

THE ORIGIN AND EVOLUTION OF ORIENTED-NETWORK POLYGONALLY PATTERNED GROUND; THE ANTARCTIC DRY VALLEYS AS MARS ANALOGUE. Joseph S. Levy¹, James W. Head¹, and David R. Marchant²; ¹ Dept. Geological Sciences, Brown University, Providence RI, 02912, ² Department of Earth Sciences, Boston University, Boston, MA 02215.

Introduction: Polygonally patterned ground is a common feature of polar regions on both Mars and Earth. Although classically described as networks of roughly hexagonal polygonal mounds and linear troughs [1], many polygon fields observed on Mars and Earth show a distinct preference in orientation, usually associated with orthogonally intersecting troughs [2, 3, 4]. We have examined such oriented networks of polygons in Mullins Valley and Beacon Valley, Antarctica, as an analogue for polygon formation under Mars-like conditions. The transition from oriented-network/orthogonal-intersection polygons in upper Mullins Valley to hexagonal polygons where Mullins debouches into central Beacon Valley may provide a time-series of polygon initiation and evolution.

Oriented-Network Polygons on Mars: Polygonally patterned ground on Mars is dominated by hexagonal crack networks, associated with a variety of origins, including thermal cracking and response to tectonic stress [4, 5, 6, 9]. Recent observations using Mars Orbiter Camera (MOC) data have located regions characterized by multiple generations of polygon formation, including those in which oriented networks of orthogonal-intersection polygons are adjacent to and mixed with hexagonal polygon networks (Figure 1) [3]. These oriented networks of polygons are commonly observed within large impact craters [3]. At present, the origin of such radial polygon networks with orthogonal intersections remains undetermined, however, several possible mechanisms for near-surface cracking are testable, including structural stress induced by the slope of the crater walls, thermal stresses associated with uneven insolation as a result of the slope of the crater walls, or even thermal stresses associated with the presence of an ancient crater lake [2].

Oriented-network Polygons on Earth: Using the Antarctic Dry Valleys (ADV) as a climate analogue for Mars (in particular the upland frozen zone), we examined surface morphology in upper Mullins Valley. The valley contains a debris-covered glacier with several proximal lobes showing radial, or feathered, polygonal patterning (Figure 2). These “feathered polygons” are up to tens of meters long, 1-3 m wide, and often segmented by small troughs cutting orthogonally across the long axis. The polygons are distinguished by linear mounds of dolerite and sandstone cobbles and boulders with up

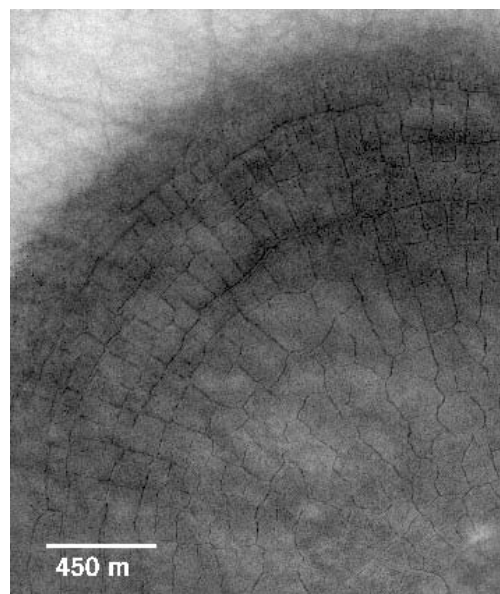


Figure 1—The northwest quadrant of a crater showing signs of radial/orthogonal polygon morphology as well as finer-scale hexagonal polygonal patterning, from MOC image R1104544.

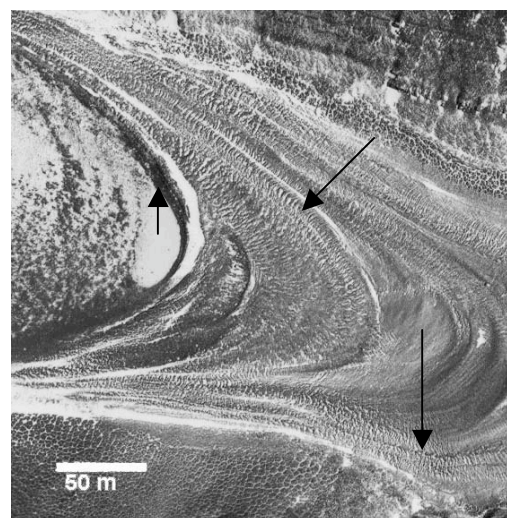


Figure 2—Upper Mullins Valley, ADV. Arrows point to oriented polygon fields with radial/orthogonal geometry. Down valley is to image right.

to a meter of relief between the mound crest and the snow banks that collect in the polygon troughs. Many of the lobes are bordered by a terminal snow bank in a local topographic low. At this boundary, the widths

of polygon troughs often flare out from a few tens of centimeters to a meter or more, producing triangular terminal embayments in the troughs and tapering polygon mounds.

Although no radial polygons are observed on the dark ridge (left of Figure 2, marked with a small arrow), the ridge is cored by glacial ice that is veined throughout with radial cracks, 1-10 cm in width, that are parallel to troughs on distal lobes, and filled with sand and secondary ice. Smaller sand-filled veins cross the radial cracks at near 90° angles. These features may be interpreted as nascent polygon troughs. Where Mullins glacier debouches into Beacon Valley, both radial and hexagonal polygons are present (Figure 3).

Five Physical Controls on Polygon Growth and Evolution: In contrast to polygonally patterned ground on Mars, which has been largely classified on the basis of 1-10 m scale morphology, polygonal terrain found in Earth's polar regions can be best classified by the physical processes which dominate its formation and evolution [4, 7]. Five physical processes can be isolated which account for the bulk of the morphological characteristics of polygonally patterned ground: thermal contraction [2], material failure in response to non-thermal structural stress, marginal cryoturbation, variable sublimation rates, and marginal slumping [8].

In the upland frozen zone of the Antarctic Dry Valleys [7], cryoturbation is minimal, leaving four other physical processes to account for the observed polygon network morphologies (in relatively warm microclimate zones of the ADV, cryoturbation associated with changes in the cross-sectional profile of polygons is usually manifested as raised rims alongside ice-wedge polygons)[10].

Interpretation of Mullins Valley Oriented Polygons: We are currently testing the hypothesis that the radial/orthogonal crack polygons in upper Mullins Valley are produced largely from structural stresses induced by the flowing of the glacial sublobes. The expansion of a lobate flow seems to be consistent with the radial pattern of the fracture network. Once the cracks have initiated, they are deepened by enhanced sublimation along the crack boundary in a process similar to the growth of simple sublimation type polygons in Beacon Valley [8]. Enhanced sublimation along the cracks may result in the enlargement of the crack at the terminal snow banks, as at these locations the crack is exposed along its top and front due to the break in slope.

We are testing several models for the transition from zones of oriented to non-oriented polygons in

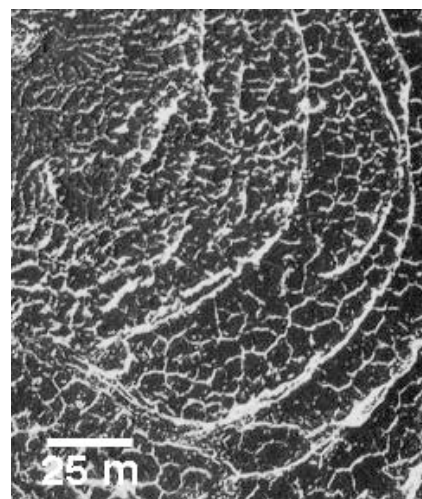


Figure 3—A portion of lower Mullins Valley into Beacon Valley. Both radial (upper left) and hexagonal (lower right) polygons are visible.

Mullins and the adjacent Beacon Valley, including simple deformation of radial polygons due to glacial flow, alterations in apparent trough orientation due to sublimation (similar to the formation of the terminal embayments), and deformation coupled with sublimation-driven trough reorientation.

Oriented polygonal terrain implies either an oriented stress field acting on frozen ground, oriented defects within the frozen ground material, or time transgressive polygon development as in the progressive draining of small lakes. On Earth oriented polygon networks are often associated with non-uniform stress fields or thermal stresses associated with liquid water [2]. As the search for evidence of glacial and fluvial activity continues on Mars, efforts should be made to decipher the signal present in the orientations of polygon networks, as it may have significant bearing on past and present martian hydrological and glacial activity.

References: [1] Pewe T.L. (1974) *Geomorphic Processes in Polar Deserts*, Polar Deserts, ed. By T.L. Smiley & J.H. Zumberge, Univ. of Ariz. Press. [2] Lachenbruch A. H. (1962) *GSA Spec. Papers Number 70*, 1-69. [3] Abramenko O. N. & Kuzmin R. O. (2004) Abstracts of the 40th Brown-Vernadsky Microsymposium. [4] Mangold N. et al, (2004) *JGR*, 109, E08001 [5] Hiesinger H. & Head J. W., (2000) *JGR*, 105, 11,999-12,022 [6] Mellon M. T. (1997) *JGR*, 102, 25, 617-25,628 [7] Marchant D. & Head J. (2004) *LPSC35 #1405*. [8] Marchant, D. R. et al. (2002) *GSA Bul.* 114, 718-730. [9] Malin M. C. & Edgett K. S. (2001) *JGR*, 106, 23,429-23,570. [10] Berg T.E. & Black R.F. (1966) *AGU Ant. Res. Ser.* 8, 61-108.