IDENTIFICATION OF MICROFEATURES ON EUROPA'S SURFACE IN HIGH RESOLUTION IMAGES: ASSESSING THE COMPLETENESS OF AVAILABLE DATASETS. C. A. Zamora[1], J. L. Noviello[1], and A. R. Rhoden[1,2] [1]School of Earth and Space Exploration, Arizona State University, ISTB4-795, 781 E. Terrace Mall, Tempe, AZ 85287. CAZamor2@asu.edu [2]Southwest Research Institute, Boulder, CO 80302

Introduction: Europa is a main target of future solar system exploration [1], but our present understanding of it is hindered by limited data. Europa's surface is predominantly (90%) imaged at low mean ground resolutions [2]. The low resolution images of (≥1.5 km/pix) can obscure the existence of small-scale geologic features, making it challenging to investigate their presence on a majority of Europa's surface. Of particular interest are "microfeatures", which are features less than 100 km^2 in area that are thought to be endogenic in origin. The categories of microfeatures are: domes (positive topographic features); pits (negative topographic features); microchaos (small chaos patches); spots (dark areas with no visible interior disruption or topographic variation within the feature boundaries); and hybrids (a cross between microchaos and domes); examples are shown in Fig. 1 [3–6]. Microfeatures have been mapped in moderate resolution images (the "RegMap" images) using the data provided by the *Galileo* mission [2].

Previous work on microfeatures has focused on identification and classification of different feature types based on these morphological characteristics at regional resolutions better than ~230 meters per pixel [1,3–8], and characterized the spatial distribution of microfeature types. Across all studies, few microfeatures under 10 km^2 in area have been identified, although only one study has specifically searched for them [7]. It is unclear whether features of this size do not exist or if it is not possible to see them in most of the imaging currently available, even at regional map scales (~220 m/pix). Here we present work on the identification and classification of domes, pits, microchaos, spots, and hybrids smaller than 10 km^2 in area by analyzing images with image resolutions ≤100 m/pix. We also make note of the morphologies and locations of features we find that fall outside of our microfeature group definitions.

Detecting microfeatures in high resolution (≤100 m/pix) imaging of Europa can provide a more thorough understanding of the characteristic sizes of microfeatures because it tests the completeness of existing datasets. These observations can then be used to constrain microfeature formation models and heat transport in Europa's ice shell, and yield deeper insights into the geophysics of Europa and icy satellites in general [9–11]. The Europa Clipper mission will be taking the best photos of the surface to date [1, 12], but these data will not be available for years. Gathering as much data and information as possible from the *Galileo* mission about these microfeatures will help with the understanding of the satellite now and aid the upcoming Europa Clipper mission and its findings.

Methods: To look for microfeatures below 10 km^2 in area, we examine raw *Galileo* images, including regions in which mapping has already been done, with mean ground resolutions less than or equal to 100 m/pix that were taken with the clear filter [13]. We then note any potential microfeatures and classify them according to previous methodology [3–8]. Classification rests on observational constraints [2] and minimum feature size, which we determined to be at most 500 m. Of the 126 high resolution images, 95 showed potential microfeatures. The images were then organized into groups of similar incidence angles. Including a broad range of incidence angles is important in identifying features at high resolutions because different lighting conditions will aid in the detection of either topographic (high incidence angles) or albedo features (low incidence angles) [2]. The analyzed images are then narrowed down by selecting images with the clearest features to identify, map, and classify them more easily.

Results and Discussion: The pits observed in most of the raw images tend to be localized and are often oriented and trend in the same general direction, consistent with previous work [3,7,8]. We noted 27 total pits. The grouped pits also share similar relative sizes, again consistent with previous work [14]. Of the 95 images, 5 showed pits with this cluster and orientation trend, 1 depicted a pit cluster lacking general orientation, 5 showed singular pits, and 2 images contained both singular and clustered

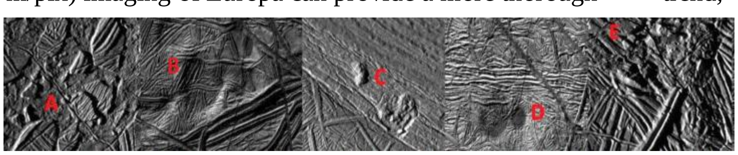

Figure 1: A, B, C, D, and E (left to right) show examples of chaos, pits, domes, spots, and dome/chaos (hybrid) at high resolution images respectively. A-B sunlight source is from the top right. C-E lighting is from the right.

Figure 1	Image ID	Mean Ground Resolution
A	7513r	54.28 m/pix
B	8726r	63.34 m/pix
C	9526r	51.55 m/pix
D	8713r	64.03 m/pix
E	6726r	32.55 m/pix

pits. Also observed was the lack of special preference for where these features are formed and found. This includes albedo brightness, surface roughness, and elevation differences (pits found on top of ridges and in low topography). The qualitative analysis of these images show that pits are found in disruptive surfaces. When found in this environment, they tend to form singularly, when compared to the typical closeness of clustered pits on far less disrupted ice [3,15].

Small domes were also observed on the surface, but in fewer numbers than pits, 20 altogether. The majority of the tiny domes were found in groups (Fig. 2). Hybrids were found in images which included microchaos and yielded to 5 identified features.

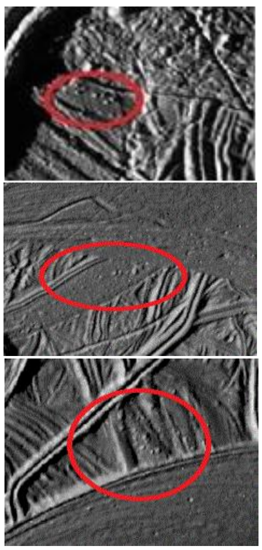

Figure 2: Small bright positive concave features found across Europa's surface circled in red.

Figure 2	Image ID	Mean Ground Resolution
Top	6700r	32.08 m/pix
Middle	0213r	40.55 m/pix
Bottom	0152r	41.63 m/pix

The identification and classification of small black spots and microchaos was easier as these features tend to have a distinct lower albedo and/or a rough surface. The black spots do tend to occur in groups at relatively the same density as pits but in less abundance, 16 spots in total. These spot groups typically number 2-3 spots. Patches of small chaos can be found in groups or solitarily, and were much more abundant than other microfeatures observed in this study totaling at 38.

The investigation of microfeatures led to the recognition of the spongey terrain surrounding Manannán Crater, which extends radially and becomes less rough with increasing distance from the crater. The surface of the disrupted terrain has a uniform high albedo atop its topography with dark albedo, or possibly shadowed, depressions throughout its formation. This material is specific to Manannán Crater and, to our knowledge, has not been noted elsewhere on Europa. A few relatively uniform circle-shaped depressions within the spongey terrain were discovered. The "sunk-in" surfaces could possibly be pit formations in the rugged terrain or secondary crater ejecta; future work will address this question. If the circular features found in the deformed terrain are in fact singular pits, then it supports the result that pits can arise in various terrain type on Europa.

Conclusion: The presence of microfeatures on Europa's surface have been identified in resolutions equal to or less than 100 m/pix. Given that the pits tend to form in clusters, finding and studying these small features could lead to locating more small pits. Additionally, analyzing their orientation trends to look for a common pattern of spatial distribution and/or correlations with other features types (e.g. nearby ridges) could offer clues to their formation. Further investigation of pits should move in the detection of these features in various terrains, including chaotic/disrupted areas, as preference for pit formation in certain areas or locality types is not fully understood. The tiny positive topographic features also need further analysis; they may be boulders and/or crater ejecta. The advantage in discovering these uplifts is that they also tend to form in groups. Microchaos was found abundantly. Spots, microchaos, and domes do not appear to share orientation direction.

Future work will including retrieving morphometric data regarding the size and shapes of these features, and will evaluate the degree of clustering of these microfeatures. Definitively describing and categorizing these features will help in understanding their various morphologies, broadening the known information of these structures. This information will increase the use of the *Galileo* data to evaluate current geological and geophysical models by providing additional observational constraints. Doing the same for the possible pits on the Manannán crater terrain, and studying the formation mechanisms of the spongey terrain in general, can also help with understanding the endogenic system of Europa and its endogenic processes.

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