

EFFECT OF COVER THICKNESS ON THE RELATIONSHIP OF SURFACE RELIEF TO DIAMETER OF NORTHERN LOWLAND QCDs ON MARS .

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Introduction: Previous work has established that there is a relationship of surface relief to diameter for quasi-circular depressions (QCDs) around the Utopia Basin [1]. This relationship has been used to support the contention that the QCDs represent impact craters buried beneath a differentially compacting cover material. 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, differential compaction models also predict that surface relief will be proportional to the diameter of the buried crater [2]. It is highly unlikely, however, that the material covering the QCD impact craters is a consistent thickness throughout the entire northern lowlands of Mars. We explore the effects that changes in cover thickness would have on the surface relief vs. diameter relationship of QCDs.

Analytical Analysis: *Buczkowski and McGill* [2] postulated that surface relief (SR) is a function of basement relief (BR) and the average percent compaction (C) for a particular thickness of cover (T).

$$SR = BR * C \quad 1)$$

This is too broad a simplification. Rather, the change in elevation (Δ) due to compaction at the surface of a cover material is equal to the thickness of compressible material beneath the surface multiplied by the average fractional compaction. Thus, when T is defined as the thickness of cover over the crater rim, Δ over the crater rim is:

$$\Delta_r = T * C_r \quad 2)$$

Over the center of a completely buried crater Δ is:

$$\Delta_c = (D + T) * C_c \quad 3)$$

where D is the depth of the crater from rim to floor. Surface relief then is the difference between the change in elevation over the center of the crater and the change over the rim.

$$SR = \Delta_c - \Delta_r \quad 4)$$

We have no way of evaluating the original (pre-compaction) elevation of the surface of the cover material and so have no way of determining the actual values of Δ_c and Δ_r . Similarly, without knowing more about the nature of the cover material we can not determine the actual values of C_c and C_r . We can say that C_c and Δ_c will always be greater than C_r and Δ_r , regardless of the value of T, because the greater thickness of material over the center of the buried crater will always result in a greater overburden pressure. However, this does not necessarily mean that surface relief will increase with increasing T.

Garvin et al. [3] determined that there was a linear relationship of depth to diameter for impact craters 7 to 100 km in diameter. Their equations can be used to determine D for any diameter crater in this size range, but D is then a fixed value for that particular diameter crater. The difference between the total thickness of material over the rim and center of this crater is the fixed value D; as T increases, this differ-

ence becomes less and less significant. Thus, as T increases, the difference between Δ_c and Δ_r (surface relief) becomes smaller.

The change in material elevation over the rim of a buried impact crater Δ_r is proportional to T, while Δ_c is proportional to T+D. The ratio of Δ_r to Δ_c is:

$$\frac{\Delta_r}{\Delta_c} \propto \frac{T}{D+T} \quad 5)$$

Solving equation 5 for Δ_r and substituting it into equation 4, we can then say that surface relief is:

$$SR \propto (1 - \frac{T}{D+T}) \quad 6)$$

We can calculate D for a range of crater diameters [3], and so can determine a proportional value for surface relief for a range of D and T (Fig. 1). The slope of the relationship between the proportionality and diameter decreases with increasing cover thickness.

Observations: There are differences in the slope of the surface relief vs. diameter trends (hereafter referred to as trend slope) of QCDs around the Utopia Basin in the various distance contours determined by [4]. Trend slopes steepen consistently with increasing distance from the center of the Utopia Basin (Fig. 1); furthermore, trend slopes for QCDs in the southern part of each distance contour are consistently steeper than trend slopes for the northern QCDs (Table 1).

The distance contours were arbitrarily selected by [1,4] but QCDs were also evaluated by geology. The first geology-

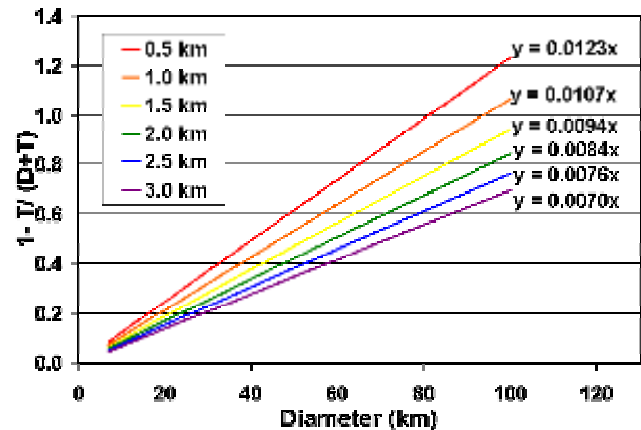


Figure 1. The surface relief of the depression that forms over a completely buried impact crater is proportional to $1 - [T / (D+T)]$, where T is the thickness of cover over the crater rim and D is the depth of the crater from rim to floor. The relationship of this proportionality vs. crater/depression diameter has a slope that decreases with increasing thickness of cover.

based subsets were 1) within the polygonal terrain, 2) outside the polygonal terrain and 3) basinward of the polygonal terrain. As with QCDs in the arbitrary distance contours, the trend slopes of the surface relief vs. diameter relationship for QCDs in these geologically determined contours become steeper with increasing distance from the center of the Utopia Basin (Table 2).

A second set of geologically determined subsets looked only at QCDs in the region of the circular grabens studied by [5]. When arbitrarily divided into subsets of QCDs in the circular graben terrain 1) close to the center, 2) far from the center and 3) in the middle, once again an increase in trend slope was observed with increased distance from the center of the Utopia Basin (Table 2).

Many researchers [e.g. 5,6,7,8] have proposed that cover thickness should increase towards the center of the Utopia basin. The *Buczowski and Cooke* [5] model for circular graben formation required increasing thickness of cover material within the circular graben terrain toward the center of the Utopia Basin. The comparison of trend slopes shown in Tables 1 and 2 thus implies that trend slope becomes steeper with decreasing cover thickness.

Discussion: The model trend slopes of the proportionality vs. diameter (Fig. 1) are very different from the trend slopes of surface relief vs. diameter (Table 1), because in the latter we evaluate actual surface reliefs that have incorporated real compaction. However, it is notable that the decrease in trend slope with increasing cover thickness for the model proportionality vs. diameter trend (Fig. 1) is consistent with the decrease in trend slope of surface relief vs. diameter with decreasing distance from the center of the Utopia Basin (Table 1). This is a direct support of previous work by many researchers [e.g. 5,6,7,8] who have proposed that cover thickness should increase towards the center of the basin.

Trend slopes of the southern QCDs are consistently higher than trend slopes of the northern QCDs (Table 1), implying that cover material is thinner to the south of the Utopia Basin than to the north. A thinner southern cover would explain the observation of numerous partially buried impact craters to the south of the basin approaching the dichotomy boundary; no such partially buried craters are evident to the north of the basin. The deduction that the cover material is thinner to the south of the Utopia Basin has important implications for the nature of the buried lowland floor.

The surface of the northern lowlands has a northward regional slope of $< 0.1^\circ$ [7,9]. If the lowland basement did not have a northward slope, cover material would be thicker to the south of the basin. This relationship would hold true whether the cover was deposited in one event or several. If the lowland basement had a slope similar to the surface, then cover material would be a comparable thickness north and south. Only if the lowland basement has a northward slope of greater degree than the surface could the cover material be thicker to the north than to the south.

The above discussion assumes that the QCD impacts struck the same basement material as the Utopia Basin impact. QCDs would probably only be discernable if the material covering the underlying impact crater was relatively thin. Thus, the conclusion that the lowland basement slopes north-

northward to a greater degree than the present-day surface assumes that there are only a few kilometers of cover material over the entire Utopia Basin basement. However, recent work indicates that there might be as much as 18 - 20 km of material filling the Utopia Basin [10,11]. If these estimates of extremely thick cover are accurate then the QCDs could not possibly be forming over impacts in the Utopia basement. The QCD impacts would have to be on some intermediate level of fill within the complete package of Utopia cover material. This implies some period of time between the formation of Utopia and the formation of the QCD craters imposed on it. It would be this QCD substrate that has more covering material to the north than to the south and is thus sloping more to the north than the present-day surface.

References: [1] Buczowski D.L. et al. (2005) *JGR*, in press. [2] Buczowski D.L. and McGill G.E. (2002), *GRL*, 29(7), 10.1029/2001GL014100. [3] Garvin et al. (2003) *6th Int. Conf. Mars*, abs. 3277. [4] Buczowski et al. (2004) *LPSC XXXV*, abs. 1150. [5] Buczowski D.L. and M.L. Cooke (2004) *JGR*, 10.1029/2003JE002144. [6] McGill G.E. (1989) *JGR*, 94, 2753-2759. [7] Heisinger H. and J.W. Head (2000) *JGR*, 105, 11,999-12,022. [8] Tanaka K.L. et al. (2001) *Geology*, 29, 427-430. [9] Smith D.E. et al. (1999) *Science*, 284, 1495-1503. [10] Searls M.L. and R.J. Phillips (2004) *LPSC XXXV*, abs. 1822. [11] Banerdt W.B. (2004) *LPSC XXXV*, abs. 2043.

Distance (km)	All QCDs		Northern QCDs		Southern QCDs	
	Slope	R ²	Slope	R ²	Slope	R ²
325 - 750	2.14	0.87	-	-	-	-
750 - 1000	2.90	0.88	2.74	0.89	3.69	0.93
1000 - 1250	3.54	0.89	3.55	0.91	4.09	0.93
1250 - 1500	4.03	0.92	3.72	0.93	4.27	0.92

Table 1. Slope and coefficient of determination (R²) of the linear best fit through the surface relief vs. diameter relationship for QCDs around the Utopia Basin. QCDs have been subdivided into contours based on distance from the center of the basin and QCDs to the north and south of the basin within each distance contour. The 325 - 750 km contour has not been divided into north and south components, as these QCDs are spatially close enough together to reasonably assume a relatively consistent cover thickness.

Polygonal Terrain		Circular Graben Area	
Relative Distance	Slope	Relative Distance	Slope
Basinward of polygonal terrain	2.17	Nearest basin center	2.06
Polygonal terrain	2.82	Middle of area	3.02
Outside of polygonal terrain	2.95	Far from basin center	3.73

Table 2. Slope of the linear best fit through the surface relief vs. diameter relationship for QCDs around the Utopia Basin. QCDs have been subdivided into contours based on geology.