MORPHOMETRY OF LARGE MARTIAN IMPACT STRUCTURES AND IMPLICATIONS FOR RESURFACING PROCESSES ON MARS. Ryan B. Anderson[1], Walter S. Kiefer[2], Herbert V. Frey[3], and James H. Roark[4], [1]Dept. of Astronomy, University of Michigan, Ann Arbor MI 48109, rba@umich.edu, [2]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058, kiefer@lpi.usra.edu, [3]Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt MD 20771, Herbert.V.Frey@nasa.gov, [4]SAIC at the Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt MD 20771.

Introduction: One of the more surprising results of the Mars Global Surveyor mission was the discovery of quasi-circular depressions (QCDs), which are roughly circular, low relief topographic basins that have no obvious expression in visible images of the martian surface. Based on their topographic morphology, they are interpreted as impact structures that have been subject to large amounts of post-impact filling, producing their subdued topography [1-3].

On both the Moon and Mars, the depth of pristine impact craters is primarily a function of their size, usually expressed as a power law function of diameter [4-6]. By comparing the current rim-to-floor depth of an impact structure with the pristine depth expected for its diameter, one can estimate the amount of post-impact fill [7]. Here, we apply this technique to a globally distributed set of large QCDs and use our results to place some constraints on the nature of resurfacing on early Mars.

Methods: We made detailed measurements of 36 large QCDs with diameters between 120 and 675 km that were selected from the catalog of Frey et al. [2]. We also measured 5 multi-ring impact basins with diameters between 350 and 880 km that can be mapped on visible wavelength images of Mars [8]. The topography of each basin was analyzed using the MOLA altimetry [9] gridded at 64 pixels per degree (930 meters per pixel). The large size of the structures being analyzed ensured that they were well resolved by the altimetry (130 to 950 pixels across).

Each structure was analyzed using the interactive program GRIDVIEW [10]. Structures were identified using shaded relief maps, adjustable topography color scales, and by looking for circular, closed topography contours. Crater rims were defined by looking for sets of arcuate mountain rings that collectively define a clear rim. In some cases, isolated massifs were also used in combination with arcuate rings to define the rim. A circle was fit to each set of crater rim massifs and used to define the crater diameter.

The elevation of the crater rim was determined by selecting typically 4-6 high points along the rim and averaging the elevations. These structures are all degraded to a significant degree; by measuring rim elevations at the high points, we have attempted to minimize the influence of rim degradation on our inferred crater depth. The crater floor depth was measured by locating the minimum elevation point within half a crater radius from the center, avoiding obvious superimposed impacts. The crater's rim-to-floor depth is determined by the difference between the averaged rim elevation and the minimum floor elevation. The expected, pristine depth for each crater was calculated using the measured diameter and the power-law depth versus diameter relationship determined by Howenstine and Kiefer [11] for large martian impact craters (D > 130 km). The difference between the measured depth and the expected pristine depth is used as an estimate of the post-impact fill thickness on the floor of each impact basin [7].

There are several potential sources of error in these measurements, which we have sought to minimize. First, the crater rims are clearly not pristine, so part of the calculated depth reduction may be due to changes in the rim height rather than filling of the crater floor. At most, the crater rim can be eroded down to the level of the surrounding plains. Based on the power-law results of Garvin et al. [5], this is an elevation change of up to 500 to 1000 meters for the craters studied here. Based on studies of lunar craters, Hőrz [12] suggested that the typical rim degradation is about half its original rim height, which would imply that our fill thicknesses are overestimated by 250 to 500 meters. Because our measurements emphasize the highest points on the crater rims, we think that our error due to this effect is usually smaller than this.

Second, the craters used to define the depth versus diameter power-law [11] might not be completely pristine. This would cause us to underestimate the pristine depth and thus also underestimate the subsequent fill thickness; the errors due to causes 1 and 2 have opposite sign and thus at least partly offset each other. Error type 2 should result in a nearly constant offset in the calculated fill thicknesses and thus would not alter the interpretation of the mapped patterns in Figure 1. On the other hand, the magnitude of error type 1 would vary randomly from crater to crater.

Results: Figure 1 shows our estimated fill thicknesses mapped over the surface of Mars. 38 of the 41 structures have at least 2 km of post-impact fill, with a maximum of 4.2 km. These values do not include the effects of flexural subsidence of the fill, which will increase the required thicknesses. Calculations of this effect are in development. A variety of processes may contribute to filling these craters, including fluvial deposition, flooding by lavas, and mantling by ballistically emplaced impact ejecta. In the northern lowlands, sediments deposited from a possible northern ocean may also contribute.

The spatial patterns in Figure 1 provide clues to the resurfacing mechanisms. Although only a limited set of measurements are available for the northern lowlands, those fill thicknesses are consistently > 2.5 km, and the cluster of measurements north of Elysium are all 3.0 to 3.5 km. These large, uniform fill thicknesses are consistent with deposition in a northern ocean. The concentration of large fill thicknesses on the periphery of Argyre is consistent with ballistically emplaced ejecta playing an important role in transporting fill material into older, nearby craters. Surprisingly, the Hellas impact basin does not have a concentration of such deeply-filled structures on its periphery. Because Hellas is larger than Argyre, its ejecta would have been distributed over a broader area and might have contributed to the fill thickness around Argyre. Conversely, Argyre ejecta would be less widely distributed and might not contribute as much to fill in the Hellas region. Additional measurements of crater depths and fill thickness both in the Hellas rim region and in the highlands between Hellas and Argyre are planned to better assess how crater fill thickness varies with distance from these two large basins.

References: [1] Frey et al., Geophys. Res. Lett. 26, 1657-1660, 1999. [2] Frey et al., GRL 29 (10), doi:10.1029/2001GL013832, 2002. [3] Buczkowski et al., J. Geophys. Res. 110 (E03007), doi:10.1029/2004JE002324, 2005. [4] Pike, GRL, 1, 291-294, 1974. [5] Garvin et al., 6th International Mars Conf., abstract 3277, 2003. [6] Boyce et al., JGR 110 (E03008) doi:10.1029/2004JE002328, 2005. [7] Williams and Zuber, Icarus 131, 107-122, 1998. [8] Schultz and Frey, JGR 95, 14,175-14,189, 1990. [9] Smith et al., JGR 106, 23,689-23,722, 2001. [10] Roark et al., LPSC 35, abstract 1833, 2004. [11] Howenstine and Kiefer, LPSC 36, abstract 1742, 2005. [12] Hőrz, Proc. LPSC 9, 3311-3331, 1978.

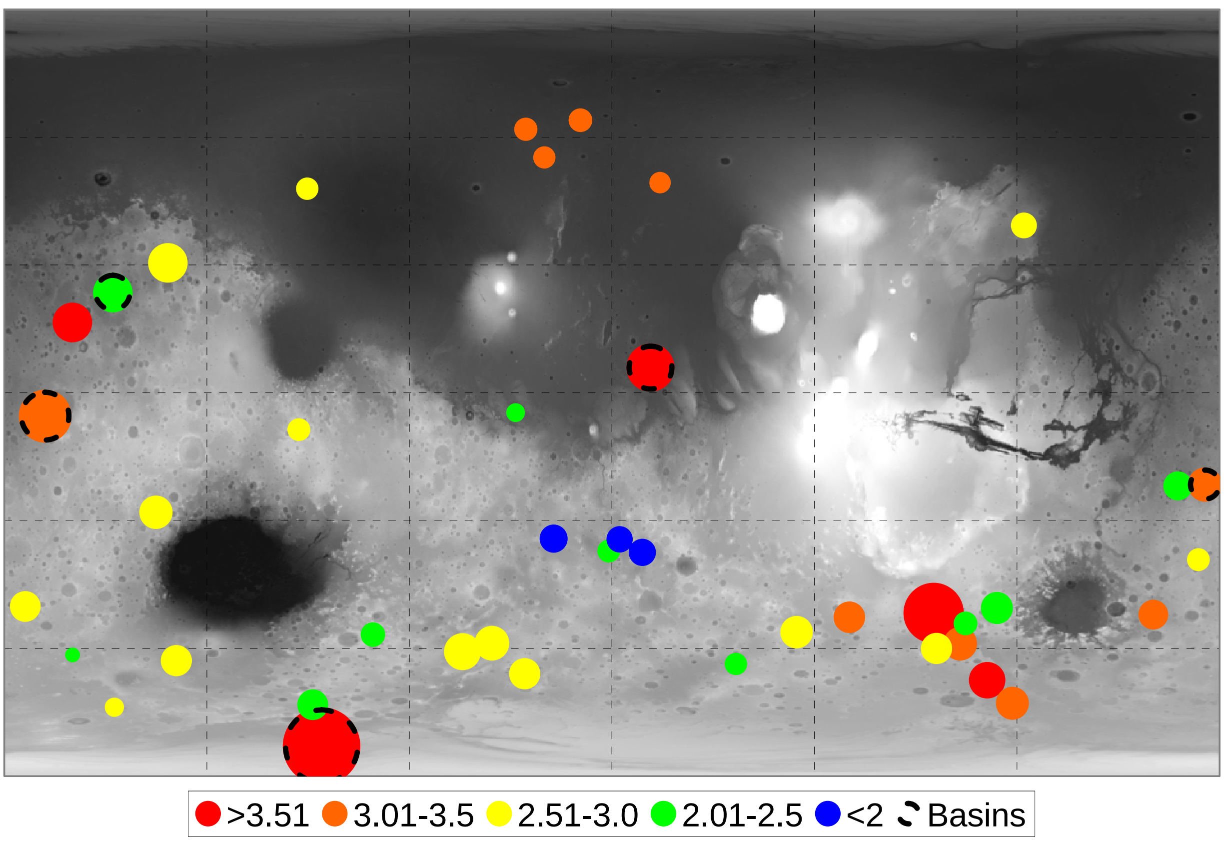

Figure 1. Inferred crater fill thickness in kilometers mapped across the surface of Mars. Structures defined by black dashes on their rims are visible multi-ring impact basins [8]. All others are QCDs. The background image is a gray-scale version of the topography.