BURIED IMPACT BASIN DISTRIBUTION ON MARS: CONTRIBUTIONS FROM CRUSTAL THICKNESS DATA L. A. Edgar [1] and H. V. Frey [2] , [1]Earth Sciences Department, Dartmouth College, Hanover, NH 03755, Lauren.A.Edgar@Dartmouth.edu. [2]Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, Herbert.V.Frey@nasa.gov.

Summary: Quasi-Circular Depressions (QCDs) indicate the presence of buried impact basins, but can not reveal basins buried so deeply that no topographic signature remains. We found a very large population of Circular Thin Areas (CTAs) in stretched versions of a crustal thickness data set; these CTAs sometimes correspond to mapped QCDs but often do not. If the non-QCD CTAs are additional, more deeply buried impact basins, then (1) the buried population is much larger than previously thought, especially in the lowlands and Tharsis regions of Mars, (2) crater retention ages previously estimated from QCDs alone are too low, (3) the lowlands and highlands may have the same N(300) crater retention age, substantially older than previously estimated, and (4) Tharsis is significantly younger than the oldest highland (and lowland) crust.

Introduction: Mars Orbiter Laser Altimeter (MOLA) data reveal a large number of "Quasi Circular Depressions" (QCDs) in both the highlands and lowlands of Mars, many of which are interpreted as buried impact basins [1,2]. Most of these roughly circular basins lack visible structure, but high precision topographic data have exposed their existence. QCDs have been used to relatively date the age of several different regions in the Martian lowlands as well as to compare the relative age of the lowlands and highlands of Mars [2]. However, ages based on QCDs only are minimum ages, since it is very likely there are many basins too deeply buried to have a signature in the topography alone. Another possibly useful data set includes crustal thickness anomalies from Neumann et al's [3] model derived from Mars Global Surveyor (MGS) gravity field and Mars Orbiter Laser Altimeter (MOLA) topography data. It assumes a uniform crust/mantle density contrast and a given mean crustal thickness. Additional corrections were made for density anomalies in the polar caps, major volcanoes, and the hydrostatic flattening of the core. Using an interactive software program called GRIDVIEW [4] to stretch the data (as was done to reveal the subtle QCDs in MOLA data), a large number of Circular Thin Areas (CTAs) – round features that represent thinner crust completely or partly surrounded by thicker crust – are revealed. Some examples are shown in Figure 1. Many of these do correspond to previously mapped QCDs, but many do not. The non-QCD CTAs may be additional, more deeply buried, impact basins. If true, a better total crater retention age for the basement is obtained by combining QCDs with CTAs in the same regions. This combined data set can then be used to construct a more precise timescale for major events in Martian history and to improve our understanding of the evolution of Mars.

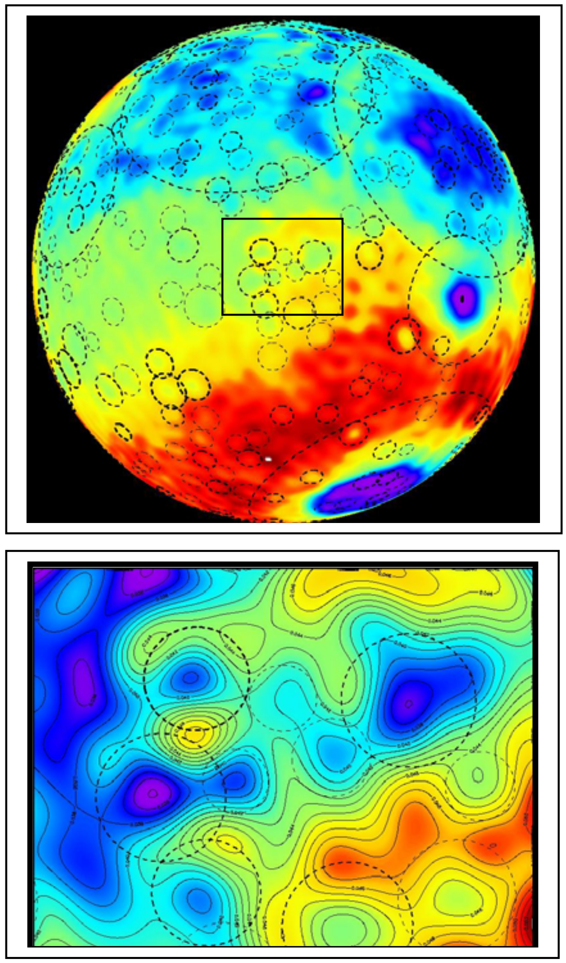

Figure 1. Top: Global Distribution of CTAs >300km. Red and orange colors reflect thicker crust, while blue indicates thinner crust [3]. Dotted rings represent likely CTAs. Large basins Chryse, Acidalia and Utopia are visible in the northern hemisphere, and Isidis and Hellas are visible on the right and lower right. Bottom: Colored and contoured crustal thickness data from boxed area (top). Contour interval 1 km. Colors have been stretched to reveal CTAs (dotted rings).

CTAs and QCDs: We used GRIDVIEW [4], an interactive graphics software package, to stretch the crustal thickness data in the same way MOLA data were stretched to reveal the QCDs [2]. We searched for Circular Thin Areas larger than about 300 km diameter (a constraint imposed by the resolution of the gravity model used in the crustal thickness model), compared the CTAs found with the previously reported population of large diameter (> 200 km) QCDs [2]. Many CTAs have a nearly coincident QCD, and many QCDs produce a signature in crustal thickness data. Presumably these represent the less deeply buried impact basins. Examples of CTAs with corresponding QCDs are shown in Figure 2.

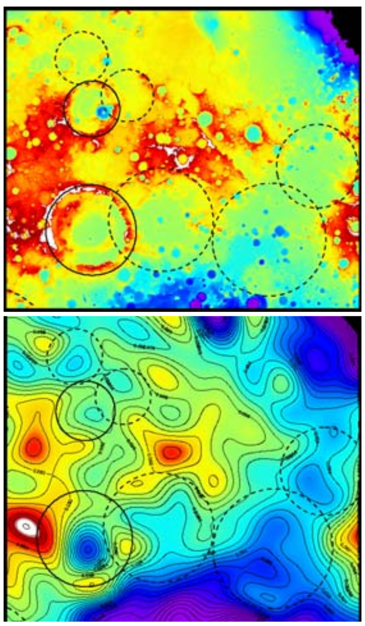

Figure 2. QCDs with signatures in crustal thickness data. Top left: Previously mapped QCDs shown in colored topographic data from the highlands, just north of Hellas. Solid black rings represent visible basins, dashed rings represent buried basins. Bottom left: QCDs plotted on colored and contoured crustal thickness data, illustrating that previously mapped QCDs often have an expression in crustal thickness. Contour interval 1 km.

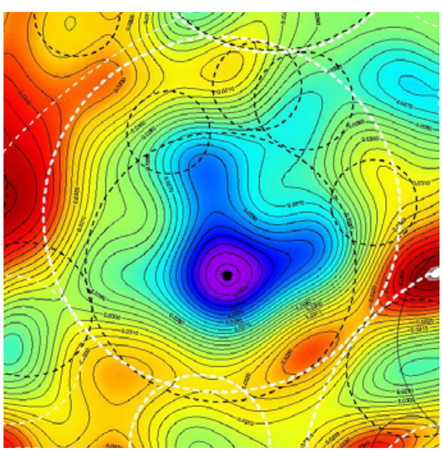

Figure 3. Limitations imposed by low resolution crustal thickness data. Colored and contoured crustal thickness data illustrates what appears to be a large CTA represented by the dashed white ring (850 km in diameter), is actually composed of several smaller QCDs, drawn in black rings. Contour interval 0.5 km.

Since QCDs often have an expression in crustal thickness data, this suggests that CTAs may indeed represent buried impact basins. However, there are several difficulties with the current crustal thickness data. Due to the low resolution, sometimes a CTA may look like a single circular object, but is actually related to several smaller basins grouped close together. Additionally, the topography and gravity data are in spherical harmonic form so some circular features (especially small ones) may be spurious, and the overlap with QCDs is not always perfect. Some of these difficulties are seen in Figure 3. Care needs to be taken when counting CTAs as possible buried impact basins, but there does seem to be a significant population of CTAs which do not have corresponding QCDs that are possibly older, more deeply buried, basins. If true, then (1) the buried population is larger than previously estimated, (2) crater retention ages that were previously determined for buried and total surfaces are too low, and (3) many areas (and maybe the lowlands as a whole) are older than originally thought based on QCDs alone [5].

After mapping the global distribution of CTAs, cumulative frequency curves were then produced for QCDs, CTAs and a combined population of QCDs and non-QCD CTAs for three major areas of Mars: the highlands, lowlands and Tharsis. Figures 4 and 5 show cumulative frequency curves for the combined data set in the highlands and lowlands, compared to cumulative frequency curves using only the QCDs. Figure 6 shows cumulative frequency curves for the highlands, lowlands and Tharsis using the combined data set. From these curves we derive N(300) crater retention ages for the three areas and compare those with N(300) ages based on QCDs alone (extrapolated from the N(200) ages reported by Frey [2]). These are shown in Table 1.

Table 1. Crater retention ages (CRA) for the combined data set and QCDs alone, showing that the use of CTAs in addition to QCDs significantly raises the N(300) value. Furthermore, using QCDs alone, it appeared that the lowlands were younger than Tharsis, which is not the case in the combined data set.

	QCDs alone N(300)	QCDs & CTAs N(300)
Highlands	1.98	3.19
Lowlands	0.87	3.21
Tharsis	1.01	2.20

Results: In the highlands there are more CTAs with corresponding QCDs (i.e., most CTAs have already been identified as QCDs), but in the lowlands and in Tharsis there are more CTAs with no corresponding QCDs. The ratio of non-QCD CTAs to QCDs in the highlands is 0.5:1; in the lowlands the same ratio is 2:1 and in Tharsis it is nearly 1.3:1 (Table 2). In other words, in the lowlands and Tharsis there may be a greater proportion of basins buried so deeply they cannot be detected by topography alone. Presumably, this is because the lowlands and Tharsis contain great thicknesses of burying material.

As seen in the cumulative frequency curves, the presence of CTAs in the highlands and lowlands means both areas are likely older than previously thought. The very much larger proportion of non-QCD CTAs in the lowlands means the lowlands may be very much older than estimated from QCDs alone. From Figure 6 it is clear that the combined QCD+CTA N(300) crater retention age for the highlands and lowlands is essentially the same, and that this CRA is significantly older than previously thought based on QCDs alone (Table 1). The Tharsis curve parallels that of the lowlands and highlands but is lower, so Tharsis is younger than the highlands and lowlands. Note also the population of large diameter basins for the highlands and lowlands. The lack of such basins in Tharsis (which are of a diameter that should most easily be preserved) may indicate that there is no ancient highland basement below Tharsis. However, the possible presence of two more large basins in the Tharsis region [6] – though very uncertain – might suggest the alternative: if these two basins are included in the data set, then it appears that the basement might be as old as the ancient highlands [6]. That is, Tharsis might be built on ancient highland crust.

	Highlands	Lowlands	Tharsis
#Non-QCD CTAs	83	83	18
# QCDs	157	42	14
CTAs/(CTAs+ QCDs)	.34	.66	.56
#CTAs/#QCDs	.53	1.97	1.28

Table 2. Ratio of non-QCD CTAs to QCDs. The high ratios in both the lowlands and Tharsis suggest that in these regions most of the population is so deeply buried that it does not have a topographic expression.

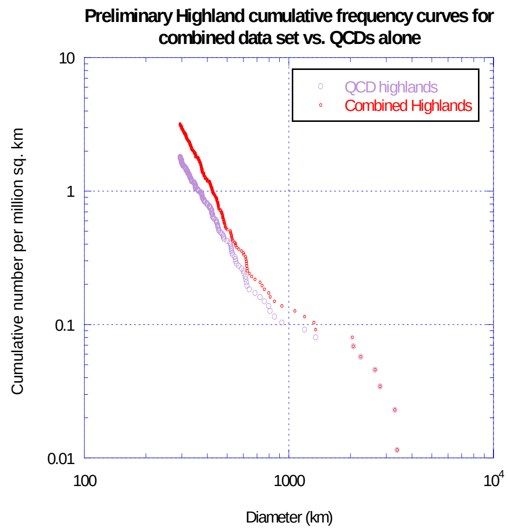

Figure 4. Cumulative frequency curves for the highlands based on QCDs alone (purple) and the combined data set (red). The combined curve suggests that the highlands are somewhat older than previously thought.

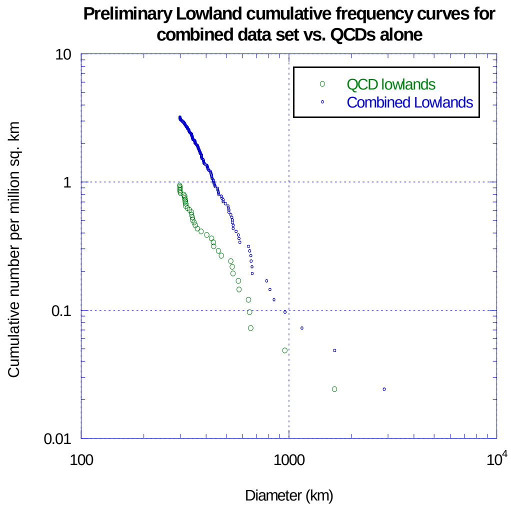

Figure 5. Cumulative frequency curves for the lowlands based on QCDs alone (green) and the combined data set (blue). The combined curve suggests that the lowlands are significantly older than previously thought.

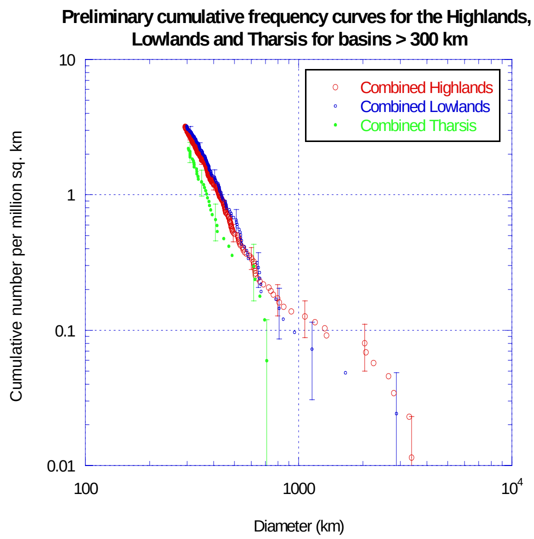

Figure 7. Cumulative frequency curves for highlands, lowlands and Tharsis using the combined data, revealing older ages for all regions, and a similar age for the highlands and lowlands (shown in red and dark blue).

Conclusions: Based on a preliminary global survey of CTAs and comparison with QCDs > 300 km diameter on Mars, we suggest: (1) CTAs do represent a population of (often, more) deeply buried impact craters than is revealed by MOLA-derived QCDs alone, (2) ages previously determined for the highlands and lowlands based on QCDs are too low, (3) the combined data set, using non-QCD CTAs in addition to QCDs, is a better estimate of the true crater retention age of the (buried) surfaces of Mars, and that is older than previously thought, and (4) the N(300) crater retention ages derived from the combined QCD and CTA population are similar for the highlands and lowlands, but are significantly younger for Tharsis. Implications of this much larger population of buried basins for the early evolution of Mars and the origin of the lowlands and Tharsis are discussed in a companion abstract [Frey, Edgar and Lillis, *this meeting*].

Future Work: Several important questions arise from this study, given that the highlands and lowlands now appear to have similar basement ages. Future work will aim to address how and when the lowlands formed, how and when Tharsis formed, when the magnetic field disappeared, and the nature of the material filling the basins.

Upon completion of a new gravity map from the Mars Reconnaissance Orbiter, a revised crustal thickness model should become available. The revised crustal thickness data will be used to refine this study and search for additional impact basins. Furthermore, new work will involve testing the robustness of the CTAs at small diameters. Although the resolution of the crustal thickness data limits this study to basins larger than 300 km in diameter, we have been able to detect CTAs with corresponding QCDs at diameters of 200 km and smaller. We plan to see how such features come and go as the wavelength cutoff for the crustal thickness model is varied.

In addition to comparing CTAs with QCDs, we would like to compare CTAs with basins being discovered by radar, such as MARSIS [7] or SHARAD. The combination of QCDs, CTAs, and features uncovered using radar sounding could produce the best possible inventory of buried basins.

References: [1] Frey H. V. et al (2002), GRL, 29 (10), 1384, doi: 10.1029/2001GL13832. [2] Frey, H.V. (2006), JGR (Planets) 111, E08S91, doi:10.1029/2005JE002449. [3] Neumann, G. A. et al (2004), JGR (Planets), 109, E08002, doi : 10.1029/2004JE002262. [4] Roark, J. H. et al (2004), LPSC 35, Abstract #1833. [5] Frey H. V. and Fristad K. E. (2006), LPSC 37, Abstract #1391. [6] Frey and Edgar, LPSC 38 (2007), Abstract #1716. [7] Watters T. R. et al (2006), *Nature* 444, 905-908, doi: 10.1038/nature05356.