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EXTENSION AND STRAIN IN NORTHERN THARSIS; J. B. Plescia, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109

The northern areas of Tharsis, south of Alba Patera, are remarkable in that they are dominated by extensive, generally north-trending graben. Some graben are small isolated features whereas others are complex overlapping features in which individual fault pairs are impossible to separate. This pattern indicates an east-west extensional stress regime, consistent with stress models for Tharsis [1].

To estimate the regional east-west extension and strain, graben along a profile at 35°N latitude, between longitudes 135° and 93° were studied. This profile (about 1800 km long) was chosen because the graben have a northerly trend, the structures are relatively simple, the profile is anchored to ancient Noachian age crust, and high resolution images are available. The western end of the profile begins at Acheron Fossae (long. 135°W) and ends in the east at the southwestern part of Tempe Fossae (long. 93°W. Plains units cut by the graben include Hesperian- and Amazonian-age members of the Alba Patera and Ceraunius Fossae Formations [2,3,4]. The ages of the faults have been studied [4]; all are Stage III faults--early Amazonian (700-1800 my) in age.

Study of graben morphometry allows an estimation of the extension and strain. Martian graben are almost certainly similar in nature to terrestrial graben--i.e., brittle extension of the crust along normal faults dipping at about 60° toward the center of the graben [5,6]. For each graben the width and depth were measured. Using this data and assuming a 60° fault dip, the extension and the thickness of the faulted layer (the depth at which the graben-bounding faults intersect) were calculated. Depth measurements were obtained by use of shadow measurements and photoclinometry [7]. Shadow measurements were derived using the solar incidence angle at the location of the measurement (obtained from SEDR data) and counting shadowed pixels. The length of the shadow could be overestimated by a maximum of 2 pixels, though 1 pixel is probably a better limit. Typical incidence angles were 70° and typical pixel scales were 75 m/pixel, resulting in an uncertainty of 25 m in the estimated depth. For those graben that did not have shadows, photoclinometric profiles were used to estimate depths. Corrections for atmospheric haze were determined for each frame from true shadows elsewhere in the scene. Photoclinometric depths have an uncertainty of about 10-15% [8].

Observed wall slopes were considerably less than the 60° fault dip assumed. The difference between the observed and expected slopes indicate that either the walls have been subjected to scarp erosion or the controlling faults have a low dip. Scarp retreat would be expected in any geologic environment and is observed for terrestrial, lunar, and martian graben; whether the faults are shallower than expected is unknown, but estimates for normal faults elsewhere on Mars [6] suggest that they have steep dips near 60°. If however, the faults do dip at a more shallow angle, then the amount of extension across the graben would be greater than that estimated here (about a factor of 5 for a 20° dipping fault).

Data were collected within 2°-3° latitude of 35°N and averaged for each graben. Average measured graben widths ranged from 979 to 8661 m with a mean value of 3652 m; graben depths ranged from 10 to 636 m with a mean value of 117 m. The corresponding extension ranged from 11 to 734 m with a mean value of 135 m. Total cumulative extension along the profile amounts to 8062 m and would correspond to a regional strain of 0.0045 (0.45%). This value is a minimum because data was not obtained for a few small graben and a 60° fault dip was assumed; the addition from the other grabens is negligible; but shallower fault dips would produce a corresponding

increase in the extension. The thickness of the faulted layer varies across the region, ranging from about 848 to 7500 m. The morphometry of the graben are not uniform along the profile. Graben along the eastern and western ends of the profile (west of 115° and east of 100°) are narrow (<3000 m), shallow (<150 m) and with small extension (<100 m). Between 115° and 100° (maximum at about 109°) the graben are much larger; widths up to 8000 m, depths in excess of 500 m, and extensions in excess of 500 m occur in a narrow band. Within this central zone, strains (as calculated from the individual graben extension and the preextension graben width) range from 2 to 9%, compared with 2% or less to the east and west. The thickness of the faulted layer is also at a maximum near longitude 110°, about 3-7 km whereas to the east and west it is much shallower at about 2 km.

Extension, strain, and morphology all vary across the profile with the extremes occurring in the center near longitude 110°. This region has clearly experienced considerably greater deformation than adjacent areas and could reflect either a variation in the stress field or the response of the material. This area lies directly north of the intensely fractured Ceraunius Fossae area--a locally high area extensively cut by north-trending graben (Stage II faulting; 3-3.5 by [4]). The geology would suggest that many of the young faults examined here are a reactivation of older structures now buried by the volcanic plains.

Morphometric data for graben at 35°N between longitudes 135° and 93° indicate post early Amazonian cumulative east-west extension of about 8062 m corresponding to a regionally averaged extensional strain of 0.45%. Extension and strain are at concentrated near longitude 110°W where local strains in excess of 5% are observed. All of the extension is oriented in an east west direction.

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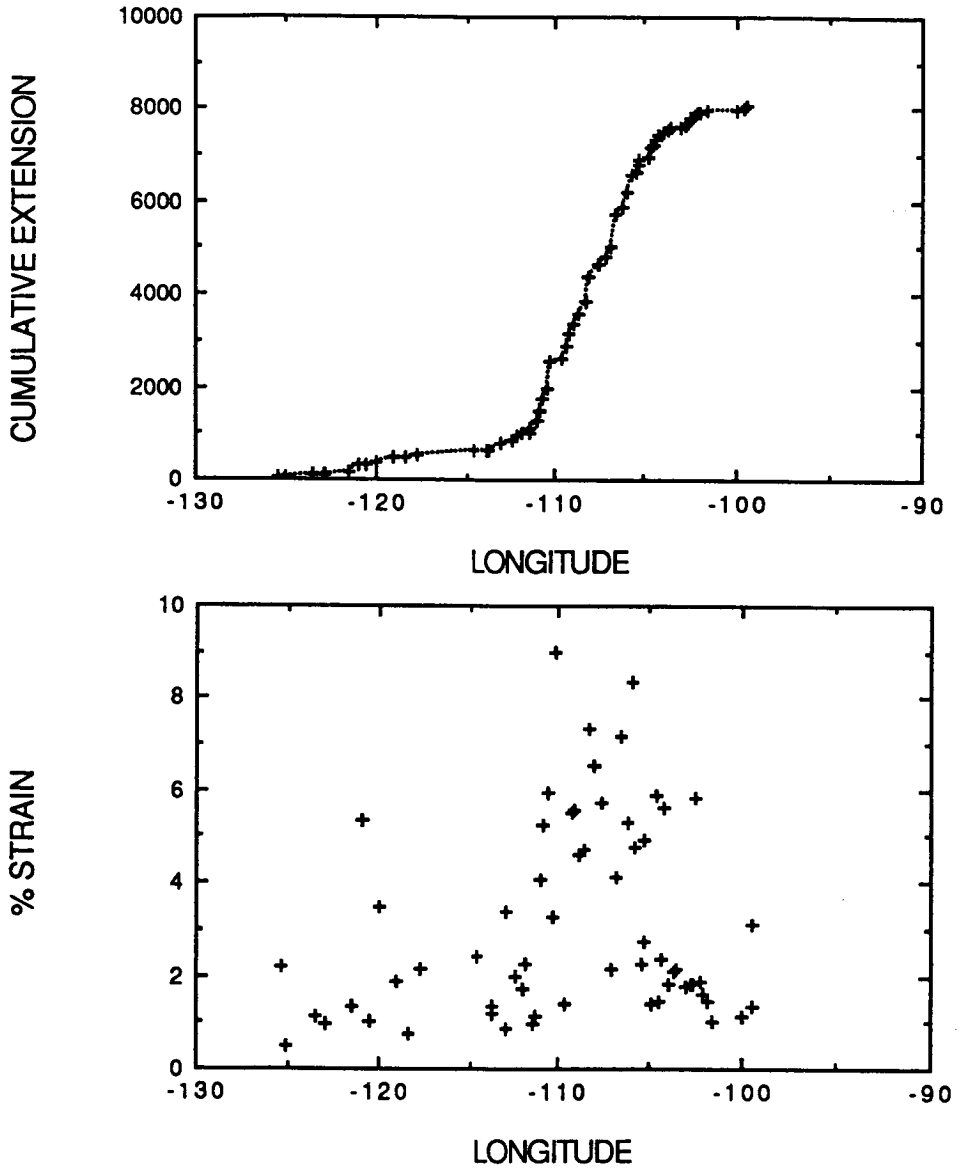
Figure Captions: Upper panel shows the cumulative extension across the profile. Crosses represent values for individual graben. Extension is expressed in an east-west direction having been corrected for the strike of the graben. Lower panel shows the amount of extensional strain across individual graben as a function of longitude.


CUMULATIVE EXTENSION
10000
8000
6000
4000
2000
0
-130
-120
-110
-100
-90
LONGITUDE
% STRAIN
10
8
6
4
2
0
-130
-120
-110
-100
-90
LONGITUDE