GEOMORPHOLOGY OF CHAOS AREAS ON EUROPA Rónadh Cox[1] and Taylor Mikell[1], [1]Williams College, Department of Geosciences, Williamstown MA 01267 (rcox@williams.edu)

Introduction: Chaos areas on Europa—regions where the surface has been disrupted, with blocks of remnant crust set in a hummocky matrix of slushy appearance—are poorly understood, and no satisfactory explanation for their formation has yet been presented [1]. One of the proposed interpretations is that impact penetration could create holes in the ice layer, exposing underlying water [2,3]; and while it's clear that not all questions can be answered with current data, ongoing analysis and simulations [4] continue to suggest that this may be a viable hypothesis.

We present here GIS analysis of chaos area geomorphology. The geometry of chaos areas on Europa matches predictions from impact experiments [3], and their distribution corresponds to that expected for an ecliptic impactor population [5].

Methods: We created a georeferenced basemap of chaos areas from *Galileo* images, using 230 m/pixel as a lower resolution limit. At this resolution the smallest chaos areas are ≈90 pixels across; so as 96% of mapped chaos areas are ≥2.5 km diameter, mapping is not hindered by resolvability. About 13% of Europa's surface is imaged at this resolution, including the two longitudinal image strips, REGMAP 01 (centred on 225° W, about 40° E of the antapex of motion) and REGMAP 02 (centred near 80° W, i.e. 10° E of the apex).

We recorded the locations of all chaos areas in the base map areas (N=1092). For completely-imaged features (N=1076) we digitised the chaos area boundary, and measured perimeter length and area. We calculated an Edge Complexity Index:

$$ECI = \left(\frac{ChaosPerimeter}{EquivCirclePerimeter} - 1\right) x100$$

by which we compare chaos perimeter length to the circumference of a circle with area equal to that of the chaos (multiplied by 100 to produce whole numbers). A circular chaos area would have ECI = zero. As the perimeter of the feature becomes more complex and convoluted, the ECI becomes larger.

Larger chaos areas have more complex boundary shapes: A plot of chaos ECI versus area shows a marked increase in boundary complexity with increased size (Fig. 1). Smaller chaos areas have simpler, more circular shapes whereas larger areas have more jagged or irregular outlines. This trend is predicted by impact experiments that show progression from simple bullet-hole-type features at lower energy to wide-field destruction and complex hole creation at higher energy [3]. These data are consistent with small chaos areas representing small penetrating impacts, and larger chaos areas being related to high-energy impact events.

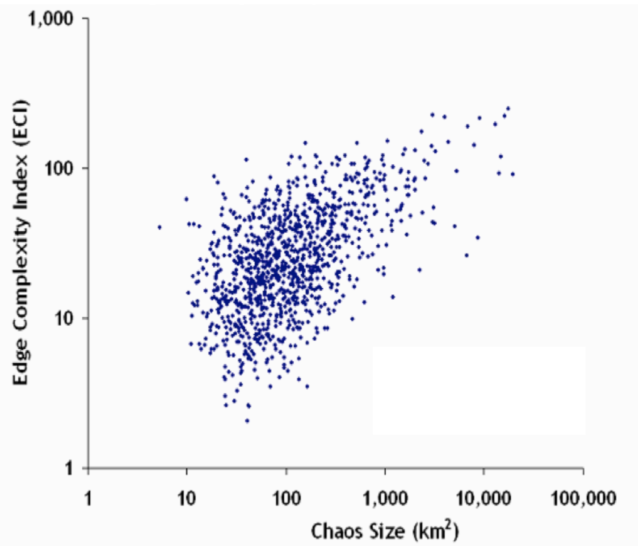

Fig. 1: Relationship between chaos ECI and area. Larger chaos areas have more complex boundaries. P<0.0001.

Chaos areas are concentrated at low latitude: The equatorial concentration of chaos terrain has been documented previously (as reviewed in [1]) and is quantified by this dataset. The total percent of surface area represented by chaos terrain is greatest at low latitudes, with a large peak at the equator because the few large chaos areas centred near the equator cover a very large proportion of the surface [4]. Almost 60% of chaos areas (N=653) are clustered between 30° north and south (Fig. 2). This matches expectations for ecliptic impactors in general [5], and is also remarkably similar to results from numerical models for Ganymede [6], in which 59% of simulated impactors land within 30° of the equator.

What does it mean? If chaos areas do represent penetrating impact sites, the range in mapped sizes (from a few km^2 to 10^4 km^2) can only be explained by ice thickness variations: whereas hydrocode simulations [7] show that a 20 km ice layer can be penetrated by large impactors, a 2 km hole representing a comet of ≈100 m diameter [87] requires far thinner ice to permit full penetration. Such thickness variations would have to be local, because the crater database shows clearly that many small impactors make normal craters, not holes. Regional or secular variations in crust thickness would, however, permit both penetrating and non penetrating impacts to occur at different times and/or places. By this model, very small impactors (capable of producing craters <2 km diameter) would always make craters, intermediate impactors (producing features 2-40 km diameter) would make either craters or holes, depending on local crust thickness; and überpenetrators (making features >40 km diameter) would always produce holes [3]. Whether such thickness variations are feasible for Europa remains to be determined: although it is not the favoured model, current data do admit the possibility of a thin shell with lateral thickness variations [9]. But for now it is possible only to show that the data are consistent with an impact model.

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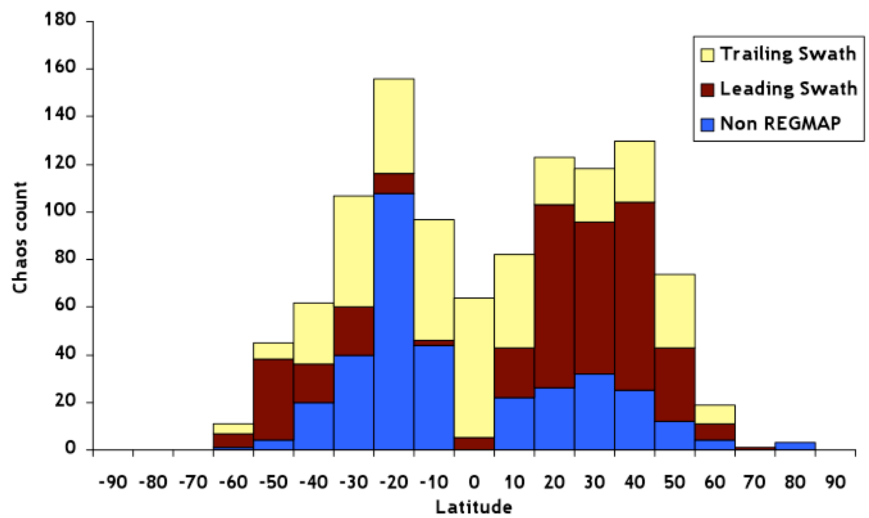

Fig. 2 Numbers of chaos areas with latitude showing poleward decrease in both hemispheres. Trailing swath = REGMAP01; Leading Swath = REGMAP02; Non REGMAP = all other imagery >230 m/pixel. The low numbers in the equatorial zone itself reflect presence of a few very large individual chaos areas in those areas. Total surface area occupied by chaos areas peaks near the equator and decreases steeply towards both poles [4].