BOUNDARY ELEMENT MODELLING OF THE POLYGONAL FAULT NETWORKS OF UTOPIA PLANITIA.
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Introduction: The giant polygons of Utopia Planitia, Mars are characterized by troughs tens of meters deep that define polygonal fault networks that have 1 to 30 km spacing between troughs. 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.

Polygonal fault networks have been found in layers of mudrocks and chalks beneath oceans in sedimentary basins around the world. These terrestrial polygons were first documented in Lower Tertiary mudrocks from the North Sea Basin by Cartwright [2]; 28 basins have currently been identified through 2D and 3D seismic studies to have extensive fault systems defining polygons with diameters up to 1 km. Earth polygonal terrains are located on passive margins in onlap fill units and are generally comprised of very fine-grained sediments [2,3,4,5,6,7,8]. The overlap in scale between the 1 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. Polygonal terrains occur in the lowest parts of the northern lowland, the most logical places for water to pond and sediments to accumulate if oceans or large lakes did occur [9,10,11]. Craters superposed on these terrains are dominantly characterized by fluidized ejecta, generally thought to be due to significant volatile content in the target material [12]. The upper elevation limit for polygonal terrain exposures along the south flank of the Utopia Basin occurs close to an elevation of -4350 meters [13], approximately coinciding with a topographic terrace along the flank of the Utopia Basin that has been interpreted to be a paleoshoreline [14]. Utopia Planitia is thought to be covered with sedimentary and volcanic material by Tanaka [15]. Luchitta et al. [9] support the material being of sedimentary origin deposited in a standing body of water.

On Earth, the North Sea polygons form in a sequence of smectite-rich volcanic mudrocks produced from altered volcanic glass [7] and thus may be a possible model for the martian polygonal terrains materials. Sub-sea polygonal terrains on Earth occur in decoupled tiers associated with vertical and lateral lithological variations, with the largest fractures crossing multiple lithological units [2]. Major faults cut through two or more tiers and are widely spaced, suggesting a direct correlation of polygon width with layer thickness. The minor faults are confined within polygons defined by major faults, and thus are inferred to be younger [5]. If these sedimentary basins are an analog for the giant martian polygons, fracture sets from multiple tiers on Mars may be present. Current research is addressing this possibility.

North Sea polygons exhibit radial strain patterns in plan view with approximately 20% apparent areal extension within any one layer [4]. The deformation is layer bound and there is no evidence of extensional displacement transfer onto basement structures [4]. Cartwright and Lonergan [4,6] think the only explanation for the apparent extension is for layer-parallel volumetric contraction to have occurred. McGill and Hills [16] also required 20% extensional strain to produce the grabens in Utopia Planitia based on a 2D differential compaction model (desiccation shrinkage of wet sediments) with the scale of the giant polygons determined by the topography of the underlying surface. Using Fric2D, a boundary element method (BEM) modeling code developed by Cooke et al. [17], Buczkowski and Cooke [18] have also shown that volumetric compaction is a feasible model for the Utopia Basin. Volume contraction seems to accommodate the extensional faulting observed in earth polygonal terrains and the giant martian polygonal terrains.

Model: In order to understand whether volumetric contraction may have created the giant polygons, BEM models can be used to simulate them as a first-order mechanics of the process. A BEM code based on the displacement discontinuity method of Crouch and Starfield [19] was used by Tuckwell et al. [20] to demonstrate that polygonal fracture networks can be created that resemble the North Sea polygons and the giant polygons of Mars. The models investigated map-view development of polygonal structures from an initial set of fracture seeds of different lengths that represented flaws of different strengths. The elastic moduli, loading rate and fracture seed distribution were varied to study which parameters produced and controlled polygonal fracture networks [20].

To investigate whether the earth polygonal terrains are an analog for the martian polygonal terrains, we are developing Fric2D models that use key martian parameters. The scale of the model is an area 1 km in

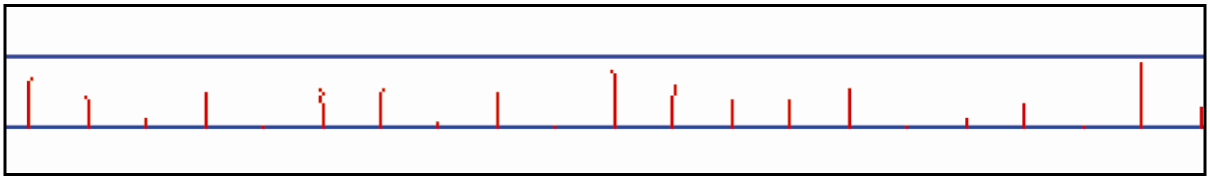

Figure 1: Cross-sectional view of a 23 km segment of the 1 km by 50 km model that exhibits tiers.

height by 50 km in length to bracket typical estimates of the range in thickness of materials within which polygonal terrains occur, and the diameters of the giant polygons, respectively. Material properties for wet, fine sediment were applied to simulate a water-laid depositional environment. Martian gravity was applied and equally spaced fracture seeds of variable sizes were placed at the base of the model to represent the underlying uneven topography. The fracture seeds were placed at 1 km intervals since this is the range where the overlap in scale between earth sub-sea polygons and the giant martian polygons occurs.

In the model, individual fractures grow by fracture propagation or linkage. Fractures propagate when the stress intensity exceeds the fracture toughness of the material for an applied extensional strain, which simulates volumetric contraction. Models compared slow and fast loading, and varied the amount of extension (volumetric contraction).

Findings and Conclusions: The preliminary results indicate that fracture seeds simulating uneven topography will produce martian and earth scale spacing between fractures (1-10 km). The longest seeds propagate to the surface of all models whereas many smaller fracture seeds propagate only halfway under slow loading and low extension; this results in a two-tiered fracture spacing (Figure 1). Regardless of loading rate, large displacements produced similar populations of fractures and comparable fracture spacing and tiers. Future investigations will include layered models, and other distributions of fracture seeds to study spacing and tiers.

References: [1] Pechmann J.C. (1980) *Icarus, 42*, 185-210. [2] Cartwright J.A. (1994) *Geology*, *22*, 447-450. [3] Cartwright J.A. and Lonergan L. (1996) *Basin Res.*, *8*, 183–193. [4] Cartwright J.A. and Lonergan L. (1997) *Expl. Geophys.*, *28*, 323–331. [5] Lonergan L. et al. (1998) *J. Struct. Geol.*, *20(5)*, 529–548. [6] Cartwright J.A. and Dewhurst D.N. (1998) *Geol. Soc. Am. Bull.*, *110(10)*, 1242–1257. [7] Dewhurst D.N. et al. (1999) *Mar. Petr. Geol.*, *16*, 793–810. [8] Gay A. et al. (2004) *Basin Research*, *16(1)*, 101-116. [9] Lucchitta B.K. et al. (1986) *JGR*, *91*, E166-E174. [10] McGill G.E. (1989) *JGR*, *94*, 2753-2759. [11] Smith D.E. et al.(1999) *Science*, *284*, 1495-1503. [12] Mouginis-Mark P.J. (1979) *JGR*, *84*, 8011-8022. [13] Hiesinger H. and Head J.W. (2000) *JGR*, *105*, 11,999-12,022. [14] Thompson B.J. and Head J.W. (1999) *LPS XXX*, Abs. #1894. [15] Scott and Tanaka (1986) Geologic Map of the western equatorial region of Mars, USGS I-1802-A. [16] McGill G.E. and Hills L.S. (1992) *JGR*, 97, 2633-2647. [17] Cooke M.L. and Pollard D.D. (1997) *J. Struct. Geol.*, *19*, 567-581. [18] Buczkowski D.L. and Cooke M.L. (2004) *JGR*, *109*, E02006. [19] Crouch S.L. and Starfield A.M. (1990) *Boundary Element Methods in Solid Mechanics*, Chapman and Hall, New York. [20] Tuckwell G.W. et al. (2003) *J. Struct. Geol.*, *25*, 1241–1250.