BRINGING ORDER TO CHAOS: INSIGHTS ON THE FORMATION OF CHAOS TERRAIN FROM GEOLOGIC MAPPING OF EUROPA AT THE REGIONAL SCALE.

E. J. Leonard[1], S. Howell[1], A. Mills[2], D. A. Senske[1], D. A. Patthoff[3], and R. T. Pappalardo[1]
[1]Jet Propulsion Laboratory, California Institute of Technology (Erin.J.Leonard@jpl.nasa.gov), [2]University of Alabama, [3]Planetary Science Institute.

Introduction: The formation of chaos terrains—consisting of blocks of preexisting terrain and hummocky matrix material—on Europa has been intensely studied and debated, with end-member hypotheses including melt-through, sill formation and collapse, and diapirism induced by thermal and/or chemical buoyancy [1-6]. To constrain chaos formation models with concrete observations, we mosaic and map Europa's chaos terrains that are imaged at 100-250 m/pixel. In this work, we discuss and compare preliminary results from regional scale mapping (1:2M) of regional chaos terrains (Fig. 1), including chaos block size distributions and the potential implications for chaos formation.

Two areas of chaos that we have studied are Conamara Chaos and Murias Chaos. At the global scale, the Conamara Chaos region consists primarily of Low Relative Brightness Chaos and Regional Plains [7]. Some other regional chaos terrains such as Murias Chaos (informally known as "The Mitten"), however, are dominated by High Relative Brightness Chaos. At the regional scale, our initial observations of a variety of chaos instances (Fig. 1) reveal significant differences in the morphology of the outcropping materials that go to make up each occurrence of chaos terrain (Fig. 2). For example, the morphology of the chaos in the Conamara Chaos region is platy—dominated by large blocks or slabs (>1 km characteristic length scale) of pre-existing material and finer-scale intervening matrix material—whereas the Murias Chaos contains few recognizable blocks of preexisting terrain. Thus, our mapping reveals a spectrum of chaos morphologies (Fig. 2), which we investigate further by analyzing block size distributions within each chaos terrain.

Methods: To gain greater insight into how chaos is formed, we are specifically interested in comparing the chaos morphologies quantitatively through block size distributions.

From our regional mapping, it is apparent that there are distinct differences in the abundance, size, and distribution of elements making up different chaos terrains. We map ten individual areas of chaos within the regions shown in Fig. 1, focusing on blocks—outcrops of pre-existing terrain—down to ~1 km size (for example, Fig. 3). The area of each block is measured using ArcGIS, and the representative width is determined by taking the square-root of this block area. For each chaos terrain we bin the blocks by size, using Sturges Law [8] to determine the number of bins. We then evenly space the bins in log-space and report the cumulative block count (all blocks with a representative width greater than the x value). Because larger chaos terrains would naturally have more blocks, we normalize the cumulative block count by the total area of the chaos terrain.

Preliminary Results and Future Work: Our initial results show that the size-distribution of chaos blocks follow an exponential relationship of the form: $y = A * exp(-mx)$, where x is the characteristic length scale of the chaos block, y is the cumulative count of blocks with a width greater than x, and A and m are constants. This functional form for the data is consistent with block size distribution analyses on Earth and Mars [e.g., 9]. We plot the data points and fits in Figure 4 in the form $y' = -mx + b$ where $y' = ln\, y$ and $b = ln\, A$.

The data distribution is shown in Figure 4. Preliminary analysis indicates that steeper slopes (larger m) relate to more knobby chaos morphologies (Fig. 2). This suggests that chaos morphology may be quantified and used as a direct comparison to any future formation model outputs.

Additionally, we will use the parameters from our regional chaos mapping and block size distribution analysis (chaos area, total block area, center longitude of the chaos terrain, center latitude of the chaos terrain, A, m, and morphological rank) to perform a correlation analysis. By determining which values are correlated, with statistical confidence, we aim to identify the potential controls on chaos formation and morphology.

Acknowledgments: Portions of this research were carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. This work was supported in part by NASA under the Europa Clipper Project.

References: [1] Pappalardo, R. T. et al. (1999) *JGR, 104,* 24,015-24,055. [2] Greenberg, R. et al. (1999) *Icarus, 141,* 263–286. [3] O'Brien et al. (2002), *Icarus*, *156*, 152-161. [4] Collins and Nimmo (2009), Europa, *UA*, 259-281. [5] Schmidt, B. E. et al. (2011) *Nature, 479,* 502-505. [6] Michaut and Manga (2014), *JGR*, *119*, 550-573; [7] Leonard et al. (in production), USGS. [8] Sturges HA (1926), J American Statistical Association 21:65–66; [9] Golombek and Rapp (1997), *JGR*, *102*, 4117-29.

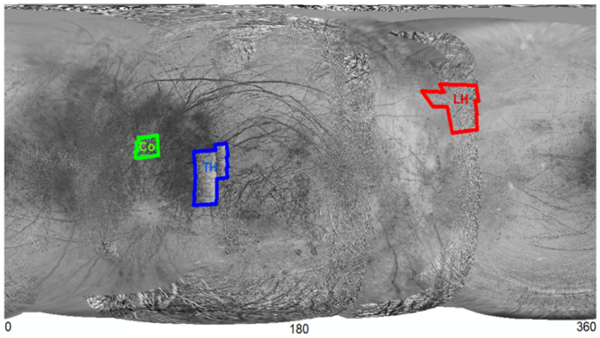


Figure 1 (top): Global basemap of Europa with three regions (Co – Conamara Chaos; TH – Trailing Hemisphere; LH – Leading Hemisphere labelled where we have begun mapping chaos terrains at the regional scale.

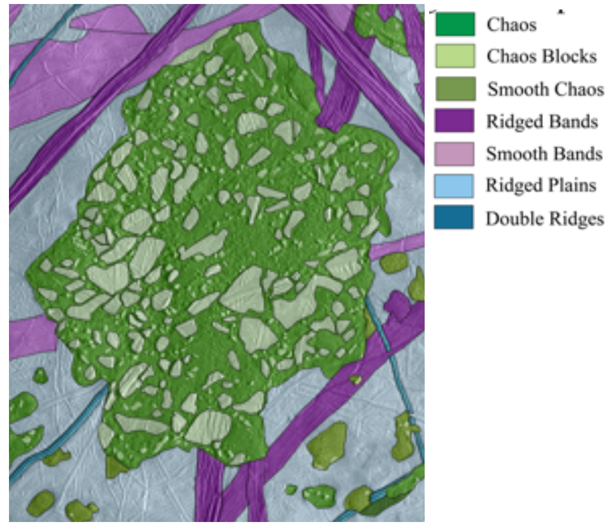
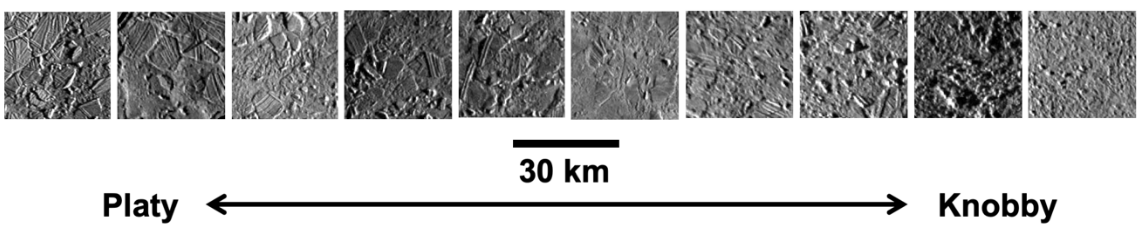


Figure 3: Part of the regional geologic map of the Conamara Chaos region with key (right) for the units. The images that were mapped were taken by Galileo during the E6 flyby and have a resolution of ~180 m/pixel.

Figure 2: Spectrum of chaos morphologies.



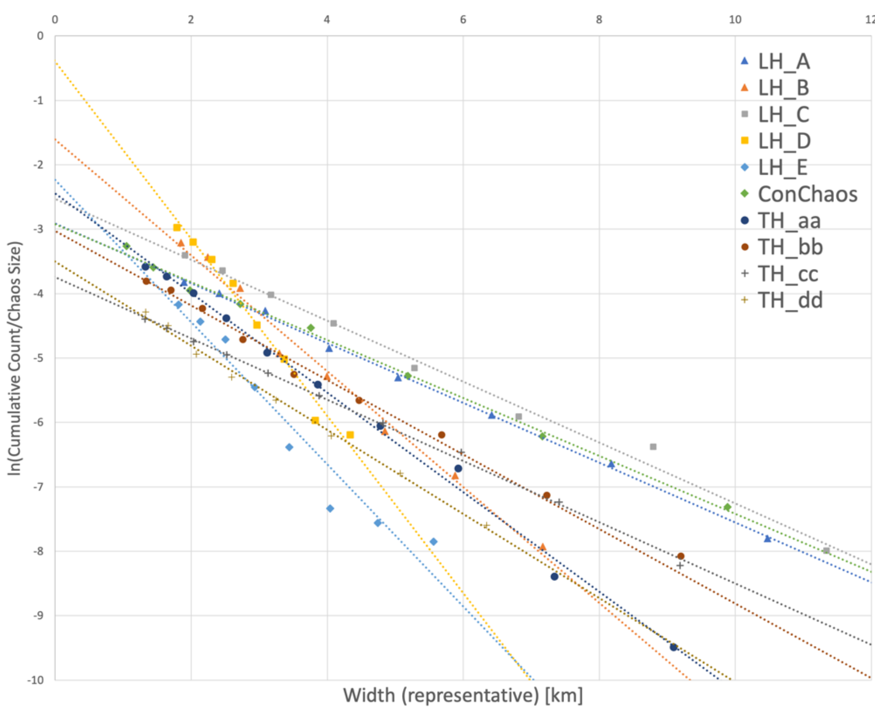


Figure 4: Chaos block size-distributions for ten different chaos regions in the regions outlined in Figure 1. The x-axis is the representative width of a chaos block (squareroot of the area) and the y-axis is the natural log of the cumulative block count (blocks greater than width of x) normalized by the chaos size.