MAKING SENSE OF CHAOS: GEOMORPHIC INVESTIGATIONS OF MARTIAN CHAOS TERRAIN.

J.H. Gearon[1], J.S. Levy[1], and T.A. Goudge[2], [1]University of Texas Institute for Geophysics, Austin, TX, 78758. jake.gearon@gmail.com, joe.levy@utexas.edu, [2]Jackson School of Geosciences, Austin, TX.

Introduction. Chaos terrain (or simply, chaos) is a widely-studied, but still poorly understood global geomorphic unit on Mars. Chaos terrain is characterized by the presence of polygonally-shaped mesas and massifs, separated by deep canyons that form a polygonal "jigsaw pattern" [1]. Chaos terrain is globally distributed, but is concentrated in the Tharsis/Valles Marineris region of Mars [2]. Chaos is spatially associated with outflow channels and is widely held to be related to outflow channel formation mechanisms (e.g., fracture of the surface and release of groundwater) [2-4].

Accordingly, three major hypotheses for the formation of chaos terrain exist: 1) subsidence/collapse associated with breaching of the martian cryosphere and release of subsurface melt water due to volcano/ground ice interactions; 2) clay/silt dewatering to form megapolygons similar to those observed in terrestrial deep water marine environments; or 3) dewatering of polyhydrated sulfate minerals.

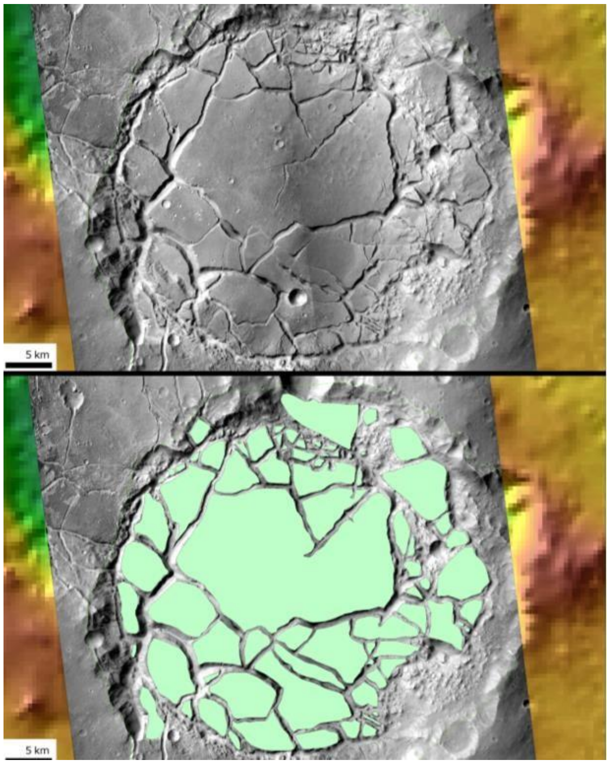
Each of these hypotheses is associated with a specific inference about how much subsidence/erosion should have occurred during chaos formation, based on the host phase and the mixing ratio of water/ice in the ground. However, each of these hypotheses fails to fully account for several key characteristics of chaos on Mars, including: 1) Chaos terrain is not always associated with outflow channels. 2) Chaos almost exclusively occurs in craters and basins, including at the bottom of the Hellas Basin, a region isolated from major volcanic features. 3) Chaos is defined by the presence of mesas and massifs that are a basin-filling unit (they postdate the craters or other depressions in which they sit), meaning that any model of chaos formation must account for the emplacement of the sedimentary units that remain as mesas and massifs in chaos terrain, not just their fracture and subsequent erosion.

Methodology. To address these competing hypotheses regarding the origin of chaos terrain and to help constrain the potential volatile budget associated with their formation and evolution, we use new, high-resolution, stereo-derived digital elevation models (DEMs) and images to measure the distribution of chaos, the details of its structure and fabric, and the volume of "missing" (eroded or removed) material. We then use these measurements of chaos terrain attributes to evaluate the above-detailed hypotheses to determine if a single process explains the attributes of global chaos deposits, or if different fracture systems formed through different mechanisms.

Chaos units in Xanthe Terra, Hydraotes Chao, Aromatum Chaos, and Aram Chaos were mapped on a CTX image mosaic overlain with CTX stereo-derived DEMs [5-8], with gap-filling topography provided by MOLA gridded data [9]. Outlines of coherent mesa features as well as outlines of eroded massifs features were mapped (Fig. 1) and morphometric and topographic geostatistics were extracted from these polygons. Measurements included: cell area, cell distance from centroid, mean mesa slope, and "missing volume" (the difference in volume between a 3D surface fitted to chaos mesa and massif cell tops and the measured topography) (Fig. 2). Calculations were also made of chaos fractured unit volume by fitting a lower surface to the chaos inter-mesa trough network, and differencing the upper surface (interpolated between mesa high points) from the lower surface.

Results and Discussion. Several notable trends emerge from our preliminary measurements. In general, chaos features (mesas and massifs) get smaller in area the farther they are from the center (Fig. 4). This suggests either non-uniform fractured unit thickness or spatially controlled stress. Mean mesa slope increases toward the edge of chaos units, showing an overall increase of block tilt toward the edge of the chaos areas (Fig. 3). This suggests possible downsag of the fractured unit, or draping of the fractured unit on existing basin topography. Calculations of "missing volume" produce a surprising result for Aromatum Chaos (Fig. 2)—out of ~550 km^3 of total mapped chaos volume (upper surface minus lower surface elevation), ~450 km^3 of material is "missing" from the void spaces between the massifs (~80%). These volumetric measurements are consistent with pronounced post-fracture erosion in Aromatum Chaos, as indicated by the apical massif morphology and the presence of a draining outflow channel.

References: [1] Pedersen et al. (2010) *EPSL*, doi: 10.1016/j.epsl.2009.08.010. [2] Sharp (1973) *JGR*, 78, 20, 4073-4083 [3] Rodriguez et al. (2005) *GRL*, 33, 18, doi:10.1029–2006GL026275 [4] Leask et al. (2006) *JGR*, 111, E8, doi: 10.1029/2005JE002549 [5] Broxton & Edwards (2008) *LPSC39* [6] Moratto et al. (2010) *LPSC41*, #2364 [7] Beyer et al. (2014) *LPSC45* [8] Shean et al., (2016) *ISPRS J. Photo. & Remote Sensing*, 116, 101-117 [9] Smith et al. (2001) *JGR*, 106, E10, doi: 10.1029/2000JE001364



Figures 1-4 (clockwise from upper left). Fig. 1. Example mesa mapping. (Top) Chaos in an unnamed crater NW of Orson Welles crater and Valles Marineris. Chaos terrain consists of mesas and knobs, surrounded by erosional valleys. (Bottom) Example mapping of mesa tops in the chaos. Fig. 2. Schematic illustration of volume calculations. Topography is for Aram Chaos and is extracted from a CTX stereo DEM. Fig. 3. Measured mesa/massif area versus distance from the chaos centroid for three chaos units. Distance is normalized to the maximum distance. Fig. 4. Mean mesa surface slope versus distance from the Hydraotes Chaos centroid. Despite the scatter, there is a statistically significant positive linear relationship ($p < 0.003$) between mesa slope and distance from the chaos centroid, suggesting the possibility of listric tilting of blocks.