ANALYSIS OF THE FIRST-ORDER MECHANICS OF POLYGONAL FAULT NETWORKS: EARTH & UTOPIA PLANITIA, MARS. Fariha Islam, Michele L. Cooke and George E. McGill, Department of Geosciences, University of Massachusetts, Amherst, MA, (fislam@geo.umass.edu).

Introduction: The giant polygons of Utopia Planitia, Mars are characterized by troughs tens of meters deep that define polygonal fault networks with 1 to 30 km spacing between troughs [Figure 1]. A number of hypotheses for their origin have been proposed such as desiccation of water saturated sediments, thermal cooling and contraction in permafrost, cooling of lava, and tectonic deformation. Pechmann [1] has demonstrated that none of these terrestrial analogs would lead to a satisfactory description of the mechanisms and scales involved on Mars.

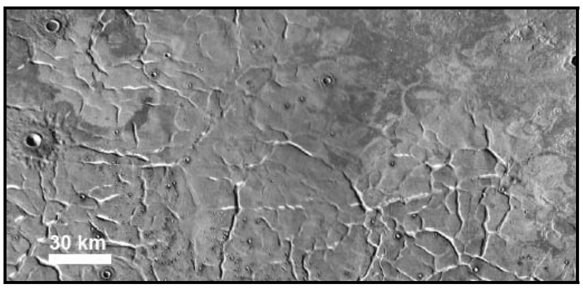


Figure 1: THEMIS Daytime Infrared Mosaic of a region in the Utopia Basin [19].

Polygonal fault networks have been found in layers of mudrocks and chalks beneath oceans in sedimentary basins around the world [Figure 2]. These terrestrial polygons were first documented in Lower Tertiary mudrocks from the North Sea Basin by Cartwright [2]; 28 basins have currently been identified by seismic studies to have extensive fault systems defining polygons with diameters up to 3 km. Earth polygonal terrains are located on passive margins in onlap units that are generally comprised of very fine-grained sediments [2,3,4,5,6,7,8]. The overlap in scale between the 3 km terrestrial polygons and the giant polygons of Mars suggests that they may have similar origins.

Geologic Background: A number of observations support a water-laid sedimentary origin for the materials where the giant martian polygons occur [9,10,11, 12,13,14,15]. On Earth, the North Sea polygons form in a sequence of volcanic mudrocks derived from altered volcanic glass [7], which may be a possible model for the martian polygonal terrain materials. The spacing of major faults suggests a correlation of polygon diameter with layer thickness. North Sea polygons exhibit isotropic strain patterns in plan view with approximately 20% apparent areal extension within any one layer [3]. Cartwright and Lonergan [3,6] propose that volumetric contraction is the most reasonable explanation for the apparent extension.

McGill and Hills [16] suggested that differential compaction, desiccation shrinkage of wet sediments, could produce the grabens in Utopia Planitia over buried topographic highs. The scale of the giant polygons is thus determined by the topography of the underlying surface.

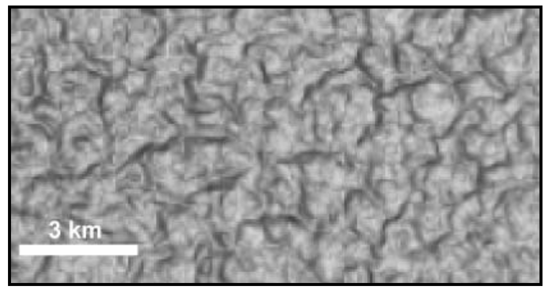


Figure 2: Seismic map of a polygonal network in sediments in the Lower Congo Basin [8].

Using Fric2D, a Boundary Element Method (BEM) modeling code, Buczkowski and Cooke [17] have also shown that volumetric compaction is a feasible model for the development of faults associated with buried craters within Utopia. Volumetric contraction seems to accommodate the extensional faulting observed in earth polygonal terrains and the giant martian polygonal terrains.

Using a 100m/pixel THEMIS Infrared Daytime mosaic [19] of Utopia, we measured average surface trough spacing of the giant polygons along radial transects from the center of the basin. The average trough spacing ranges from 5 – 6.5 km, depending on the specific transect. If trough spacing correlates to layer thickness, as with the North Sea, the thickness of sediments in this area should be 5-6.5 km thick. This is larger than the 1-2 km thickness expected along the edges of the Utopia Basin [15,17]. Consequently, buried topography may be controlling trough spacing more than layer thickness.

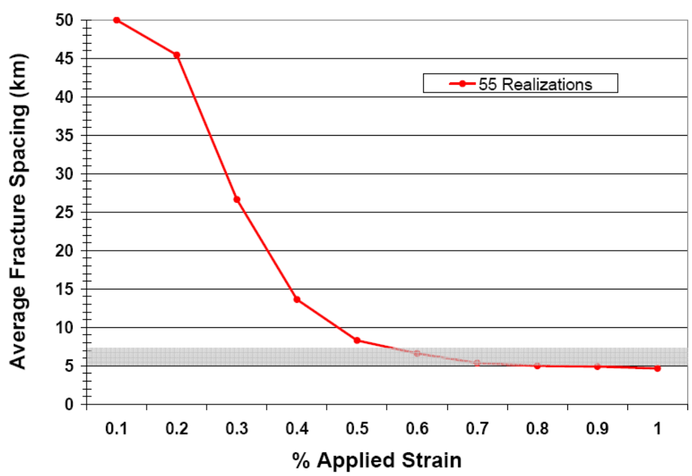
Model: In order to understand whether basement topography may account for the spacing of the giant polygons, we use BEM models to simulate the first-order mechanics of the faulting process. Our Fric2D cross-sectional models use material properties for wet, fine sediment to simulate a water-laid depositional environment. The model is 1 & 2 km in height, and 50 km in length to encompass typical diameters of the giant polygons. The model deforms under horizontal extension, which simulates volumetric contraction.

Earlier researchers have inferred that the underlying topography of the Northern Lowlands is similar to the topography of the older, Southern Highlands [16,20]. Within the model, fracture seeds of variable lengths are evenly placed along the base of the model to represent the underlying uneven topography observed in the Highlands. 30 MOLA tracks were selected from an arbitrarily chosen section of the Highlands to simulate the topography beneath Utopia. The absolute value in the change in slope from one shot point along the track to the next point follows a power-law distribution; there are many small changes in elevation (with a resolution limit of 5m) and relatively few large changes in elevation. This power-law distribution was used to constrain the length of the fracture seeds along the base of the model. The fracture seeds were spaced 300m apart, the distance between shot points along a MOLA track.

Individual fractures grow by fracture propagation when the stress intensity at the fracture tip exceeds the fracture toughness of the material. Although the putative grabens that form the polygonal terrain develop via pairs of normal faults that differ from the opening-mode fractures investigated here, the first order mechanics of propagation are similar. The overall patterns of grabens are matched within the models with opening mode fractures [18,21]. Consequently, the spacing of opening mode fractures that reach the upper surface of the model can be compared to the spacing of troughs within the polygonal terrain on Mars.

Findings and Conclusions: Many realizations with the power-law distribution of fracture seeds were used in order to explore the statistical robustness of the findings. The results of 55 realizations further support the premise that spacing between troughs within the polygonal terrain reflects buried topography. The average surface fracture spacing for the 1 km model is ~5km, on the order of the measured trough spacing in Utopia [Figure 3]. The model results show that largest buried topographic irregularities control the spacing of the faults that grow to the surface [16] rather than layer thickness. The applied strain that produces martian scale polygons is below the 20% extensional strain proposed for the Utopia Basin [16], and the North Sea [3]. However, the low strain implied by model results is in order to produce surface fracture spacing only; the model does not address the strain required to produce faults with displacement. Future work involves measuring trough spacing as a function of distance from the center of the basin and an investigation of surface fracture spacing using other material properties.

Figure 3: Results of 55 realization of our 1 km Highlands basement topography model. Gray shaded area represents the measured trough spacing in Utopia along radial transects (5-6.5 km).



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