GEOLOGIC HISTORY OF THE EZINU QUADRANGLE OF CERES, DERIVED FROM A GEOLOGIC MAP BASED ON DATA FROM THE DAWN MISSION.

Jennifer E. C. Scully[a], D. L. Buczkowski[b], D. A. Williams[c], S. C. Mest[d], C. A. Raymond[a], J-P. Combe[e], A. Neesemann[f], J. H. Pasckert[g], K. Hughson[h], T. Kneissl[f], O. Ruesch[i], A. Frigeri[j], C. T. Russell[h], A. Nass[k], A. Ermakov[l], R. Jaumann[k], M. Hoffmann[m], A. Nathues[m], R. Park[a], C. M. Pieters[n], T. Platz[m], F. Preusker[k], T. Roatsch[k], M. Schaefer[m], [a]*Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA (jennifer.e.scully@jpl.nasa.gov)*, [b]*JHU-APL, Laurel, MD, USA,* [c]*ASU, Tempe, AZ, USA,* [d]*PSI, Tucson, AZ, USA,* [e]*Bear Fight Institute, Winthrop, WA, USA,* [f]*Free University of Berlin, Berlin, Germany,* [g]*University of Münster, Münster, Germany,* [h]*UCLA, CA, USA,* [i]*NASA GSFC, Greenbelt, MD, USA,* [j]*INAF/IFSI, Rome, Italy,* [k]*German Aerospace Center (DLR), Berlin, Germany,* [l]*MIT, Cambridge, MA, USA,* [m]*Max Planck Institute for Solar System Research (MPS), Göttingen, Germany,* [n]*Brown University, Providence, Rhode Island, USA.*

Introduction: The Dawn spacecraft is the first to visit and orbit Ceres, a dwarf planet in the asteroid belt (mean radius of 470 ± 1 km) [1]. Pre-Dawn research predicted that Ceres is composed of an anhydrous silicate core, a layer of hydrated silicates and a water-rich outer layer [2-3]. The outer layer was predicted to be mostly featureless, because of viscous relaxation [4].

However, Dawn data shows there are numerous impact craters on Ceres' surface, and the simple-to-complex transition diameter of impact craters indicates that the outer layer contains only <40% water ice [5-6]. While less abundant than originally predicted, this water ice may control the formation of domical features and particular types of ice-related lobate flows [7-9], especially at higher latitudes, where thermal modeling shows surface and subsurface ice will be more stable [10]. In addition, distinctive bright areas are observed, in particular within the floor of the 92-km-diameter Occator crater, which are commonly referred to as the 'Occator crater bright spots' [11].

Here we present a geologic map and geologic history of Ezinu quadrangle, located from 21-66 °N and 180-270 °E. Ezinu quadrangle is positioned in the northern mid-latitudes, a transitional region of water-ice thermal stability, which makes it an ideal location to study: (a) whether the <40% water ice is heterogeneously distributed within Ceres' subsurface, and (b) whether the <40% water ice influences the morphology expressed on Ceres' surface.

Materials and Methods:

Mapping approach. The Dawn science team conducted a systematic geologic mapping campaign at Ceres, similar to that undertaken at Vesta [12], in which the surface is divided into fifteen quadrangles (Fig. 1 inset) [13]. Each quadrangle is mapped by a lead mapper, supported by the lead mappers of neighboring quadrangles and other members of the Dawn science team. We primarily use ESRI ArcMap 10.3 software for our geologic mapping. On the basis of United States Geological Survey (USGS) guidelines and the spatial resolution of our basemap (see Data sources), we mapped at a scale of 1:100,000-1:125,000 and display the geologic map with a publication scale of 1:500,000. We also use map symbols that are based on the standardized symbology recommended for planetary geology features by the USGS [14].

Data sources. The basemap is an uncontrolled mosaic of clear filter Framing Camera images (35 m/pixel, produced by DLR). We also use additional ancillary datasets to inform our geologic mapping: (i) clear filter Framing Camera mosaics that we produced using the USGS ISIS software (35 m/pixel); (ii) photometrically corrected mosaics of clear filter Framing Camera images (140 m/pixel, produced by DLR); (iii) enhanced color mosaics and color composite mosaics, made from color Framing Camera images (140 m/pixel, spectral range of 440 – 965 nm, produced by MPS and DLR); and (iv) a shape model derived from clear filter Framing Camera images (135 m/pixel, height accuracy of 12 m, produced by DLR).

Results:

Maps. We implement a number of minimum dimension criteria in our geologic map of Ezinu quadrangle (Fig. 1), to avoid the map becoming cluttered: (i) only display geologic units and surface features that are ≥5 km wide; (ii) only display line features that are ≥5 km long and spaced at distances of ≥3 km; (iii) only display the rims of impact craters that are ≥5 km in diameter; and (iv) only display point features that are spaced at distances of ≥3 km. We also produce inset maps of regions of particular geologic interest, in which minimum dimension criteria are not applied.

Definition of Map Units. We describe and interpret the geologic units in a detailed table, which is too large to include in this abstract, and will be included in the presentation based on this abstract. Furthermore, our detailed observations and interpretations of linear features, surface features and point features mapped in Ezinu quadrangle will also be included in the presentation based on this abstract. Here we show a schematic representation of the geologic units, their cross-cutting relationships and contacts (Fig. 2).

Discussion: geologic history:

Stratigraphically oldest period. We interpret the cratered terrain (crt) as the stratigraphically oldest geologic unit within Ezinu quadrangle, because it does not cross-cut any other geologic units. Ezinu, Geshtin and Kaikara craters formed during this period. We interpret that a set of impact crater chains, furrows and clusters of small craters, along with a set of pit chains and grooves, also formed during this period, because these linear features are cross-cut by Occator crater and its associated geologic units, which formed during the subsequent, stratigraphically intermediate period.

Stratigraphically intermediate period. Impacts occurred in the crt that resulted in the formation of craters such as Occator, Ninsar, Messor and Datan. These impact craters contain the following geologic units: hummocky crater floor materials (hcf), crater central peak material (ccp) and crater terrace materials (ct), and are surrounded by crater materials (c). The hcf and ct likely continued to form after the c and ccp, because mass wasting and slumping can continue in an impact crater long after its formation, whereas impact crater ejecta and central peaks are emplaced immediately following an impact.

Stratigraphically young period. On the basis of cross-cutting relationships, we interpret that the lobate material (l) formed next. For example, lobate material cross-cuts and appears to flow out on top of the Datan crater material. There are also additional types of lobate materials found exclusively within Occator crater: the lobate material bright (lb) (the 'Occator crater bright spots'), the knobby lobate materials (lk), and the smooth lobate materials (ls). The exact natures of these lobate materials are currently under investigation by the entire Dawn team, because of their proximity to the 'Occator crater bright spots'.

Stratigraphically youngest period. On the basis of cross-cutting relationships, we interpret that the hummocky lobate materials (lh) and talus material (ta) formed during the stratigraphically youngest period. However, gradational contacts between the lh, lb and ls indicate that emplacement of the lh began during the stratigraphically young period.

Future work:

By investigating whether mass wasting features, in particular the lobate materials, are ice-related or dry, we will use Ezinu quadrangle as a study area to investigate whether: (a) the <40% water ice is heterogeneously distributed within Ceres' subsurface, and (b) the <40% water ice influences the morphology expressed on Ceres' surface. In addition, we will assess whether there is a correlation between the distribution of the lobate materials, linear features and bright spots, and provide contextual geologic information about Occator crater and its bright spots.

References: [1] Russell C. T. et al. (2016) *Science* (in revision). [2] Castillo-Rogez J. C. and McCord T. B. (2010) *Icarus*, 205, 443-459. [3] McCord T. M. and Sotin C. (2005) *JGR*, 110, E05009. [4] Bland M. T. (2013) *Icarus*, 226, 510-521. [5] Hiesinger H. et al. (2016) *Science* (in revision). [6] Bland M. T. et al. (2016) *Nature Geoscience* (in revision). [7] Buczkowski D. L. et al. (2016) *Science* (in revision). [8] Ruesch O. et al. (2016) *Science* (in revision). [9] Schmidt, B. E. et al. (201 *Nature Geoscience* (in review). [10] Hayne P. O. and Aharonson O. (2015) *JGR* (in press). [11] Nathues A. et al. (2015) Nature, 528, 237-240. [12] Williams D. A. et al. (2014) *Icarus*, 244, 1-12. [13] Roatsch T. et al. (2016) *PSS*, 121, 115-120. [14] Federal Geographic Data Committee (2006) *FGDC Digital Cartographic Standard for Geologic Map Symbolization.*

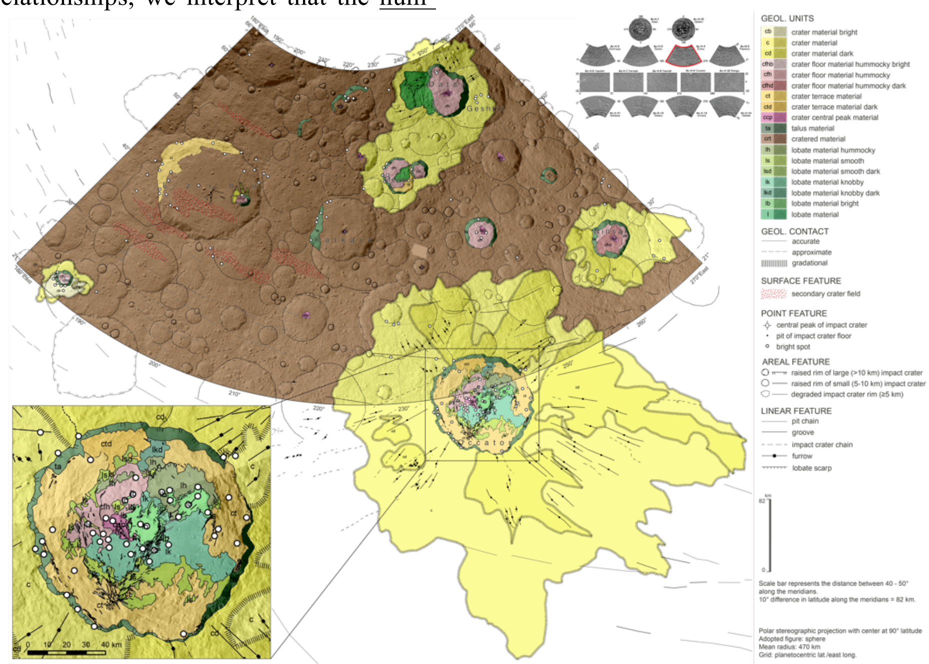

Fig. 1. Geologic map of Ezinu quadrangle, and inset map of 15 Cerean quadrangles.

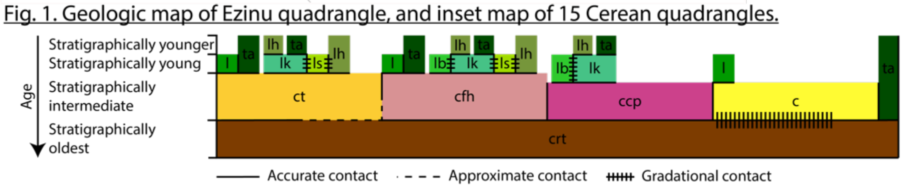

Fig. 2. Schematic representation of the geologic units in Ezinu quadrangle, their cross-cutting relationships and contacts.