GEOLOGIC MAPPING OF CERES' OCCATOR CRATER AND ITS FACULAE. J. E. C. Scully[1], D. L. Buczkowski[2], C. A. Raymond[1], T. Bowling[3], D. A. Williams[4], A. Neesemann[5], P. M. Schenk[6], J. C. Castillo-Rogez[1], C. T. Russell[7], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (jennifer.e.scully@jpl.nasa.gov), [2]JHU APL, Laurel, MD, USA, [3]The University of Chicago, IL, USA, [4]ASU, Tempe, AZ, USA, [5]Free University of Berlin, Berlin, Germany, [6]LPI, Houston, TX, USA, [7]UCLA, Los Angeles, CA, USA.

Introduction: Ceres is the largest object in the asteroid belt (radius of ~470 km) and was first explored from orbit by the Dawn mission, which reached the dwarf planet in March 2015 [1]. Occator is a ~92 km diameter crater located at 20 °N, 239 °E. It is one of Ceres' most intriguing and recognizable features thanks to its bright regions, called faculae, which are distributed across its floor and are much brighter than average Ceres: a single scattering albedo of up to 0.67-0.80 versus 0.09-0.11 [2]. The central region is called Cerealia Facula and the Vinalia Faculae are in the eastern floor. A ~9 km wide and ~800 m deep central pit contains both a ~300-700 m high central dome and most of Cerealia Facula [3-4]. The faculae are mostly composed of sodium carbonate [5]. Here we present a detailed map of Occator's interior and ejecta, which is part of a group of studies about Occator that will be presented in an upcoming special issue of '*Icarus*' [6].

Methods: The basemap upon which we based our geologic map of Occator is a mosaic of clear filter Framing Camera images (~35 m/pixel), produced by the German Aerospace Center (DLR) [7]. We also used supplementary datasets to assist with our analysis: the shape model of Occator (horizontal spacing of ~32 m/pixel and vertical accuracy of ~1.5 m) [8] and a photometrically corrected mosaic of clear filter Framing Camera images, also produced by DLR (~140 m/pixel). Our map area extends from the center of Occator crater to the farthest mapped extent of its ejecta blanket. When mapping Occator, we used ESRI ArcMap 10.3 software and a scale of 1:100,000.

Results: *Regional setting.* Occator is located within the ~500 km wide, topographically high Hanami Planum, which has the strongest negative Bouguer anomaly on Ceres [9]. Nearby complex craters have ejecta blankets, crater terrace material, hummocky crater floor material and talus material similar to Occator [10-11].

Crater/dark crater material. We interpret that these units are an ejecta deposit and that the dark crater material around Occator was excavated from deeper within Ceres' subsurface than the crater material. The concentration of dark crater material to Occator's east could be explained by an inhomogeneous distribution of dark source material laterally and/or vertically within the subsurface.

Hummocky crater floor material and crater/dark crater terrace material. These units likely formed shortly after the formation of the crater, as material collapsed from Occator's walls, infilling the floor, and as portions of the walls collapsed in a coherent fashion to form a stepped morphology, respectively.

Lobate materials. The lobate materials are located within two regions of Occator: (1) in an extensive deposit that fills the southern and eastern crater floor and (2) in separate pond-like deposits at different elevations throughout the crater interior. We interpret the lobate materials as flows that superpose the underlying units. The smooth lobate material may lack entrained blocks and/or be thick enough to bury any pre-existing topographic features. The knobby lobate material may contain entrained blocks and/or be thin enough for underlying, pre-existing topographic features to disrupt/break the surface of the flow. Post-emplacement modification, such as inflation, may have given the hummocky lobate material its distinctive texture [12].

Bright Occator pit/fracture material. This unit corresponds to the Cerealia and Vinalia Faculae. The Cerealia Facula consists of an inner, roughly circular continuous deposit of bright material that is surrounded by a discontinuous outer edge of more diffuse bright material. The Vinalia Faculae are a cluster of roughly circular diffuse bright material deposits. We interpret that the outer edge of Cerealia Facula was emplaced before the formation of the central pit, because the concentric fractures, which likely formed during pit collapse, cross-cut the outer edge of Cerealia Facula. A bright cap of Cerealia material could have been stranded on an otherwise dark hill during pit collapse. There are no cross-cutting relationships observed between the inner part of Cerealia Facula and the concentric fractures. Thus, the inner part of Cerealia Facula could have been modified or continued to form after the formation of the concentric fractures/central pit.

Talus material. This is one of the youngest units within Occator crater and is a mass-wasting deposit.

Point, linear and topographic features. Bright spots (<5km point features) are small impact craters/ejecta blankets or are the source regions of bright, elongate mass wasting deposits. Linear features inside and surrounding Occator crater are impact-derived crater chains or tectonically derived pit chains [see 12-13 for details]. In addition to Occator's central pit, which contains a central dome, there are three topographic rises (≤1 km high) within the crater center.

Discussion: *Insights derived from geologic mapping.* Our mapping of Occator's ejecta blanket is consistent with the Occator-forming impactor originating from the northwest with an impact angle of ~30-45°. Our mapping also indicates that the Vinalia Faculae deposits are a maximum of ~50-100 m thick and that Cerealia Facula is at least ~30 m thick.

The lobate materials have previously been interpreted as impact melt, as mass wasting deposits, or as cryovolcanic flows [e.g. 3, 8, 14 and references therein]. We observe that the lobate materials superpose, and appear to have flowed out onto, the hummocky crater floor material and crater terrace material. We find that the geomorphological characteristics of the lobate materials are consistent with an impact melt [see also 15]: their location within an impact crater, the occurrence of separate, pond-like deposits at different elevations throughout the crater, and the lack of clear origination points. One set of model ages derived for Occator crater find that the ejecta and lobate materials are essentially contemporaneous [16], which is consistent with the lobate materials being an impact melt. Impact modeling predicts that more than enough material would be heated above the melting point of water ice [17] to form the lobate materials as a slurry of impact-melted water mixed with salts in solution and boulders of unmelted silicates and salts.

Proposed geologic history.

- Occator crater forms, possibly excavating material from different subsurface layers or regions, which are deposited in its ejecta [see also 14, 18].
- Crater-wall collapse and mass wasting forms the crater terrace material and hummocky crater floor material. Converging sets of collapsing terraces form ~90° bends in the crater rim.
- Impact-derived heat melts some of the target material. The resulting slurry is mobile for a geologically short timescale after the impact and flows around the crater interior [see also 15-17].
- The outer edge of Cerealia Facula and the knobby lobate material are emplaced prior to the formation of the central pit, because they are crosscut by fractures concentric to the central pit.
- The inner part of Cerealia Facula may have been modified or continued to form after the formation of the central pit. See [6] for a detailed discussion of how this feature formed, which is based on multiple studies from this special issue.
- The hummocky lobate materials are formed by post-emplacement inflation [12]. Multiple sets of fractures are also formed within the crater, which are analyzed in [12].
- The Vinalia Faculae are emplaced by a ballistic process, superposing the hummocky lobate materials [see also 14, 19, 20].
- The central dome forms within the Cerealia Facula. See [6] for a detailed discussion of how this feature formed, which is based on multiple studies from this special issue. There are no clearly defined stratigraphic relations to indicate when the dome formed with respect to the Vinalia Faculae.
- Geologically recent mass wasting forms talus material and geologically recent small impacts expose bright material from the sub-surface.

Conclusions:

- The geologic units of Occator crater that make it unusual are the lobate materials, the Cerealia Facula and the Vinalia Faculae.
- We propose the lobate materials are a slurry of impact-melted water mixed with salts in solution and boulders of unmelted silicates and salts.
- The knobby lobate material and outer edge of Cerealia Facula were emplaced prior to the central pit. After central pit formation, the inner part of Cerealia Facula may have continued to form or have been modified.
- Our mapping does not identify any clearly defined stratigraphic relations between the Cerealia Facula region and the Vinalia Faculae region.
- The diffuse morphology of the Vinalia Faculae and of the outer edge of Cerealia Facula suggests they may have been emplaced in a similar process.
- Small impact craters and their ejecta blankets indicate the sub-surface Cerealia Facula material is even brighter, indicating darkening since initial emplacement [see also 21-23].

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