WRINKLE RIDGES IN HESPERIA PLANUM AND THE STRESS STATE IN THE EASTERN HEMISPHERE OF MARS. C.L. Goudy[1] and R.A. Schultz[1], [1]Geomechanics Rock Fracture Group, Dept. of Geological Sciences/172, University of Nevada, Reno, NV, 89557 (cgoudy@mines.unr.edu).

Summary: Using digital elevation models (DEM) we identify the relative ages of the two sequential sets of wrinkle ridges in Hesperia Planum. By resolving Coulomb failure stress changes (ΔCFS) from a source fault along a preexisting perpendicular receiver fault we find that the stresses produced by a source fault are likely to initiate slip in an orthogonal direction. Therefore the stress state in Hesperia Planum has rotated approximately 90° between the formation of the older, Noachian NE-trending, and younger, Late Noachian/ Hesperian NW-trending, sets of wrinkle ridges.

Introduction: Hesperia Planum (20ºS, 250°W) is the basis for the Hesperian Epoch [1], and contains wrinkle ridges which show a bimodal distribution of orientations [2, 3]. Over the past 20 years the temporal relationship between each set of wrinkle ridges and with Tyrrhena Patera has been ambiguous, with the cross-cutting relationships in the western portion of Hesperia Planum indicating that the NW-trending wrinkle ridges are younger than the NE ridges and contemporaneous with the emplacement of Tyrrhena Patera [4]. In eastern Hesperia Planum no such pattern was found [5]. Throughout all of Hesperia Planum, a larger number of older wrinkle ridges is observed in the NW-trending direction. The wrinkle ridges in this area are interpreted to result from two temporally distinct events [3, 6].

We reevaluate timing relationships between the wrinkle ridges and Tyrrhena Patera in order to evaluate timing, orientations, thrust fault dip directions, and the Late Noachian regional stress state. We show that wrinkle ridge intersections observed in Hesperia Planum are due to reactivation of the older wrinkle ridge thrust faults by the younger set, similar to terrestrial observations of fault reactivation during earthquakes [e.g., 7, 8].

Observations: DEMs of Hesperia Planum were created using Mars Orbiter Laser Altimeter (MOLA) data. A consistent relationship of topographically lower NE-trending wrinkle ridges is now observed throughout Hesperia Planum (Fig. 1). The NW wrinkle ridges override the NE wrinkle ridges and are interpreted to be younger based on this relationship (Fig. 1). These findings are not readily apparent in the Viking Orbiter and MOC images used in previous studies, because the DEMs provide an opportunity to view a larger area than the MOC images with a higher resolution than the Viking Orbiter images [2−6].

The broad rise of the younger NW-trending wrinkle ridges is developed consistently on the SW side of the ridge, and is apparent on the DEM (Fig. 1A) as well as in individual MOLA profiles. The position and topography of the broad rise is consistent with a thrust fault dipping toward the SW beneath the wrinkle ridge [9, and references therein]. The older NE-trending wrinkle ridges have thrusts that consistently dip in the NW-direction (Fig. 1A). This suggests that the stress field in all of Hesperia Planum has rotated roughly 90º between the formations of the two sets of wrinkle ridges.

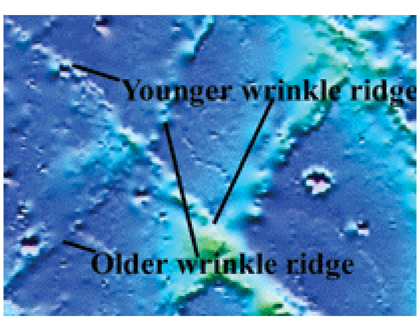
We also find that morphology between each set of wrinkle ridges is different. An echelon pattern is displayed in the older wrinkle ridges that is not observed in the younger wrinkle ridges (Fig. 1). Older wrinkle ridges also parallel thrust fault scarps outside of Hesperia Planum [e.g., 10, 11]. Therefore, we investigate the possibility of younger wrinkle ridges reactivating preexisting buried Noachian thrust faults.

Methods: Reactivation in the NE direction is tested by calculating the Coulomb failure stress changes (ΔCFS) along a preexisting receiver fault, corresponding to the older thrust faults, due to slip on a younger, crosscutting source fault [e.g. 7, 8]. The relative dip directions of the source and receiver faults are obtained from the DEM. An elliptical slip distribution is prescribed along the source fault and the attendant values of ΔCFS are calculated along the plane of the receiver fault. Positive ΔCFS promotes frictional sliding along the receiver fault, while negative ΔCFS hinders slip [7, 8]. ΔCFS is calculated along the receiver fault for cases in which the source fault is at a distances of 0 km, 5 km 10 km (Fig. 2), simulating growth of the younger wrinkle ridge thrust faults toward, and across, the preexisting thrust fault. These values are determined for 20 slip patches on the receiver fault by resolving the induced stress onto the frictional slip surfaces.

Results: All receiver faults show a positive ΔCFS close to the source fault that diminishes with distance from the source fault (Fig. 2). ΔCFS is generally larger where the receiver fault intersects the source fault. Negative ΔCFS, associated with slip impedance, exist in areas perpendicular to the source fault at distances greater than 40 km from the source fault. This means that in all cases, slip along the source fault is predicted to induce slip along the receiver fault once the younger fault closes to within 40 km of the preexisting fault. Therefore, Late Noachian slip along the younger NW trending wrinkle ridges likely triggered slip and wrinkle ridge growth along the older NE trending thrust faults.

Conclusions and Implications: The results of this study identify three temporally distinct deformational events in Hesperia Planum: 1. deformation resulting in the formation of the NE-trending faults; 2. deformation resulting in the NW-trending thrust faults and wrinkle ridges, and 3. reactivation of the thrust faults in the NE direction, producing the NE set of wrinkle ridges above them. Porter and others (1991) found the (older) NE-striking wrinkle ridges are either older or temporally inseparable from the Tyrrhena Patera flank flow unit. Greeley and Crown (1990) suggest several large linear tectonic structures control lava channels and are consistently parallel to the NE-trending wrinkle ridges [12]. Therefore, since Tyrrhena Patera formed in the Noachian [13] the NE-trending wrinkle ridges formed no later than the Late Noachian/ Early Hesperian [4, 12, 13]. We infer that the most compressive regional stress during the Late Noachian/ Early Hesperian was oriented NW-SE, subsequently a NE-SW oriented regional compressive stress during the Early Hesperian led to formation of new NW-trending wrinkle ridges, and reactivated some older NE-trending faults in Hesperia Planum.

References: [1] Scott, D.H., and Carr, M.H. (1978) *USGS Misc. Invest. Ser. Map I-1803*; [2] Goudy (2002) *M.S. Thesis, SUNY Buffalo*, 130p.; [3] Goudy, C.L., and Gregg, T.K.P. (2002) *LPSC abstracts*, *34*, #1135; [4] Porter, T.K., et al. (1991) *LPSC abstracts, 22*, 1,085−1,086; [5] Chadwick, J.D. (1991) *GSA- Abstracts with Programs, 23*, 277; [6] Goudy, C.L., and Gregg, T.K.P. (2001) *LPSC abstracts*, *33*, #1393, [7] Harris, R.A., and Simpson R.W. (1998) *JGR, 103*, 24,439−24,451; [8] Freed, A.M., and Lin, J. (1998) *JGR*, *103*, 24,393−24,409; [9] Schultz, R.A. (2000) *JGR, 105*, 12,035−12,052; [10] Watters, T.R. (1993) *JGR, 96*, 15,599−15,616; [11] Mangold, N., et al. (1998) *Planet. Space Sci., 46*, 345−356; [12] Greeley, R.A., and Crown, D.A. (1990) *JGR, 90*, 7,133−7,149; [13] Gregg, T.K.P. et al. (1998) *USGS Misc. Invest. Ser. Map I-2556.*



A.

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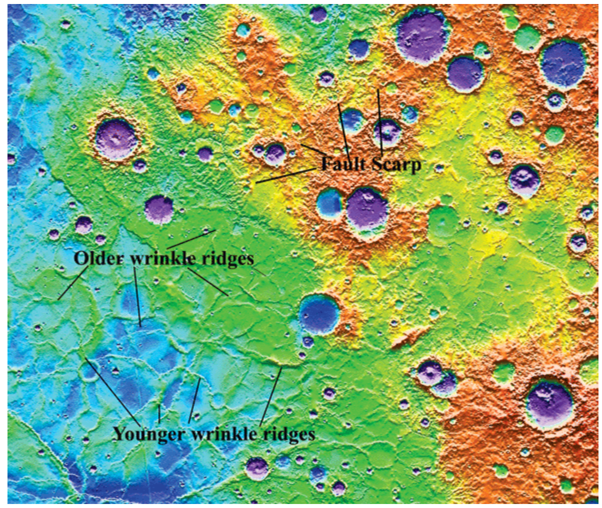

Figure 1. A) An enlarged portion of Hesperia Planum showing the cross-cutting relations of the younger and older wrinkle ridges. B) DEM of the eastern portion of Hesperia Planum showing older NE-trending wrinkle ridges and younger NW-trending wrinkle ridges. An older wrinkle ridge continues along strike as a fault scarp in the upper part of the image. Blue indicates topographic lows and red indicates topographic highs.

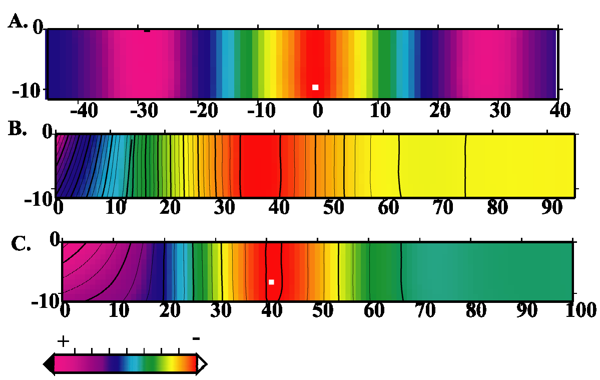

Figure 2. Change in Coulomb failure stress on a receiver fault A) intersecting source fault, B) 5 km from source fault, and C) 10 km from source fault. All panels indicate reactivation of the older, pre-existing NE thrust faults (receiver faults) by slip along the younger, crosscutting wrinkle ridge thrust faults of the NW set.