URVARA AND YALODE BASINS: STRATIGRAPHIC MARKERS IN THE GEOLOGIC RECORD OF CERES. R.A. Yingst[1], D.A. Crown[1], H.G. Sizemore[1], S.C. Mest[1], D.C. Berman[1], T. Platz[1,2], N. Schmedemann[3], R. Wagner[4], F. Preusker[4], A. Nathues[2], M. Hoffman[2], M. Schaefer[2] and the Dawn Science Team; [1]Planetary Science Institute (1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719; yingst@psi.edu); [2]Max Planck Institute for Solar System Research, Göttingen, Germany; [3]Freie Universitat Berlin, Berlin, Germany; [4]German Aerospace Center (DLR), Berlin, Germany.

Introduction: On Earth, fossils provide powerful stratigraphic markers that facilitate the correlation of isochronous strata and provide the basis upon which a chronostratigraphic time scale may be constructed. To establish a relative time scale for other planets, impact structures and associated ejecta are often used, as these events constitute datable events with widespread effects. Global stratigraphic systems that include impact basins as key stratigraphic markers have been developed for several bodies, including the Moon, Mercury and Mars [e.g., 1-3]. Large impact basins are now recognized on the surface of Ceres, and this research explores their use in stratigraphic studies.

NASA's Dawn spacecraft arrived at Ceres on March 5, 2015, and has been studying the dwarf planet through a series of successively lower orbits, obtaining morphological, topographical, mineralogical, elemental, and gravity data. Using these data, we have characterized the stratigraphic relationships between the impact structures Urvara (45.9°S, 249.2°E) and Yalode (42.3°S, 293.6°E), and suggest that these basins may be used as stratigraphic markers in deconvolving the geologic history of Ceres.

Basin morphology: Preliminary geologic maps of the Urvara and Yalode basins have been created as part of ongoing geologic mapping of quadrangles on Ceres [4, 5]; these impact structures are shown in Figure 1. At ~260 km diameter, Yalode basin is the second largest basin identified on Ceres. It has a variably preserved rim, which is continuous and sharply defined to the north/northwest, and is irregular or subdued and degraded elsewhere. Rim scarp morphology indicates enlargement by collapse and mass wasting. The presence of a potential interior ring is indicated by a raised circular to semi-circular mound that rises gradually from the basin floor to the NE and includes a more rugged portion to the SW. The basin floor also includes hummocky and smooth areas (some bounded by scarps), crater chains, and a lineated zone. It lacks discrete ejecta deposits.

The ~170 km diameter Urvara impact lies west of Yalode. Urvara basin displays a distinct morphological dichotomy. The northern Urvara rim is sharply defined, with evidence of fluidized ejecta draping rim terraces. An extended smooth region mapped to the north of the basin likely represents a major portion of the continuous ejecta blanket [4]. In the south, the Urvara rim is less distinct, with pronounced rugged terraces interior to the rim and hummocky ejecta extending from the rim toward the S pole. The Urvara floor contains both smooth and pitted terrain, associated with a system of grooves or lineaments; these could be the result of impact fluidization and/or volatile release [4, 6]. Differences in morphology from SW to NE are consistent with variations in the material properties of the subsurface.

Stratigraphic relations: Cross-cutting and superposition relationships allow the relative ages of Urvara and Yalode to be determined [6-9]. Yalode basin and its floor deposits appear to have been strongly affected by the Urvara impact. The Yalode western rim is irregular and partially buried by subsequently-emplaced material; this is consistent with disruption and embayment of Yalode by formation of Urvara. The presence of regional tectonic fabric (lineaments radial to Urvara) influences the formation and orientation of Yalode structural features. Finally, mass wasting along the northern rim scarp has enlarged Yalode, unlike Urvara. All these observations indicate a younger relative age for Urvara.

Extent of influence: Work on modeling the distribution, extent and characteristics of impact structures in the environment of Ceres is in its very early stages. However, lineaments that can be traced back to Yalode and Urvara extend over 400 km in some cases [8], indicating that the stratigraphic influence of these basins extends at least that far. Additionally, we can compare large impact structures on other small, airless, rocky bodies, to make a gross estimate of the extent of the influence of Urvara and Yalode on the surface geology. This will help us assess their use in determining a global stratigraphic system for Ceres,

For example, Yalode basin, at 260 km diameter, measures ~9% of Ceres' circumference (assuming a ~470 km sphere radius). Similarly, a common estimate of the diameter of the Imbrium basin, ~1145 km [e.g., 1], is ~11% of the Moon's circumference, assuming a 1735 km lunar radius. The Apollo 16 site, 1600 km from the basin rim, is widely considered as influenced by Imbrium ejecta. Further, basin formation modeling has indicated that Imbrium ejecta may occur up to three basin diameters distant from the rim (e.g., [10-12]) and mix to a depth of 100s of meters even 600-700 km from the basin rim [13].

Using these numbers as a baseline, we estimate the extent of the Yalode and Urvara impact ejecta as perhaps 3x each basin diameter (this is a simplification; the difference in surface gravity might result in differences in the number and nature of secondary impacts that actually reach the surface, for example). Because the basins are essentially tangential, scaling from Imbrium basin yields a circle ~1800 km in diameter in which Yalode, Urvara or both ejecta blankets would influence the geologic record, and thus the stratigraphic record. This would, in turn, equate to roughly 60% of Ceres' circumference. Even a more conservative estimate of one crater diameter for ejecta extent would yield recognizable Urvara or Yalode ejecta within a circle 780 km across (>25% Ceres' circumference).

Conclusions: The Urvara and Yalode basins are clearly separated in time as determined by cross-cutting and superposition relationships, yielding two significant stratigraphic markers for Ceres. The extent of ejecta, though not rigorously known, can be estimated by analogy with lunar basins. While we make no estimate of ejecta thickness or coverage, we note that the gross estimate of ejecta extent is significant enough that these basins should be considered potential stratigraphic markers in the Ceres chronostratigraphic record. Future work will include mapping the two basins and their environs using Low-Altitude Mapping Orbit (LAMO) data, which will help reveal the full extent and distribution of ejecta and distal impact features (e.g., secondary clusters, crater chains, fractures [7, 8, 14]).

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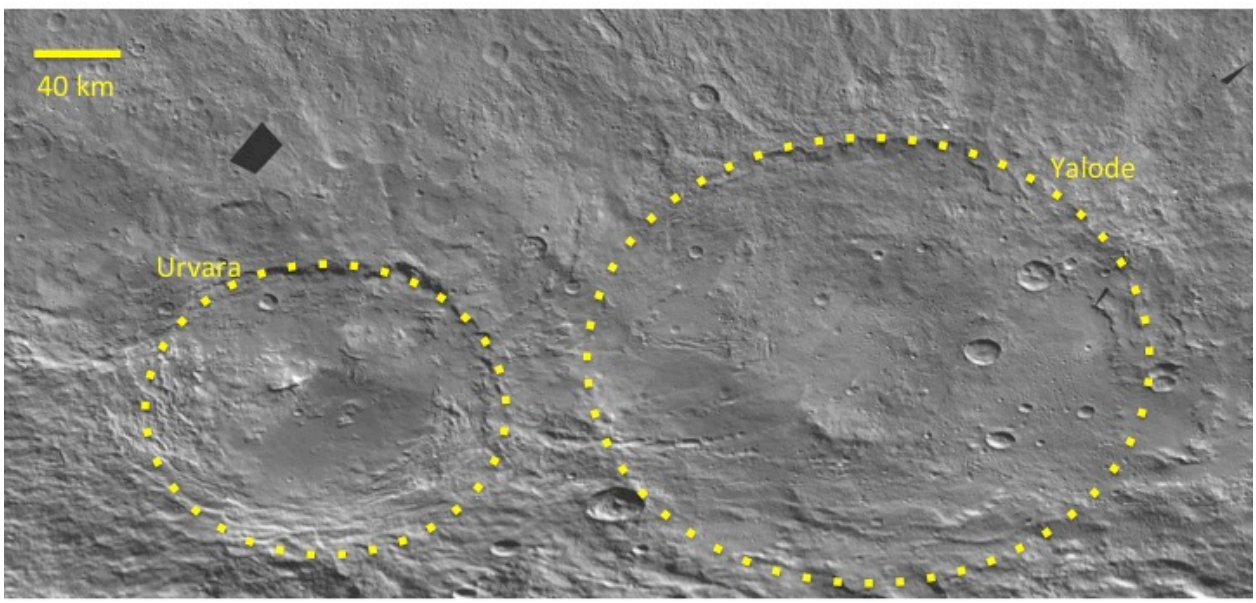

Figure 1. The impact structures Urvara (left) and Yalode (right). Image taken from Dawn Framing Camera mosaic acquired at 415 m/pxl. North is up.