THE DETAILED GEOLOGIC HISTORY OF EUROPA'S PWYLL AND MANANNÁN IMPACT CRATERS.
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Introduction: Europa has one of the least cratered surfaces in the Solar System: only 24 confirmed impact craters ≧10 km in diameter [1]. Yet, these impact craters can reveal crucial insights into the subsurface structure, in particular the ice shell thickness. Constraining the ice shell thickness is of the utmost importance for understanding the habitability of Europa [e.g., 2, 3]. While simple and regular complex craters have predictable morphologies, those above a diameter of ~20 km (irregular complex craters and multiring basins) have unusual morphologies: e.g., a lack of coherent central structures, poorly developed/missing rims, and multiring morphology at unusually small sizes [4]. The properties of the larger craters (above ~20 km) are proposed to be attributed to the presence of a subsurface ocean [e.g., 5]. Some larger impacts may even have penetrated through the ice shell [e.g., 6].

Pwyll and Manannán are two key impact craters that occur in the transition diameter to more unusual crater morphologies. Pwyll's central peak is one input to the conclusion that the ice shell is at least 10-19 km thick [4]. Authors [5, 7, 8] conclude that both the Pwyll and Manannán crater-forming impacts did not penetrate through the ice shell. In contrast, authors [6, 9, 10] suggest that Manannán's lack of a well-defined central peak, and the crater's generally anomalous appearance, indicate that it impacted into liquid and/or slushy ice and/or warmer, thinner ice than the Pwyll-forming impactor, which did not penetrate through the ice shell.

Goal: In contrast to the existing non-standardized maps of these impact craters, our geologic maps will have consistent extents and scales, contain the same high level of detail, and will be mapped by the same team using the same techniques. Thus, the goal of the current project is to create detailed geologic maps of Pwyll and Manannán impact craters (publication scale of 1:250,000), which will fill a gap in the available data by providing detailed, definitive and consistent GIS-format geologic maps. These maps are needed to provide real-world constraints for future modeling studies that seek to infer ice-shell thickness based on detailed crater morphologies.

Results – Data Sets: In addition to producing the geologic maps, we are also processing greyscale, color and DEM data on which we will base the geologic mapping. This data is aligned and georeferenced using the newly developed SPICE kernels for Europa [11]. We will make this data available to the community at the end of our project, for use in future studies.

The primary basemap is composed of individual greyscale images taken by the Galileo Solid-State Imaging (SSI) camera, which have a spatial resolution of up to tens of meters per pixel. We are supplementing the primary basemap with color mosaics, which we make from color images also taken by the Galileo SSI camera. We are also creating digital elevation models (DEMs) from the available SSI stereo pair images.

Results – Pwyll: We have processed and aligned the greyscale, color and DEM data for Pwyll. The spatial resolution of the greyscale data ranges from ~50 to ~250 m/pixel, and the vertical range of the DEM is ~400 m. The color mosaic shows that the crater interior and continuous ejecta are distinctly brown, in contrast to the white/pale blue-colored surrounding terrain. We measure the diameter of Pwyll crater to be ~26 km, which is significantly smaller than the IAU-listed diameter of 45 km [12]. The 45 km diameter corresponds to the diameter of the continuous ejecta.

Certain, approximate and inferred contacts define the geologic units, which we divide into three groupings based on superposition relationships:

Older grouping. The lineated and blocky terrain (lb) and band material (b) are superposed by Pwyll crater, and thus pre-date the impact. The lineated and blocky terrain is similar to the regional plains material and/or chaos materials of the global geologic map [13], but cannot be conclusively identified as either in our relatively small mapped area. The band material is the same type of geologic unit as the band material in the global geologic map, but is too small in area to include in the global geologic map. The global geologic map was mapped at a much broader scale of 1:15M, and defines the area surrounding Pwyll as continuous ejecta material and Pwyll radial crater ejecta material [13].

Younger grouping. The crater material (c), dark crater material (dc), massif material (m) and terrace material (t) were all formed during the Pwyll-forming impact. The dark crater material is readily identifiable in the greyscale data as being distinctly darker than the surroundings, and in the color data as being distinctly brown. We interpret it as the continuous ejecta. The crater material does not have a distinct brightness/darkness or color, and thus we define it using textural differences with the surroundings. We interpret it as the discontinuous ejecta. The massif and terrace materials formed simultaneously with the ejecta, as the crater interior was broken up and partially collapsed. In the global geologic map, the entire crater interior is mapped as one unit (crater material) and the ejecta is mapped as continuous ejecta material [13]. There is a discontinuous raised rim around parts of the impact crater, but elsewhere there is no clear rim or contact between the crater ejecta and the interior.

Youngest grouping. The bright, smooth bright and dark crater floor materials (bcf, sbcf and dcf, respectively) are located in the floor of Pwyll and often have lobate margins. One deposit of smooth bright crater floor material is strikingly yellow in the color data. Based on the work of authors such as [14, 15 and references therein], we interpret that all three crater floor materials are deposits of impact melt slurry that would have flowed around the crater interior under a solid carapace for geologically short timescales after the crater formed (i.e., on the order of thousands of years), before finally solidifying in place superposing the massif and terrace materials.

We also mapped linear features and point features. Many of the roughly circular depression point features are likely secondary craters formed by the Pwyll impact. The linear features radial to the crater are also likely formed by material ejected during the Pwyll-forming impact. The secondary craters and radial linear features concentrate to the south, perhaps indicating an oblique impact from the north. The almost perfectly circular shape of the impact crater indicates that the impact was not highly oblique, perhaps ~45-90°, based on [16].

Results – Manannán: We have processed and aligned the greyscale and DEM data for Manannán crater and the surrounding region. The color mosaics are in progress. The spatial resolution of the greyscale data ranges from ~20 to ~220 m/pixel, and the vertical range of the DEM is ~400 m. The highest spatial resolution DEM data (based on ~20 m/pixel stereo pair images) covers the interior of Manannán, and was used for creating a DEM that indicates the presence of high-standing massifs and low-elevation regions scattered throughout the crater interior. A clearly defined crater rim is not visible in the DEMs.

Conclusions and Future Work: Our work demonstrates the additional insights that can be derived from mapping at higher scales in localized regions (e.g., 1:250,000 versus 1:15M), and thus the importance and complementary nature of localized geologic mapping in comparison to global geologic maps. Next, we will finish the color mosaic(s) for Manannán, refine the mapping of Pwyll and map Manannán.

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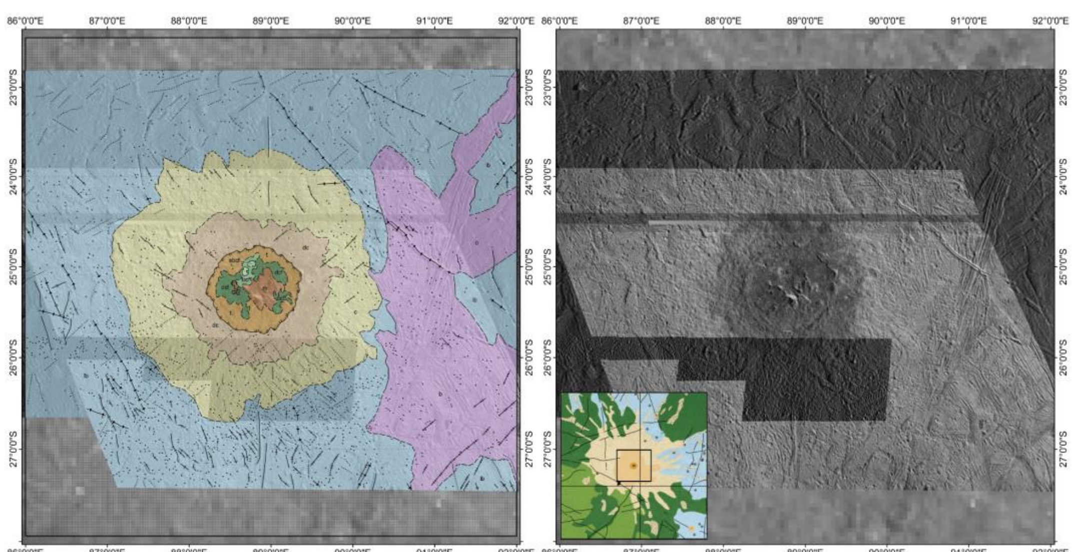

Figure 1: Preliminary geologic map of Pwyll crater and the immediate surroundings (left), and the greyscale data on which it is based (right). The black box in the inset image shows the same region in the global geologic map [13].