ANALYTICAL IDENTIFICATION OF MAJOR GEOCHEMICAL TERRANES IN MERCURY'S NORTHERN HEMISPHERE. P.N. Peplowski[1*] and S.V. Gleyzer[2], [1]Johns Hopkins Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723 USA, [2]University of Florida, 2001 Museum Road, Gainesville, FL 32511 USA; [*]Patrick.Peplowski@jhuapl.edu.

Introduction: Mercury's present-day crust is the end result of ~0.5 Gy of global effusive flood volcanism, followed by ~4 Gy of impact gardening and more limited volcanic activity. The nature of the magmatic processes that produced this crust are revealed via measurements of crustal elemental composition. The MESSENGER Mercury orbiter provided measurements of the elemental composition of Mercury's surface, including global maps of major elements (Mg and Al; [1]) and northern hemisphere maps of minor elements (K; [2]) and bulk compositional parameters (neutron absorption - Σ_a; [3] and average atomic mass – <A>; [4]). Information is also available for other elements, including Fe, Ca, S, Na, and Cl [1, 5-6].

MESSENGER elemental composition maps were used to identify and map "geochemical terranes" – regions of distinct chemical composition – across Mercury's northern hemisphere [1,3]. The properties of these terranes are actively being used as the basis for petrologic modeling of Mercury's surface (e.g. [7-8]). Those efforts seek to derive the composition of the parent magmas from which Mercury's present-day crust was derived, thereby probing the composition of Mercury's mantle.

Motivation: The geochemical terrane assignments of [1, 3] were provisional. Specifically, they: 1) used just two compositional parameters (Mg vs. Al only, [1]; and Σ_a vs. Mg only; [3]), 2) placed Mercury's surface into "binary" terrane categories, 3) used qualitatively chemical definitions for each terrane, and 4) in the case of [1] *a priori* adopted some terrane boundaries to match geomorphological features, despite evidence that Mercury's chemical and geological features are frequently uncorrelated [3]. This work is an attempt to resolve these issues by providing a robust, analytical identification of terranes using all available datasets, without regard to correlation with geomorphological features.

Terrane Mapping: Geochemical terranes are derived from a principle component analysis (PCA) of elemental composition maps. PCA reduces the dimensionality of an ensemble of correlated data to a set of orthogonal, uncorrelated "principle components" (PCs; alternatively known as eigenvectors) that preserve the information content of the original dataset. The contribution of each PC to the total variability of the ensemble is quantified by the corresponding eigenvalues. k-means clustering analysis is used to quantitatively assign individual data points (in PC space) to clusters, e.g. distinct chemical terranes.

Lunar Benchmark. The PCA analysis outlined above was tested using elemental [9] and neutron maps [10] from Lunar Prospector. The analysis yielded three PCs, consistent with prior terrane mapping (e.g. [11]). PC1 is ilmenite-bearing mare basalts (e.g. Mare Tranquillitatis), PC2 is the KREEP-rich terrane in Oceanus Procellarum, and PC3 is the anorthositic highlands. These results provide confidence that the analysis is valid and can be extended to Mercury.

Application to Mercury: The analysis is repeated for Mercury using the Mg, Al, [1] K [2], and GRS/ACS neutron [3] maps. These datasets were chosen due to complete northern hemisphere coverage; they may not be ideal for characterizing geochemical variability on Mercury. The neutron maps are updated to include >2x the data from prior work [3], and count rates are used in place of the count-rate-derived neutron absorption parameter Σ_a. Prior to the PCA, the maps were smoothed to a common spatial resolution. The analysis was restricted to the northern hemisphere due to lack of and/or poor spatial resolution coverage of the southern hemisphere by MESSENGER datasets.

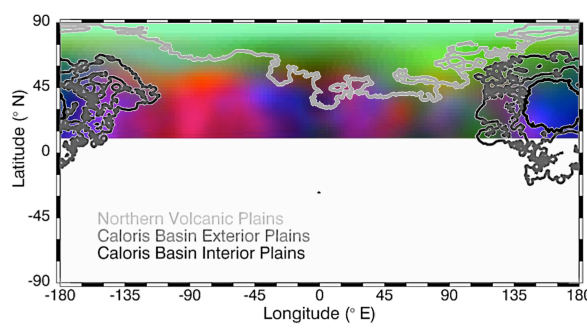

Figure 1. Results of the PCA analysis of Mercury elemental composition data. Red = PC2, Green = PC1, Blue = PC4. Plains outlines are from [12]. White areas are unmapped.

Results: The results of the PCA analysis are shown in Fig. 1. PC1, assigned to green channel, corresponds to a low Mg, low Al, and high K unit similar to the "northern terrane" unit of [3] and the "low-Mg northern terrane" of [1]. PC2, assigned to the red channel, corresponds to the high Mg, low Al and high neutron absorption "High-Mg terrane" of [1] and [3]. PC3 picks out an assortment of features, including the "low-fast" terrane of [4], and is not mapped. PC4, assigned to the blue channel, is a low-Mg, high Al unit that corresponds mainly to the “Caloris interior terrane” of [1,3]. PC1, 2, 3, and 4, contain 60%, 24%, 11%, and 5% of the total variability on the surface respectively.

Scatter plots of the Mercury geochemical data, color-coded by geochemical terrane, are shown in Fig. 2. With the exception of the neutron measurements, data points are shown here at their native (pre-smoothing) resolution. S, Ca, and Fe data, which were not used in the PCA due to incomplete coverage in the northern hemisphere, also appear in clusters corresponding to the terranes.

Discussion: Overall, these results are consistent with prior geochemical terrane mapping [1,3]. Unlike [1], our terrane boundaries are derived entirely from elemental data. No spatial or value cutoffs are applied to the data. There are suggestions of previously unrecognized terranes, for example the Caloris exterior plains frequently appear as purple (PC2 + PC4). Variability within all terranes will be explored via petrologic modeling of the elemental composition data (Fig. 2).

Relation to geomorphology: Fig. 1 includes outlines of the major geomorphological units of the northern hemisphere [12]. The Caloris interior plains terrane (blue) is the only unit to be closely correlated with a geomorphological unit, although the western border of the high-Mg terrane appears correlated with the eastern edge of the Caloris exterior plains. The northern terrane extends beyond the boundaries of the northern volcanic plains, complicating efforts to link this terrane to the lavas that formed the plains [7,8]. The exact nature of the relationships between geochemical terranes and geomorphological units will be explored, however its clear that, unlike for the Moon, there is a no consistent correspondence between Mercury’s geomorphological, geochemical, and spectral units [1, 3, 12].

Future work: We are working to apply machine-learning techniques to this dataset to enhance our ability to identify and characterize geochemical units. The results presented here provide a valuable benchmark for those efforts.

References: [1] Weider, S.Z. et al. (2015), *EPSL* 416, 109. [2] Peplowski, P.N. et al. (2012), *JGR Planets* 117, E00L04. [3] Peplowski, P.N. et al. (2015), *Icarus* 253, 346. [4] Lawrence, D.J. et al. (2017), *Icarus* 281, 195. [5] Peplowski, P.N. et al. (2014), *Icarus* 228, 86. [6] Evans, L.G et al. (2015), *Icarus* 257, 417. [7] Namur, O. et al. (2016), *EPSL* 439, 117. [8] Vander Kaaden, K. E. et al. (2017), *Icarus* (in press). [9] Prettyman, T.H. et al. (2006), *JGR Planets* 111. [10] Peplowski, P.N. et al. (2016), *JGR Planets* 121. 388. [11] Chevrel, S.D. et al. (2002), *JGR Planets* 107, 5132. [12] Denevi, B.W. et al. (2013), *Icarus* 118, 891.

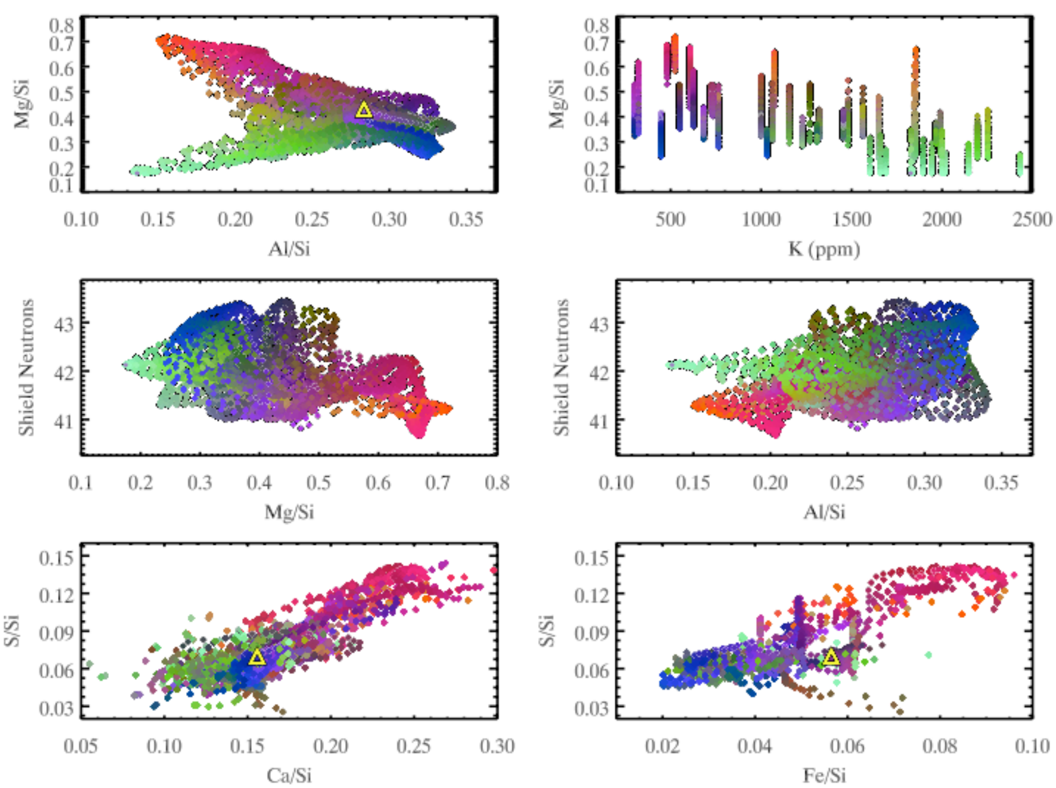

Figure 2. Elemental scatter plots for Mercury, colored coded by PCA unit (Figure 1). Data points are for northern hemisphere measurements at their native resolution. Yellow triangles are the mean values for the southern hemisphere, thought to represent a “mean” Mercury surface composition. Vertical “bands” in the K data reflect the large pixel sizes of the K map relative to Mg/Si data.