METHODOLOGY FOR COMPUTER-AIDED, INTERACTIVE RAPID ASSESSMENT OF LOCAL OR REGIONAL STRESS FIELDS. S. L. Colton[1], D. A. Ferrill[1], D. W. Sims[1], D. Y. Wyrick[1], N. M. Franklin[1], [1]CNWRA, Southwest Research Institute® (6220 Culebra Road, San Antonio, TX 78238, USA, scolton@swri.edu).

Introduction: On Earth, crustal deformation such as faulting, fracturing, and folding strongly influences surface topography, distribution and exposure of rock units, flow and accumulation of surface water, flow and entrapment of subsurface fluids (such as groundwater, oil, and natural gas), ore mineralization, climate conditions, heat flow in the crust, and seismicity. For a wide range of purposes and processes, understanding deformation features at or near the Earth's surface has been instrumental in exploring for natural resources, and for understanding the evolution of the Earth's crust and its relationship with the hydrosphere, atmosphere and mantle. Based on the many similarities between Earth and Mars, Mars deformation processes and features and the variability of resolved stresses on deformation features have a profound influence on fluid movement, related surface and subsurface mineralization, and the potential for past and present existence of life on Mars.

Deformation features on Mars, including normal faults and resulting grabens, contractional wrinkle ridges, extension fracture systems, and relatively rare strike-slip faults have been mapped in local areas of investigation and in some cases, deformation features have been analyzed in detail [1-8]. These investigations have concentrated on mechanics or statistics of particular deformation features, or on details of deformation mechanisms compared with similar features on Earth. Only a few studies focus on the larger-scale structural evolution of the crust of Mars [1,2]. In the present investigation, we focus on a range of scales, from regional patterns of deformation to the details of fault morphology, including corrugations, linkages, and interactions of faults. We have developed a methodology for detailed mapping of large-scale structural features on Mars, determination of stress orientations responsible for deformation, and analysis of resolved stresses along such structures. We present preliminary results for northern Utopia Planitia on Mars to demonstrate our approach.

Methodology: We used Mars Orbiter Laser Altimeter (MOLA) data as the basis for interpreting deformation features on Mars. MOLA data come from two sources and include (i) Mission Experiment Gridded Data Record (MEGDR), the publicly available digital terrain models at 1/64th degree pixels and 1/128th degree pixels; and (ii) Precision Experiment Data Record (PEDR), data organized along satellite orbital tracks. We prepare digital terrain models by extracting PEDR data for our selected model area, projecting the data, and gridding the data. Grid characteristics (e.g., cell size and spacing) are selected as suitable for examination of surface features, while honoring the resolution of PEDR data. The projection was chosen primarily to preserve structural orientations, while minimizing area distortion. Maps have a Mercator projection with a spheroid of radius 3396 km and latitude of true scale centered on the area of interest (e.g., 60° N for northern Utopia Planitia; Fig. 1). The resulting digital terrain model is compared to MEGDR and used to create shaded relief, contour, and slope maps, from which fault scarps are digitized. Faults are analyzed with 3DStress™, software that supports interactive evaluation of stress fields based on tendency of faults to slip or dilate under prevailing conditions. 3DStress™ has been used extensively for terrestrial geology analyses [9], and has recently been modified to allow user entry of the gravitational force, making it applicable to planetary as well as terrestrial analyses. We are currently assessing Mars stress magnitudes based on likely rock densities, depths, and gravity on Mars.

Preliminary Results for Utopia Planitia: Utopia Planitia is a large plain in the northern hemisphere of Mars, containing a partially filled basin referred to as the Utopia basin (diameter ≈ 3300-4700 km) that is thought to be the result of a giant impact during the Noachian [10,11]. Prominent geomorphic features of Utopia Planitia include impact craters, buried craters, mesas, scattered knobs, ring fractures, and polygonal terrain [10,11,12].

We mapped 64 faults with a combined length of approximately 14,000 km in the northern Utopia Basin from positive east longitude 100-150° E and areocentric latitude 47-73° N (Fig. 1a). Two dominant fault sets are present: (i) the principal set trends NW and occupies the central area of the image, (ii) the south-central area of the image shows a second population of faults that trend N-to-NE. Generally, elevation decreases from the northern to southern boundaries of the image (i.e., NW-trending fault traces are at higher elevations than N-to-NE-trending fault traces), reflecting increasing depth within the Utopia Basin. Normal faults on Mars show remarkable similarities to normal faults on Earth, including fault segmentation, *en echelon* arrangement of faults, curved fault tips, corrugations, and horsts and grabens [13]. Faults in Fig. 1a display several of these features, including corrugations and a prominent graben, indicating normal faulting is the dominant feature of northern ing is the dominant feature of northern Utopia Planitia. Fault traces in the primary set change orientation gradually from approximately N10°W in the southwest area of Fig. 1a to N30°W at the northeast area of Fig. 1a. Curvilinear faults are also found on Earth (e.g., Canyonlands), and suggest a regional variation in the stress field during propagation. The N-to-NE-trending fault set, however, intersects the primary trend at angles of approximately 30-80°, indicating that this set formed at a different time than the primary set.

Analysis of likely stress fields was conducted using 3DStress™ software. In a normal faulting regime, the maximum principal compressive stress is vertical. Our analysis suggests a stress field with σ_2 trending NW and σ_3 trending NE during nucleation of the primary (NW-trending) fault set (Fig. 1b). Under this stress field, slip tendency, the ratio of normal stress to shear stress [14], is highest on faults trending NW (i.e., perpendicular to extension). Because of the corrugations of faults, stresses resolved on the fault surface vary significantly along fault traces (Fig. 1b). Another set of faults, which trend N-NE, is interpreted to have had σ_2 trending N-NE and σ_3 trending S-SW during nucleation. Correspondingly, slip tendency in this stress field is highest on faults trending N-NE.

Summary: Stress fields are important for a wide range of reasons, including their influence on mineralization and fluid pathways. We have developed a method for rapid assessment of geologic structures and stress fields on Mars at a regional or local scale. Steps include mapping geologic structures, calculating stress fields, and determining resolved stresses on faults. Preliminary results for northern Utopia Planitia show at least two dominant fault sets that reflect regionally (or temporally) different stress directions at the time of fault nucleation.

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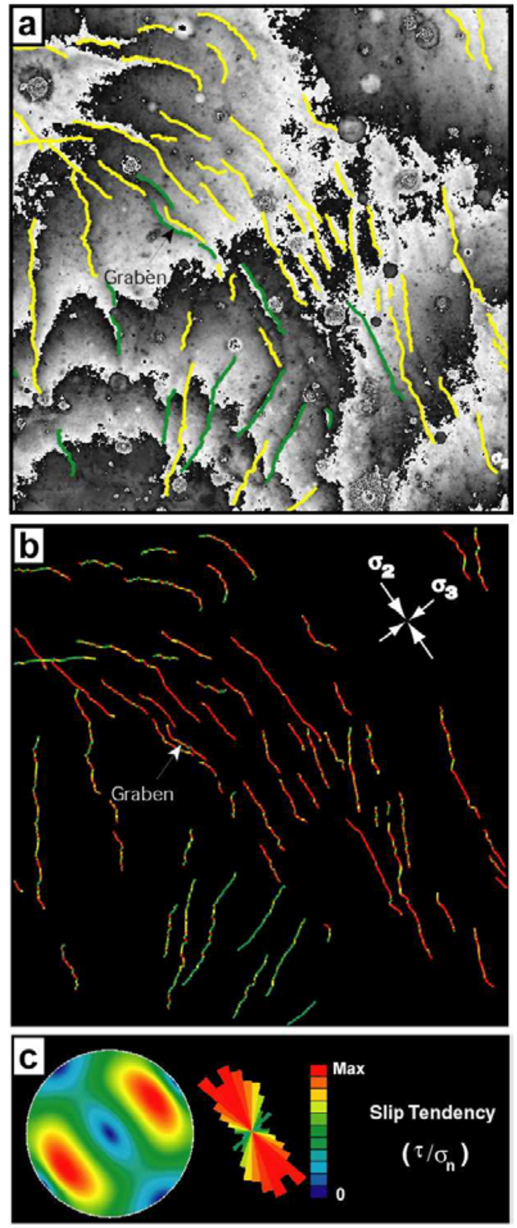

Fig. 1. (a) Fault map of northern Utopia Planitia. Faults mapped as yellow traces dip towards the western half of the compass (dip directions 180-360°), and faults mapped as green traces dip towards the eastern half of the compass (dip directions 0-180°). Longitude 120-150°E, latitude 50-70°N (b) Fault traces from (a) colored according to slip tendency. Slip tendency analysis shows at least two dominant fault populations. (c) Length-weighted rose diagram shows the dominant fault trends in northern Utopia Planitia for stress orientation shown in (b).