HIGH-RESOLUTION GEOLOGIC MAPPING OF URVARA CRATER, CERES: BASEMAP, CRATER COUNTING, AND FEATURE MAPS.

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Introduction: *Objectives:* We are developing a detailed geologic map and accompanying chronostratigraphy of Urvara crater, Ceres, based on high-resolution image data (3.5-20 m/px) acquired at the end of the Dawn mission. Crater diameter: 170 km. Map region: -128° to -93° E longitude, -59° to -35° N latitude. Publication scale: 1:250,000. Digitization scale: 1:50,000.

Science drivers: Two major landscape development questions arose from the Dawn mission at Ceres: What was the role of impacts in facilitating the development of putative cryovolcanic landforms? And to what degree did individual large impacts contribute to observed regional and hemispheric variation in crustal ice content? Reconstructing the chronological evolution of individual crater interiors and ejecta deposits is critical to addressing both questions. Recent analysis and mapping based on high-resolution images of Occator crater, Ceres, have produced a detailed chronological sequence of crater floor evolution and strengthened the case for prolonged hydrothermal activity and/or cryovolcanism at Occator [1,2]. Performing a comparable analysis at Urvara will allow us to evaluate whether extrusive processes have occurred at Urvara and draw conclusions about crater evolution and the impact redistribution of volatiles that have global relevance for Ceres.

Mapping Approach & Progress:

Basemap Mosaic Development: We have produced two sets of image mosaics: v.1 was produced quickly at the beginning of the project to allow preliminary mapping assessments; v.2 substantially reduced registration errors and was completed in October 2020.

There are ~1600 Level 2b images of the Urvara region at resolutions down to ~3-4 m/px, ~1200 are better than 10 m/px. Procedurally, to produce the mosaics we found image-to-image control points with the ISIS "findfeatures" routine. We then added ground control points manually to tie images to the DLR LAMO basemap (v.2 includes a much larger number of ground control points) and performed a bundle adjustment with the ISIS "jigsaw" routine to update pointing. As a side benefit, we were able to generate improved SPICE CK and SPK kernels for all component images from the updated pointing info. We performed photometric correction, map projection (polar stereo at 5 m/px), and mosaicking, with the highest resolution images generally placed on top.

The final result is a ~40000 x 57000 pixel mosaic at 5 m/px resolution with minimal registration errors between images and minimal offsets from the DLR

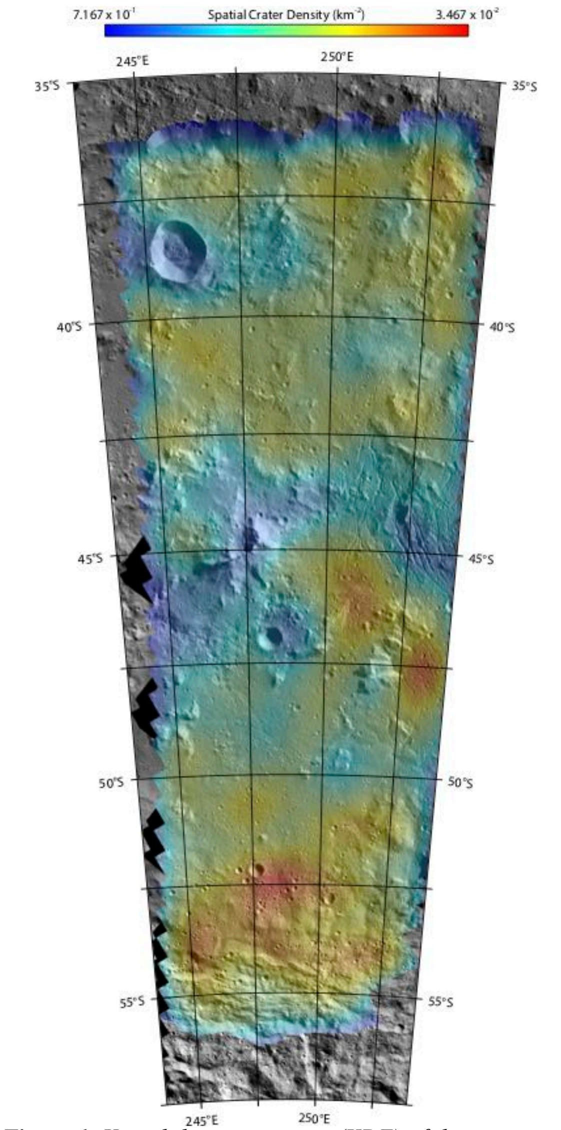

***Figure 1**. Kernel density estimate (KDE) of the interior of Urvara crater. The KDE was geodesically calculated by using the 3403 craters larger than 300 m in diameter identified within the area continuously covered by XM07 data at ground resolutions between 4 and 10 m/px and applying a statistically derived search radius or bandwidth of 9 km. At the current resolution, defined by the bandwidth or number of craters, respectively, lower crater densities correlate with the two biggest younger impact craters, the central peak, and the fracture system. Higher densities correlate with a (probably secondary) crater cluster. Extending the crater data by including smaller craters may reveal more local crater density variations, and possible correlations with specific geomorphic units.*

LAMO basemap – a significant improvement over original the SPICE pointing (and over the v.1 mosaic). We also produced smaller mosaics to guide the mapping team's awareness of coverage at pixel scales >5 m/px. The v.2 mosaic or subsequent improved versions will be archived in the PDS in 2021-2022.

Crater Counting: We began counting craters when the v.2 mosaic was completed. On the new dataset, we have already identified and counted 20,800 craters larger than about 60 m in diameter. Fig. 1 shows the kernel density estimate (KDE) developed using only craters larger than 300 m in diameter, as measurements below that size are still incomplete. We will develop a crater data base complete for craters larger than ~100 m in diameter. Subsequent analysis will likely expose crater density variabilities comparable to sizes of smaller geomorphologic units, adding quantifiable information for establishing a detailed stratigraphic chart. Based on results of the KDE, we will evaluate the feasibility of determining absolute model ages for specific regions or units of interest.

Feature Mapping: A primary science goal of this mapping effort is to define the relative ages of geologic units on the floor of Urvara crater and assess the hypothesis that a portion of the floor materials are cryovolcanic in origin. However, the muted character of Ceres' surface makes drawing unit boundaries challenging. For this reason, the mapping team is focusing on mapping a set of discrete geologic features prior to defining the set of geologic units to be mapped. Prioritized feature types include: domes/hills, pits, pit chains, crater chains, ridges, grooves, troughs, channels, and hillslope features (including slump blocks, boulders, and boulder tracks). We will present these feature maps at the 2021 Geologic Mappers meeting, along with comparisons to previously published LAMO and HAMO maps. Fig. 2 shows some of the fantastic detail visible in the basemap mosaic, including individual boulders and boulder tracks.

Acknowledgments: This work is supported by the NASA Discovery Data Analysis Program through grant 80NSSC20K1150. We gratefully acknowledge the use of Dawn FC2 (Framing Camera 2) level 1b calibrated images available on the PDS Small Bodies Node: Nathues et al., 2016; https://sbn.psi.edu/pds/resource/dawn/dwncfcL1.html.

References: [1] Scully J. E. C. et al (2019) *Icarus, 320,* 213-225. [2] Scully J. E. C et al. (2020) *Nat. Comm., 11,* 3680. [3] Crown D. A. et al. (2018) *Icarus, 316,* 167-190. [4] Neesemann A. et al. (2019) *Icarus, 320,* 60-82.

Figure 2. (Below) Detail of the Urvara crater rim as seen in the v.2 basemap mosaic, including a prominent slump block, and individual boulders and boulder tracks.