MAPPING AND PRELIMINARY ANALYSIS OF WRINKLE RIDGES IN THE AEOLIS DORSA REGION, MARS. R. M. Borden[1] and D. M. Burr[1], [1]University of Tennessee, Knoxville, TN USA 37996 (rborden4@vols.utk.edu and dburr1@utk.edu).

Introduction: The Aeolis Dorsa (AD) region of Mars is a sedimentary basin located just north of the highland-lowland boundary. This region shows evidence of tectonic deformation, including several wrinkle ridges that have been documented in this area (Figure 1) [1]. For this project, we are mapping wrinkle ridges and using their morphology and orientations to infer the contractional tectonic history of the AD region.

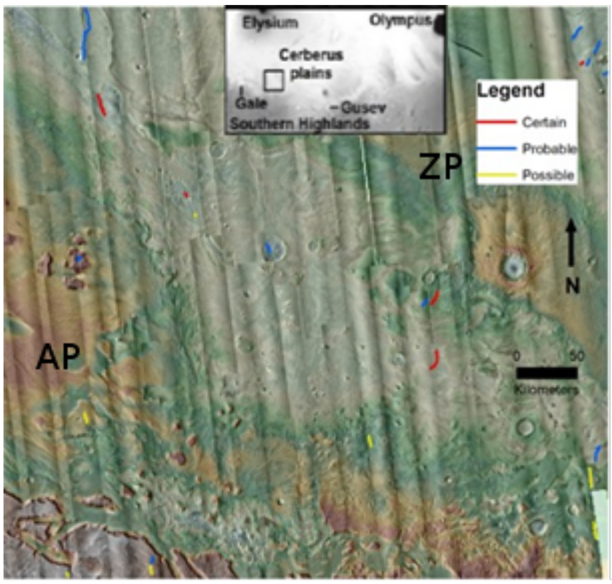

Figure 1: Currently mapped wrinkle ridges in the Aeolis Dorsa mapping area, with context map. Figure background is MOLA topography over CTX mosaic. Colored lines denote wrinkle rigde certainty categories: red denotes certain, blue denotes probable, and yellow denotes possible (see Table 1).

Background: The Aeolis Dorsa region consists of a basin located between two plana: Aeolis Planum on the west and Zephyria Planum on the east (Figure 1). Multiple geologic processes have occurred in the region, as evidenced by fluvial, volcanic, aeolian and tectonic landforms [1-4].

Wrinkle ridges are found on other terrestrial planetary bodies, including Mercury, Earth, the Moon, and Mars [5,6]. They generally consist of three main geomorphologic parts: a low underlying topographic rise, a broad arch, and a narrower crenulated ridge (the "wrinkle") on top [7]. They are usually asymmetric in their transverse profile. Wrinkle ridges can also have en echelon segments, consisting of several segments that are parallel and offset (Figure 2). These segments are interpreted as being caused by a rotation of the stress field during wrinkle ridge formation [8].

The currently accepted interpretation of wrinkle ridges is that they are formed as fault-related folds by slip along blind thrust faults [9]. Based on this interpretation, it is possible to use wrinkle ridges to find the amount of shortening and directions of the strain axes at the time of ridge formation. Subtracting the straight-line length of a transverse topographic profile across a ridge from the integrated length of the same profile will give the amount of shortening across the ridge [10]. The geographic orientation of a ridge can be taken as perpendicular to the direction of greatest compression, and thus the directions of the other stress axes can be derived [11]. This information derived from wrinkle ridges can provide data for understanding the stress field that led to their formation.

Hypothesis: Based on preliminary observations of wrinkle ridges in Aeolis Dorsa (Figure 1) [1] and current theories on their formation in the literature, the following hypotheses will be used for this work:

Null hypothesis: The Aeolis Dorsa region underwent contraction that was the same throughout the region (regional control on the stress direction). The evidence for this hypothesis would be wrinkle ridges with a single strong preferred orientation or with a pattern of orientations consistent with a single geographic location as the origin of deformation.

Alternate hypothesis: The Aeolis Dorsa region underwent contraction that was more localized (not controlled at the regional level). The evidence for this hypothesis would be ridges across AD without a preferred orientation and/or with random orientations.

Data and Methods: For this project, wrinkle ridges in the Aeolis Dorsa region are being mapped using a mosaic of images from the Context Camera (CTX) [12], which have a resolution of ~6 m/pixel. The CTX image mosaic is overlain by Mars Orbiter Laser Altimeter (MOLA) [13] data to get elevations for the mapped features. Mapping will be completed at 1:100,000 scale. In addition to wrinkle ridges, this region also contains several other types of ridge features: sinuous ridges interpreted as inverted fluvial deposits [2 and references therein], yardangs from Aeolian erosion [3], and dunes from Aeolian deposition [4 and

Mapping Criteria	Certainty		
	Certain	Probable	Possible
Profile view: 1. Topographic rise (or "arch") 2. Asymmetry	2/2 profile criteria needed	1/2 profile criteria needed	1/2 profile criteria needed
Map view: 1. Narrow ridge 2. En echelon segments 3. Curvilinear shape 4. Broad arch (sometimes "hill")	3 map view criteria needed	3 map view criteria needed	2 map view criteria needed

Table 1: Criteria for mapping wrinkle ridges.

references therein]. Because of the abundance of other ridges in the AD region, we are using several criteria, based on the literature on wrinkle ridges, to provide levels of certainty in our mapping (Table 1). For example, their asymmetry helps to distinguish them from other types of ridges in the AD mapping area, which do not show asymmetry [2].

Along with the mapping, we will collect data on ridge locations, orientations, and lengths. We will also use stereo pair CTX images to make Digital Elevation Models (DEMs) using Ames Stereo Pipeline software [14]. From these DEMs, we will take topographic profiles in at least 30 places along each ridge so as to have a robust data set for statistical analysis. If stereo pair CTX images are not available for a wrinkle ridge, alternative methods of obtaining topographic data will be used, such as photoclinometry (also known as shape-from-shading) [15].

Analyses. Once the data collection is complete, they will be analyzed in several ways. First, the orientations of all of the wrinkle ridges will be made into rose diagrams. These rose diagrams will be analyzed to determine if there is a preferred orientation of the wrinkle ridges. A clustering analysis of the locations of the wrinkle ridges will be completed using a nearest-neighbor analysis tool in ArcGIS or Excel [16,17]. This analysis will be used to determine if the locations are random or if there is a pattern to the distribution of wrinkle ridges. The topographic profiles will be used to find the amount of shortening due to folding by subtracting the straight-line width of each ridge (current width) from the integrated length of the transverse profile across the ridge (original width). The strain will be found by dividing the shortening by the original width [18].

Preliminary Results and Future Work: About 1/2 of the study area has been mapped so far, with 23 wrinkle ridges that have been identified: 5 certain, 10 probable, and 8 possible (Figure 1). Once mapping and data collection are complete, the analysis of wrinkle ridge orientations will be done to determine if there is a preferred orientation or orientations. The topographic profiles will be used to calculate shortening and strain, and those results will be used to explore displacement-length relationships [19]. The clustering analysis will also be done after mapping is complete. The results of this work will have implications for understanding contractional deformation in this sedimentary basin along the highland-lowland boundary on Mars.

References: [1] Kite E. S. et al. (2015) *Icarus, 253,* 223-242. [2] Jacobsen R. E. and Burr D. M., *Geosphere*, in revision. [3] Ward A. W. (1979) *JGR, 84(B14),* 8147-8166. [4] Boyd A. S. and Burr D. M (2016) *Planetary Mappers Meeting*, Flagstaff, AZ. [5] Watters T. R. (1988) *JGR, 93*, 10236-10234. [6] Plescia J. B. and Golombek M. P. (1986) *GSA Bulletin, 97,* 1289-1299. [7] Lucchitta B. K. (1977) *Proceedings of LSC,* 2691-2703. [8] Smart K. J. et. al. (2006) *LPSC 37, #1966*. [9] Mueller K. and Golombek M. P. (2004) *Ann. Rev. of EPS, 32,* 435-464. [10] Golombek M. P. et. al. (1991) *Proceedings of LPSC 21*, 679-693. [11] Anderson E. M. (1951) *The Dynamics of Faulting.* [12] Malin M. C. et al. (2007), *JGR, 112,* E05S04. [13] Smith D. E. et al. (2001) *JGR, 106,* 23689-23722. [14] Moratto Z. M. (2010) *LPS XLI,* Abstract #2364. [15] Shean D. E. et. al. (2016) *ISPRS J. Photogrammetry and Remote Sensing.* [16] Davis J. C. (1973) *Stats. & Data Analysis in Geol.* [17] Ebdon D. (1985) *Stats. in Geog., 2^{nd} Ed.* [18] Fossen H. (2012) *Structural Geology.* [19] Schultz R. A. et. al. (2006) *Journal of Structural Geology, 28,* 2182-2193.

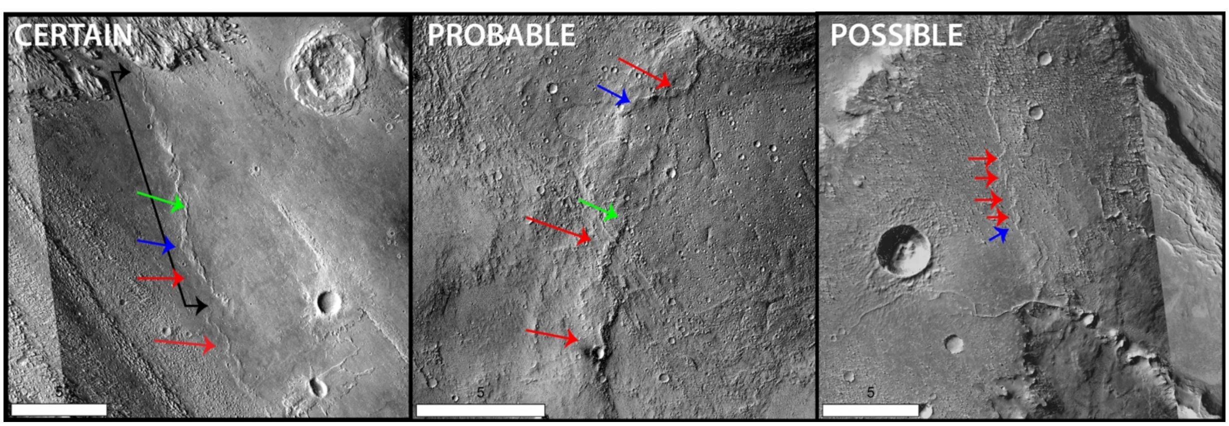

Figure 2: Examples of wrinkle ridges for each of the mapping classifications from within the study area. All scale bars are 5 km. Arrows indicate characteristics of wrinkle ridges. Black arrows indicate curvilinear map trace, blue arrows indicate ridge, green arrows indicate wrinkle, and red arrows indicate en echelon segments.