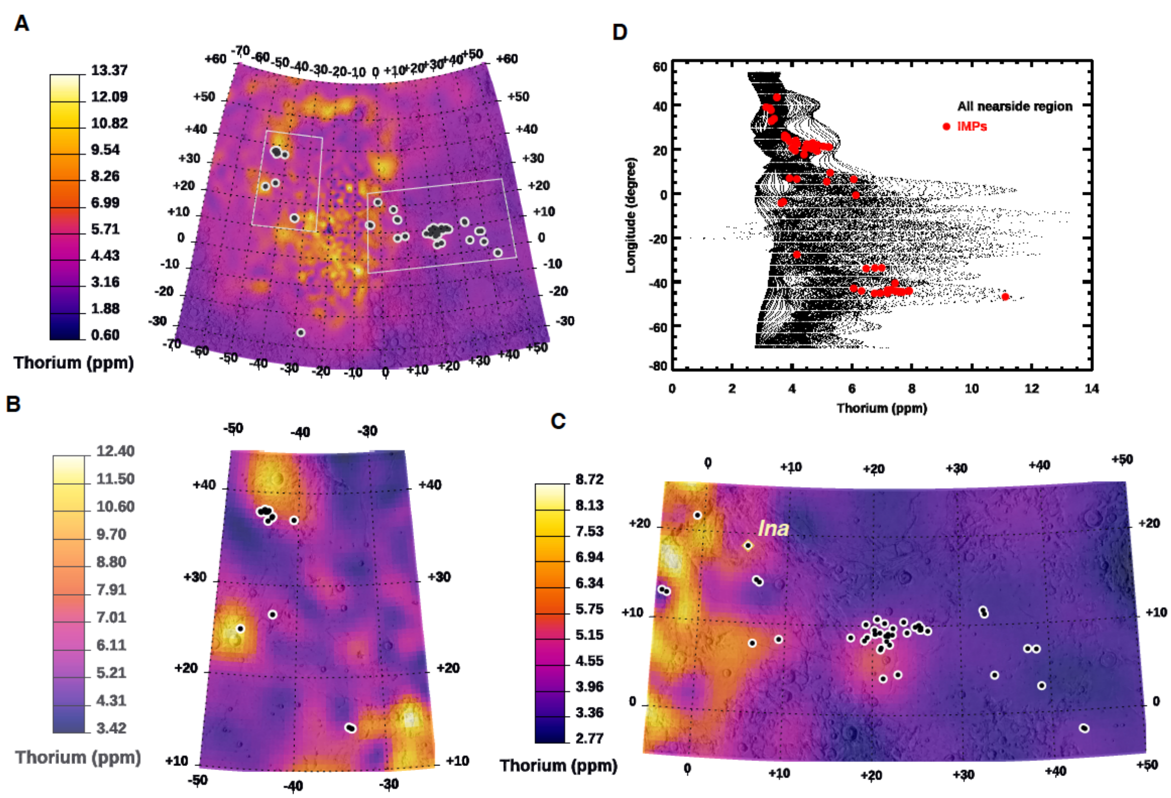

Figure 1. A) Nearside map of thorium abundances from [13]; circles show identified locations of IMPs from [4]. B) Thorium abundances in western region that is outlined in part A; C) Thorium abundances in eastern region that is outlined in part A. Ina IMP is labeled; D) Scatter plot of thorium abundances versus longitude for the full nearside region. The thorium abundances for all the IMPs are shown with red data points.