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Displacement-length relationship of normal faults in Acheron Fossae, Mars: new observations with HRSC.

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For Earth, data sets and models have shown that for a fault loaded by a constant remote stress, the maximum displacement on the fault is linearly related to its length by $d = \gamma \cdot l$ [1]. The scaling and structure is self-similar through time [1]. The displacement-length relationship can provide useful information about the tectonic regime. We intend to use it to estimate the seismic moment released during the formation of Martian fault systems and to improve the seismicity model [2].

Only few data sets have been measured for extraterrestrial faults. One reason is the limited number of reliable topographic data sets. We used high-resolution Digital Elevation Models (DEM) [3] derived from HRSC image data taken from Mars Express orbit 1437. This orbit covers an area in the Acheron Fossae region, a rift-like graben system north of Olympus Mons with a "banana"-shaped topography [4]. It has a fault trend which runs approximately WNW-ESE.

With an interactive IDL-based software tool [5] we measured the fault length and the vertical offset for 34 faults. We evaluated the height profile by plotting the fault lengths l vs. their observed maximum displacement (d_{max}-model). Additionally, we computed the maximum displacement of an elliptical fault scarp where the plane has the same area as in the observed case (elliptical model). The integration over the entire fault length necessary for the computation of the area supresses the "noise" introduced by local topographic effects like erosion or cratering.

We should also mention that fault planes dipping 60° are usually assumed for Mars [e.g., 6] and even shallower dips have been found for normal fault planes [7]. This dip angle is used to compute displacement from vertical offset via $d = \frac{h}{\sin\alpha}$, where h is the observed topographic step height, and α is the fault dip angle.

If fault dip angles of $30°$ are considered, the displacement differs by 40% from the one of dip angles of $60°$. Depending on the data quality, especially the lighting conditions in the region, different errors can be made by determining the various values. Based on our experiences, we estimate that the error measuring the length of the fault is smaller than 10% and that the measurement error of the offset is smaller than 5%. Furthermore the horizontal resolution of the HRSC images is 12.5 m/pixel or 25 m/pixel and of the DEM derived from HRSC images 50 m/pixel because of re-sampling. That means that image resolution does not introduce a significant error at fault lengths in kilometer range.

For the case of Mars it is known that in the growth of fault populations linkage is an essential process [8]. We obtained the $\frac{d}{l}$-values from selected examples of faults that were connected via a relay ramp. The error of ignoring an existing fault linkage is 20% to 50% if the elliptical fault model is used and 30% to 50% if only the dmax value is used to determine $\frac{d}{l}$. This shows an advantage of the elliptic model. The error increases if more faults are linked, because the underestimation of the relevant length gets worse the longer the linked system is.

We obtained a value of $\gamma = \frac{d}{l}$ of about $2 \cdot 10^{-2}$ for the elliptic model and a value of approximately $2.7 \cdot 10^{-2}$ for the d_{max}-model. The data show a relatively large scatter, but they can be compared to data from terrestrial faults ($\frac{d}{l} =\sim 1 \cdot 10^{-2} ... 5 \cdot 10^{-2}$; [9] and references therein). In a first inspection of the Acheron Fossae 2 region in the orbit 1437 we could confirm our first observations [10]. If we consider fault linkage the $\frac{d}{l}$-values shift towards lower $\frac{d}{l}$-ratios, since linkage means that d remains essentially constant, but l increases significantly. We will continue to measure other faults and obtain values for linked faults and relay ramps.

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