

FRACTURE NETWORKS, GALE CRATER, MARS. B. Hallet¹, R.S. Sletten¹, W. Stewart¹, R. Williams², N. Mangold³, J. Schieber⁴, D. Sumner⁵, G. Kocurek⁶, and MSL Science Team, ¹University of Washington, hallet@uw.edu, ²Planetary Science Institute, ³CNRS & Université de Nantes, ⁴Indiana University, ⁵University of California, Davis, ⁶University of Texas.

Introduction: HIRISE images reveal distinct networks of fractures over much of the landing ellipse of the Mars Science Laboratory (MSL) in Gale Crater, and the rover Curiosity landed within a few hundred meters of a particularly well-developed network (Fig. 1-2). The geometry of the fractures, the lack of a preferred fracture orientation, and the uniform size and shape of the intervening polygons suggest that they formed by contraction most probably related to water loss or ice-related contraction and expansion. Thus, they are of direct interest to the primary goal of the MSL, which is to shed light on the past and present habitability of Mars.

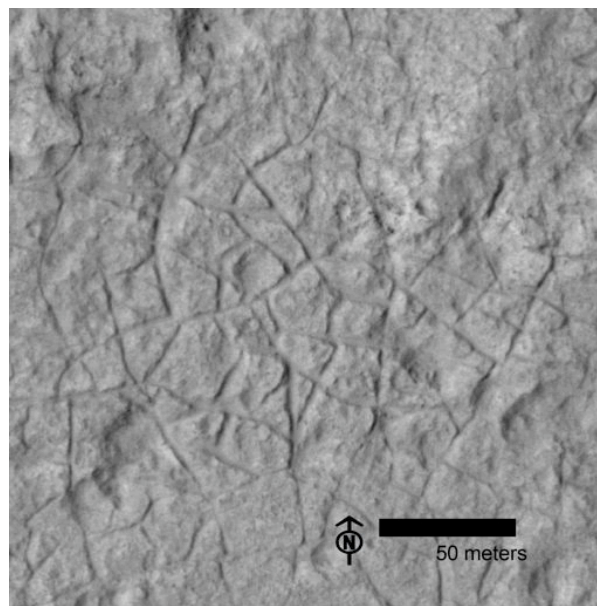


Figure 1. Curving contraction cracks ~500 m N-NW of Curiosity's landing site. Scale bar: ~ 100 m.

Distinct fracture types occur in bedrock, including contraction cracks, dense criss-crossing cracks, and cracks with mineralized fillings that produce inverted relief. These fractures contain valuable, as yet unused, information about the mechanical properties of the material. Here we focus on contraction cracks defined as curvilinear cracks with orthogonal junctions, few cracks crossing one another, and a distinct separation between adjacent polygons. In the Glenelg region, this separation is ~10-20% of the polygon size, suggesting large volumetric contraction. Located downslope of the Peace Vallis alluvial fan [Palucis et al., this volume],

the contraction cracks are associated with high thermal inertia terrain, reflection of a compact lithology.

Water likely played a role in the formation of the cracks, in at least in two ways. First, the loss of water can lead to large volumetric contraction in moist cohesive surface materials. Secondly, water provides sufficient cohesion for loose surface material to transmit stresses over length scales vastly exceeding the grain size, and to fracture either by forming ice in coarser, non-cohesive granular material, or by precipitating minerals that cement adjacent mineral grains.

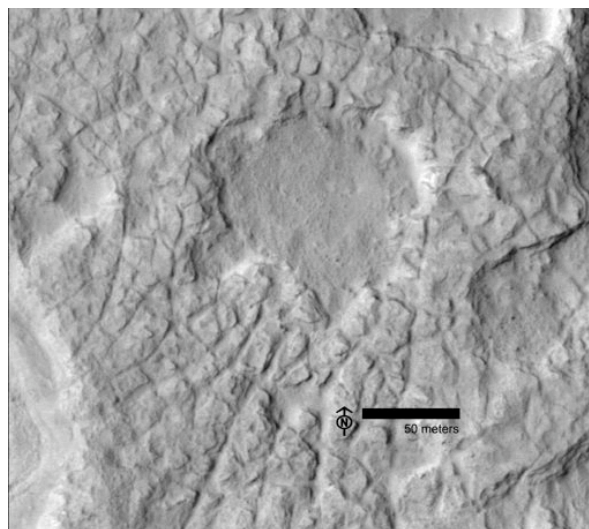


Fig. 2. Contraction cracks ~3.1 km N-NW of Curiosity's landing site, Gale crater. Scale bar: 50 m.

Hypotheses: Diverse testable hypotheses for Gale crack arrays are suggested by known Earth analogs; several of these have strong implications for the geologic setting of the region explored by Curiosity. **Drying playas:** Networks of giant desiccation cracks (Fig. 3), up to several hundred meters in length, are common on dry lake beds comprised of very fine-grained sediment [1]. In the American southwest, playas are often the vestige of extensive lakes that formed under wetter climates in former pluvial eras. On Mars, outside of high latitude regions, polygons have been widely recognized on crater floors. They range in diameter from 15 to 350 m [2].

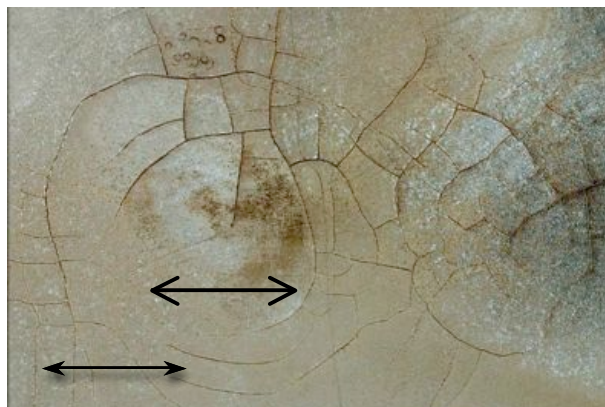


Fig. 3. Giant desiccation cracks, Lucerne Valley Playa, CA. Scale bar: ~100 m

Cracking indurated sand: Polygonal fractures are relatively common in some sandstone exposures (Fig. 4). Their formation is attributed to the former presence of evaporites as cement that provided the cohesion and ability to contract necessary for polygon formation [3]

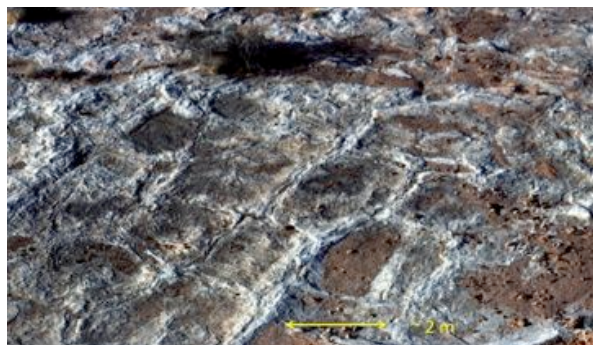


Figure 4. Sandstone polygons along a major regional unconformity on the upper surface of Navajo Sandstone. Scale bar: 2 m. Photo by Kocurek.

Cooling permafrost. Polygonal patterned ground is the hallmark of permafrost regions on Earth, and it is pervasive in the high latitude regions of Mars [4]. Polygons are widely recognized on Mars, where they tend to be rather small (often dia. <10 m), uniform in size and regular in shape with 4 to 6-sided [5,6,7]. On Mars, mean annual temperature for the entire surface is currently well below 0C.

Cooling lava lakes: Cracks were observed forming at the surface of Makaopuhi lava lake during Kilauea eruptions [8]. "Cracks open within a minute after molten lava is exposed at the surface, and form either random or oriented orthogonal networks which outline large plates of unjointed crust. Within a few hours, additional cracks subdivide the plates into polygons averaging 15 ft (4.6 m) in width."

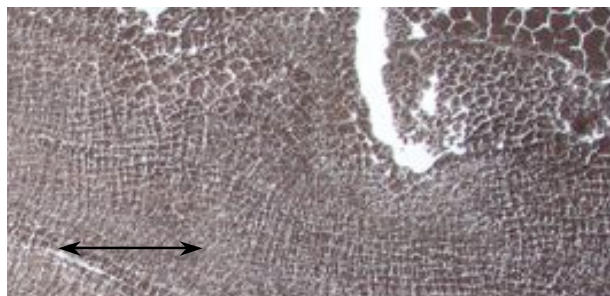


Figure 5. Permafrost polygons of diverse shapes and sizes on debris-covered Mullins glacier ice, Dry Valleys, Antarctica. Scale bar: 300 m.

Deep-water polygonal fault systems: A recent study [9] suggests that polygonal fault systems are appropriate analogs for large-scale Martian polygons, and that those on the northern plains of Mars most likely formed under deep-marine conditions (>500 m water depth). Several processes and conditions seem to be involved in the formation of terrestrial polygonal faults: syneresis, low coefficients of residual friction, and/or diagenetically induced shear failure instead of thermal contraction

Discussion: Each of the five mechanisms (with the possible exception of cooling lava) has direct implications for habitability because they require H₂O. Curiosity's array of powerful instruments enables observations that promise to help differentiate between hypotheses. Specific characteristics of special interest are 1) crack geometry, organization, micro-relief, and filling material (Mastcam); 2) crack variation with stratigraphy (Mastcam, MAHLI, ChemCam); 3) lithology: volcanic vs sedimentary (Mastcam, MAHLI, ChemCam, APXS, ChemMin); sediment size distributions (MAHLI); and spatial patterns in sediment mineralogy & chemistry (MAHLI, ChemCam, ChemMin, APXS, SAM)

Conclusions: Direct observations by Curiosity promise to help eliminate certain hypotheses and support others.

References: [1]Antrett et al. (2012) AAPG Bull., 96, 1279– 1299. [2] El Maarry, M. R., et al. (2010) JGR, 115, E10006, doi:10.1029/2010JE003609. [3] Kocurek, G. & Hunter, R.E. (1986) J. Sed. Pet. 56, 895-904. [4] Mangold, N. (2005), Icarus, 174, 336– 359, doi: 10.1016/j.icarus.2004.07.030. [5] Mellon, M. (1997) JGR,102 (E11), 25617-25628; [6] Mellon, et al. (2008) JGR, 113, E00A23. Mellon, M. et al. (2009) J Geophys Res, 114, E00E06. [7] Mellon, M. T., and Jakosky, B. M. (1993) JGR, 98, 3345–3364, doi:10.1029/92JE02355. [8] Peck, D.L. and Minakami, T. (1968) GSA Bull. 79, 1151-1166. [9] Moscardelli, L., Dooley, T., Dunlap D., Jackson, M. and Wood, L. (2012) GSA Today. 22, 4-9, doi: 10.1130/GSATG147A.1.