CHAOS TERRAINS ON PLUTO, EUROPA, AND MARS – MORPHOLOGICAL COMPARISON OF BLOCKS.

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Introduction: Chaotic terrain is formed by disruption of preexisting surfaces into irregularly shaped blocks with a “chaotic” appearance (Fig. 1; [e.g., 1-3]). This typically occurs through fracturing and can be induced by a variety of processes. The subsequent evolution of these blocks after fractures form can follow several paths. If the blocks are completely destabilized and free from the surface below they may rotate, translate, or potentially even float in a liquid or solid with sufficient density contrast [2,3]. Alternatively, the blocks may remain in place and the fractures around them may deepen over time by erosion [4]. These distinctive areas of broken terrains are most notably found on Pluto, Mars, and Jupiter’s moon Europa.

Several models for chaos formation have been proposed, and comparing across worlds may yield extra constraints on the formation and evolution of this enigmatic terrain type [e.g., 1,2,4,5]. This work focuses on providing a morphological comparison of the blocks that make up chaoses on Pluto, Mars, and Europa. We measure block diameters, heights, and axial ratios.

Mapping Method: Chaotic terrain blocks were mapped on Pluto across mountain ranges extending from the NW to SW extent of the Sputnik Planitia using New Horizons base mosaics with a resolution of ~315 m px^{-1}. Images from the Galileo mission’s regional mapping campaign (East and West RegMaps) were used to map chaos blocks across regions on Europa, using topography with a resolution of 180 m px^{-1} and base mosaic resolutions 220 and 210 m px^{-1} [6] for the East and West RegMaps, respectively. Base mosaics from the THEMIS instrument on Mars Odyssey with a resolution of 100 m px^{-1}, and a 200 m px^{-1} resolution topographic product from the MOLA instrument on Mars Global Surveyor were used to map blocks in equatorial regions near the Xanthe Terra.

Chaotic terrain blocks were mapped in ArcGIS using polygons to outline the perimeter of each block along their apparent base, using visual and topographic mapping. A general visual diameter cutoff around 2 km was assigned to improve accuracy of measurements due to resolution constrains. The apparent height of each block was determined by subtracting the average base elevation of the perimeter of the polygon from the highest elevation point within each polygon. To derive a measure of the mountain block size (diameter) we used the geodesic area of the feature to calculate an equivalent diameter (if the feature were a circle). The axial ratio (long axis divided by short axis) of each block was derived by creating a rectangle of the smallest area enclosing the mapped block.

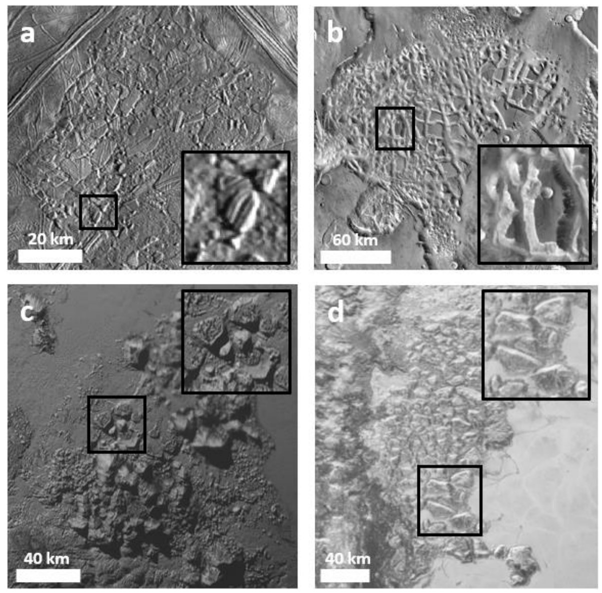

Figure 1. Examples of chaotic terrain blocks. a) Conamara Chaos on Europa, b) Hydraotes Chaos on Mars, c) and d) Chaos on Pluto in Tenzing Montes and Al-Idrisi Montes, respectively.

Observations and Discussion: The size vs. height distribution of blocks mapped across all regions of study are presented in Fig. 2. A positive linear relationship can be observed for chaos blocks on Pluto and Mars (Figs. 2,3). The blocks on Europa exhibit a flat trend, as block height does not generally increase with increasing block size (Fig. 4).

The size and height distributions of chaotic mountain blocks could provide information about the lithologic structure of the crust. If the blocks are all the same height or reach a maximum height and level-out (i.e. cease to increase in height with increasing diameter), then this could yield information about the layer thickness of the fractured unit. The blocks on Europa are an example of this kind of distribution (Fig. 4). The block heights in Conamara have been previously used to estimate a 0.2-0.3 km thickness of the icy lithosphere assuming the blocks were floating and reached an isostatic level [7]. The same analysis for the untilted blocks in the West RegMap region measured here yields a slightly thicker lithospheric estimate of ~0.2 to at least 6 km because the blocks are slightly taller (for the same range of ice and liquid densities as [7]).

On Pluto, it is possible the chaotic blocks could have been partially or fully floating icebergs in the nitrogen ice sheet of Sputnik Planitia, which could assist with destabilization or breakup/tilting [8-9]. Pure water ice and nitrogen ice may have a density contrast of >5% at Pluto's surface temperatures, however other components are likely present as well (e.g., CH_4, CO, tholins; [e.g., 10-13]). However, the distribution in Fig. 3 does not match what is expected of floating blocks, which implies that at least at the present moment the blocks are likely not floating. It is possible that the very largest blocks on Pluto may be reaching a maximum height (see Fig. 2,3) of ~4 km, but there are insufficient data points to infer if this could be indicative of layer thickness.

For Mars a different process could lead to an estimate of layer thickness. The competence of lithologic layers could influence the maximum height of blocks spatially, as different layers are more resistant to erosional or deformational processes such as faulting and fracturing. The tops of martian blocks commonly matches the same high elevation as the surrounding plateau [2], and therefore the maximum height of blocks in a region could be used to infer the relative layer thickness of a lithologic layer as erosional or deformational processes could have carved the weaker surface layers down to a more resistant layer.

Future work: Our mapping will be extended to include an additional chaos region on Europa. In addition, a comparison of martian chaos and fretted terrain in the Ismenius Lacus Quadrangle on Mars will be included to quantify any morphological similarities, and potentially unveil any genetic relationships.

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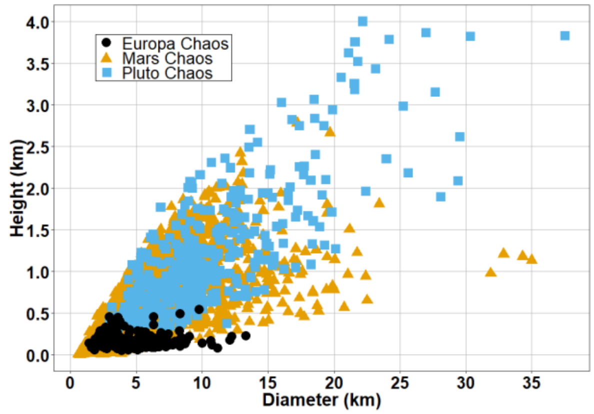

Figure 2. Size distributions for chaotic terrain blocks in mapped chaoses on Pluto, Mars and Europa. A positive linear relationship between height and size can be observed for chaos blocks on Pluto and Mars.

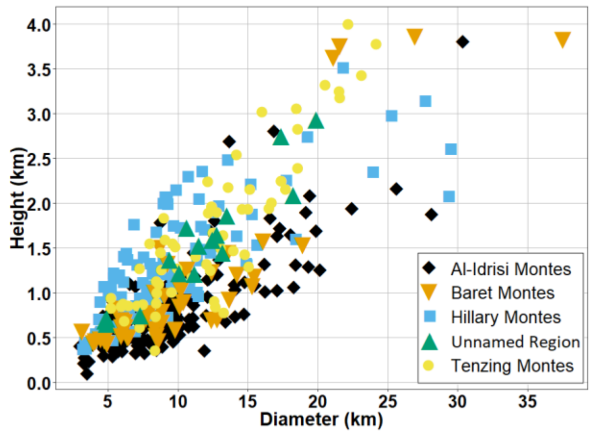

Figure 3. Mapped chaotic terrain regions on Pluto in the NW to SW extent of Sputnik Planitia. Size distributions vary between regions, displaying their individual characteristic morphologies.

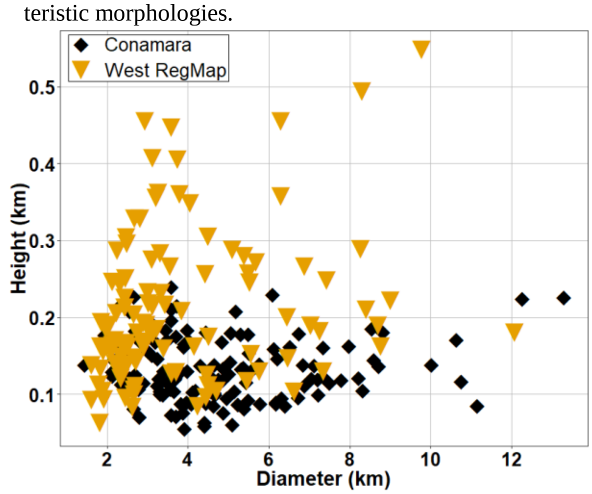

Figure 4. Chaotic terrain regions on Europa, showing no apparent correlation between height and diameter. Note that there are minimal differences in maximum apparent height, which could imply a crustal layer thickness.