ORIGIN OF FRACTURES, MARTIAN POLYGONAL TERRAIN

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It has been proposed that the origin of the polygonally fractured terrain on Mars is due to stress caused by differential settlement of material deposited over an irregular base topography (McGill, 1986). The eventual goal of this study is to evaluate this proposal by construction of mathematical models for this process. These models will attempt to determine what combinations of base topography, covering material composition and depositional rate would cause the fractures observed. Because fracture formation would largely be a function of generated stress, the first step in modeling is calculation of stresses created during settlement.

A preliminary 2-dimensional model was constructed using as a base topography the cross-section of a crater 5 km in diameter and 900 meters deep (Pike, 1980). This size crater was chosen since average fracture spacings are reported at 4-5 km. The cover material selected was a fine-grained clastic. Possible source areas in the region surrounding the polygonal terrain support a choice of water saturated sediment or pyroclastics as the covering material. The Terzaghi theory for one-dimensional consolidation of saturated clay (Terzaghi, 1925) is a conventional method for treatment of the magnitude of settlement under applied loads. An average clay was chosen with material properties: density of 2.6 gm/cc, liquid limit of 80%, and initial void ratio of 0.5 (Rieke & Chilingarian, 1974). To evaluate stress induced during the settlement process an elastic beam bending model was used (Gere & Timoshenko, 1984; Turcotte & Schubert, 1982). A Poisson's ratio of 0.4 was used along with a range of values for the elastic modulus.

To evaluate consolidation and bending, as they occur together, the cover material was modeled in two parts. The lower part is the fill material, extending from the underlying topography up to the level of topographic highs. The upper part is the layer material extending from the fill material to the ground surface. A force balance is considered to have occurred during the depositional process. After deposition of the lower, fill material further consolidation is caused by a load exerted by the upper, layer material. Conversely, the load available for bending in this upper material is controlled by how much has gone into consolidating the lower material. The balance point between these two processes was found numerically for a range of upper layer thicknesses by calculating deflections and redistributing loads until a balance was reached.

The results of running this model are contained in the table showing maximum tensional surface stresses, which occur at topographic highs. Stress is actually underestimated for a number of reasons. These include further settlement in the fill material due to its self-weight after being covered by the layer material, tensional stress due to extension of the layer material, and also surface tension caused by shrinkage due to desiccation of the material.

Table of surface stress due to bending

Elastic Modulus	Thickness of covering layer 300 meters	500 meters	1000 meters
10 MPa	3.5 MPa	4.2 MPa	5.7 MPa
20 MPa	5.1 MPa	6.3 MPa	8.3 MPa
50 MPa	8.3 MPa	10.4 MPa	13.9 MPa
100 MPa	12.2 MPa	15.2 MPa	20.8 MPa
500 MPa	29.3 MPa	37.3 MPa	46.4 MPa

The stresses shown in the table above are large enough to exceed both the tensile and the shear strength of the soil for near surface conditions, making fracture creation by this process a reasonable possibility. Model refinements in progress include a nonelastic, time dependent depositional model, use of a pyroclastic cover material, and evaluation over a wider range of initial conditions including 3-dimensional base topography.

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