HIGH-RESOLUTION GEOLOGIC MAPPING OF URVARA CRATER, CERES: PRELIMINARY MAPS & CRATER COUNTS.

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Introduction: We are developing a detailed geologic map and accompanying chronostratigraphy of Urvara crater, Ceres, based on high-resolution images (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 variations 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]. We are conducting a comparable analysis at Urvara 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: There are ~1600 Level 2b images of the Urvara region from the XM2 mission phase at resolutions down to ~3-4 m/px; ~1200 have resolutions between 3 and 10 m/px. From these images, we have produced a mosaic covering most of the map area, as well as smaller higher resolution mosaics. Procedurally, we found image-to-image control points with the ISIS "findfeatures" routine to produce the mosaics. We then added ground control points manually to tie images to the DLR LAMO basemap and performed a bundle adjustment with the ISIS "jigsaw" routine to update pointing. We were also able to generate improved SPICE CK and SPK kernels for all component images from the updated pointing information. 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 basemap is a ~40000 x 57000 pixel mosaic at 5 m/px resolution with minimal registration errors between images and minimal offsets from the DLR LAMO basemap – a significant improvement over original the SPICE pointing. We also produced mosaics consisting only of the subsets of images with native resolutions of 3-7, 7-14, and 14-28 m/px (geometric mean values of 5, 10, and 20 m/px). The current mosaic or subsequent improved versions will be archived in the PDS in 2022.

Crater Counting: Based on the new basemap mosaic, we developed a crater database complete for craters larger than ~100 m in diameter, identifying and measuring more than 20,800 craters. We also produced crater density estimates (KDE) for crater diameters >400 m and >300 m. The goal of this analysis is to correlate variations in crater density with 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 potential for cryovolcanism after the impact. Because the muted character of Ceres' surface makes drawing unit boundaries challenging [e.g., 3, 4], we have focused on mapping geologic features prior to defining the set of geologic units to be mapped. Prioritized feature types include: mounds, domes, pits, pit chains, crater chains, ridges, grooves, troughs, channels, lobate flow margins,

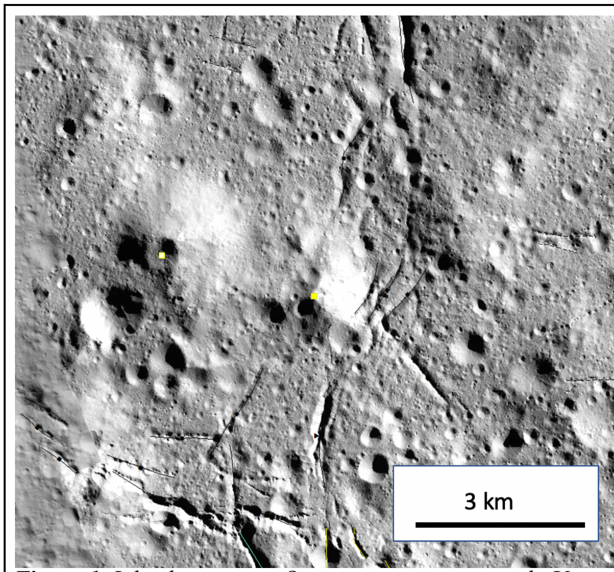

***Figure 1**. Like the younger Occator crater to its north, Urvara crater hosts a variety of distinct conical and dome-shaped hills with diameters <2 km, which are associated with smooth materials on the crater floor. Similar features in Occator have been hypothesized to form via hydrologic processes in a progressive freezing environment, similar to terrestrial pingos.*

and hillslope features, including slump blocks, boulders, and boulder tracks.

Understanding hillslope features and mass wasting is of particular importance in defining geologic units and establishing a chronostratigraphy. As such, we have carried out a detailed analysis of talus slopes, boulders, and boulder tracks at scales significantly below the map digitalization scale of 1:50K. We identified boulders and boulder tracks at 1:10K-1:20K scale on Urvara's rim scarps and central peak by systematically surveying XM2 mosaics; we subsequently revised and updated this database at 1:5K scale. Details of this analysis are described by [5].

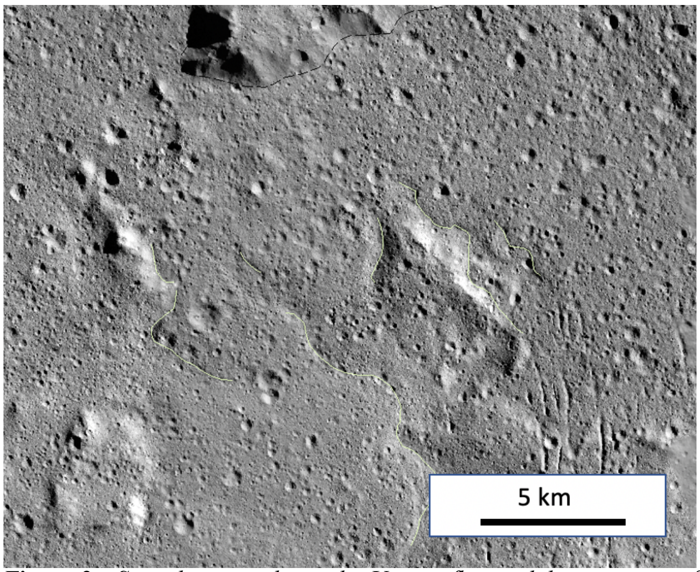

***Figure 2**. Smooth materials on the Urvara floor exhibit a variety of localized, lobate margins and embayment relationships with more rugged high-standing material. These clear contacts are not continuous across the smooth floor of the crater, however, despite variations in floor texture, color, and crater density. Our mapping approach is designed to systematically guide extension of these contacts.*

We have also scrutinized small hills and mounds on the Urvara floor, as similar features have received substantial attention in Occator crater as candidate hydrologic or cryovolcanic constructs [6; 7]. We performed initial surveys of the map area at 1:20K scale to identify all distinct, round to oblate high standing features smaller than 3 km. We then refined our morphological classifications through repeat surveys at 1:30K and 1:50K. Our end goal is to establish clear morphological classifications of small mounds in Urvara and correlate them with their host floor material units. This will allow us to make direct comparisons to previous analyses of Occator crater [e.g., 2] and assess whether particular morphologies are associated with specific types of floor materials.

The floor of Urvara exhibits a variety of distinct linear features. The most prominent are (1) the ~20 km long central ridge, trending SW to NE at the crater center; and (2) an extensive system of troughs and ridges in the crater's NE quadrant. In terms of local topographic relief, the Urvara trough and ridge system is intermediate between the fully developed fault system of Nar Sulcus in neighboring Yalode crater and more flat-lying systems of floor fractures in Occator crater and elsewhere. The Urvara floor also exhibits smaller fracture networks in the northern half of the crater, including those adjacent to conical mounds (Fig. 1). Some fracture systems in the NE quadrant terminate in sinuous channels and proto-networks [3]. Curvilinear and lobate flow margins are also apparent in the southern crater floor.

One of the major challenges of delineating the geologic history of Occator crater was the presence of multiple superposed floor material types, many of which have locally distinct flow margins [e.g., 2]. The generally muted or "softened" character of Ceres' surface has challenged the definition of clear unit contacts in geologic mapping efforts at all length scales [3, 4]. These challenges are amplified at Urvara, which shows evidence of the same complexity seen at Occator, but with a higher degree of muting and degradation due to its greater age. In this context, the initial point and line feature mapping has provided a foundation for defining floor material units. Boulder tracks and boulder clusters aided definition of a talus unit and small crater ejecta unit. Linear features – particularly troughs, grooves, channels, and lobate flow margins -- have been useful in differentiating between smooth floor materials and older, high-standing materials. Further differentiation between smooth floor material types will be guided by surface texture analysis and color image data.

We will present feature maps, preliminary unit maps, and preliminary absolute ages at the 53rd LPSC.

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