Survey of Europa's E15 and E17 Regions for Putative Cryovolcanic Domes. Sierra N. Ferguson[1], Lynnae C. Quick[2], Lori S. Glaze[3], Louise M. Prockter[4]. [1]Northern Arizona University, Department of Physics and Astronomy, Flagstaff, AZ 86001, snf38@nau.edu, [2]Planetary Science Institute, Tucson, AZ 85719, lquick@psi.edu, [3]NASA Goddard Space Flight Center, Greenbelt, MD 20771, Lori.S.Glaze@nasa.gov, [4]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723, louise.prockter@jhuapl.edu.

Introduction: There is evidence that certain domal lenticulae on Europa may be cryovolcanic in origin [1-5] (Fig. 1). Cryovolcanic domes may form from extrusive eruptions of viscous cryolavas delivered to the surface in cylindrical conduits or dike-like fractures [1,6]. These fractures may be produced when shallow fluid reservoirs in the crust become over pressurized due to partial freezing or tidal stresses, or from fluid-filled fractures that extend from the surface to the ocean [1, 7]. Because domes may form in areas of enhanced local heating [8, 9], pinpointing their locations and geological settings could shed light on areas of the surface that have been recently geologically active. In an effort to determine how these kinds of lenticulae are emplaced, we model formation by viscous cryovolcanic flows on the surface. The modeling efforts will aid in assessing the extent to which effusive volcanism has affected the surface. We used morphological indicators to determine the likely origins of domes in our survey. All domes studied were circular to elliptical positive-relief features ≥ 7 km in diameter. These domes were assumed to have formed either via the extrusive eruption of viscous fluids onto the surface [1-5], or, via diapiric intrusion of warm ice into the crust [1, 2, 10, 11]. To determine if an observed dome would be classified as having extrusive or diapiric origins, domes that were identified as having extrusive origins generally show evidence of smooth material adjacent to the dome, with evidence of embayment of the surrounding terrain [12].

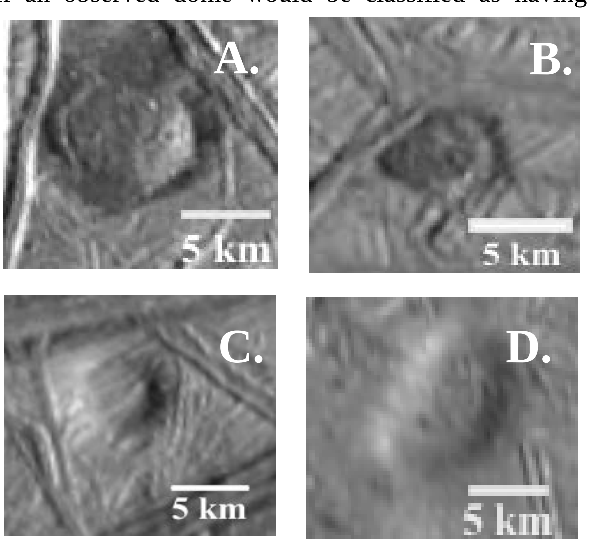

Figure 1. Domes A-B are examples of domes that may have been produced by extrusive cryovolcanism. Domes C-D are categorized as being consistent with diapiric origins.

We use Galileo images to investigate whether the morphology of a subset of domes on Europa is consistent with their formation via extrusive cryovolcanism. Identifying locations of possible effusive volcanism on the surface will aid in the planning for NASA's upcoming Europa flagship mission. The results of this survey will be used to define physical parameters of putative cryovolcanic domes, which will in turn be used as inputs to analytical models for the formation and emplacement of cryovolcanic domes on Europa [3-5].

Method: Many of the best-imaged domes in the Galileo data are found in the Regional Map (i.e., RegMap) sections of Europa. The RegMaps provide coverage of the surface, in two longitudinal strips, one in the leading hemisphere and one in the trailing hemisphere, thus reducing the possibility of longitudinal bias in the analysis. This survey utilizes Galileo E15 and E17 RegMap data. E15Regmap01 is comprised of images from Europa's northern trailing hemisphere, centered at 38°N, 222°W, while E15Regmap02 is centered at 37°N, 89°W in Europa's northern leading hemisphere. E17Regmap01 is centered at -20°N, 210°W on the trailing hemisphere, and Regmap02 is located on the leading hemisphere at -33°N, 82°W. The image resolution for these regions is ~200 m/pixel, which is sufficient to resolve features with radii on the order of 3.5 km. As the diameters of Europa's domes range from 7-20 km [11, 13], these resolutions fit the needs of our survey. Domes were mapped using ArcGIS to determine whether or not a relationship exists between dome type (i.e. extrusive vs intrusive origin) and location.

Results: A total of 70 domes were surveyed during the study. Figure 1 shows examples of two domes that were classified as being consistent with an extrusive origin and two other domes with apparent diapiric origins. Mean diameters and areas were obtained for each dome type, along with other locational parameters, all of which are summarized in Table 1. The mean diameter of domes inferred to have formed from extrusive cryovolcanism is 9.09 km ± 1.77 km, and the error is calculated from 2 times the standard error of the mean. Of the total area surveyed, candidate domes comprise a mean area of 86.06 km^2. The mean diameter of domes consistent with a diapiric origin is 7.56 km ± 1.15 km. These domes comprise a mean area of 85.29 km^2. Fig. 2 shows dome frequency as a function of diameter. We also examined the distribution of domes on the surface. Domes whose morphologies are consistent with cryovolcanic origins are mostly concentrated around 17.50°N, while those whose morphologies are consistent with diapiric origins are mostly concentrated around 21.26°N (Fig. 3).

Discussion: The vast majority of domes included in our survey were located below 30°N and the number of domes observed in the southern hemisphere was very small. This could indicate a preference for dome formation near the equator, perhaps due to enhanced temperatures caused by tidal heating [14, 15]. We also found that the diameters of putative extrusive domes were larger than their counterparts of diapiric origin however, this difference is not statistically significant. A larger sample size would aid in reducing the uncertainty in our results, as well as allow for further investigation into possible differences between the two dome populations.

References. [1] Fagents, S. A. (2003) JGR 108, 5139. [2] Pappalardo, R.T, et al (1999) JGR 104, 24015. [3] Quick, L. C. et al, (2014) 45th LPSC Abstract # 1581. [4] Quick, L. C. et al, (2015) 46th LPSC Abstract #1060. [5] Quick, L. C. et al. (2016) Icarus, submitted. [6] Quick, L. C. & Marsh, B. D. JGVR submitted. [7] Pappalardo, R. T. (1998) Nature 391, 365. [8] Greenberg, R. (1999) Icarus 141, 263. [9] Greenberg, R. (2003) Icarus 161, 102. [10] Rathburn, J. A. (1998) Geophys Res Lett 25, 4157. [11] Figueredo, P. H. (2002) JGR 107, 5026. [12] Prockter, L. M., Schnek, P. M., (2005) Icarus 177, 305. [13] Spaun, N. A., et al (2000) 31st LPSC Abstract #1044 . [14] Sotin, C. et al, (2002) Geophys Res Lett 29, 1029. [15] Tobie, G. et al, (2003) JGR 108, 5124.

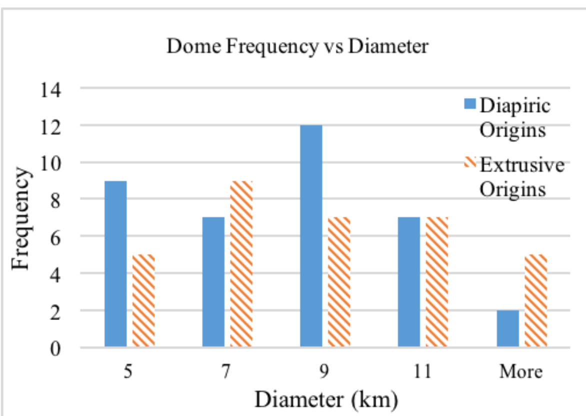

Figure 2. Dome frequency vs diameter. Most domes surveyed have diameters around 9 km. Domes whose morphologies are consistent with diapiric origins tend to be smaller than candidate cryovolcanic domes.

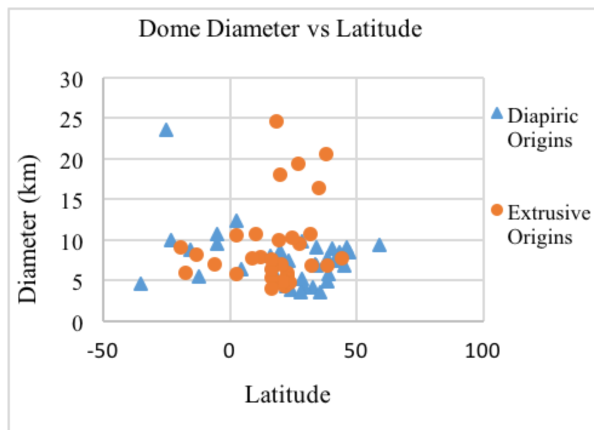

Figure 3. Dome latitude vs. diameter; Each variation of dome is plotted against latitude and diameter. The majority of the candidate cryovolcanic domes are located closer to the equator, whereas the diapirs appear to be more spread out over the surface.

Dome Type	Average Diameter (km)	Median Diameter (km)	Average Area (km^2)	Median Area (km^2)	Average Latitude (°N)	Median Latitude (°N)	Total Number of Domes
Extrusive	9.09 ± 1.77	7.60	86.06	52.00	17.50	20.46	33
Diapir	7.56 ± 1.15	7.48	85.29	52.00	21.26	28.09	37
Combined Dome	8.26 ± 1.04	7.48	85.65	52.00	19.49	21.85	70

Table 1. Physical parameters of the domes observed on the surface.