ORIENTATION OF DIFFERENT TYPES OF LENTICULAE ON EUROPA.

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Introduction: Lenticulae are some of the most recent and common features on Europa's surface. This term describes features that can be depressions, uplifts, spots, and small patches of chaotic terrain. Chaos is characterized by a terrain-disrupting lump or hummocky matrix and no topography [1]. Spots are enclosed features with a consistent dark albedo [2]. Domes and pits feature positive and negative topography, respectively, and preserve the surrounding terrain. The term "hybrid" has recently been introduced to describe features that have positive topography but disrupt the terrain with a texture similar to chaos or a dark halo [2]. These features are often considered together under the assumption that they share a common geological origin, likely involving a rising diapir and possibly water [1, 3–7]. We add here orientation and elongation to the morphological and topographic data that has previously been used to investigate the origin of lenticulae.

Methods: Elongation and orientation information is added to the map of lenticulae produced by [2]. Based on the high-resolution mosaics obtained during the E15 and E17 Galileo flybys of Europa, this map outlines domes, pits, spots, chaos, and hybrids in the trailing and leading hemispheres. We imported in ArcGIS the shapefiles provided by [2] and the Europa Galileo SSI Global Mosaic 500m v2 for reference. No new mapping was conducted at this point. For consistency, we recalculated the area for each feature in ArcGIS using four distinct sinusoidal projections that were centered on the trailing hemisphere (E15RegMap01 and E17RegMap01) and leading hemisphere (E15RegMap02 and E17RegMap02) Galileo mosaics.

Calculating Orientation and Elongation. We determined the elongation and orientation of each object using the Minimum Bounding Geometry (MBG) tool in ArcGIS. This tool creates a new polygon shape file that contains an attribute table with orientation, minimum width, and maximum length values based on the provided shapefile. We selected the convex hull method to define the Minimum Bounding Polygon (MBP). A convex hull is the polygon with the shortest perimeter that encloses a set of specified points or vertices. The MBG tool also reports the orientation of the convex hull defined as the angle between the line connecting the two vertices separated by the largest distance and the north direction. The orientation values calculated using this method ranged from 0 to 180 degrees. The elongation of each microchaos is obtained by dividing the minimum width by the maximum length of the MBP. Thus, an elongation value of 1 indicates a perfect circle.

We examined the distribution of MBP orientations for different feature types and ranges of latitude. Circular statistics help identify regions where features of different types have consistent or uniform orientation. The

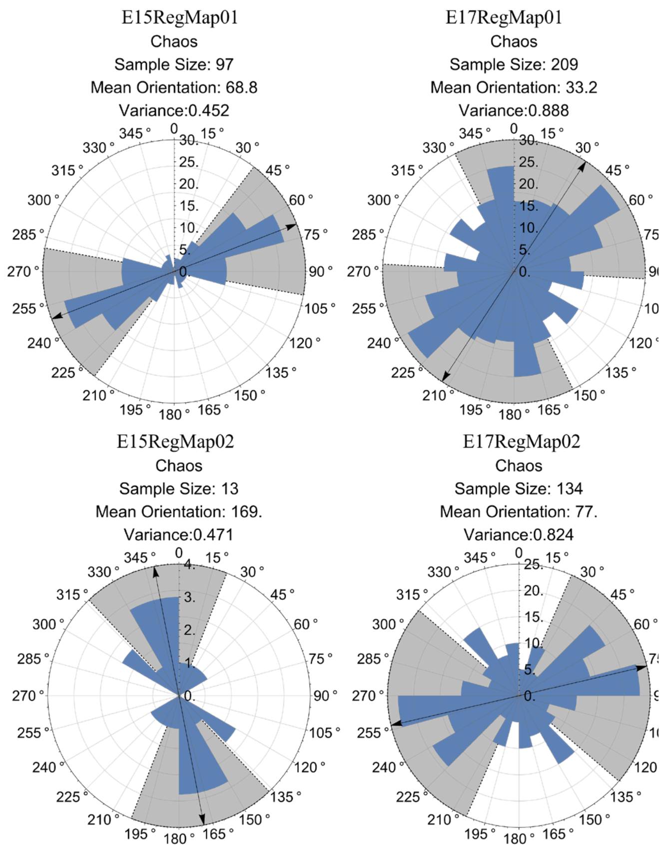

Figure 1. Rose diagrams of chaos in all four regions mapped [2]. The black arrow indicates the mean orientation while the grey region represents the standard deviation of the orientation

Region	Number of Features	Mean Area km^2	σ of Area	Mean Elongation	σ of Elongation	Mean Orientation	Circular Variance
E15RegMap01	347	44.4	46.5	0.66	0.15	57.9	0.61
E15RegMap02	299	326.8	1434.4	0.65	0.16	1.1	0.86
E17RegMap01	221	190.2	542.5	0.66	0.14	59.3	0.91
E17RegMap02	168	23.9	19.5	0.69	0.2	14.3	0.53

Table 1. Summary of the morphological characteristics of lenticulae in four Galileo mosaics. All chaos, hybrids, domes, pits, and spots are tallied to arrive at the number of features in each mosaic region.

circular variance is a quantitative indicator of how dispersed a distribution of orientations is, with a tight distribution having a low circular variance.

Results: Lenticulae of all types have similar elongations but differ in orientation and area in different regions (Table 1). Chaos are typically the largest lenticulae, followed by hybrids, pits, domes, and spots in all regions. When all lenticulae types are merged together, their orientation distributions have high circular variance, especially in the northern leading hemisphere (E15RegMap02) and southern trailing hemisphere (E17RefMap01).

Tighter distributions appear when each feature type is examined individually. For example, Figure 1 focuses on chaos. In the E15RegMap01, chaos are typically oriented at ~70° whereas chaos in the E17RegMap01 have a much wider distribution and possibly bimodal orientation.

In some regions, different feature types follow similar orientations. For example, in the E15RegMap01 region, chaos, pits, and hybrids all have similar well-defined orientations. In contrast, only chaos and pits have similar orientations in the E17RegMap01 region.

Discussion: The larger size but similar orientation of chaos to other types of lenticulae supports the hypothesis that chaos are a more evolved version of these lenticulae. The characteristics of hybrids are consistent with them being in an intermediate evolutionary stage. The possibility of tight orientation distribution suggests that lenticulae are influenced by the large-scale stress field, possibly arising from diurnal tides. Figure 2 shows that feature orientation in the E17RegMap02 region rotates progressively clockwise from pits and domes to hybrid to chaos. This could imply that lenticulae formation was long-lived enough to be subjective to a global stress field that changes perhaps due to non-synchronous rotation. regions where orientation is broadly distributed, such as E17RegMap01 (Figure 1) could also be explained by chaos formation over a geologically long period, in contrast to regions such as E15RegMap02 where there appears there was only a single, short-lived episode or chaos formation.

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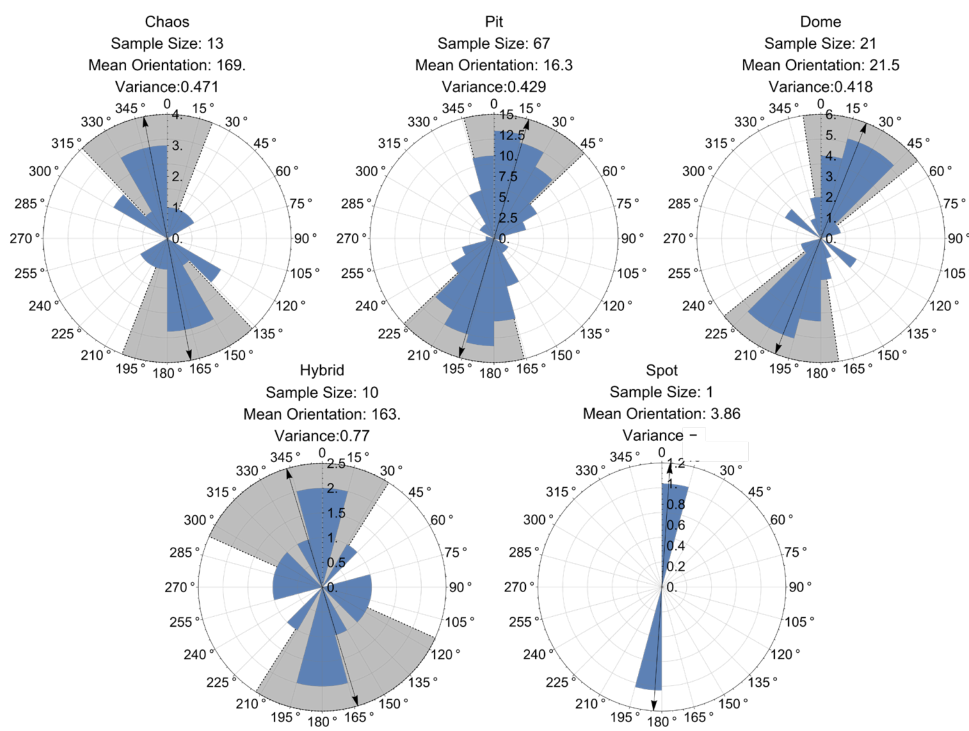

Figure 2. Rose diagrams of lenticula orientation in the E17RegMap02 region separated by feature type (chaos, pits, domes, hybrids, and spots). In this region, pits are the smallest feature then domes, hybrids, and chaos. Following this increasing area relationship, we see a progressive rotation of the mean orientation values which may correspond to a changing stress.