HIGH-RESOLUTION GEOLOGICAL MAPPING OF DWARF PLANET CERES FROM NASA's DAWN MISSION. D. A. Williams[1], D. L. Buczkowski[2], S. C. Mest[3], J. E. C. Scully[4], K. Krohn[5], D.A. Crown[3], A. Nass[5], R. Jaumann[5], C. A. Raymond[4], and C. T. Russell[6], [1]School of Earth & Space Exploration, Arizona State University, Box 871404, Tempe, AZ 85287 (David.Williams@asu.edu); [2]Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA; [3]Planetary Science Institute, Tucson, Arizona, USA; [4]NASA Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109; [5]German Aerospace Center (DLR), Berlin, Germany; [6]Department of Earth and Space Sciences, UCLA, Los Angeles, CA.

Introduction: NASA's Dawn spacecraft arrived at dwarf planet Ceres on March 5, 2015. As part of the Ceres orbital mission, the Dawn Science Team instituted a geological mapping campaign, building on the successful mapping campaign for asteroid (4) Vesta [1]. In this abstract we report on the current progress of the Ceres mapping campaign.

Data for Mapping: Dawn's Nominal Mission at Ceres [2] consisted of operations in four orbital phases: Approach (Framing Camera (FC) spatial resolution 10-1.3 km/pixel), Survey (415 m/pixel), High Altitude Mapping (HAMO, 140 m/pixel), and Low Altitude Mapping (LAMO, 35 m/pixel). Geologic feature identification on Ceres began during approach, and a series of geologic maps are being generated using FC image basemaps and stereo-based digital terrain models (DTMs) from Survey, HAMO, and LAMO orbits. The first Survey-based geologic map was published in [3].

HAMO-based Global Map: S.C. Mest is leading the effort to construct a global geologic map based on HAMO images. This map not only describes the global geology of Ceres, but also is used to define Ceres chronostratigraphy and geologic time scale. For details on the HAMO global map, see the companion abstract by Mest et al. [this meeting].

LAMO-based Quadrangle Maps: The surface of Ceres was divided into 15 quadrangles to aid in cartographic processing of Framing Camera images [4], and these 15 LAMO-based image quadrangles served as basemaps for our high-resolution geologic mapping. The goal of this mapping campaign was to conduct detailed geological studies of interesting reagions/features on Ceres to aid in determination of Ceres geologic history, and to provide geologic context to support analyses of the Visible and Infrared spectrometer (VIR) and Gamma Ray and Neutron Detector (GRaND) and gravity data sets. Preliminary geological maps were presented as a series of 14 posters at the 47th LPSC. Since March 2016 we have received final FC image mosaics, revised DTMs, and preliminary VIR data to complete final 'nominal mission' versions of our quadrangle-based geologic maps. All mapping is being done using ArcGIS™ software. Generating consistent project data (w.r.t. structure and geometry) and comparable map sheets (w.r.t. cartographic symbology) required creation of a GIS template [5]. The map results are being included in a series of papers for a Special Issue of Icarus to be published in 2017, in which the individual quadrangle map papers are under review (as of January 2017). In the following sections we highlight some of the key results from several of our quadrangle maps.

Kerwan Quadrangle. The 284-km diameter Kerwan impact basin (center 10.77˚S, 123.99˚E) is the largest indisputable and oldest impact crater on Ceres, based on 1) the degradation state of its rim [6, 7] and the lack of any identifiable ejecta from Kerwan, suggesting the terrain has been gardened to the point where Kerwan is indistinct from the surrounding cratered terrain; 2) the lack of any larger, definitive impact craters [8]; 3) preliminary crater size-frequency distribution measurements of 'smooth' material in and surrounding the Kerwan basin, indicating it is the oldest unit outside of the 'cratered terrain' that makes up most of Ceres' crust [7]; and 4) modeling suggesting that the Kerwan basin has undergone considerable viscous relaxation compared to Ceres smaller craters, suggestive of advanced age [6]. Crater counts of the 'smooth' material within and around the Kerwan basin indicate an absolute model age (AMA) of 1.30 Ga (Lunar-Derived chronology Model, LDM: [7]) and 0.27 Ga (Asteroid-Derived Model, ADM: [7]). Although there are no contact relations between Kerwan and Yalode basin materials, based on our current crater counts of their ejecta blankets, we infer that Kerwan is older than Yalode, and that the Kerwan impact event marks the base of the cerean geologic timescale, separating the Pre-Kerwanan cratered terrain from younger Kerwanan materials [9].

Urvara-Yalode Quadrangles. Urvara (170 km diameter) and Yalode (260 km diameter) are adjacent impact basins in Ceres' southern hemisphere. Cross-cutting and superposition relations show that Urvara superposes Yalode, that their ejecta blankets are complexly intermingled, and that large areas of smooth material now cover much of their floors and extend beyond their rims, with some possible evidence of localized ice-rich flows. AMAs of their ejecta blankets indicate Urvara formed ~120-140 Ma (LDM) whereas Yalode formed ~1.1 Ga or earlier (LDM) [10]. For additional details see the companion abstract by Crown et al. [this meeting].

Occator Quadrangle: Occator Quadrangle has four large craters that have fractured, shallow floors, morphologically similar to lunar floor fractured craters. The fractures are interpreted to be caused by uplift from cryomagmatic plumes. The 92 km diameter crater Occator is well known for its bright spots, now named Cerealia Facula (central bright spot) and Vinalia Faculae (eastern bright spots). The Vinalia Faculae occur over the Occator floor fractures, thought to be the source vents for explosive cryovolcanic venting (for more details, see the abstract by O. Ruesch et al. [this meeting]. Cerealia Facula may also have had explosive venting, but is dominated in its center by a ~2 km diameter dome within a 9 km wide central pit [11], interpreted as an extrusive cryovolcanic construct [12].

Haulani Quadrangle: 34 km diameter Haulani crater is one of the youngest features on the surface (~1.7-2.5 Ma, both chronology systems). This crater displays distinctive rays and a bright ejecta blanket, as well as a complex interior morphology including terraces, a central peak, and both smooth and hummocky floor materials. Lobate materials suggest ice flows or possibly cryovolcanic flows [13].

Endgame: Once final revisions to the quadrangle maps have been completed, and all of the quadrangle mapping papers have been accepted, we will merge together the 15 quadrangle maps in ArcGIS™ to make a final LAMO-based global map of Ceres (**Figure 1**). This will be made freely available by the Dawn Science Team, and will serve as the definitive map until a USGS-publishable global map of Ceres can be proposed to NASA, probably in 2018.

References: [1] Williams, D.A. et al. (2014) *Icarus, 244,* 1-12. [2] Russell, C.T. and Raymond, C.A. (2011) *Space Sci. Rev., 163*, 3-23. [3] Buczkowski, D.L. et al. (2016) *Science, 353,* dx.doi.org/10.1126/science.aaf 4332. [4] Roatsch, T. et al. (2016) *PSS 129*, 103-107. [5] Nass, A. et al. (2017) LPSC, this meeting. [6] Bland, M.T. et al. (2016) Nat. Geosci., 9, 538-542. [7] Hiesinger, H. et al. (2016) *Science, 353*, dx.doi.org/10.1126/science.aaf4759. [8] Marchi, S. et al. (2016) *Nat. Comm.*, dx.doi.org/10.1038/ncomms 12257. [9] Williams, D.A. et al. (2017) *Icarus*, in review. [10] Crown, D.A. et al. (2017) *Icarus*, in review. [11] Schenk, P. et al. (2015) EPSC EPSC2015-400. [12] Buczkowski, D.L. et al. (2017) *Icarus*, in review. [13] Krohn, K. et al. (2017) *Icarus*, in review.

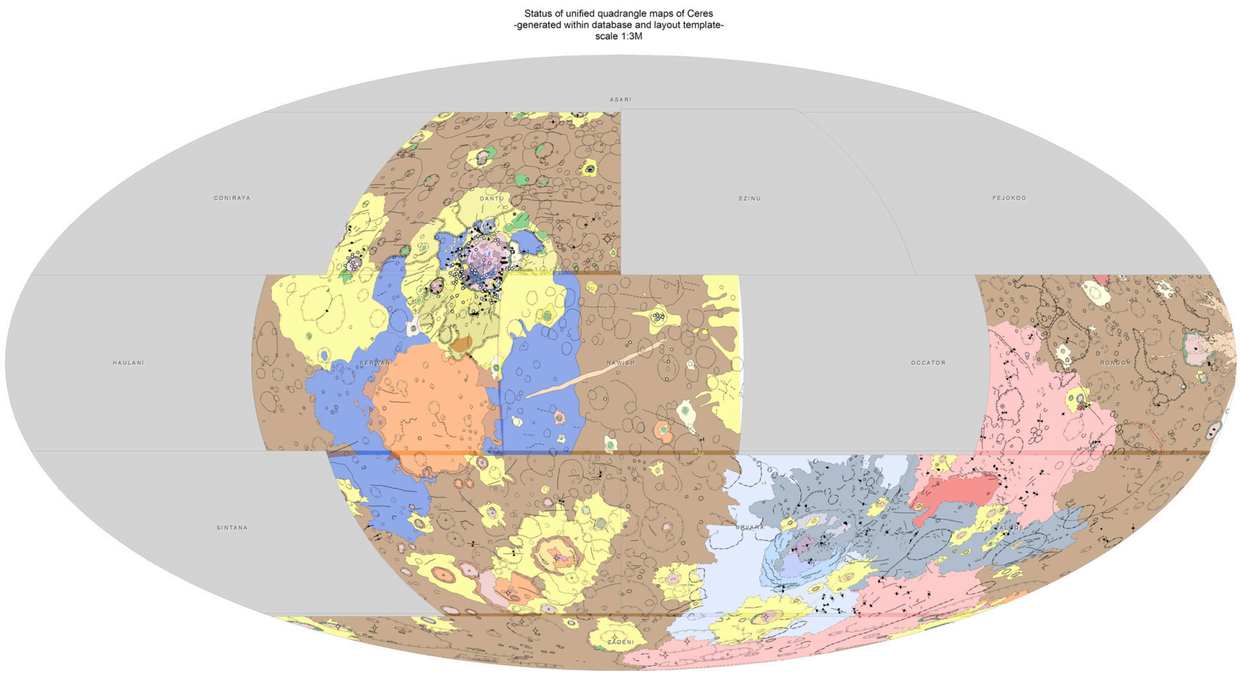

Figure 1. First conversion of 8 of 15 LAMO-based quadrangle maps of dwarf planet Ceres into one single geologic map (imaged as Molleweide projection). This matching was implemented by the help of the predefined ArcGIS™ template. NOTE: These quadrangle maps are undergoing peer review, and will be adapted and updated before final publication. GIS processing and cartographic support by Andrea Nass, DLR.