MAPPING AND DIP MEASUREMENTS OF TECTONIC SHORTENING STRUCTURES IN WESTERN ARABIA TERRA, MARS.

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Introduction: Oxia Planum (the proposed landing site of the now-delayed ExoMars 2022 Rosalind Franklin rover [1, 2]) is located in transitional terrain between the Arabia Terra highlands and the Chryse Planitia lowlands. The region is modified by tectonism, as expressed by a regional fabric of shortening structures. However, the impact of tectonism (on both regional and global scales), on the geological history of western Arabia Terra, and the total shortening experienced there, is poorly understood.

To improve understanding, we mapped tectonic features in Oxia Planum and along the dichotomy between Arabia Terra and Chryse Planitia (expanding our previously mapped area [3]; Fig. 1). We identified 13 faulted impact craters in which we could use the fault trace geometry across the crater to calculate the dips of the thrust faults (Fig. 2). These dips are required to estimate the amount of shortening across the study area, but also provide globally relevant data; few studies have directly measured martian compressional fault dips [4].

Structural Mapping: Mars has widespread tectonic features, globally mapped at a 1:20,000,000 scale [5]. We conduct a detailed structural survey of a 3 million km^2 study area (Fig. 1) at 1:50,000 scale using 6 m/pixel CTX images [6], 100 m/pixel THEMIS daytime infrared images [7], 463 m/pixel gridded MOLA [8] topographic data, and HRSC [9] slope maps and hillshade models constructed using multiple illumination angles. Our mapping approach was structure-based and we recorded fault vergence, scarp height, fault trace orientation, and morphological complexity (denoting features referred to as either wrinkle ridge, lobate scarp, or high-relief ridge).

Dip Measurements: We measured the thrust fault dips by two methods at 13 faulted craters. For both, we used the HRSC DEM and inspected its quality before using it. Firstly, for the ***crater rim offset method*** [10] we manually fitted six circles to each crater rim (3 on either side of the fault) and then added center points to these circles and drew 9 profile graphs between the 3 points denoting the footwall and hanging wall. Dip was then calculated from the horizontal displacement (distance between footwall and hanging wall center points) and vertical displacement (difference in crater rim height between the footwall and hanging wall from the profile graphs). Secondly, for the ***fitted plane method*** we digitized the fault trace, placed points along it every 100 m, extracted HRSC-derived elevation data for each point, and then used the ‘Trend’ tool in ArcGIS Pro to fit a dip-plane.

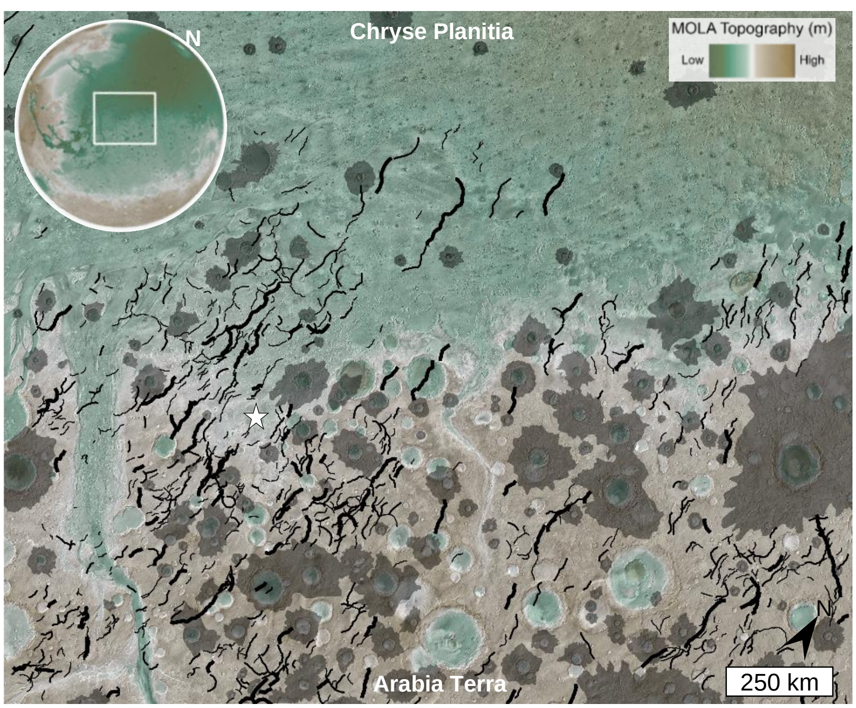

Figure 1. *Map of shortening structures in western Arabia Terra and Chryse Planitia. Shortening structures are interpreted as the surface expressions of thrust faulting with varying degrees of folding. The globe shows the location and extent of study area (note globe is rotated to match main map). The black lines on the main map show the tectonic shortening structures. The thickest lines show the largest scarp heights (>100 m) thinnest lines show small scarp heights (<50m). The transparent grey areas show impact ejecta. The star shows the proposed ExoMars Rover landing site in Oxia Planum.*

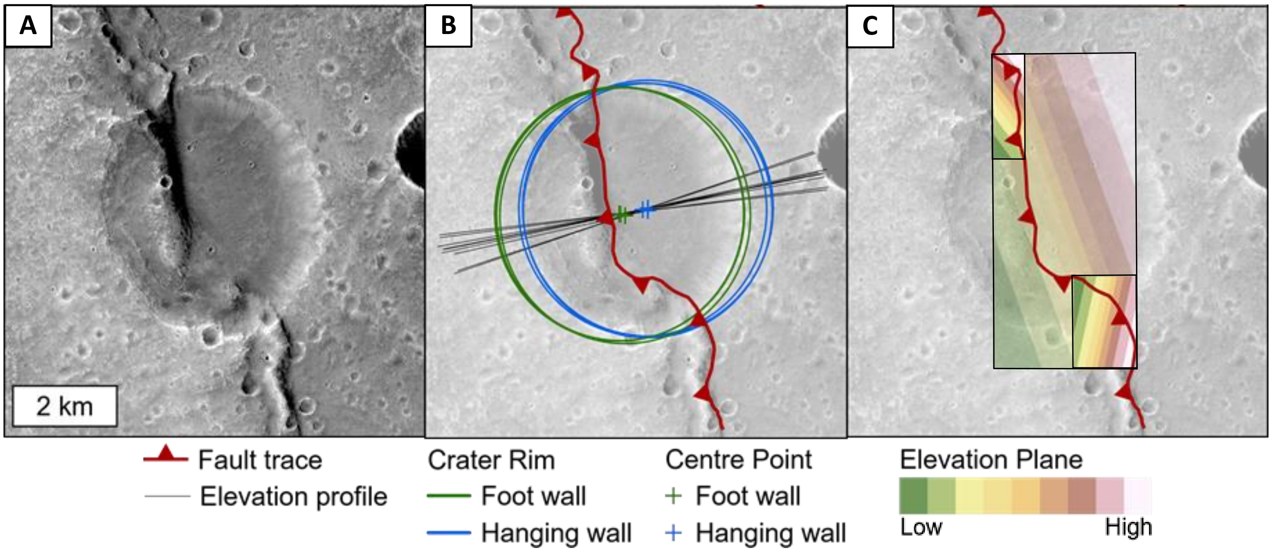

Figure 2. *Example of the two methods used to measure the thrust fault dips.* ***A)*** *CTX image of crater 13.* ***B)*** *The crater rim offset method, showing three repeat measurements, resulting in 6 crater rim circles and 9 profiles.* ***C)*** *The fitted trend method, showing three fitted planes (one for the whole crater and two for the rim).*

Mapping Results: We identified abundant compressional tectonic structures in the study area, but no extensional structures (grabens). In total, we found 845 shortening structures, with a combined length of ~28,000 km. The mean length of the structures is 33.2 km and the mean scarp height is 60 m. The shortening structures show large variation in scale, morphological complexity, degree of erosion, and planform patterns. Although the shortening structures are distributed across the highland-lowland transition region they have a dominant north-south orientation.

Dip Results: Using the fitted plane method, we find that thrust fault dips range from 3.1° to 18.8° with a mean dip of 9.1° (n=25 measurements from 13 craters). Using the rim offset method, thrust fault dips range from 1.6° to 17.8° with mean dips of 9.0° (n=105 from 12 craters). For each crater, nine dip measurements were made across the different methods, and all dips were between 1.0° and 5.0° of each other in each crater.

Discussion: There are very few studies directly measuring martian thrust fault dips [e.g., 4], however a dip of 30° has generally been assumed [e.g., 11]. For a given structure height, a lower dip results in a larger horizontal displacement, which in turn points to larger strain, and a larger global contraction. If the dips of typical martian thrust faults are closer to our measurements of 9° than the previously assumed 30°, then current estimates of fault displacement, strain, and global contraction are significantly underestimated.

Conclusion: We present a CTX-scale tectonic mapping survey of a 3 million km^2 study area along the dichotomy region between western Arabia Terra and Chryse Planitia. We mapped 845 tectonic shortening structures with a combined length of ~28,000 km.

We used 13 faulted craters to measure the dips of thrust faults using two different methods. The results of both methods are consistent, and we find a mean thrust fault dip of 9.1° and 9.0° for the fitted plane method and rim offset method respectively. The measured dips are lower than generally assumed, so our results have significant implications for displacement, strain, and global contraction estimates.

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