

**TESTING FORMATION THEORIES OF NW ARABIA TERRA, MARS: NEW CLUES FROM OLD CRATERS.** S. J. Robbins<sup>1,2</sup> and B. M. Hynek<sup>2,3</sup>, <sup>1</sup>APS Department, UCB 391, University of Colorado, Boulder, CO 80309, <sup>2</sup>LASP, UCB 392, University of Colorado, Boulder, CO 80309, <sup>3</sup>Geological Sciences Department, UCB 392, University of Colorado, Boulder, CO 80309.

**Introduction:** Northwest Arabia Terra (AT) and Terra Meridiani comprise a broad region of middle ground between the Martian Southern Highlands (SH) and low-lying Northern Plains (NP). Their topography, crustal thickness, and crater population have shown them to have unique formation and modification histories from the planet and each other, but histories that have yet to be satisfactorily explained. A new technique for determining the depth and diameter of craters was developed to study the crater population in AT and the neighboring SH. The purpose was to directly test two different proposed formation mechanisms: (1) AT represents a region of the SH that had up to ~1 km of crust removed by erosion, and (2) AT was a region of the ancient NP that was buried and subsequently exposed, showing the original Noachian-aged surface. The crater size-frequency distributions, crater depth/Diameter ratios, and the thickness of Mars' crust suggest that neither scenario is easily reconcilable with the new datasets.

**Hypotheses Tested:** We tested Hynek & Phillips' hypothesis [1] that AT is a region of the SH that experienced massive erosion in the Late Noachian. We predict that this would manifest as a deficit of craters smaller than ~10-20 km in AT compared with SH, and most craters in AT would be significantly shallower because of erosion and redeposition. We also tested a Zuber *et al.* [2] proposal that AT is a region of original NP that was buried but subsequently exhumed, showing the original cratered basement material. This has no specific crater size-frequency prediction because the authors do not propose a timeframe for burial nor exposure, but it does suggest that craters in AT should be shallower than the neighboring SH.

**Data Sets:** We used MOLA 1/128°-gridded topography [3] to determine crater depth and diameter. ~8300 craters with diameters  $\geq 5$  km from AT and SH regions were selected, based upon a subset of the Barlow Database [4]. Crater diameter was manually and automatically calculated, and crater depth was determined automatically [5]. We selected sub-regions to represent AT and SH, shown in Fig. 1. Crustal thickness maps [2] were also examined as an ancillary test.

The manual diameter calculation was based upon locating an *N*-dimensional irregular polygon that represented topographic highs along the crater rim. A list of circles by matching sets of 3 points along this polygon was then created and averaged to determine the crater center and diameter, registered to the MOLA

coordinate system. The automated routine worked by collapsing the 3-D topography into a 2-D crater profile (converting latitude and longitude into distance from the crater's center); it used the curvature of the then binned profile to identify the rim locations. Next, the depth was calculated from the average height of the rim on both sides of the profile minus the lowest point within the profile. For more information, see [5].

**Size-Frequency Results:** For this analysis, the manually calculated diameters were employed because they are a more accurate representation of degraded craters. We used a relative non-cumulative size-frequency plot to study the differences between AT and the SH. The plot (Fig. 2) is created by dividing one non-cumulative size-frequency plot by another. This technique was used because the Barlow Database - from which our craters originate - has significant structure, including a deficit of smaller craters. This structure made it difficult to observe subtle differences within our sub-regions, so we removed the overriding signal by dividing each bin by the "All-Mars Barlow Database" crater-count bin value.

*Test of Hynek & Phillips [1].* In this scenario, one would expect craters at large sizes to exist with the same relative frequency in AT as the SH. Craters in the teen-diameters should be somewhat deficient because those would be the maximum size eroded. If the SH eroded prior to AT, then the SH's small crater population would be in a steeper production than AT's, resulting in divergent slopes at smaller diameters.

We observe two of these trends (Fig. 2). The first is parity at larger diameters ( $\geq 40$  km). The second is the divergent slopes (going from larger to smaller diameters) for craters 5-10 km; however, both SH and AT are deficient in small craters relative to the average Barlow Database. The main difference is a relative enhancement of ~35 km craters in the neighboring SH that changes to a deficit at sizes of ~20 km, while the craters in AT have statistically the same relative frequency as the all-Mars database. We conclude that because the predicted inflection in the teen-diameters is not observed, these data do not completely support the hypothesis in [1].

**depth/Diameter Results:** Fig. 3 shows the depths and diameters of ~600 total craters in the sub-regions of AT and SH shown in Fig. 1. It shows two main features. First, there is a significant bimodal distribution of deep and shallow SH craters; while this is also present in AT craters, it is significantly muted. Sec-

ond, the deepest craters in the SH are ~100-200 m deeper than craters in AT, indicating possible deposition or a weaker crust in AT.

*Test of Hynek & Phillips [1].* For this hypothesis, the craters in AT should be significantly more eroded than those in the SH due to the removal of crust and some local redeposition. This is not seen. An alternative prediction hinges upon the timing of the erosive event: If the SH formed and were eroded (pursuant with research over the past 4 decades, c.f. [6]) in the Middle Noachian and *then* AT was resurfaced during the Late Noachian, the existence of the Late Heavy Bombardment of asteroids during the AT erosion event would produce a range of modification stages. This is what we see given the muted bimodality of shallow and deep craters in AT.

*Test of Zuber et al. [2].* The basic prediction from [2] is for craters in AT to be shallower than those in SH because they were covered (producing some erosion) and then exhumed, leaving remnant material that will also help create a shallower crater. While we cannot rule this out with our data, the expected heavy bimodal distribution of deep, fresh craters vs. shallow, eroded craters is not seen, and hence our data are inconsistent with this prediction from their hypothesis.

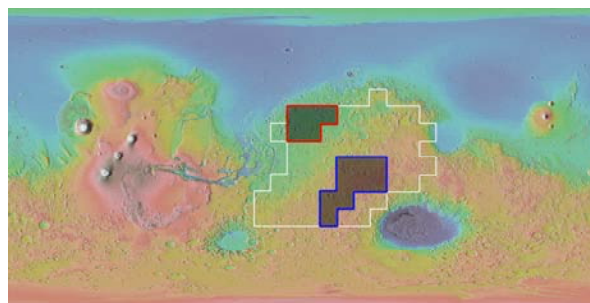
*Area Trends.* We also examined  $10^\circ \times 10^\circ$  binned regions with the bin value as the average  $d/D$  within each bin for crater diameter ranges 5-10, 10-15, 15-20, 20-30, 30-40, and 40+ km. None showed any statistically significant trend across the region (white outline, Fig. 1). This is contrary to predictions from both hypotheses, where one would expect craters in AT to be, in general, shallower than craters in the adjacent SH. Rather, the data indicate that craters in AT are on par for the broad region (27% of the planet).

**Crustal Thickness Results:** We examined the thickness of the crust for three transects made orthogonal to AT (Northwest to Southeast, data from [2]). For [1], the thickness of AT should be similar to the SH near their boundary, show a minor thinning towards the NP, and then a sharp thinning at the boundary as seen elsewhere along the planet's North/South dichotomy. For [2], the thickness of AT should be similar to the NP and show a rapid thickening near the SH proper. The data show AT rapidly thickens to about  $2\times$  the NP crust. It then slowly increases in thickness by a factor of 2-3 through the adjacent mid-latitude region as it transitions to the thicker SH crust. These data are not easily reconcilable with either hypothesis.

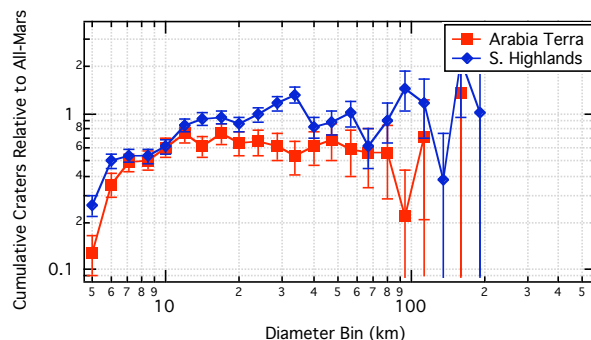
**Conclusions:** Arabia Terra's formation and modification history still remain a mystery. Two very different mechanisms were tested for consistency with new crater depth and diameter data as well as published crustal thickness maps, and the data do not

strongly support either hypothesis [1-2]. This complex region deserves further study due to its large planetary footprint and unique features that have yet to be satisfactorily explained.

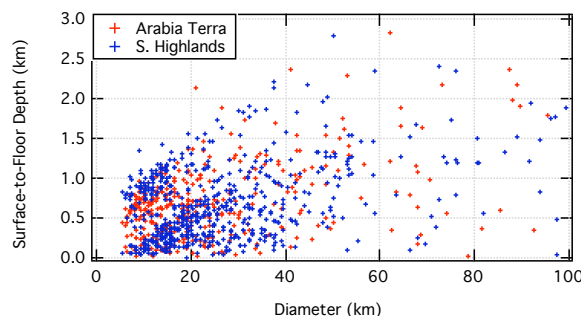
**References:** [1] Hynek B. M. and Phillips R. J. (2001) *Geology*, 29, 407-410. [2] Zuber M. et al. (2000) *Science*, 287, 1788-1793. [3] Smith D. E. et al. (2001) *JGR*, 106, 23689-23722. [4] Barlow N. G. (1990) *LPSC XXI*, #44. [5] Robbins S. J. and Hynek B. M. (2007) *10<sup>th</sup> Mars Crater Conf.*, #1006. [6] Craddock R. A. and Howard A. D. (2002) *JGR*, doi:10.1029/2001JE001505.



**Figure 1:** MOLA map of Mars [3] showing the broad region of interest (white border) and two smaller regions of interest, isolating Arabia Terra (red border) and the adjacent Southern Highlands (blue border).



**Figure 2:** Non-cumulative crater plot of Arabia Terra and Southern Highlands craters relative to the All-Mars Barlow database.



**Figure 3:** Crater depth vs. Diameter scatter plot for the two sub-regions of interest in Fig. 1.