REGIONAL STUDIES OF HIGHLAND-LOWLAND AGE DIFFERENCES ACROSS THE MARS CRUSTAL DICHOTOMY BOUNDARY

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Summary: Regional differences in crater retention ages (CRAs) across the Mars dichotomy boundary are compared to the global highland-lowland age difference previously determined from visible and buried impact basins based on MOLA-derived Quasi-Circular Depressions (QCDs). Here Western Arabia (WA) is compared with Ismenius Lacus (IL). We find the buried lowlands in the two regions have total CRAs essentially identical to the global average. Even more intriguing, the WA cratered terrain appears to have a CRA like that of the adjacent buried lowlands, whereas in IL the highlands are definitely older than the adjacent lowlands.

Introduction: Global, total population, crater retention ages (CRAs) derived from visible and buried impact basins have demonstrated both the very ancient age of the lowland crust below the visible plains and an apparently older but buried highland surface that significantly pre-dates the oldest exposed highland terrains [1,2,3]. The N(200) age (cumulative number of buried and visible impact basins > 200 km diameter per million square km) for the whole buried lowlands is about 2.5 (significantly older than the N(200) ~ 0.6 age for the visible highlands). By contrast, the global highlands have an average N(200) age of ~4.5, because of a large population of buried basins, including some > 100 km in diameter. We have previously suggested the lowlands were formed at about N(200) ~3.0-3.2 based on the total crater retention age of large "lowland-making" basins such as Utopia, Chryse and Acidalia [3,4], and have used this "lowland-making" event to separate the preserved and "visible" Early Noachian from a still earlier period of martian history we informally call the "pre-Noachian" [5,6].

In the global cumulative frequency curves there is a resolvable CRA difference between the original highlands and the buried lowlands. But global averages may mask possible real regional variations in the ages of the highlands or the lowlands. It is well recognized that the exposed highland surfaces have a variety of ages. The distribution of buried impact basins in the lowlands also suggests there may be regional age differences [1], but this has not yet been tested. Real variations in the age of different parts of the lowlands might be evidence for different mechanisms of formation in different areas. By contrast, a common age throughout all parts of the buried lowlands might indicate either a single mechanism ("event") produced the lowland crust or that multiple mechanisms occurred at the same time.

We have begun a series of regional investigations of the total (visible and buried) crater retention ages (CRAs) of the highland cratered terrain (CT), the lowland smooth plains (SP) and the intervening border transition zone (TZ) at selected locations along the crustal dichotomy boundary. To date we have completed a short-term pilot study in the intriguing Western Arabia (WA) area, a much more thorough investigation of the very pronounced transition in Ismenius Lacus (IL), the adjacent highlands stretching into eastern Arabia, and the lowlands stretching into the Utopia Basin, and are nearly finished with counts in the Tempe-Mareotis portion of the dichotomy in western Mars. Results from the first two studies are reported here, and comparisons made with the global average highland-lowland CRAs.

Study Areas and Cumulative Frequency Curves: We first selected two areas along the dichotomy boundary with very different boundary character. A short pilot study involved counting Quasi-Circular Depressions larger than 20 km diameter seen in 64-pixel per degree MOLA data in the NW portion of Arabia. The total area was 3.84 km^2. Here the TZ (0.75 km^2) between CT (0.95 km^2) and SP (2.14 km^2) is weakly expressed in terms of the morphological characteristics far more visible in other parts of the boundary (knobs, massifs, embayed and partially buried craters). The elevation change across the boundary is also much less than elsewhere, and the highlands adjacent to the boundary are anomalously low compared to cratered terrain elsewhere on Mars. We previously suggested, before our discovery of buried impact basins in the lowlands, that this portion of Mars might be a good analog of the crust below the northern lowland plains [7]. In a preliminary study, one of us (RML) found 438 craters overall and 396 craters larger than 25 km diameter throughout the region. These are shown in Figure 1.

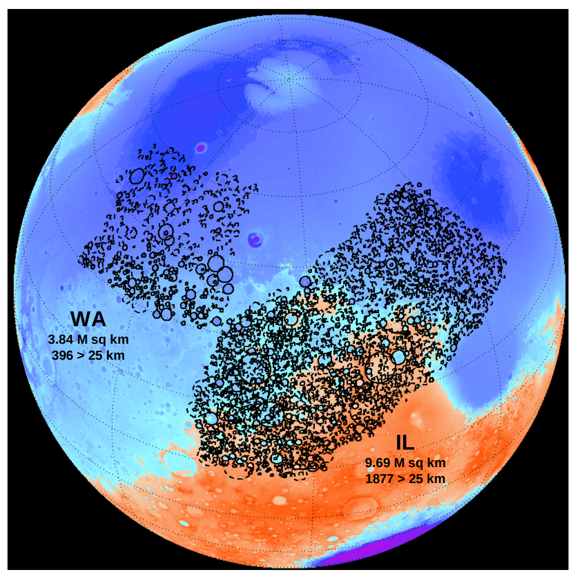

Figure 1. QCDs in study areas over MOLA topography. WA = Western Arabia. IL = Ismenius Lacus. WA has 396 craters > 25 km in 3.8 M sq km; IL has 1877 craters > 25 km in 9.7 M sq km.

A much more detailed study [8] was done in the Ismenius Lacus boundary region just NW of the Isidis impact basin. The total area surveyed was 9.69 km^2. The TZ (1.80 km^2) here varies in character and width. The CT (5.95 km^2) contain a number of large Cassini-sized impact basins including the original large "MOLA-hole" QCD [9] and are 4-5 km above the lowland SP (1.94 km^2) which comprise the western side of the Utopia impact basin. GED found 2635 QCDs throughout the area, 1877 > 25 km].

Cumulative frequency curves were generated separately for visible, buried and total (visible + buried) populations in each of the physiographic units (CT, SP, TZ). For simplicity, we consider the crater retention ages derived from those curves at three diameters. N(100) provides some information on the large diameter population, although the statistics are weaker because the number of such basins is relatively small. Most of the cumulative frequency curves follow a -2 power law slope through middle diameters (30-90 km) and we use an N(50) age for direct comparison between physiographic units and between areas. At smaller diameters many of the curves begin to fall off a -2 power law slope, perhaps indicative of depopulation events such as resurfacing. We use N(25) CRA to investigates differences in such processes between areas.

In this report we concentrate on total population CRAs, mostly N(50). For comparison with the global averages we have extrapolated the N(200) ages previously found [3-6] to smaller diameters (100, 50, 25 km) assuming a -2 power law slope. These are shown in Table 1 below, along with the results for the two different areas, for visible, buried and the total populations.

TABLE 1. GLOBAL AND REGIONAL CRATER RETENTION AGES

	N(100)			N(50)			N(25)		
	G	IL	WA	G	IL	WA	G	IL	WA
CRATERED TERRAIN									
Visible	2	3	3	10	21	23	38	80	108
Buried	15	13	5	61	35	19	243	131	34
Total	18	16	8	72	56	42	288	210	142
SMOOTH PLAINS									
Visible	0	1	2	2	1	4	6	15	8
Buried	10	11	7	40	40	38	160	167	87
Total	10	11	9	41	41	42	166	182	95
TRANSITION ZONE									
Visible	N/A	1	9	N/A	12	16	N/A	38	35
Buried	N/A	8	1	N/A	33	19	N/A	118	48
Total	N/A	9	11	N/A	45	35	N/A	157	83

Preliminary Results: From Table 1 several key observations emerge. Perhaps the most striking is the total CRA for the regional lowlands in both Western Arabia and in Utopia NE of Ismenius Lacus appears to be the same (unlike the case for the adjacent highlands, see below). We find N(50) ~ 41-42 for both of these lowland areas. Even more interesting, *this is identical to the extrapolated N(50) CRA for the lowlands as a whole*, based on the global average.

This similarity in CRA for the lowlands extends to the higher diameters as well: N(100) ~ 10 for the two regions and the lowlands as a whole. If this result holds up for other regions around the dichotomy boundary, it may be that most or all of the lowlands have a common CRA.

At smaller diameter the lowland N(25) CRAs show much greater differences, as might be expected if these reflect resurfacing processes which can be expected to vary more from region to region. Note that in both regions studied the ratio of the N(25) ages for buried to visible craters is about the same (a factor of 10), but the totals are much lower for WA than for IL. On a global basis the buried to visible ratio is a factor 25, but this may not be meaningful given the extrapolation from much larger diameters and the likely regionally dependent resurfacing that probably controls the N(25) age.

The highlands do NOT show any commonality of large diameter crater retention age for the few areas studied here. The Western Arabia total population CT age is 50% the Ismenius Lacus age for N(100) and 75% the Ismenius Lacus age for N(50). Note that the global average CT age extrapolated from N(200) includes a population of about a dozen very large impact basins [3,6]. These follow a -2 power law from D=1000 km to D=3000 km with an [extrapolated] N(200) age of 8.5 (which in turn extrapolates to N(50) = 136), and would therefore be expected to have an N(100) or an N(50) age greater than any observed region which is too small to include these very large basins. This is supported by the extrapolated N(50) global age of 72 which is greater than the observed N(50) age of Ismenius Lacus (56) or western Arabia (42).

At N(100) and N(50) the total population CRAs of the cratered terrain in the highlands in Ismenius Lacus (16 and 56) and on a global average basis (18 and 72) are significantly older than those ages for the lowlands (10-11 and ~41, for N(100) and N(50) respectively). Even more intriguing is the fact that in Western Arabia the N(100) and the N(50) ages for cratered terrain (8 and 42) are essentially identical to that for the lowlands in this region (9 and 42) and these are the same ages found for the global lowlands and for the Utopia lowlands (10-11 and 41). That is, the total population CRA for the WA highlands is the same as for the adjacent lowlands and the lowlands as a whole.

Discussion: These results are preliminary, the first of an extended study that compares crater retention ages across the dichotomy boundary on a regional basis with the global average highland-lowland age differences. It is interesting that in both regions studied the total population lowland CRA is the same, and identical to the global average. It may be that the lowlands all formed at about the same time, as we have previously suggested [3-6], but further regional studies will be needed to know for sure. Cratered terrain history is clearly more variable, as the limited results shown here demonstrate. We also find interesting relationships for the transition zones in these two areas, as described in a companion paper [8].

Conclusions: The total (visible and buried) large diameter crater population derived from mapping QCDs suggest the buried lowlands in the two areas studied have a crater retention age identical with the global average age for the lowlands as a whole. In Ismenius Lacus (as with the planet as a whole) the cratered highlands are older than the adjacent lowlands, but in Western Arabia the highlands and lowlands have the same total population age and this is the same as the global average lowlands. If similar results are found elsewhere, it may be all of the lowlands formed at the same time. The cratered terrain has a more complex history, and though in general the highlands are older than the lowlands, at least in one area (Western Arabia) the cratered terrain may date only from the time of lowland formation.

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