GEOMORPHIC ANALYSIS OF MARS CHAOS TERRAINS USING GLOBAL CTX MOSAIC, HIRISE, AND MOLA-HRSC BLENDED DEM GLOBAL IMAGERY: FRACTURE DENSITY AND BLOCK THICKNESS SUGGEST BASIN CONTROL OF CHAOTICALLY-CRACKED UNITS

I. King[1], L. Kuentz[1,2], M.C. Rapoza[1], L. Kuang[1], H. Wang[1], and J. Levy[1] [1]Colgate University Department of Geology, Hamilton, NY 13346, [2]Now at University of Oregon, Department of Geography, Eugene, OR 97403. iking@colgate.edu

Introduction: Chaos terrains are large fractured areas on the Martian surface characterized by irregular mesa tops, isolated massifs, and canyons [1, 2].

While chaos terrains have wide geographic occurrences and morphological variety, their geologic evolution has yet to be fully understood. For example, some models suggest the collapse of a subsurface lake [1] while others point to magmatic activity and subsidence [2]. A more recent study proposes caldera collapse associated with volcanic inflation/deflation, a process that does not need water [3].

Instead of hypothesizing about chaos formation mechanisms and working to link the resulting fracture patterns to surface observations, we take the reverse perspective, mapping chaos blocks using 2.5D imaging and elevation datasets in order to evaluate whether block size correlates with fractured unit thickness or location within the chaos terrain. For this study, we focused on several named chaos terrains on Mars: Atlantis, Aureum, Eos, Gorgonum, Pyrrhae, Hydroates, Xanthe Terra, and the fill inside Orson Wells crater. Aureum, Pyrrhae, and Eos Chaoses sit among a cluster of other chaos terrains including Hydraotes, Arsinoes, and Aram. Atlantis and Gorgonum Chaos lay more isolated however in close proximity to each other.

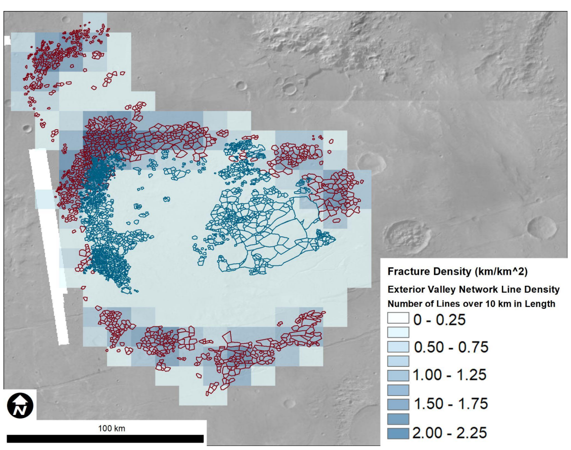

Figure 1. Gorgonum Chaos fracture density map. Shading shows a trend of increasing fracture density closer to the rim.

Methods: Chaos valleys and mesas were mapped using the Murray Lab Global CTX Mosaic [4] (supplemented by HiRISE imagery), and MOLA HRSC-MOLA Blended DEM Global (200m per pixel). Specifically, we manually digitized the chaos edge, mesa tops, and valley networks. Once landforms were digitized, it was possible to compute geomorphic values for each mesa, massif, or valley-network polygon. For mesa top units, area, thickness (mean surface elevation minus mean elevation of the bounding valley network), distance from the center of the chaos, and surface slope orientation were calculated.

For fracture block networks, area, thickness (the difference between mean elevation of the fracture network and maximum elevation within the fracture polygon footprint), distance from the center of the chaos, and axial orientation (direction) were determined.

In order to determine basal elevations for thickness calculations, fracture valley network polygons were converted to points, the elevation of the DEM was extracted into each point, and an interpolated raster dataset was created using a nearest neighbor interpolation between valley points. To calculate the distance to the center of the chaos for each valley and mesa top polygon, the centroid of the chaos was derived from the chaos edge polygon and each valley polygon and mesa top polygon was converted to point (that indicate the center of the polygon). Distance from valley and mesa top polygon points to the centroid point of the chaos was then calculated.

Finally, the “lids” for the chaoses were interpolated using chaos edge points using a 2nd-degree polynomial fit to the bounding topography of the chaos basin. The volume between the “lids” and chaos surface was calculated as the volume of material removed from the chaoses.

Results: Fracture density (valley line density) shows increasing fracture density closer to the chaos rim at nearly all sites (Figure 1). Pyrrhae does not show this trend, however, Pyrrhae Chaos appears to include a small crater impact in the southeast corner, which is also filled with fractured material. Neglecting that area, Pyrrhae shows fracturing concentrated around the edge rather than at the center.

We find that larger chaos blocks (whether intact mesas or eroded, valley-bounded massifs) are thicker at all sites (Figure 2). Block size and thickness vary nearly linearly at low block sizes, with more spread in thickness values at the largest, least common chaos block sizes.

In terms of fracture number and direction, rose plots of valley fracture direction show no preferred directionality of fracture at Gorgonum and most other sites. However, if fracture length is taken into account, most sites show a slight enhancement of fracture length in orthogonal directions, e.g., 10˚, 90˚, and 170˚ at Gorgonium (Figure 3).

Across all sites, the lid-to-surface volumes of the chaos sites were large: Atlantis 10300 km^3, Aureum 46800 km^3, Eos 510200 km^3, Gorgonum 1050 km^3, and Pyrrhae 20800 km^3.

Discussion: The fracture density map of Gorgonum Chaos shows denser fracture networks at the rims while the inner areas of the chaos show the opposite trend (Figure 1). When combined with the observation that fractured block area and thickness are strongly correlated, we interpret this result to indicate that chaos fracture density is controlled by the thickness of the fractured unit. During fracture formation, thinner fills of material near the edges of the chaos basins fracture more and at finer spatial scales, than the thicker material located in the deeper, central parts of the basins.

Our observations of fracture density in chaos units contrasts with previous analog experiment studies that suggested the fracture density was more concentrated in the center of the simulated chaos material where displacements from inferred inflation and deflation of an underlying magma chamber were greatest, leading to more abundant fractures at the chaos center and less as displacements approached zero at the chaos boundary [3].

The increased fracture density closer to the chaos rim found by our work suggests that basin geometry and material fill geometry are driving controllers of chaos morphology, rather than specific fracture formation mechanisms.

It is notable that fracture length-direction data from our sites broadly supports the trend of partially orthogonally oriented fractures. In small-scale fracture systems, synchronous stress relief due to rapid fracture initiation favors ~120˚ ("hexagonal") fracture angles, while sequential cracking leads to ~90˚ ("orthogonal") fracture intersections. The abundance of orthogonal intersections in chaos terrains suggests the possibility for sequential fracture formation, one after another, rather than forming all at once. Chaos formation may be a much slower formation process than, for instance, a single chaos-forming event [1].

Conclusions: Our study of the valley and block morphology of martian chaos terrains provides new insight on the detailed geometries of these complex features. The area-thickness observations and fracture length-direction data suggest that chaos formation may be basin controlled and may occur in a time-transgressive manner rather than catastrophically [1]. Chaos terrains may not be that chaotic.

References: [1] Roda, M., et al. (2014). *Icarus*, 236, 104-121. [2] Meresse, S., et al. (2008). *Icarus*, 194, 487-500. [3] Luzzi, E., et al. (2021) *GRL* 48, e2021GL092436. [4] Dickson et al. (2020) 51st LPSC, Abstr. #2309.

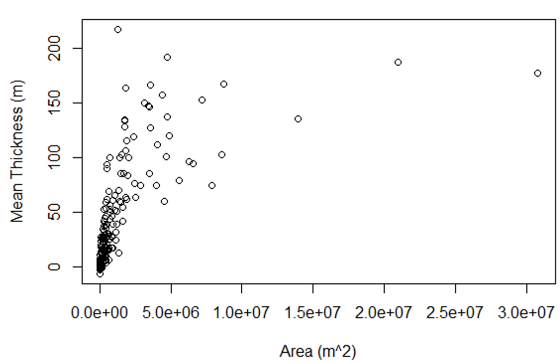

Figure 2. Gorgonum Chaos block area versus mean thickness. Large chaos blocks are thicker than more common, smaller blocks in this chaos.

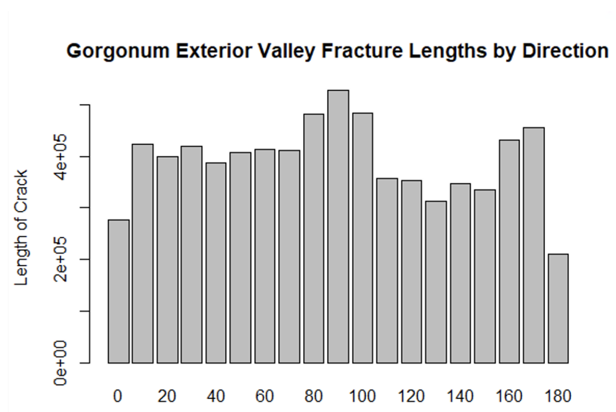

Figure 3. Gorgonum Chaos fracture length by direction. Small peaks at 10˚, 90˚, and 170˚ (i.e., 90˚ and 180˚ in radially-symmetric space) suggest a slight preference for orthogonal, sequential cracking.