LINEAR RIDGES IN THE NILOSYRTIS REGION OF MARS: IMPLICATIONS FOR SUBSURFACE FLUID FLOW.

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Introduction: A large number of linear ridges, hundreds of meters to kilometers in length and meters high, are exposed in the Nilosyrtis Highlands and Nili Fossae on Mars. These ridges have been identified by a number of researchers [e.g. Head and Mustard 2004. Mustard et al., 2009; Ivanov et al., 2011] and may be of impact, volcanic, tectonic, glacial, or hydrologic origin. First hypothesized to be impact related deformation structures and breccia dikes exhumed by erosion [1], detailed mappying with CTX data led to the hypothesis that these ridges are erosionally exposed impact-related fractures, faults, or deformation bands that hardened relative to the host rock; a phyllosilicate-bearing unit. [2].

This project substantially expands on the work by Saper and Mustard [2] regarding the ridges and their orientations in Nili Fossae, extending the study to the Nilosyrtis Highlands. Analysis was continued to determine if their hypothesis of mineralized impact fractions extended to the broader region. Ridge density and elevation with respect to the topography were calculated in this study.

Methodology: The area Northwest of Nili Fossae, from approximately 27°N-33°N and 70°E-73°E (Region C) was mapped for this study (Regions A and B were mapped by Saper in a previous study [2]) (Figure 1). Ridges were digitized at a scale of 1:20,000 in ArcMap on CTX images calibrated and processed in ISIS. Saper and Mustard's [2] criteria for mapping ridges states they are "sharply tapered linear to curvilinear features…that express topographic relief…[and] often bifurcate at orthogonal to suborthogonal angles and can form interconnected networks" [2]. Some capping material, defined as the smooth, overlying and uneroded strata near ridges, was also digitized (Figure 2) [2,3,4]. The density of ridges was determined for all regions of the study and compared to the topography, obtained from HRSC DTMs (Figure 2). In addition, a histogram of the elevation of ridges (and capping material in Region C) with respect to topography was produced (Figure 3).

Results: A total of 3662 ridges were mapped in Region C, which is 40,090 km^2 in area. The total range of elevation was from -8000 m to 1000 m. The elevation of ridges in Region C varied from -7500 m to -2000 m, and the ridges in all Regions A, B, and C varied from -7500 m to -1500 m. Ridges showed a bimodal distribution with one concentraton of ridges between -4000 m and -3500 m and the other between -3000 m and -2500 m. The capping material (only partially mapped in Region C) varied in elevation from -5500 m to -2500 m, and peaked between -3500 m and -3000 m. The highest density of ridges was in craters and on the rims of topographic highs. Very few ridges were found north of 31°N because of the obscuration of the surface by the well studied latitude dependent mantle (e.g. [5]).

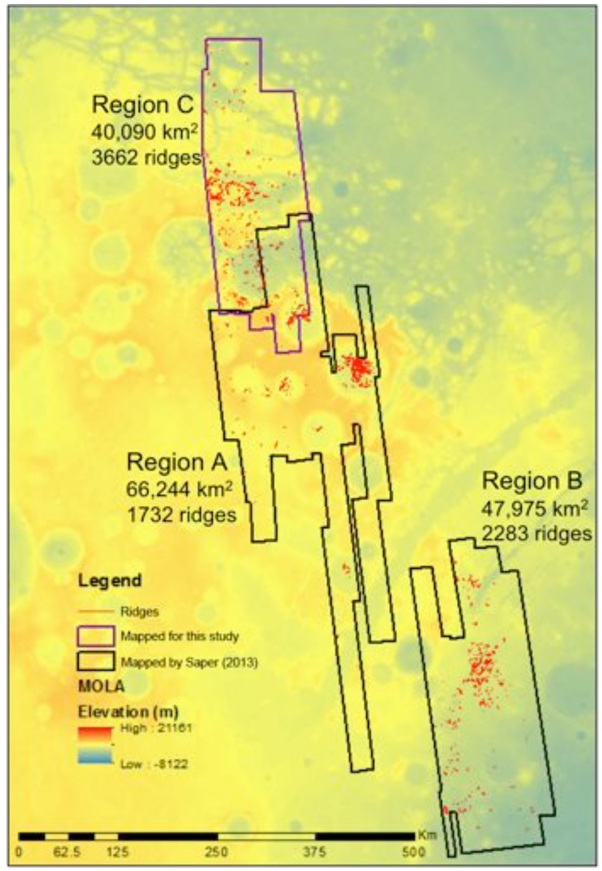

Figure 1: Mars Orbiting Laser Altimeter (MOLA) elevation maps of regional topography around all mapping areas: Regions A, B, and C. Regions A and B were mapped by Saper in the Nilosyrtis Highlands and the Nili Fossae, and Region C was mapped for this study in the Nilosyrtis Highlands and Mensae.

Discussion: The results from this study support Saper's theory of ridge formation. The elevation of capping material is greater than the elevation of ridges, which supports the hypothesis that ridges lie under the capping material and are visible on the surface when exposed via erosion of the capping material. In addition, the ridges are most dense in craters and around

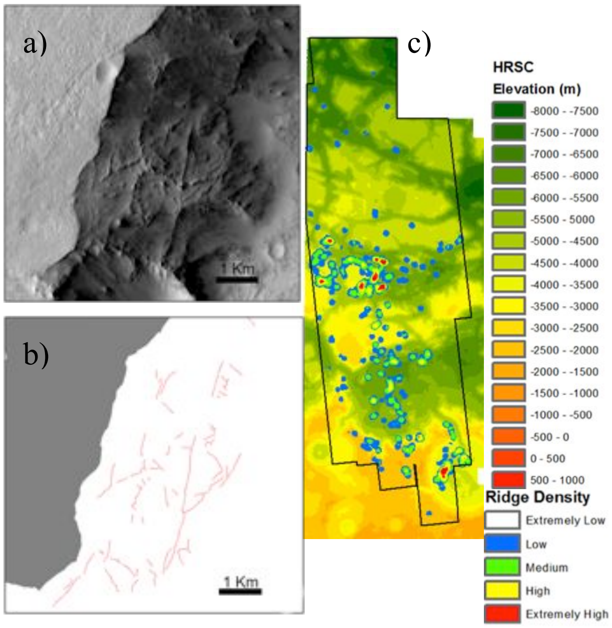

Figure 2: a) CTX and b) digitized images of ridge networks (red lines) and capping material (grey area) in G23_027335_2097_XN_29N288W, and c) density of ridges in Region C with HRSC topography.

topographic highs, supporting Saper's hypothesis that ridge formation is a product of crater formation.

However, the ridges are evenly distributed across the elevation range of the study, and there are many ridges found outside of individual craters and instead around topographic highs, below eroded capping material. This is true for both Regions B and C. Therefore, there might be another formation process associated with ridge networks. Saper and Mustard considrered the ridges to be mineralized fracture zones from fluids circulating in fractures from the Isidis impact Basin formation, but a possible alternative is that other impacts of lesser size fractured the crust and also contributed to ridge formation by fluid mineralization, after the Isidis Basin formed.

It is also important to note that the ridges were controlled by regional latitude because very few ridges were found north of 31°N. Latitude dependent terrain – ground ice in the crust and soil between 30°-60° in both hemispheres [5] – may have permeated and cemented the ground, inhibiting erosion and/or blanketed the region with a meters-thick mantle.

There are implications from this study for Martian hydrology, particularly because the linear ridge networks are confined to a phyllosilicate-bearing clay unit. Impact-induced fracture and faulting, which is hypothesized to have created the ridge network features currently exposed on the surface, may have supported regional-scale groundwater circulation. Thus, overlapping fracture zones and a multitude of large impact events could have maintained a large-scale interconnected hydrologic network, making it a possibility that the early crust of Mars was hydrothermally active [2].

Further studies will be conducted to achieve more quantitative results. Density and elevation analysis will be continued and extended to the northwest where there are more exposed ridges. The relationship between ridges and regional stress, as completed by [2] may also be calculated. The angles between ridge intersections will also be measured because if they are orthogonal it will further show that these ridges formed by fluid mineralization in a fracture.

References: [1] Mustard J.F. et al. (2009) *Journal of Geophysical Research 114* [2] Saper L.M. and Mustard J.F. (2013) *Geophysical Research Letters 40.2, 245-249* [3] Mustard J.F. et al. (2007) *Journal of Geophysical Research 112* [4] Head J.W. and Mustard J.F. (2006) *Meteoritics & Planetary Science 41.10, 1675-1690* [5] Rifkin M.K. et al. (2001) *Nature 412, 411-414*

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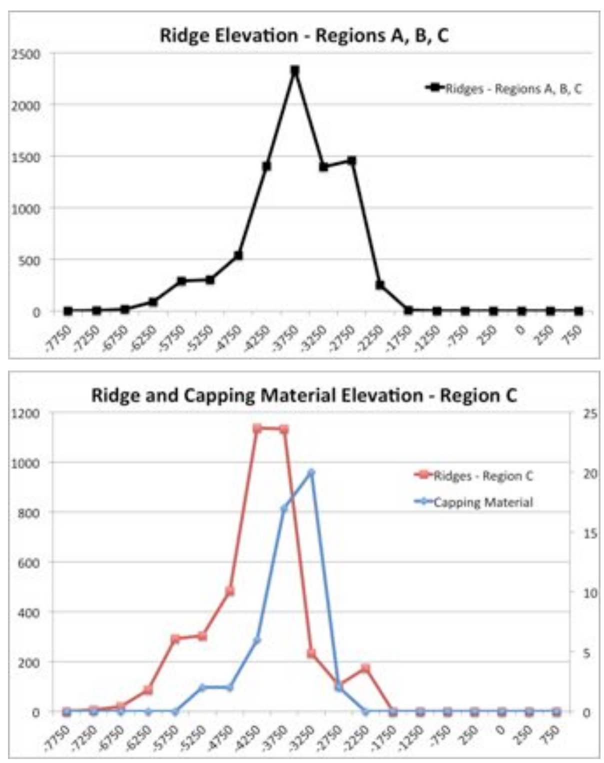

Figure 3: Elevation of a) ridges and capping material in Region C and b) of ridges in Regions A, B, anc C. Capping material is at a higher elevation than the ridges, and over all three regions there is a bimodal distribution of ridges