THE DISTRIBUTION OF PEAK-RING BASINS ON MERCURY AND THEIR CORRELATION WITH THE HIGH-Mg/Si TERRANE. G. P. Hall[1], A. Martindale[1], J. C. Bridges[1], E. J. Bunce[1], [1]School of Physics & Astronomy, University of Leicester, LE17RH, UK. (gph11@le.ac.uk)

Introduction: As part of the target prioritisation necessary for the Mercury Imaging X-ray Spectrometer (MIXS), we identified a need for a catalogue of all craters that still retain a central peak (or peak-ring) structure. During the preparation of the catalogue, a correlation was noted between peak-ring basins and a region with high Mg/Si values determined by MESSENGER XRS [1]. We report on the statistical analysis carried out to confirm the correlation and explore impact as a mechanism for the elevated Mg/Si values.

Complex craters. Complex craters and basins, which still have the peak structures visible (hereafter referred to as 'peaked craters'), are understood to uplift material from deep crustal and upper mantle levels (e.g. [2]). Recent work on Lunar peaked craters confirm that the central peaks act as 'drill cores' into the lower strata [3]. Analysis of the peaks reveals compositions different from the surrounding terrain.

The High-Mg/Si Terrane. The High-Mg/Si Terrane (HMT) on Mercury exhibits the highest Mg/Si ratios as well as low Al/Si ratios. It covers an area from approximately 120° W to 45° W and 10° S to 50° N, with an area >5,000,000 km^2 [1].

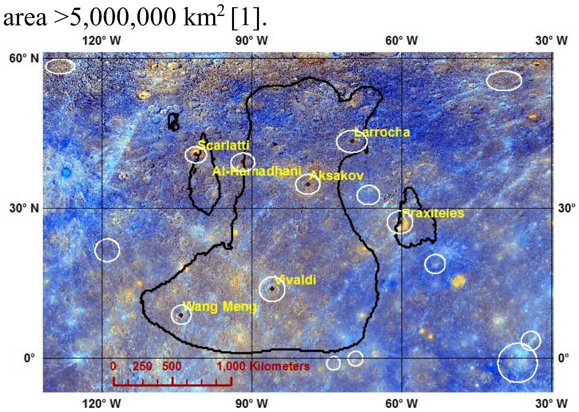

Figure 1. The mean+2σ contour used to define the high-Mg terrane (black line). White circles outline basins that appear in the logical intersection of the Baker and Hall catalogues, with the 7 basins coincident with the contour named (Larrocha, Scarlatti, Al-Hamadhani, Aksakov, Praxiteles, Vivaldi, and Wang Meng). The map is in simple cylindrical projection, so the scale bar is only accurate at the equator. The basemap used is the Mercury enhanced colour mosaic of Denevi et al [4]

Methods: The HMT was initially defined by Weider et al. [1], however a precise definition was required for robust statistical analysis. It was determined that the best approach was to use a one-tail hypothesis test to define confidence contours, so the mean and error values from Nittler et al. [5] were used. This gives the hypotheses, $H_{C,0}$: Mg/Si = 0.436, $H_{C,1}$: Mg/Si > 0.436. Using the error, $\sigma = 0.106$, we can determine the confidence contours for the HMT (Figure 1).

A similar methodology was applied to assessing basin statistics – to reliably quantify basin density across the planet. 10,000 random points were selected from across the surface of Mercury and used to generate statistics of the basin-count over the whole surface as follows. The points acted as the centres for circular buffers, with an area equal to that enclosed by the specific Mg/Si confidence contour. Another one-tailed hypothesis test was then carried out. Let μ be the mean number of basins within the buffer radius and C be the actual number of basins within the specific confidence contour, then we have the general hypotheses, $H_{B,0}$: $C = \mu$, $H_{B,1}$: $C > \mu$. The global mean and standard deviation for basin counts was calculated for each buffer size and crater set, then the hypotheses were tested for each buffer to determine if a greater-than-mean basin count is present. Three catalogues have been used for the analysis in this work: A catalogue of all Mercurian craters that retain a central peak structure, created by the authors for the express purpose of target prioritization for MIXS – the 'Hall' catalogue. Key features were visually categorised as MIXS-T can likely resolve these features in the future; Baker et al. [6], which morphometrically catalogues peak-ring basins, protobasins, and ring-cluster basins; Fassett et al. [7], which catalogues all of the craters on Mercury with diameter ≥20 km.

Excavation depth was calculated from [8] and stratigraphic uplift was calculated for key basins using methods outlined in [9]. Stratigraphic uplift equations are assumed to only hold for material that has not been excavated. The equations have also been derived from lunar data, so [9] urge caution when using them on other planetary bodies. Crustal thickness data was taken from [10] and combined with estimated basin depths to estimate the depth to the crust-mantle boundary.

Results: The greatest overall confidence level (97.68 %) is for the logical intersection (∩) of the Baker and Hall sets, within the 2σ-contour. Figure 2 shows a confidence map for this data set. Overall, a high confidence level is also observed for the Baker and Hall sets when analysed independently (>96.65 % when using a 2σ-contour), with slightly lower (~1 %) confidences when protobasins and ring-cluster basins are also included. The Fassett sets exhibited confidence distributions which do not coincide with the Baker ∩ Hall distributions, or the HMT.

Using methods and data referenced above, uplift and excavation calculations suggest that the 7 basins coincident with the contour (Figure 1) were unlikely to have directly excavated mantle material, although all but 1 (Praxiteles) uplifted mantle material to within ~10 km of the basin floor. However, calculations suggest that the impacts excavated material from crustal depths of ~13 km (smallest basin) to ~20 km (largest basin).

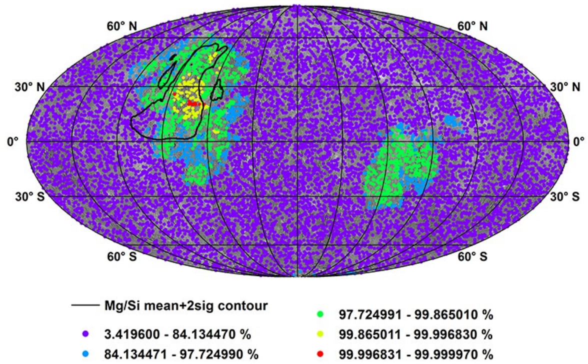

Figure 2. This figure shows the correlation between the number of basins in a buffered region and the High Mg/Si Terrane (black contour). Specifically, the figure shows a confidence map for the data set Baker ∩ Hall basins with a 2σ-buffer size. The 10000 random points indicate the centre of buffers, coloured to indicate the confidence level for rejecting $H_{B,0}$ within each buffer. The colour boundaries have been chosen to represent confidence levels of; ≤ 1σ (purple), 1σ-2σ (blue), 2σ-3σ (green), 3σ-4σ (yellow), and 4σ-5σ (red). The mean+2σ contour, derived from [4], is shown to indicate the HMT and buffer size used. The map uses a Mollweide projection, centred on 0° East. Longitudinal lines are spaced at 30° intervals.

Discussion: There are three possible hypotheses for the observed correlation: high-Mg mantle material has been excavated and/or uplifted to the surface; high-Mg deep crustal material has been excavated and/or uplifted to the surface; impacts caused fracturing in the underlying crust, which facilitated the subsequent extrusion of high-Mg magmas.

Excavation and uplift calculations indicate mantle was unlikely to be excavated, or uplifted to the surface, by the basin-sized impacts within the HMT. Deep crustal material was almost certainly excavated, although, assuming a layer of high-Mg material is ubiquitous around the planet, similar size craters over regions of similar thickness crust would be expected also to reveal a high Mg signature. Analysis of the Fassett data did not support this correlation, although there is insufficient evidence to rule out the hypothesis. From the available data, it seems most likely that the giant impactors have fractured the underlying crust and allowed the subsequent extrusion of basaltic magmas, derived from partial melting of the mantle [11]. Given the high-Mg content of the HMT, it is expected that these magmas will have compositions similar to magnesian basalts or basaltic komatiites [12].

When BepiColombo [13] arrives at Mercury in 2025, MIXS will allow more uniform coverage of X-ray emission from the surface of Mercury and, in elevated solar states, direct imaging of the composition of individual basin features to identify primitive, high-Mg compositional signatures. By analysing the ejecta and basin features, it should be possible to determine if the high-Mg signature is being caused by excavated/uplifted crustal material, subsequent magmatic events, or both. These future observations will help us to understand the evolution of Mercury's crust and mantle, revealing clear scientific priorities for BepiColombo based on the ground-breaking results of MESSENGER [5].

Conclusion: There is a strong statistical correspondence between peak-ring basins and the HMT. It is considered highly likely that the basin impacts have revealed primitive igneous material that is high in Mg, which is present at crustal depths not normally revealed by other basin-sized impacts. The material may have been directly revealed or the impact may have facilitated the subsequent extrusion of high-Mg magmas. This question may be answered definitively by BepiColombo.

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