EN ECHELON SEGMENTATION OF WRINKLE RIDGES IN SOLIS PLANUM, MARS, AND IMPLICATIONS FOR COUNTER-CLOCKWISE ROTATION OF SHORTENING DIRECTION. K.J. Smart[1], D.A. Ferrill[1], and S.L. Colton[2], [1]Department of Earth, Material, and Planetary Sciences and [2]Center for Nuclear Waste Regulatory Analyses at Southwest Research Institute®, 6220 Culebra Road, San Antonio, TX 78238, USA (e-mail: ksmart@swri.org).

Introduction: Wrinkle ridges – long, linear to sinuous anticlines separated by relatively broad, flat synclinal valleys – are formed by compression and are a prominent feature at Solis Planum (Fig. 1). In addition to Mars, wrinkle ridges have been documented on Mercury, Venus, and the Moon, with contractional fold analogs on Earth [1].

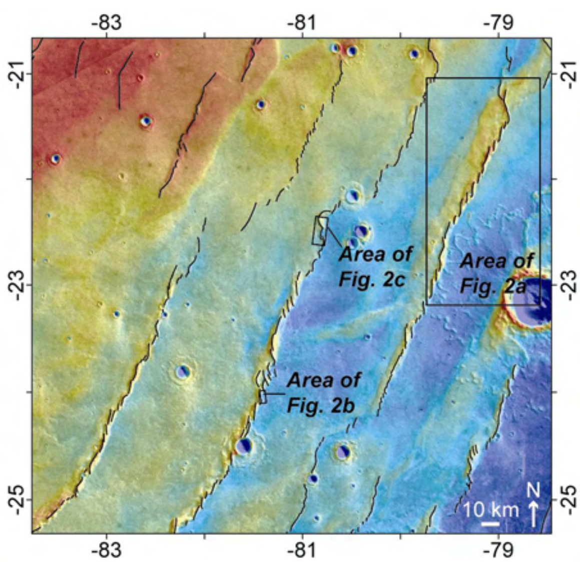

Figure 1. Wrinkle ridge traces at Solis Planum, Mars.

The wealth of data from recent missions to Mars, including images from the Mars Orbiter Camera (MOC) and Thermal Emission Imaging System (THEMIS) provides new insights into all aspects of Martian geology. High-resolution MOC and THEMIS images at Solis Planum reveal unprecedented detail of wrinkle ridge structures. In addition to confirming previous interpretations and revealing new structural characteristics of Martian wrinkle ridges, these data enable exploration of folds at various scales and detailed mapping of fold axes.

Observations: Inspection and interpretation of new THEMIS and narrow angle MOC visual spectrum images of wrinkle ridges in Solis Planum confirms many of the observations of previous wrinkle ridge researchers: (i) asymmetric folds that change vergence along strike [2, 3] are present at a wide range of scales [4]; (ii) en echelon segmentation of fold axes [1, 4] (Fig. 2a); (iii) fold crests or steep limbs with graben systems, consistent with outer-arc extension [1, 5] (Fig. 2b); (iv) fold axes offset by tear faults and lateral ramps [6] (Fig. 2c); and (v) steep fold limbs, lobate scarps, and elevation offsets that locally suggest emergent thrust faults [2, 7, 8].

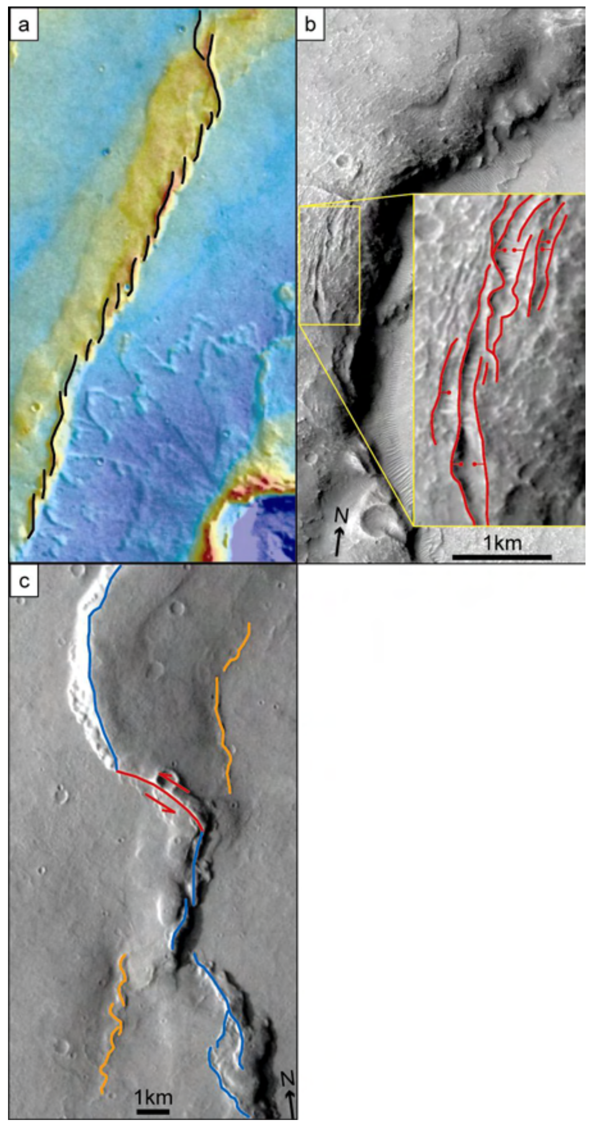

Figure 2. Wrinkle ridge structural characteristics. (a) En echelon fold axes. (b) Grabens formed by outer arc extension. MOC image E0501229. (c) Tear fault (red line with arrows marking sense of slip) and narrow anticlines (orange lines) within syncline. THEMIS image V0632003.

The new imagery also reveals examples of narrow anticlines locally developed within synclinal cores (Fig. 2c), consistent with inner-arc contraction developed by bending of a mechanical layer. This inner-arc contraction is a companion to outer-arc extension and forms part of a geologically coherent suite of related structural features (Fig. 3).

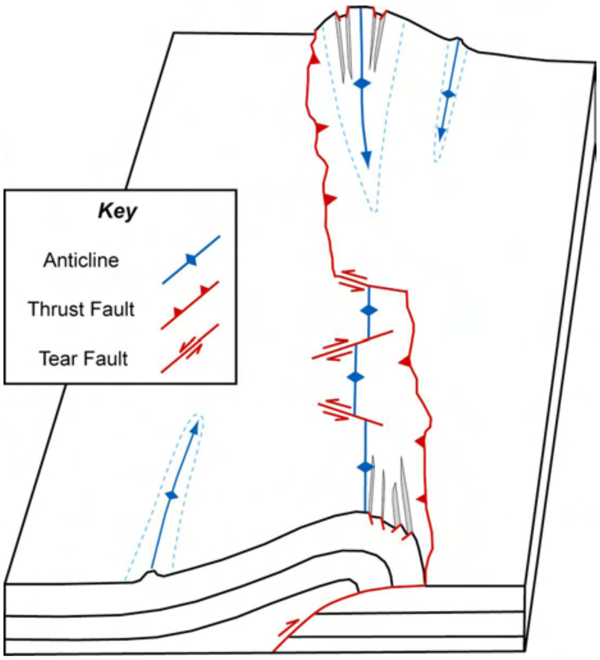

Figure 3. Illustration of suite of observed and interpreted geologic structures associated with wrinkle ridges in Solis Planum.

Mapping of Wrinkle Ridges: Dohm et al. (2001) mapped wrinkle ridges in Solis Planum as part of regional-scale study of the Thaumasia region based on a 1:5,000,000 scale Viking mosaic [9]. This mapping captures the regional fold trends, but shows each ridge as a more or less continuous fold. We remapped Solis Planum using a Viking mosaic (256 pixels/degree) overlain by partially transparent MOLA topography (128 pixels/degree) (Figs. 1, 2a). Our efforts focused on interpreting individual fold axes and capturing the highly segmented, right-stepping, en echelon nature of the wrinkle ridges (Figs. 1, 2a). The new imagery and merging of MOLA data with Viking photographic images shows consistent right-stepping en echelon arrangement of fold axes at a range of scales.

A length-weighted rose diagram (Fig. 4) shows that the overall ridge orientations (from mapping by [9]) define a tight north-northeasterly trend (025°). In contrast, individual segments display a more northerly trend (005°).

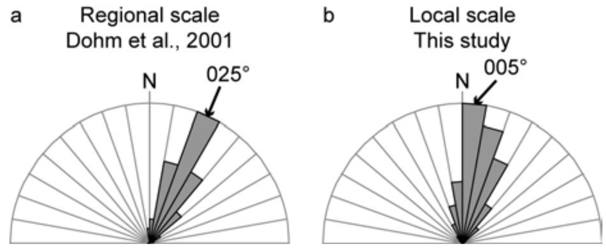

Figure 4. Rose diagrams of fold axis orientations for the area of Solis Planum shown in Fig. 1 from (a) Dohm et al., (2001) and (b) this study.

Discussion: En echelon fold patterns can be explained by strike-slip displacement approximately parallel to the arrays (trend of regional fold axes) or by reactivation of pre-existing faults in a rotated stress field. Although en echelon fold patterns commonly develop in strike-slip terranes, they are typically associated with orthogonal extensional faults/fractures, pull-apart basins, and strike-slip faults parallel or at a low angle to the array boundaries. Although strike-slip faults are mapped in Solis Planum, they are short and at a high angle to the fold axes.

A simpler explanation for the pervasive pattern of right stepping en echelon fold arrays is that the folds formed above pre-existing faults. These early faults could be extension-related normal faults [10] or reverse faults formed during a previous shortening phase. Based on our fold axis mapping and comparison of segment orientations with regional wrinkle ridge axes, we hypothesize that a 20º counter-clockwise rotation in shortening direction occurred in the context of a regional stress field rotation in Solis Planum. Further analyses of recently aquired high-resolution images and analog modeling are planned to better constain this interpretation of structural overprinting.

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