ANALYSIS OF UNUSUAL FAULT STRUCTURES IN TERRA CIMMERIA, MARS.

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Introduction: Most major geologic structures on Mars are related to a major volcanic province (Tharsis, Elysium) or a large impact basin. It is of interest then to identify and study tectonic features not attributable to known volcanic provinces or impact basins. Located in the central Terra Cimmeria region of the Southern Highlands of Mars is a set of linear scarps not clearly associated with major known tectonic provinces. Several scarps exhibit relief in excess of 500 meters and the set displays a consistent NE-SW trend for over 1500 kilometers. The analysis of these scarps of undefined origin is divided into three parts. The first element is mapping and characterization of the observable scarps. The next is construction of a geologic history aided by the determination of the relative age of the scarp set by use of crater counts and cross cutting relationships. The final point is to incorporate the formation of this scarp set into the account of Mars' geological evolution.

Methodology: Using data from Mars Global Surveyor (MGS) and imagery from the Viking missions, the scarps were mapped and characterized by recording data in tabular form. Attributes measured include relief, azimuth, dip direction, and length. The bounding coordinates of the study area are 35S to 70S and 100E to 170E. Topographic data from the Mars Orbiter Laser Altimeter (MOLA) was used at a resolution of 64 pixels/degree. A mosaic of Viking mission imagery was used at a resolution of 256 pixels/degree. To augment the Viking imagery, Mars Orbiter Camera (MOC) wide-angle images were also imported at a resolution of 256 pixels/degree.

We conducted a crater count of the region to date the surface on which the scarps developed. Using Viking imagery spanning an area of 2.2×10^6 km^2 in central Terra Cimmeria, the diameters (D) of 937 craters were recorded. The diameter values were placed in $\sqrt{2}$ bins ranging from 4 km to 256 km. An additional count was completed in Sabaea northwest of Hellas Planitia to date the scarp formation relative to the surface created by the ejection of material from the Hellas impact. Here the diameters of 585 craters were measured over an area of 7.8×10^5 km^2. Figure 3 shows an incremental size frequency distribution of both counts compared to isochrons from Hartmann[1].

To correlate scarp development with the Terra Cimmeria crater count, we assume that we can estimate the age of scarp formation as a percentage of the age of the cratered surface by discerning the percentage of unfaulted scarp-crossing craters. We first mapped all craters that cross scarps. Using topographic profiles and both MOC and Viking imagery we determined whether or not each crater was faulted. Through this examination we obtained a percentage value that yields the age of scarp development relative to the Terra Cimmeria crater count and thus relative to other features on Mars.

Results: The mean strike of 159 measured features is N35^{0}E when azimuth values are graphed on a rose plot with 10^0 bins (Figure 1). The maximum observed relief was 1050m, while scarps with relief as little as 25 meters were mapped. The maximum length of a continuous scarp was 309 kilometers, while the peak slope observed was 18^0. Of the mapped scarps 67 exhibited a northwesterly dip while 62 displayed southeasterly dips. The remaining 30 were mapped as asymmetrical ridges.

Figure 1: Rose Plot of 159 Scarps in 10^0 bins.

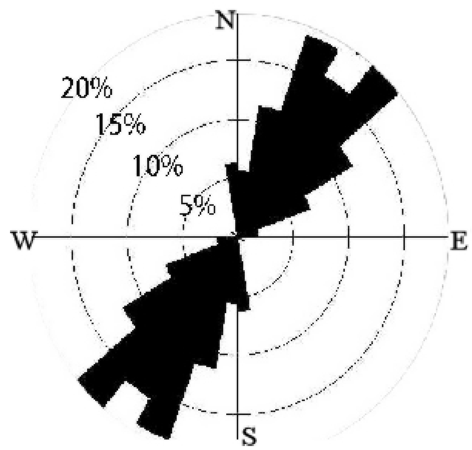
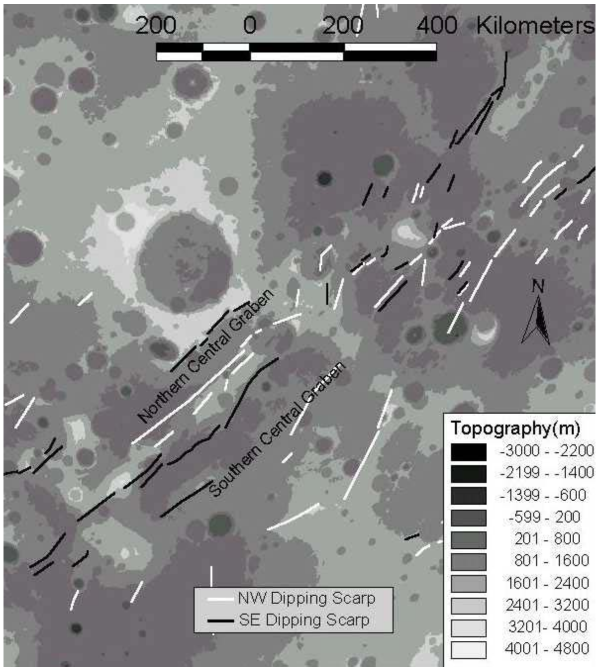


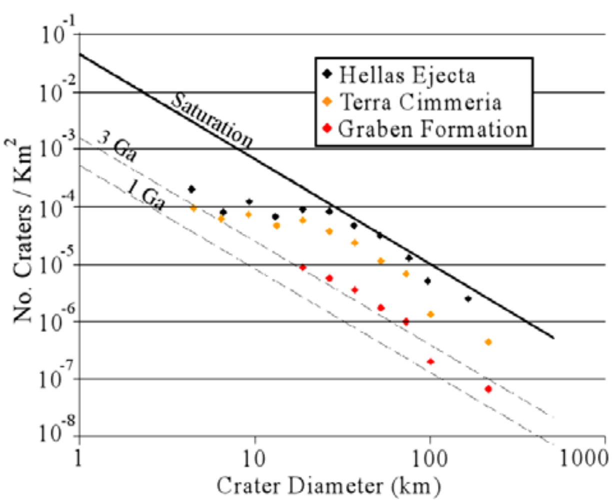
Figure 2 illustrates the map pattern of identified scarps. They outline a broad graben ~1500 km in length bounded by normal faults. The structure exhibits no regional dip with floor elevations varying from 500-1200 m throughout its length. The graben is bound to the south by the highlands of eastern Promethe Terra. Cross sections reveal elevations consistently in excess of 2000 meters to both the east and west, but variations occur. Subdividing this regional graben are two central parallel grabens ~410 km in length (Figure 2). They are bound to the north and south by broad topographic swells and are centrally divided by a horst. Both grabens display a subtle southwest dip. The northern graben exhibits floor elevations of 400m to 1350 m yielding a southwesterly dip of 0.2^0. The southern central graben exhibits a regional dip of 0.13^0 with floor elevations ranging from 300 to 1000m.

Figure 2: Scarps with Topography



The Terra Cimmeria crater count yields an age of ~3.7Ga when compared to Mars crater count isochrones, while the Hellas ejecta count yields a relatively older age approaching saturation. (Figure 3)[1]. The incremental size frequency distribution plot of identified craters displays a shallowing of slope at

Figure 3: Incremental Size Frequency Distribution Compared to Mars Crater Count Isochrons.



D<16. This suggests that infilling or erosion has removed a portion of this population. Craters where D>16 closely fall on a line of slope –2. Based on the linearity of the incremental size frequency plot in bins of D>16, D values of 16 or greater were used to date scarp formation. In bins of diameter greater than 16km in the Terra Cimmeria count, 20% of scarp crossing craters remain unfaulted. Therefore scarp development occurred prior to the deposition of 20% of the craters. This yields a value of ~3Ga for the age of scarp development (Figure 3). This age is significantly younger than the crater count age for the Hellas impact.

Interpretation: In Hesperia Planum located to the Northwest of Terra Cimmeria, Goudy and Gregg[2] mapped an orthogonal pair of wrinkle ridge sets, one radial to the Hellas Basin and one oriented concentrically to it noting that they were formed by the Hellas impact. The scarps observed in central Terra Cimmeria are not radial to the Hellas Basin, nor are they concentric to it. In addition, no cohesive orthogonal set exists as in Hesperia Planum. These observations coupled with the differing ages denoted by the crater count analysis suggest that the scarps in Terra Cimmeria originated from a mechanism other than the Hellas impact. Another possible origin of scarp formation is the Tharsis Bulge. While radial features are observable at a considerable distance from Tharsis in Terra Sirenum, the scarps in central Terra Cimmeria are not radial to Tharsis. This leads to the conclusion that the scarps are not associated with the Tharsis Bulge. While not solidly linked to the impact that formed the Hellas Basin or Tharsis, the scarps are radial to the caldera of Apollinaris Patera suggesting a possible association.

The map pattern of identified scarps produces an alternating set of Northwest and Southeast dipping features defining a horst and graben province or rift zone (Figure 2). The features must also be associated with some crustal heating because the graben is associated with a reduction in the magnetic field strength. This implies a shallowing of the depth to the Curie point. This crustal heating argues against surficial processes as an origin for the scarps and suggests that the faulting and subsequent extension required to produce the graben be deep in origin.

The disruption of the magnetic field data indicates that the faulting episode postdates the magnetic stripes in the Southern Highlands. Coupled with the crater count analysis we can infer that the graben structure was formed in the late Noachian. Further work will involve investigating the gravity data for the region and exploring the possible association of the graben structure with Apollinaris Patera.

References: [1] W.K. Hartmann (1999) Meteoritics and Planetary Science 34, 167-177. [2] C.L. Goudy and Tracy K.P. Gregg (2001), LPSC XXXII, 1393.