HIGH-RESOLUTION GEOLOGIC MAPPING OF URVARA CRATER, CERES: UNIT DEFINITIONS, CRATER DENSITIES & FEATURE CORRELATIONS. H. G. Sizemore[1], D. A. Crown[1], J. E. C. Scully[2], D. C. Berman[1], A. Neesemann[3], D. L. Buczkowski[4], and D. P. O'Brien[1]. [1]Planetary Science Institute (sizemore@psi.edu), [2]Jet Propulsion Laboratory, [3]Freie Universität Berlin, [4]Johns-Hopkins University Applied Physics Laboratory.

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 temporal 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.

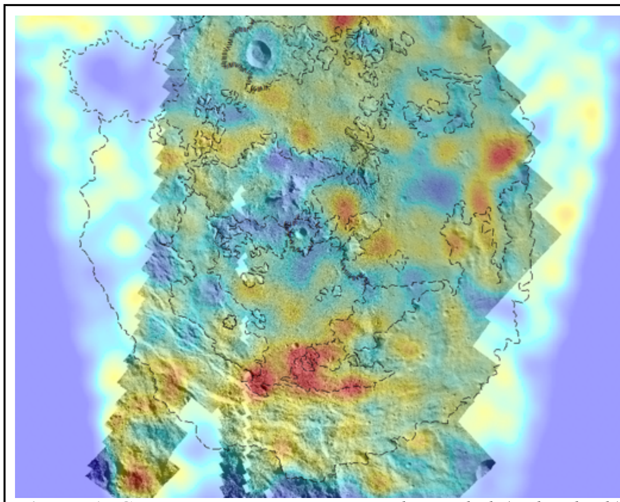

***Figure 1**. Geocontact mapping over color-coded (red is high) 400 m crater density kernel, map scale 1:1,000,000. Two extended regions of Muted terrace material separate the crater floor from terraces in the southern half of Urvara; this unit is absent in the north. Flat-lying smooth material in the south (Usfm) and northeast (Usm) are separated by a gradational contact, based on the convergence of east-trending and west-trending flow fronts and a change in texture. Crater density is dominated by secondary craters from impacts outside the map area and is not correlated with map units.*

Mapping Approach & Progress:

Basemap, crater counts, feature mapping: We previously produced a mosaic [3] covering most of the map area, using ~1600 Level 2b images of the Urvara region from the XM2 phase of the Dawn mission. The resultant 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. 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).

Using the 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 produced crater density estimates (KDE) for crater diameters >400 m and >300 m (Figure 1).

The muted character of Ceres' surface makes drawing unit boundaries challenging [e.g., 4, 5], therefore we focused on mapping discrete geologic features prior to defining the geologic units and mapping geocontacts. We sequentially mapped and analyzed hillslope features (boulders, boulder tracks), point features (mounds, domes, etc.), and large-scale linear features (scarps, troughs, grooves, fractures, etc.), using a grid-mapping approach for the latter categories. Through this process, we developed preliminary guidelines for defining units in the crater interior and mapping the clearest contacts.

Unit definitions and geocontact mapping: A key motivator for high-resolution mapping at Urvara is making direct comparisons to high resolution geologic mapping of another putative cryvolcanic region on Ceres, Occator crater. A major challenge to delineating the geologic history of the Occator interior was the presence of multiple superposed floor materials, many of which exhibit flow margins that are only locally distinct [e.g., 2]. The generally muted or "softened" character of Ceres' surface has proven challenging to the definition of clear unit contacts in mapping efforts at all length scales across the dwarf planet [4, 5]. These challenges are increased at Urvara, a location that exhibits similar complexity to Occator, but with a higher degree of muting and degradation due to its greater age.

Our ultimate goal in defining map units inside Urvara was to determine if and how smooth floor materials could be delineated from one another to facilitate age determinations and an assessment of the hypothesis that materials in the southern portion of the crater have a cryovolcanic origin.

Because the materials of highest interest in Urvara were also the most technically challenging to map, we employed a process-of-elimination approach, sequentially defining and mapping units that were clearly not "smooth" floor materials. As a preliminary step, analysis of hillslopes with boulders and boulder tracks below the map digitalization scale of 1:50K [6] allowed us to establish clear criteria for the definition of Crater material (Cm) and Talus material (Tm). Talus material was typically differentiated from surrounding material by a sharp change in slope and texture, as well as boulders and tracks. Crater material associated with relatively young impacts was commonly highlighted by boulder fields, but sharp contacts with surroundings were rare. We chose to indicate boulder fields with a stipple pattern and map Crater material contacts only where they were readily apparent.

Next, we defined a Hummocky floor material (Hfm) unit. Our three main criteria for mapping hummocky material were: (1) elevation above surrounding smooth material; (2) strong topographic variations on shorter length-scales than surroundings; and (3) at least one location where scarps or outcrops disrupt smooth veneers. These criteria allowed us to map contacts with and without clear embayment relationships, and established rules for how patches and thin veneers of smooth material on otherwise rough terrain would be handled in subsequent unit definitions.

We first applied this mapping approach to discrete patches of hummocky material in the southern crater floor, where embayment relationships were evident. We then mapped similar material, proceeding counterclockwise around the crater interior to regions where embayment relationships were less common or absent. Our working criteria for delineating smooth and not-smooth materials proved effective, and rapidly led to the definition and mapping of two additional units: Central peak material (Cpm) and Terrace material (Tm).

Mapping of terrace materials revealed a clear intermediate unit between continuous smooth material on the crater floor and the terraces, which we called Terrace material muted (Tmm). This unit is intermediate in both elevation and roughness between terraces and the crater floor. Its contact with the floor materials is marked by a sharp change in slope, and commonly exhibits a lobate character.

We defined one additional "not-smooth" unit in the crater interior: Hummocky floor material incised (Hfmi). This unit is characterized by elevations below its generally flat-lying surroundings and a muted, pitted texture at 10-100m length scales. This unit was previously hypothesized to be a degraded example of pitted ejecta faces produced by volatile outgassing and independently described on Mars, Vesta, and elsewhere on Ceres [7]. Regardless of its origin, the Hfmi unit is morphologically distinct from all other materials in the Urvara interior.

The definition of these seven units – Cm, Tlm, Hfm, Tm, Cpm, Tmm, and Hfmi – delineated a large region of smooth material on the crater floor by default. A core science question of our mapping effort is whether portions of this smooth material were distinct in terms of morphology and/or age. We ultimately divided the extended smooth region into two units: Urvara smooth material (Usm) and Urvara southern floor smooth material (Usfsm) based on textural differences between the southern floor and smooth areas in the eastern and northern floor, as well as a convergence of eastward trending and westward trending flow-fronts running approximately N-S in the southeast quadrant of the crater floor (see Fig. 1).

Interpretation: Preliminary comparisons between the unit mapping and the 400 m crater density kernel (Fig. 1) do not show clear correlations. Indeed, crater densities at this scale appear to be dominated by secondary craters from recent impacts outside the map area. We are currently in the process of reviewing all geocontact mapping and determining absolute unit ages.

Additionally, we are making a systematic comparison of point feature mapping in Urvara to work previously done in Occator crater, with a particular focus on small domes & mounds as possible markers of hydrothermal or cryogenic activity [8, 9]. We will present a preliminary assessment of the cryovolcanic hypothesis for the origin of the southern floor materials in Urvara at the 54th LPSC.

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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] Sizemore H. G. et al. (2022) *53rd LPSC*. [4] Crown D. A. et al. (2018) *Icarus, 316,* 167-190. [5] Mest S. C. et al. (2023) *Icarus,* in review. [6] Crown D. A. et al. (2022) *53rd LPSC.* [7] Sizemore H. G. et al. (2017) *Geophys. Res. Let., Vol. 44*, 13, 6570-6578. [8] Schmidt B. E. et al. (2020) *Nat. Geo,* 13, 605-610. [9] Schenk P. et al. (2020) *Nat. Comm.,* 11, art. No. 3679.