EXTENSION ACROSS TEMPE TERRA, MARS FROM MOLA TOPOGRAPHIC MEASUREMENTS.
B.W. Harrington[1], R.J. Phillips[1], and M.P. Golombek[2], [1]Washington University, Dept. Of Earth and Planetary Sciences, 1 Brookings Drive, St. Louis, MO 63130, bradley@geodynamics.wustl.edu, [2]Jet Propulsion Lab, California Institute of Technology, Pasadena, CA.

Introduction: Previously, methods of estimating the extension across grabens and rifts on Mars by necessity relied on photogeologic methods such as shadow measurement, crater ellipticity, or photoclinometry [1],[2]. With the new data being returned by the Mars Global Surveyor, specifically from the Mars Orbital Laser Altimeter (MOLA), it is now possible to directly measure the depths of these structures and therefore to estimate more accurately the amount of extension. Here we provide an example of this new approach in the Tempe Terra region.

Geologic Setting: Tempe Terra is located on the northeastern flank of the Tharsis volcanotectonic province. It is an ancient terrain of Noachian age which has been cratered and heavily fractured. The western margin is embayed by volcanic flows originating from Tharsis and Alba Patera while the eastern margin is buried under probable alluvium from Kasei Valles and other outflow channels.

The plateau is cut by a series of mostly north to northeast striking graben, which formed during two main stages of tectonic deformation. The older series of graben, which formed during the Middle to Late Noachian, consist of both narrow simple graben and wider, deeper rifts and complex graben. In places these structures curve around a volcanic center located near 37^{o}N, 77^{o}W. The younger, mainly Late Hesperian set of faults, strike slightly more to the west and cut across the older graben in places [3].

Extension From MOLA Depths: If the vertical structural relief (or throw), *d*, across a normal fault can be determinedand there is some knowledge of its initial dip, a, then it is possible to calculate the amount of extension or horizontal slip, E_x, between upthrown (footwall) and downthrown (hanging wall) blocks since

$$E_x = d / \tan \alpha$$

To a first approximation, the depth of the structure is the same as the throw since most of the extensional fault scarps on Mars are sharply delineated with fairly flat footwall and hanging wall blocks. Of course, this ignores any subsequent deposition or infilling of the structure.

Most extensional structures on Mars are simple grabens, which are bounded by two inward dipping normal faults, with flat floors and symmetric scarps. They are typically long (tens to hundreds of kilometers), narrow-width (a few kilometer) structures that have floors downdropped tens to hundreds of meters. Larger, complex grabens and rifts are also found on Mars. These structures are wider (up to 100 km wide) and deeper (up to a few kilometers deep) than simple grabens, with individual border faults that can have up to a kilometer or more of relief [4]. In Tempe Terra these larger rifts are less than 50 km wide and around a kilometer deep.

A variety of mechanical arguments and direct observations of simple graben fault dips on the Moon and Mars suggest faults bounding grabens on Mars dip about 60^o [4]. We have assumed this value for the faults bounding the simple graben, complex graben, and rifts. along with a large uncertainty (-±15^o) in our knowledge of the actual fault dip. This uncertainty is based on observed variations in normal fault dip on the Earth and the standard deviation of the measured simple graben fault dips on Mars.

Passes and Extension: We measured the depths along three MOLA groundtracks (214, 233, and 250) that strike N10^{o}E and intersect most of the structures at and angle of 40 degrees from perpendicular. The location of these groundtracks are shown in Figure 1, along with the location of the two traverses used by Golombek et. al. [5].

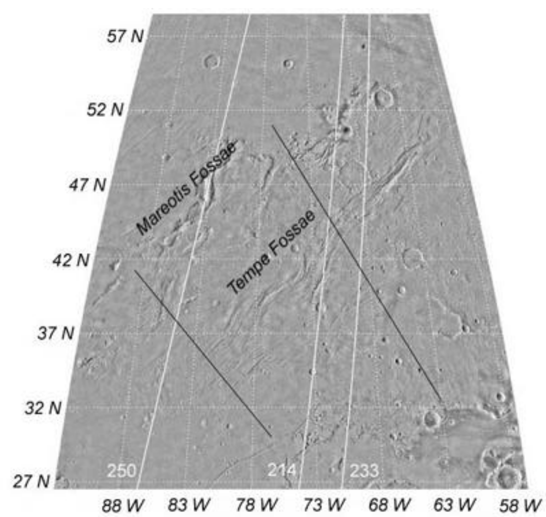

Figure 1. Tempe Terra and the locations of the three MOLA groundtracks used (white lines) as well and the two traverses used in [5] (black lines).

Pass 250 begins at (30.0^{o}N, 273.8^{o}E) intersects the southern traverse of Golombek, et al., [5] and ends at (43.0°N, 276.0°E). Passes 214 and 233 both cut across the northern traverse of Golombek, et al.., [5]. Pass 214 begins at (33.0°N, 286.5°E) and ends at (48.0°N, 289.1°E) while pass 233 begins at (34.0°N, 290.0°E) and ends at (50.0°N, 292.8°E). The depths were measured for any structures with fairly flat floors and symmetric fault scarps as well as those with asymmetric fault scarps when they could be identified from the Viking MDIM's. In all cases, an attempt was made to take mass wasting into account when choosing likely candidates and measuring scarp depths. [This sentence seems to run on. Do you take mass wasting into account only for asymmetric fault scarps. Where possible an attempt was made to correlate the structures from the MOLA groundtrack with available images of the area. However, the resolution of most of the images was too poor to resolve some of the finer structure readily seen in the MOLA groundtracks.

Along Pass 214, a total of 59 scarps were measured. The sum of the depths (12.0 km) indicates 6.9 km of extension, which results in only 0.67% strain. The majority of the extension occurred between 400 km and 600 km along the groundtrack where it crossed an intensely faulted region.

A total of 63 scarp depths were measured along Pass 233, with a total depth of 9.0 km and a resulting 5.2 km of extension or only 0.47% strain. The extension along this pass is fairly linear but does jump slightly around 750 km where it crosses the same intensely fractured terrain that pass 214 did farther to the north.

Pass 250 contained a total of 65 scarps. The total depth was 10.0 km and the extension was 5.8 km total. This results in 0.64% strain along the groundtrack. Pass 250 contains several regions of high strain which correspond to three narrow, highly faulted regions. Thus, while the overall strain is small in many places it can be locally as high as 10% to 15%.

Discussion: The strains along the groundtracks (0.67%, 0.47% and 0.64%) are significantly lower than Golombek et al. [5] who estimated strains of 2.9±2.1% and 1.7±1.3% along the southern and northern traverses respectively, as well as 1.96% from an estimate of crater elongation. Differences in the results stem from two main sources. First, many of the structures measured by Golombek et al., [5] were partially buried or even absent in the regions of the MOLA groundtrack, thus reducing the estimated strain. This problem may be circumvented by the denser MOLA coverage now becoming available. Secondly, the scarp slopes (especially those of the rifts) measured by MOLA are systematically lower than those assumed in Golombek et al. [5], , who used these slopes to estimate *d* values. The MOLA slope distribution is shown in Figure 2.

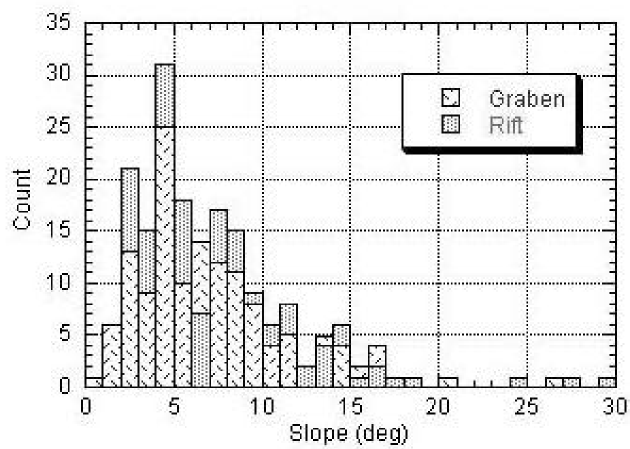

Figure 2. A plot of all the measured slopes for both graben and rift scarps.

Analysis of the strain across Tempe Terra can be compared to that predicted by various models of Tharsis formation and evolution. Ongoing work is examining the strain on Mars at a global scale and looking at the strain around Tharsis as a function of geologic age. This allows a determination of the spatial strain history of the Tharsis tectonic province as a whole.

References:

[1] Tanaka, K.L., and Davis, P.A. (1988), *JGR*, *93*, 14,893-14,917. [2] Plescia, J.B., (1991), *JGR*, *96*, 18,883-18,895. [3] Scott, D.H., and Tanaka, K.L, (1986), *U.S. Geol. Surv. Misc. Inv. Ser. Map*. I-1802-4. Scale 1:15,000,000. [4] Banerdt, W.B., Golombek, M.P., and Tanaka, K.L., (1992), *Stress and Tectonics on Mars*, Chapter 8, in *MARS*, edited by H.H.Keifer, B.M Jakosky, C.W. Snyder, and M.S. Matthews, pp. 249-297, Univ. of Ariz. Press, Tuscon. [5] Golombek, M.P., Tanaka, K.L., and Franklin B.J., (1996), *JGR*, *101*, 26,119-26,130.