DISPLACEMENT-LENGTH RELATIONS OF WRINKLE RIDGE THRUST FAULTS ON MERCURY.

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Introduction: Thrust faulting and folding of the smooth plains of Mercury are expressed predominately by wrinkle ridges, tectonic features resulting from compressional stresses (Fig. 1) [1, 2]. The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft returned image and topographic data that allow for detailed analysis of the three-dimensional morphology of tectonic landforms. By extracting morphometric data of wrinkle ridges from high-resolution digital elevation models, the displacement-length relationship of associated thrust faults may be quantified [3, 4]. Displacement-length (D/L) relationships of faults play a significant role in tectonic analysis. It provides insight into how faults develop and the D/L ratio of a fault population enables the quantification of strain. Estimates of the contractional strain of Mercury's smooth ridged plains are important because it allows a comparison with the strain expressed by the more broadly distributed lobate scarps in intercrater plains formed in response to global contraction. This will facilitate the evaluation of the contribution of stresses due to subsidence of the smooth plains volcanics and stresses from global contraction due to interior cooling of the planet in the deformation of the ridged plains.

Wrinkle ridges are complex structures consisting of an assemblage of superimposed landforms [1, 2]. The ridges of Mercury’s smooth northern plains exhibit a complex network pattern that often overprint ghost craters, shallow buried impact craters that have localized wrinkle ridge formation [5]. This project develops a careful method for measuring the relief along wrinkle ridges on Mercury to generate fault displacement profiles that can be used to determine the displacement-length relationship of wrinkle ridge thrust faults.

Data and methodology: Wrinkle ridges on the smooth northern plains of Mercury were identified in moderate- and high-incidence angle (55°-88°) images obtained by MESSENGER’s Mercury Dual Imaging System (MDIS) [6]. Digital elevation models (DEMs) derived from the Mercury Laser Altimeter (MLA) provided the necessary elevation data [7]. Mapping and measurements were performed in an ArcGIS environment.

Typically, displacement-length studies of tectonic landforms assume that maximum relief and fault displacement occur near the midpoint of the fault length and thus tend to concentrate measurements around that location. We measure relief along the entire length to unambiguously identify the maxima. The shape of the displacement profile of a wrinkle ridge provides insight into the growth of the fault [4].

To constrain the lengths and maximum displacements of the ridges identified in this study, we developed a series of displacement profiles for wrinkle ridges in the smooth northern plains. First, polylines were plotted following the midline and length of each ridge. The length of each ridge was determined from its digitized polyline. To determine the maximum displacement, a series of elevation profiles were extracted normal to the strike of each ridge (Fig. 2). Within each orthogonal profile, elevation data were examined to identify a high and representative low elevation from which to calculate the relief. The distance from the terminus of the ridge to each calculated point of relief was measured in ArcMap. Ridge relief is plotted with respect to distance along ridge (Fig. 3). The displacement necessary to restore the topography to a planar surface is given by $D = h/\sin\theta$ where h is the measured relief and θ the fault plain dip, assumed to be 30°. Displacement profiles clearly illustrate the location of maximum displacement, show how displacement varies along the fault length (Fig. 3), and simplify an accurate estimate of the D/L ratio.

Observations and future work: The displacement profile of an unrestricted fault will be elliptically shaped as predicted by a simple linear elastic fracture mechanic (LEFM) model [4]. Such a profile suggests that much of the accumulated fault growth occurred along the length of a single fault [3, 4]. The displacement profile of a restricted fault, a fault where growth is limited by some mechanical factor(s), will not exhibit a symmetric displacement profile with maximum displacement at the center of the fault. We find wrinkle ridge displacement profiles that suggest both unrestricted and restricted fault growth (Fig. 3). Wrinkle ridges with unrestricted thrust faults (i.e., elliptically shaped profiles) (Fig. 3A) appear to be generally isolated from other wrinkle ridges in the immediate area. Wrinkle ridges with restricted growth show irregular or flat displacement profiles (Fig. 3B) and are typically found in close proximity to other ridges that form complex, reticulate patterns where ridges typically abut other ridges. Other likely examples of restricted fault growth are wrinkle ridge rings or ghost craters where ridges are localized by the rims of shallow buried craters. These will also be examined to create the broadest understanding of wrinkle ridge fault growth on Mercury.

Future work involves expanding the study to include wrinkle ridges located in other smooth plains, including the Caloris basin, to determine the D/L ratio of the population of wrinkle ridges on Mercury. Displacement-length relationships revealed in the study may provide insight into how the complex, reticulate ridge patterns develop. This methodology may also be applied to wrinkle ridges in lunar maria.

Conclusions and summary: Compressional stresses in Mercury's smooth plains produce thrust faulting that is often superficially expressed by wrinkle ridges. Displacement profiles of wrinkle ridge thrust faults show evidence of both restricted and unrestricted fault growth and indicate complex interactions between developing faults.

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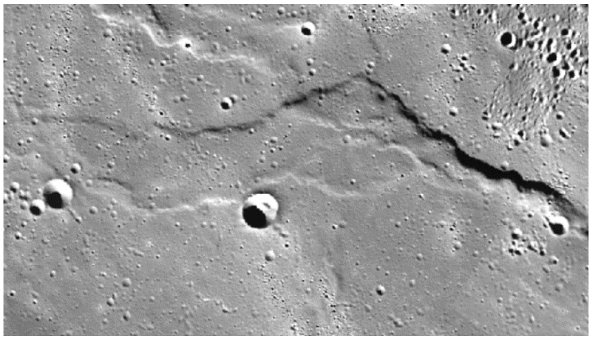

Figure 1: Moderate-incidence angle image of a wrinkle ridge located on Mercury's smooth northern plains obtained by MESSENGER's MDIS camera.

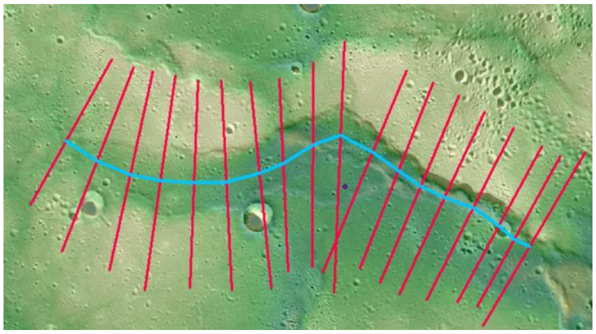

Figure 2: Wrinkle ridge topography shown in color-coded DEM derived from interpolated MLA altimetry data. The polyline for length measurements (blue) and orthogonal elevation profile locations (red) are shown on a wrinkle ridge in smooth northern plains (see Fig. 1).

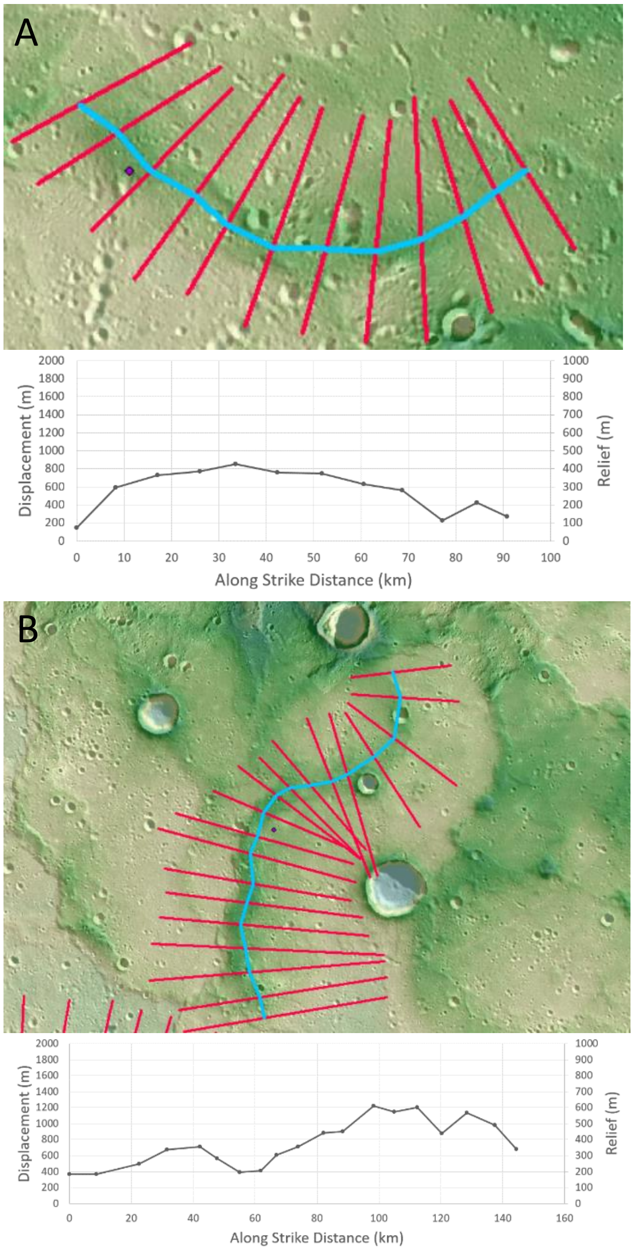

Figure 3: Wrinkle ridges in Mercury's northern smooth plains with relief and displacement plotted along length. Relief obtained from elevation data extracted from MLA DEMs. (A) Ridge exhibiting a symmetric displacement profile with the area of maximum displacement close to the center of the feature. The ridge is isolated from surrounding tectonic features. (B) Ridge exhibiting an irregular, asymmetric displacement profile likely due to restricted fault growth.