MAPPING THE CONCENTRATION OF IRON, TITANIUM, AND THORIUM IN MARE BASALTS IN THE WESTERN PROCELLARUM REGION OF THE MOON. E. L. Flor[1], B. L. Jolliff[2], and J. J. Gillis[2], [1]Rice University and NASA Missouri Space Grant Consortium, [2]Department of Earth and Planetary Sciences, Washington University, One Brookings Drive, St. Louis, Missouri 63130 <blj@levee.wustl.edu>

Introduction: Mare basalt flows in the Western Procellarum region (WPR) are extensive and include some of the youngest geologic features on the Moon. Compositional remote sensing by the Lunar Prospector gamma-ray spectrometer (LPGRS) indicates elevated Th concentrations in many of these flows relative to basalts sampled by the Apollo and Luna missions [1,2,3,4]. The primary goals of this investigation are to determine whether the Th enrichment in this region contributed to the extensive and prolonged volcanism in the WPR, and to determine whether the Th is inherent to the basalts themselves or a result of contamination from nonvolcanic material. Thorium enrichment indigenous to the basalts of the Western Procellarum Region would provide evidence that the general concentration of Th in the Procellarum region extends below the crust and possibly as deep as the sources for the basalts themselves.

The study area for this project spans from 30°N to 45°N and approximately 40°W to 80°W (**Fig. 1**). Individual basalt flows are identified by spectral and chemical differences using Clementine ultraviolet-visible (UVVIS) data [5] and LPGRS data [6,7]. Resulting compositional maps are compared to existing geological maps [e.g., 8], compositional variations are correlated to geologic units, and previously undetected flows are identified. By examining compositional variations between Fe, Ti and Th within and among individual flows and surrounding nonmare geologic formations, we seek to determine (1) sources of Th enrichment, (2) effects of lateral and vertical mixing by impact processes on Th, Ti, and Fe concentrations, (3) whether Th enrichment is inherent to the mare basalts or a result of contamination from the ejecta of large craters such as Mairan, and (4) compositional variations that might correlate with age.

Data Analysis: Data from Clementine, Lunar Prospector missions, and Lunar Orbiter images, as well as USGS maps of the region, were integrated by coregistration to investigate correlations. The Clementine UV-VIS data were used to create spectral and compositional maps.

Maps of FeO and TiO_2 concentrations derived from Clementine spectral reflectance data [9,10] and color-ratio images were then compared and integrated with Th concentrations from LPGRS [7] at half degree resolution. On the basis of spectral and compositional properties of specific geologic units, the area was subdivided into seventeen different regions of interest (ROIs), some corresponding to flow units, and some to mare-bounding highland units. To examine the cause of large ranges in composition within an ROI, compositional information was imported into an n-dimensional visualizer, and subROIs were selected from natural clusters of data or end members that appeared in the viewer. SubROIs can be distinguished on the basis of compositional and mineralogical differences, e.g. craters and crater rays. By transferring the selected pixels from *n*-dimensional space back to image-space, the validity of the subROI could be assessed. The two criteria substantiating the geologic significance of a subROI were (1) are the pixels spatially contiguous; and 2) do these pixels correspond to morphologic features (e.g., premare craters, postmare craters and crater rays) when the compositional map is compared to Lunar Orbiter images. We found that the subROIs resolved in this analysis meet both criteria, thus validating the separation of the ROI into its component parts on the basis of compositional, mineralogical, and morphological characteristics.

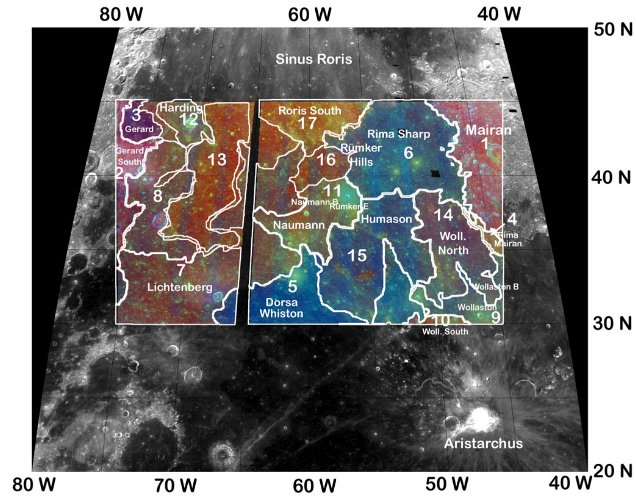

Figure 1. Clementine color ratio image of study area superimposed 750 nm image showing the north-western Procellarum region in a sinusoidal projection.

Discussion: We divided the study region into seventeen individual regions of interest (Fig 1. and Table 1). The southern ROIs of this study area (e.g., Wollaston South, Dorsa Whiston, and Lichtenberg) correspond to ROIs along the northern boundary of a region that was studied in detail by us previously [1] (e.g., Herodotus, Schiaparelli, and Briggs, respectively).

Table 1. Average compositions for ROIs. Numbers correspond to ROIs in Figure 1.

	Region of Interest	Av. FeO Wt%	Av. TiO_2 Wt%	Av. Th (ppm)
1	Mairan	13.9	1.2	9.2
2	Gerard South	14.0	1.9	4.9
3	Gerard	16.4	3.0	4.5
4	Rima Mairan	18.1	2.1	5.5
5	Dorsa Whiston	19.6	5.9	4.2
6	Rima Sharp	18.5	5.1	5.6
7	Lichtenberg	18.6	3.3	4.3
8	Lavoisier A	18.1	2.9	4.5
9	Wollaston	18.7	4.2	4.5
10	Wollaston South	18.6	2.7	6.3
11	Naumann	19.1	3.2	3.7
12	Harding	18.3	2.8	4.3
13	Sienna	18.7	2.4	3.8
14	Wollaston North	18.4	3.4	4.2
15	Humason	19.3	4.2	4.5
16	Mons Rümker	18.3	2.8	3.6
17	Sinus Roris S.	18.1	1.3	3.4

Along the eastern edge of the mare, the Mairan ROI includes mainly non-volcanic material (14% FeO) and has the highest Th concentrations in the region (Av. 9.2 ppm). The Gerard South ROI lies along the western edge of the region and also includes mainly non-volcanic material (14% FeO). It has a moderate Th concentration of ~5 ppm.

Dorsa Whiston, an extension of the Schiaparelli ROI (Region 1, to the south [1]), is considered to be one of the youngest basalt flows on the Moon because part of the flow covers crater rays from Lichtenberg, which is probably no more than 1-1.2 billion years old [11]. Dorsa Whiston has the highest average FeO (19.6 wt%) and TiO_2 concentrations (5.9 wt%) in the region. The high FeO concentration suggests minimal contamination by nonmare material, consistent with its relatively young age. Its Th concentration of 4.2 ppm is probably indigenous to the basalt.

Average FeO and Th concentrations for these three ROIs, Mairan, Gerard South, and Dorsa Whiston, define three potential mixing endmembers (Fig. 2). From the Mairan Highlands westward, FeO increases and Th decreases toward the composition of Dorsa Whiston. From Gerard South eastward, average ROI compositions also lie along a line toward Dorsa Whiston. These mixing trends intersect at high FeO, suggesting a specific average composition for young basalts in this region: ~4 ppm Th and 20 wt% FeO. Concentrations of Th higher than ~4 ppm are reasonably interpreted as a result of mixing between basalt and Th-rich nonmare rocks.

The Wollaston South ROI lies above the Mairan-Dorsa Whiston mixing line. This ROI lies just north of the Aristarchus region, which has Th concentrations reaching 11 ppm. ROIs that include the basalt flows adjacent to these regions are also enriched as a result of contamination from Th-rich nonmare material in the form of ejecta from the craters Mairan and Aristarchus.

Compositions in the Dorsa Whiston ROI form the basaltic endmember in this geologic model and closely match compositions in the Schiaparelli region to the south. Concentrations of Th in the western Procellarum basalts are high relative to most Apollo basalts and support the idea that indigenous Th content is related to extended volcanism in the Procellarum region.

References: [1] Flor et al. (2002) LPSC 33, Abst #1909; [2] Gillis et al. (2002) LPSC 33, Abst #1934; [3] Jolliff et al. (2001) LPSC 32, Abst #2144; [4] Korotev (1998) *JGR* **103** (E1), 1691-1701; [5] Nozette et al. (1994) *Science* **266**, 1835-1839; [6] Binder (1998) *Science* **281**, 1475-1476; [7] Lawrence et al. (2000) *JGR* **105**, 20,307-20,331; [8] Scott and Eggleton (1973) I-805, USGS; [9] Gillis et al. (2003) *JGR*, in press; [10] Gillis et al. (2003) *GCA*, submitted; [11] Schultz and Spudis (1983) *Nature* **302**, 233-236.

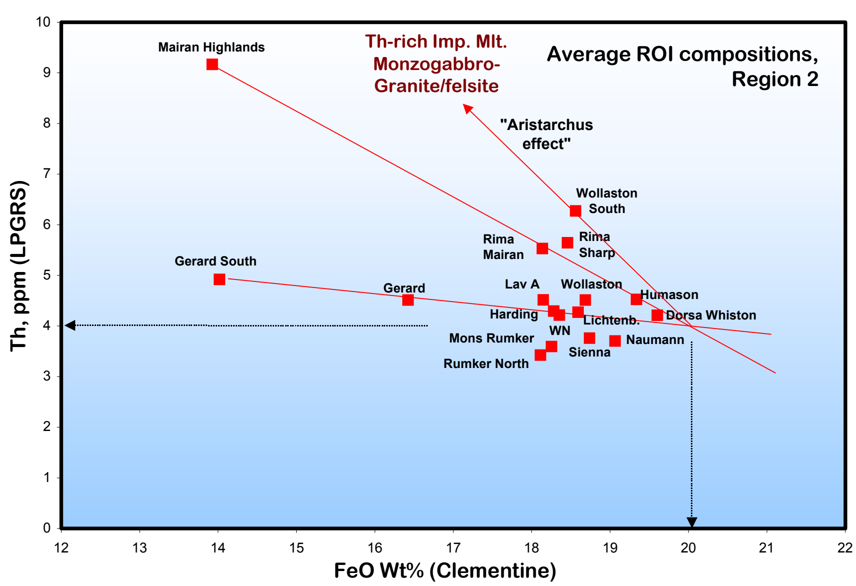

Figure 2. FeO vs. Th and inferred mixing trends. Mairan is the easternmost region; Rima Mairan, Rima Sharp, and Humason are basaltic regions adjacent to Mairan highlands and on the eastern side of the region. Gerard South is the westernmost ROI where the mare reaches the highlands; Gerard, Harding, and Unnamed A are the ROIs adjacent to the western highlands. Wollaston South represents mixing of basalt with a monzogabbro-granite component from Aristarchus.

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