THE ANATOMY OF A WRINKLE RIDGE REVEALED IN THE WALL OF MELAS CHASMA, MARS.

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Introduction: Wrinkle ridges are long (10’s to 100’s of km), quasi-linear, compressional tectonic features commonly observed on the volcanic surfaces of the terrestrial planets, including Mars [1,2]. They have a morphology consisting of one or more narrow (up to 6 km wide), asymmetric ridges superimposed onto a broad arch (~20 km wide) [1]. Based on terrestrial analogs, they are thought to form when shallow volcanic plains sequences experience horizontal shortening and folding due to an underlying blind (not surface breaking) thrust fault which may propagate into the basement material [2-4]. The narrow wrinkles on the ridge are likely the result of variable backthrust faulting which causes their sinuous expression [2]. The broad arch of the ridge has more consistent expression and likely results from folding above the blind thrust fault [2]. There is typically a topographic offset across the ridges, and they often occur in a periodic spacing that may be indicative of the maximum depth of faulting and the brittle-ductile transition depth [3,4]. Studies of wrinkle ridges model surface deformation by varying the fault properties in an elastic dislocation model in an attempt to match the surface topography. However, this approach is indirect and may yield non-unique results, and these studies often assume a typical thrust fault dip of 30° [2,4-7]. In this abstract we present direct observations of a wrinkle ridge thrust fault where it is exposed in the wall of Melas Chasma in central Valles Marineris on Mars.

Observations: The area of interest is along the south wall of Melas Chasma where a ridge descends 6 km across a distance of 70 km from the plateau to the valley floor (Fig. 1A). The Melas ridge is aligned with a wrinkle ridge on the adjacent plateau that intersects the chasma wall. A profile across the wrinkle ridge shows a topographic step down to the east (Fig. 1B). We interpret the Melas ridge as the expression of an erosionally-resistant fault plane, left as highstanding relief during the enlargement of Melas Chasma. Resistance to erosion could result from interaction with magma or water to form an erosion-resistant surface along the fault. If we assume that the structure of the Melas ridge preserves the structure of the blind thrust fault associated with the wrinkle ridge, then we can use both ridges to constrain the properties of the fault.

Topographic Analysis: We use two approaches to characterize the fault associated with the Melas ridge. First, we note a difference of ~6° between the strike of the wrinkle ridge and the that of the Melas ridge, consistent with the Melas ridge representing the subsurface expression over a range of depths of the dipping fault plane. Since both ridges are expected to lie along the fault plane, we can calculate a possible fault plane normal vector by taking the cross product of two unit vectors that align with the wrinkle ridge and the Melas ridge. This method produces a normal vector for a fault plane that dips 18° NW with a strike of N17°E.

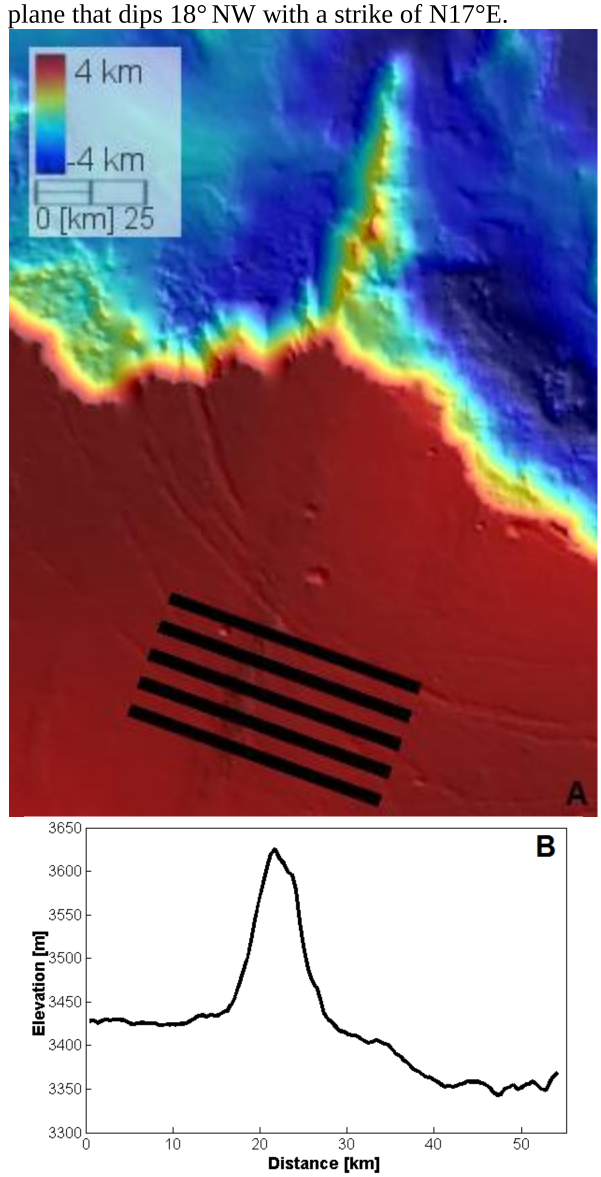

Figure 1. (A) Plan view of both ridges shown in gridded MOLA topography. (B) Five cross sections in A were taken to produce the averaged profile from west to east (shown at 100× vertical exaggeration to display the broad ridge and topographic offset).

We next used Mars Express High Resolution Stereo Camera (HRSC) digital elevation models to find the best-fit plane to the Melas ridge. As before, we assume that if the ridge was composed of resistant fault plane material, then the path of the ridge crest will lie along the fault plane. The data was analyzed by taking the point of highest elevation in each latitude row to produce a set of points that represent the crest of the Melas ridge. A plane was fit to this cloud of points using a least-squares method. The strike calculated from this plane is N21°E, which agrees with the earlier derived strike of N17°E and the wrinkle ridge's measured strike of N18°E. The dip of the fitted plane of 13°NW is in reasonable agreement with the earlier cross product approximation of ~18°. The fit of the plane is assessed using the orthogonal distance to the plane for each point (Fig. 2), revealing an RMS misfit of 298 m (relative to 2.5 km of relief along the profile).

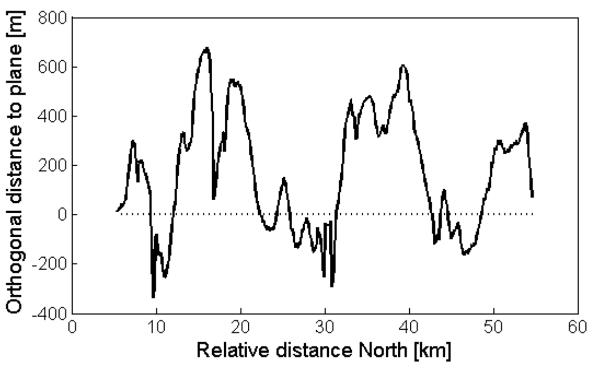

Figure 2. Plot of the orthogonal distance to the best fit plane for a fit of a section of the Melas ridge.

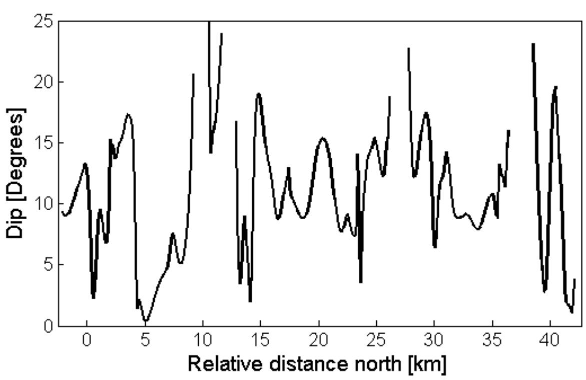

Figure 3. Plot of dip averaged over 50 points from south to north along the Melas ridge. Discontinuities come from removing spikes over 25°.

We then calculated best-fit dips for 50 point contiguous sub-sections of the data along the length of the profile in order to test for variations of the dip with depth. The lack of clear trends in the inferred dip along Melas ridge over a vertical section of 2.5 km (Fig. 3) supports the interpretation that erosion preferentially exposed a planar surface with semi-regular dip. A linear trend in the dip plot would be present if the fault were listric over this section [5]. The mean dip from this approach is 11° with a standard deviation of 5°.

Discussion: The results of this analysis suggest that the Melas ridge has a topographic expression that is likely controlled by the preferential exposure of an erosion-resistant fault plane associated with the coincident wrinkle ridge. Two methods using the topography of the Melas ridge to calculate approximate fault planes both resulted in similar dip values of 13° and 18° along a planar scarp extending from a depth of ~1.5 km down to a depth of at least 4.5 km below the plateau surface. The dip direction of the thrust fault is in agreement with that inferred from topographic profiles [2,4]. However, the dip of this thrust fault (13-18°) is more shallow than the 30° dip that is typically assumed in models [2,4-7]. The properties of this thrust fault could be used to constrain models specific to this region, and may even be generally applicable to wrinkle ridges in other regions or planets as well. We conclude that at least in some cases the dips of thrust faults producing wrinkle ridges are more shallow than expected and that listric character is not seen in the top several km. If this dip range applies to all wrinkle ridges, this would imply that horizontal normal strain may be a factor of 1.8-2.5× greater than estimates based on surface relief, or a factor of 1.1× greater than estimates based on displacement-length relationships (both assuming a dip of 30°) [7]. Analysis of global contraction using this shallower fault dip would predict that Mars has experienced a greater decrease in planetary radius from cooling and that thrust fault propogation depth may be more shallow than previously thought.

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