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 material elevation over the rim of a buried impact crater \( \Delta_r \) is proportional to the diameter of the buried crater \( D \). The ratio of \( \Delta_r \) to \( \Delta_c \) (surface relief) becomes smaller.

\[
\frac{\Delta_r}{\Delta_c} \propto \frac{T}{D+T} \quad (5)
\]

Solving equation 5 for \( \Delta_r \) 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 \( 1 - \frac{T}{D+T} \), 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.
Thus, the conclusion that the lowland basement slopes northward striking the same basement material as the Utopia Basin im-
thicker to the north than to the south. cover material would be a comparable thickness north and the lowland basement had a slope similar to the surface, then whether the cover was deposited in one event or several. If to the south of the basin. This relationship would hold true not have a northward slope, cover material would be thicker regional slope of < 0.1º [7,9]. If the lowland basement did not have a northward slope, cover material would be thicker 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 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 base-
ment. 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.


### Table 1. Slope and coefficient of determination ($R^2$) 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.

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>All QCDs</th>
<th>Northern QCDs</th>
<th>Southern QCDs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slope</td>
<td>$R^2$</td>
<td>Slope</td>
</tr>
<tr>
<td>325 - 750</td>
<td>2.14</td>
<td>0.87</td>
<td>-</td>
</tr>
<tr>
<td>750 - 1000</td>
<td>2.90</td>
<td>0.88</td>
<td>2.74</td>
</tr>
<tr>
<td>1000 - 1250</td>
<td>3.54</td>
<td>0.89</td>
<td>3.55</td>
</tr>
<tr>
<td>1250 - 1500</td>
<td>4.03</td>
<td>0.92</td>
<td>3.72</td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>Polygonal Terrain</th>
<th>Relative Distance</th>
<th>Slope</th>
<th>Circular Graben Area</th>
<th>Relative Distance</th>
<th>Slope</th>
</tr>
</thead>
</table>
| Basinward of po-
lygonal terrain    | 2.17              |        | Nearest basin cen-
ter                  | 2.06              |        |
| Polygonal terrain | 2.82              |        | Middle of area       | 3.02              |        |
| Outside of polygonal terrain | 2.95 |       | Far from basin center | 3.73              |        |

Many researchers [e.g. 5,6,7,8] have proposed that cover thickness should increase towards the center of the Utopia Basin. The Buczkowski and Cooke [5] model for circular graben formation required increasing thickness of cover material within the circular graben 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 < 0.1º [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 stuck the same basement material as the Utopia Basin impact. QCDs would probably only be discernible if the material covering the underlying impact crater was relatively thin. Thus, the conclusion that the lowland basement slopes north-