COMPOSITIONAL VARIABILITY ON THE SURFACE OF MERCURY: RESULTS FROM THE MESSENGER GAMMA-RAY SPECTROMETER. Patrick N. Peplowski[1], Larry G. Evans[2], David K. Hamara[3], David J. Lawrence[1], Edgar A. Rhodes[1], Ann L. Sprague[3], Sean C. Solomon[4]. [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723 (Patrick.Peplowski@jhuapl.edu); [2]Computer Sciences Corporation, Lanham, MD 20706; [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; [4]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015.

Introduction: The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft entered into orbit about the planet Mercury on 18 March 2011, inaugurating a one-year primary mission of orbital observations. One of the objectives of this mission is to characterize the surface composition of the planet, and to that end the spacecraft carries a suite of geochemical remote sensing instruments [1]. MESSENGER's Gamma-Ray Spectrometer (GRS) measures gamma rays of element-characteristic energies that are emitted from the uppermost tens of centimeters of the surface [2]. These gamma rays originate from the radioactive decay of unstable elements (e.g., K, Th, and U) as well as the excitation of stable elements (e.g., Si, Fe, Ca) by surface-incident galactic cosmic rays (GCRs) [3].

Early results from the GRS include a determination of upper limits on Mercury's near-equatorial abundances of Si, Fe, Ti, K, and Th [4] and the absolute abundances of radioactive elements in the northern hemisphere [5]. Sufficient data have been collected during the first six months of the mission to begin mapping the strongest gamma-ray emitters (K, Si, and O). For gamma rays with lower fluxes (e.g., Ca and S), data acquired over large geologic units are summed to search for large-scale compositional variability. All GRS measurements are limited in spatial coverage to northern latitudes of the planet, as a result of the highly eccentric orbit of the spacecraft [6].

Data Reduction: GRS measurements of gamma-ray emission from the surface of Mercury are converted to elemental abundances using methods that have been previously applied to data from the Moon, Mars, and Mercury [7, 8, 5]. This process includes (1) spectral fitting of the gamma-ray peaks to determine the measured count rates, (2) correcting the count rates for the detector response and measurement geometry, and (3) forward modeling of surface gamma-ray fluxes to determine elemental abundances on the surface. Individual GRS spectra do not have sufficient measurement statistics to provide meaningful results, so many spectra must be summed prior to analysis. Latitudinally and longitudinally summed data are examined to search for large-scale variations in the measured gamma-ray count rates by applying analysis steps (1) and (2). These results indicate that the Si and O count rates vary by ± ~ 20% over the surface, whereas the K count rate varies by a factor of three (Fig 2).

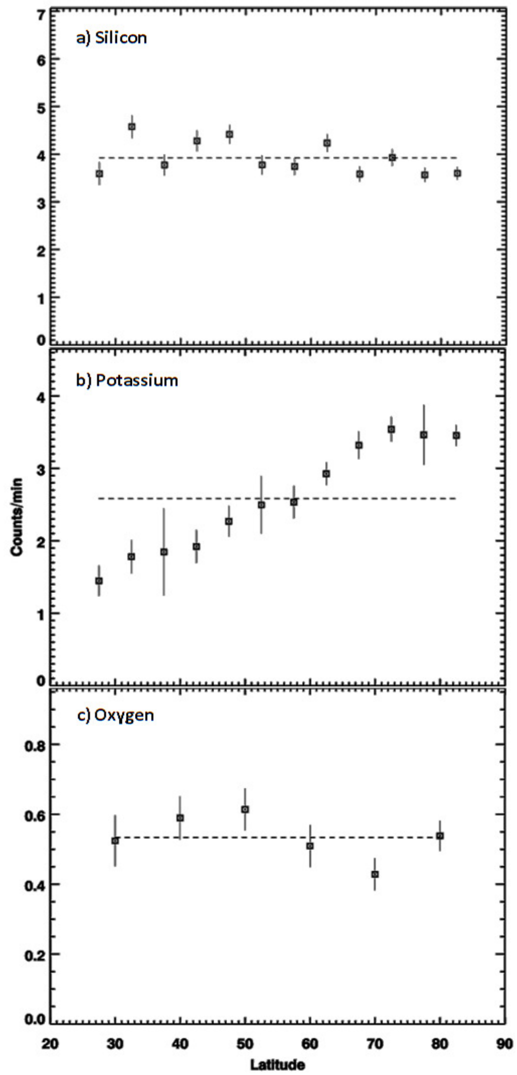

Figure 1. Measured count rates for (a) the 1779-keV Si, (b) 1460-keV K, and (c) 6129-keV O gamma rays as functions of latitude. The average count rates are shown by the dashed lines, and the dynamic range for each measurement ranges from 0 to 1.8 times the mean count rate to ensure that the relative variations between pairs of elements are comparable.

Mapping Surface Composition: The creation of surface composition maps begins with the production of spectra summed over the sub-nadir position of the spacecraft during each individual measurement. The size of the summing bins is determined by the statistical significance of the measured gamma rays. In the case of the 1460-keV K and 1779-keV Si gamma rays, data are summed in 15° × 15° bins to keep the one-standard-deviation statistical errors for each pixel to ≤ 15%. Fig. 2 details the gamma-ray count rate maps for the 1779- and 1460-keV gamma rays.

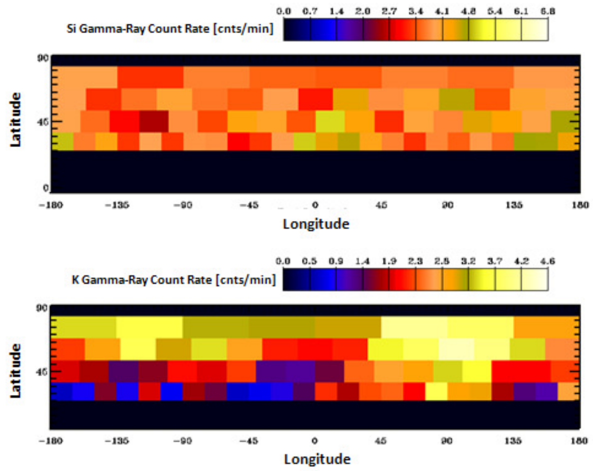

Figure 2. Maps of the 1779-keV Si and 1460-keV K gamma rays in 15°×15° equal-area bins between 25°N and 85°N. Prior to mapping, the count rates have been normalized to the solid angle at 315-km altitude to remove count rate variations due to the eccentric orbit of the MESSENGER spacecraft. The dynamic range of values for these maps covers 0 to 1.8 times the mean count rate, making the relative variations for each element comparable.

Gamma-ray count rate maps are converted to surface abundance maps through the process of forward modeling. For radioactive elements such as K, the surface gamma-ray flux per wt%. is known [3], and this quantity is propagated to the spacecraft altitude for all data acquired within each measurement pixel. Stable elements require modeling of the GCR-induced gamma-ray flux, which must include precise knowledge of the relevant nuclear reaction cross sections [8]. Dividing the measured gamma-ray flux by the forward-calculated flux per wt%. for each pixel results in a map of the surface abundance. The smoothed K abundance map is shown in Fig 3.

Regionally Summed Data: A number of other elements are detected by the GRS but do not have sufficient statistics to create composition maps (e.g., Ca and S). To identify variations of these elements on the surface, we sum all GRS data acquired within three specific regions of geologic interest: the northern volcanic plains [9], the interior of the Caloris impact basin, and all regions outside of the northern volcanic plains. The spectral reflectance properties of these regions suggest that they may have distinct compositions [10]. Results to date indicate that the variations in these elemental abundances among these regions are 30% or less.

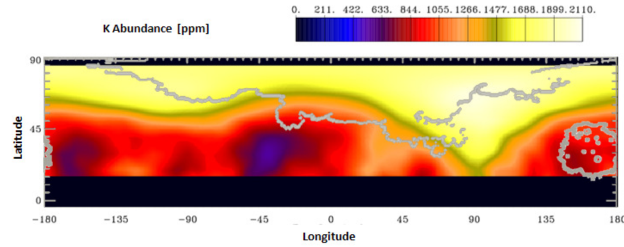

Figure 3. Map of the abundance of K on the surface of Mercury, smoothed over the mean spatial resolution of the GRS (~1000 km). The grey outlines are the boundaries of the northern volcanic plains [8] and the Caloris impact basin.

Conclusions: The abundance of K varies markedly over the surface of Mercury, with a dynamic range of values (600-2000 ppm) that is comparable to that for the Moon. Regions of enhanced K on the Moon are correlated with the mare-filled basins [7], whereas on Mercury the K-enhanced regions appear to be correlated with some, but not all, areas of high-reflectance plains. The northern volcanic plains [9] are largely within the region of enhanced K, whereas the Caloris interior plains are a region of low K abundance. Regions of low K abundance are also correlated with areas that experience the highest temperatures, an intriguing result given that K is a moderately volatile element. Because K is a major constituent of Mercury's exosphere, determining its distribution on the surface is a key step toward our understanding of the distribution of K within the exosphere.

The K result contrasts with those for the other elements. Si and O are not observed to vary within the statistical uncertainties in the measurements (~15%). Variations in the abundances of Ca and S in distinct geologic units appear to be limited to ≤ 30%. Maps of K, Si, and O, as well as the results for Ca and S summed by geological terrain type, will continue to be updated through the MESSENGER primary mission.

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