VALIDATING ANCIENT AGE OF THE BURIED FLOOR OF THE NORTHERN LOWLANDS, MARS.

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Introduction: Hesperian and Amazonian plains units cover the northern lowlands [1,2,3] but little is known about what this surface covers. Models for the creation of the lowlands and the dichotomy boundary implement mechanisms which vary from internal processes, such as plate tectonics [4,5] or first-order mantle convection [6,7,8], to external processes, such as a single large impact [9] or multiple impacts [10,11]. Different models require different time scales for lowland formation; determining the age of the buried lowland surface would help constrain the formation models.

The Mars Orbiting Laser Altimeter (MOLA) has yielded a high-precision, topographic gridded data set that reveals the presence of Quasi-Circular Depressions (QCDs) in both the southern highlands and the northern lowlands [12,13,14,15]. Most of these roughly circular depressions have no corresponding visible structural feature on the surface. It is proposed that these QCDs are the surface representation of buried impact craters [12,13,14,15]. Based on this assumption, cumulative number vs. diameter curves were constructed, which placed the age of the buried surface of the northern lowlands in the Early [15] or pre-Noachian [16]. A Noachian basement is supported by the remnants of large craters and multi-ring basins discovered in earlier research [7,17,18,19,20,21,22,23], but the QCDs provide the first evidence of this for the entire lowland. Constraining the age of the basement floor to the earliest Noachian, however, would require that the process that formed the northern lowlands either occurred in the early Noachian [13,14,15,16] or involves removal of material from the bottom of the crust [e.g. 7] without destroying the previously formed craters to achieve the modeled crustal thinning [24]. But can we establish that the QCDs do in fact represent buried impact craters, and thus validate an Early Noachian age for the buried lowland floor?

Topographic Analysis: Some QCDs do have a structural representation on the surface. *Frey et al.* [14,15] identified 644 QCDs larger than 50 km in diameter in the northern lowlands; 90 of these were visible impact craters. Viking images reveal circular grabens, with diameters less than 50 km, in the polygonal terrains of Acidalia and Utopia Planitiae that were interpreted to overlie the rims of buried impact craters [25,26] even before analysis of MOLA data showed that that they bound topographic depressions [27,28].

Differential compaction models predict that topographic depressions will form over buried impact craters [27]. The percent compaction at any depth within a cover material of uniform compressibility must be a function of the total overburden pressure. This means that percent compaction should increase with the depth of the cover deposit, and thus that the average fractional compaction should be proportional to cover thickness. Surface relief then is a function of the relief of the buried basement floor, the average percent compaction and the total thickness of the cover deposit. For any given regional cover thickness, total cover thickness is greater over the centers of completely buried craters than over their rims; thus total compaction is greater over the center of craters than their rims and topographic depressions will form. Since large craters are deeper than small craters, the differential compaction models also predict that surface relief will be proportional to the diameter of the buried crater [27].

Recent work [28] shows that this prediction holds true for 37 circular grabens southwest of the Utopia Basin (22º-42ºN, 95º-120ºE). Surface relief in this study was defined as the absolute value of the difference between the average elevation on the ring's rim, excluding anomalous highs and lows, and the lowest point it surrounds. If all QCDs, not just those bound by circular grabens, are the surface representations of buried impact craters, then the surface relief of each QCD should be directly proportional to its diameter.

It is possible that the correlation between surface relief and diameter is an effect of ring size. Any random circle is more likely to bound a lower point than a smaller ring because it covers a greater area. Thus, a large QCD should be expected to have a greater surface relief than a small QCD. A test was designed to evaluate whether the correlation of surface relief to diameter of QCDs is a result of differential compaction or an effect of size. If the coefficient of determination (R^2) of the linear best fit of the surface relief vs. diameter plot of a series of randomly selected rings is similar to the R^2 of the actual QCDs, then it is likely that any correlation of surface relief to diameter is an effect of size. However, if the R^2 of the QCDs is much closer to 1 (ie. closer to a true line) than the R^2 of the random pseudo-QCDs, then it is more likely that a correlation of surface relief to diameter is due to differential compaction of cover material over buried impact craters.

Results: Refinements to the interactive computer graphics tool GRIDVIEW [29,30] can now allow the detection of QCDs smaller than 50 km, such as the circular grabens of Utopia Planitia, which range from 7-32 km in diameter [28]. A systematic search of MOLA gridded data for 30º-60ºN, 90º-150ºE yielded 117 QCDs within approximately 1500 km to the center of the Utopia Basin that were not visible impact craters; this includes the 37 circular graben depressions reported by [28]. These QCDs have surface reliefs that are directly proportional to diameter (Fig. 1).

Since surface relief is a function of basement relief and average fractional compaction for a particular thickness of cover material, it can not be expected to be the same over two buried impact craters of similar diameter if the thickness of the cover is not comparable. Since many researchers [e.g. 21; 31; 32] have proposed that cover thickness should increase towards the center of the basin, the distance of a QCD from the center of the Utopia Basin should serve as a proxy for relative cover thickness. The QCDs were thus divided into subgroups depending on their approximate distance to the center of the Utopia Basin. The coefficient of determination of the surface relief vs. diameter relationship for QCDs within each of the distance contours was slightly closer to one than the R^2 of the entire dataset; that is, the relationship improved when QCDs were compared to those under a similar thickness of cover.

A further division of QCDs was made between QCDs to the north and QCDs to the south. The northward regional slope of < 0.1º in the northern lowlands [31; 33] suggests that cover to the south of the Utopia Basin could be a different thickness than cover an equal distance to the north of the basin. Where the thickness is actually greater depends upon the slope of the buried floor. The surface relief vs. diameter relationship improved for most cases when QCDs to the north within each of the distance contours were evaluated separately from those to the south.

Fifty-five random pseudo-QCDs were created; diameters and coordinates were randomly selected from within the range of diameters and coordinates of the observed QCDs. The majority of the pseudo-QCDs do not bound depressions, although two completely enclose actual QCDs, two partially cover actual QCDs, and three surround polygonal troughs. In many cases the lowest point within the ring is next to or very near the ring itself, rather than in its center. The lowest elevation, regardless of its position within the ring, was used in surface relief calculations, as was the average elevation of the ring's rim, disregarding any anomalous highs or lows. While there is a surface relief vs. diameter relationship for the random pseudo-QCDs, it is not good. The linear best fit of the pseudo-QCDs has a coefficient of determination of only R^2 = 0.33 (Fig. 1). In contrast, the linear best fit of the surface relief of the 115 actual QCDs has a R^2 = 0.86 (Fig. 1). Therefore, the correlation of surface relief to diameter is more likely to be an effect of differential compaction, and supports the contention that the QCDs are a surface representation of buried impact craters. This validates the use of QCDs by Frey et al. [15,16] to date the buried floor of the northern lowland.

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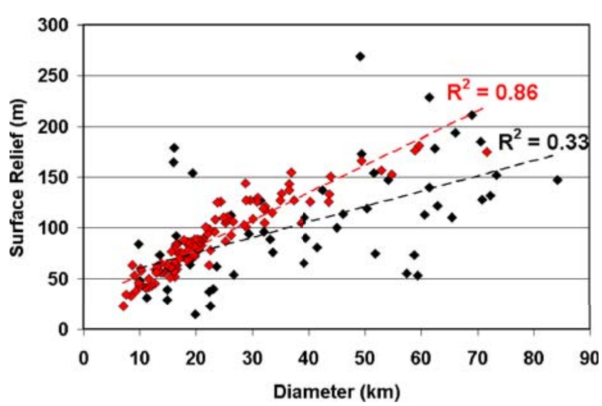

Figure 1. Comparison of surface relief vs. diameter for 115 actual QCDs around the Utopia Basin (red) and 55 random pseudo-QCDs (black).