MORPHOMETRY OF QUASI-CIRCULAR DEPRESSIONS IN THE SOUTHERN HEMISPHERE OF MARS: IMPLICATIONS FOR QCD FORMATION AND RESURFACING HISTORY

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Introduction: Measurements by the Mars Orbital Laser Altimeter (MOLA) on the Mars Global Surveyor spacecraft reveal the presence of hundreds of quasi-circular depressions (QCDs) distributed across the surface of Mars. Detectable in the elevation data as clear depressions, QCDs are roughly circular topographic features with limited relief that consequently have little or no expression in the visible wavelength imagery. Their topographic morphology suggests an impact origin with large amounts of subsequent deposition on the crater floor, accounting for the subdued topography [1,2].

Studies on the Moon and on Mars have shown that an empirical power law relationship exists between the initial depth of a pristine crater and its diameter [3-5]. Subtracting the measured rim-to-floor depth from the estimated pristine depth of a QCD therefore yields an estimate of post-impact fill thickness [4]. Here, we apply this technique to a globally distributed set of large QCDs and use the results to place some constraints on QCD formation and evolution.

Anderson et al. [6] raised an interesting question about the spatial distribution of fill thickness in large QCDs surrounding the two prominent impact basins in the southern hemisphere, Hellas and Argyre. They found several large but very shallow QCDs clustered near the rim of Argyre, suggesting the possibility that ejecta from the Argyre impact was a strong contributor to creating the shallow QCDs. On the other hand, the absence of a similar pattern around Hellas casts doubt on the importance of impact basin ejecta as a mechanism for filling QCDs. We measured the depths and diameters of 31 large QCDs in the southern highlands of Mars and added them to the results of [6]. The total database includes 67 QCDs and 5 multi-ring impact basins, ranging from 120 to 880 km in diameter. Our objective was to measure how QCD fill thickness varies with distance from large impact basins such Argyre and Hellas and to assess the possible contribution of ballistically-emplaced ejecta to QCD fill.

Methods: We used the interactive program GRIDVIEW [7] to examine MOLA elevation data, which has an approximate vertical accuracy of 1 m [8]. The topography data was gridded at 64 pixels per degree, which corresponds to a spatial resolution of 930 m. The QCDs were selected from a list compiled by *Frey et al.* [1]. Each feature was analyzed for basin-like characteristics, such as closed, concentric elevation contours and circular arcs of high rim topography. Adjustable color scales and shaded relief images aided in this examination.

A circle was fitted to the arcuate mountain rings and massifs used to define the rim of each QCD and used to determine the QCD diameter. Comparison of our rim diameter measurements with independent measurements of 12 structures by [1] and [6] show a high degree of reproducibility. The height of the crater rim was determined by averaging the elevation of 6-10 high points along the rim. The highest points represent those least affected by rim degradation, and in choosing these we have attempted to minimize this effect. Sections of the rim that were obviously affected by younger impacts or other processes were not included in the average. A minimum elevation point was chosen within one half-radius of the QCD center, again avoiding superimposed craters. The elevation difference between the average rim height and the minimum floor elevation is the rim-to-floor depth of the QCD. We estimate typical uncertainties of 0.1-0.5 km in QCD depths. Comparison of our results with 12 structures measured by [6] indicates that this error estimate is realistic. The diameter of each QCD was used to calculate its expected pristine depth using the power law relationship for large, fresh impact craters on Mars [5]. We refer to the difference between this depth and the measured rim-to-floor depth of the QCD as the depth anomaly and take it as an estimate of the post-impact fill thickness [4].

Through each step of this process we have attempted to minimize potential sources of error. One concern is the possibility of inaccurate diameter measurements due to back wasting: as a crater is eroded, its original diameter widens as material slumps off of the rim wall into the interior, which also contributes to post-impact floor fill [9]. Here we follow *Anderson et al.* [6] in adopting an upper bound of 10 km of back wasting. This translates into no more than 0.5-0.8 km of post-impact floor fill. Our average measured depth anomaly is 2.8±0.6 km (Figure 1), so the likely error due to back wasting is less than 25% of the observed depth anomalies for most of the QCDs included here.

Results: We plotted fill thickness versus distance from the rim for both Argyre and Hellas, and found that the distribution of fill in the southern hemisphere is extremely flat (Figure 1). Impact ejecta thickness, T, falls off as a power-law function of distance r from the crater, T ~ r^{-n}, where n is between 2.5 and 3 [10, 11]. This scaling law is based on a combination of laboratory experiments, terrestrial explosion craters, and the morphometry of small impact craters on the Earth and Moon. Whether this relationship can be scaled to large impact basins is not known, although the ejecta thickness must decay more steeply than r^{-2} in order to have finite mass in the ejecta blanket. Our results (Figure 1) show that the QCD depth anomaly is virtually independent of distance from Hellas. Although not shown here, results for QCDs surrounding the Argyre impact basin show a similarly flat depth anomaly versus distance profile. Although some Argyre and Hellas ejecta must be present on the floors of nearby, older QCDs, the flatness of the depth anomaly profiles suggests that ballistic emplacement of material from the impacts that formed the Argyre and Hellas basins was not the dominant filling mechanism for southern hemisphere QCDs.

There are several other possible explanations for the observed distribution of fill thickness. Ejecta from other impacts would certainly have contributed, although we do not observe a correlation between QCD depth anomaly and the location of other large impact basins. Fluvial or aeolian deposition is unlikely, as the 2.8 km of deposited sediments would have to have been eroded from the surrounding topography. Furthermore, few QCDs were observed that contained channels, and of these, most led out of the basin rather than into it. Volcanic deposits on basin floors are a possibility, and if this can be demonstrated our results would provide an important constraint on the early volcanic evolution of Mars. Alternatively, viscous relaxation of topography may be responsible for the subdued relief of the QCDs [12]. Further investigation is needed to clarify these possible explanations. For example, gravity modeling may constrain the density of the fill on QCD floors.

Conclusions: Depth and diameter measurements of QCDs in the southern hemisphere of Mars can be used to estimate the amount of post-impact deposition. The fairly uniform distribution of depth anomalies in QCDs around the Hellas and Argyre basins indicates that ejecta from the impacts that formed these basins was not the dominant source of QCD floor fill.

References: [1] Frey et al., Geophys. Res. Lett., 29, doi:10.1029/2001GL013832, 2002. [2] Buczkowski et al., J. Geophys. Res. 110 (E03007), doi:10.1029/2004JE002324, 2005. [3] Pike, Geophys. Res. Lett., 1, 291-294, 1974. [4] Williams and Zuber, Icarus 131, 107-122, 1998. [5] Howenstein and Kiefer, LPSC 36, abstract 1742, 2005. [6] Anderson et al., LPSC 37, abstract 2018, 2006. [7] Roark et al., LPSC 35, abstract 1833, 2004. [8] Smith et al., J. Geophys. Res., 106, 23689-23722, 2001. [9] Craddock et al., J. Geophys. Res., 102, 13,321-13,340, 1997. [10] McGetchin et al., Earth Planet. Sci. Lett., 20, 226-236, 1973. [11] Housen et al., J. Geophys. Res. 88, 2485-2499, 1983. [12] Mohit and Phillips, LPSC 37, abstract 1975, 2006.

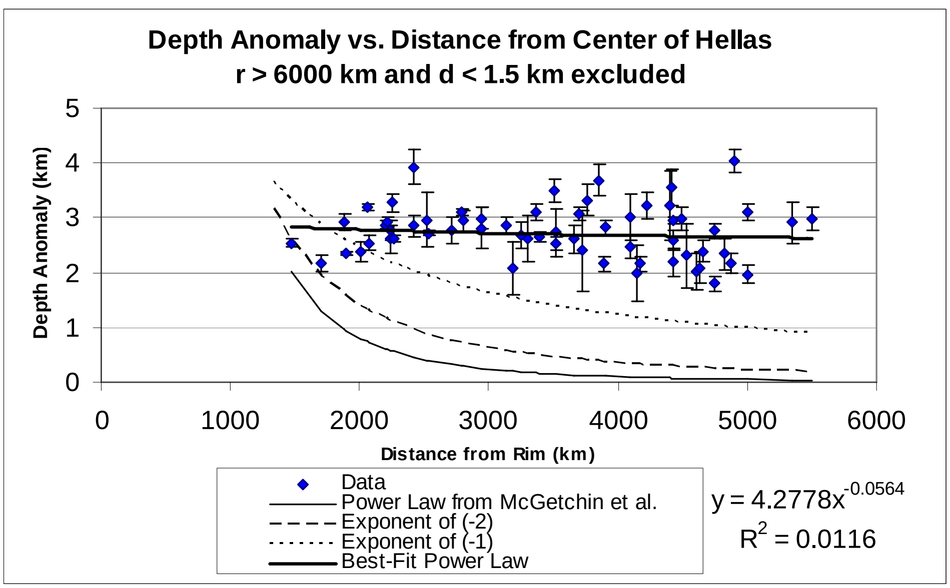

Figure 1. QCD depth anomaly plotted against distance from the rim of Hellas Basin. The thin solid line is the power law function of *McGetchin et al.* [10], which has a power law exponent of -3. Alternative fits with power law exponents of -1 and -2 are shown as dotted lines. The heavy solid line is a best-fit power law function through the data points, with a power law exponent of just -0.056.