

**GEOLOGIC MAPPING (1:10,000) OF CEREALIA FACULA BASED ON DAWN'S HIGH RESOLUTION XM2 DATA.** J.H. Pasckert<sup>1</sup>, J.E.C. Scully<sup>2</sup>, D.A. Williams<sup>3</sup>, D.L. Buczkowski<sup>4</sup>, H. Hiesinger<sup>1</sup>, A. Nathues<sup>5</sup>, T. Roatsch<sup>6</sup>, C.A. Raymond<sup>2</sup>. <sup>1</sup>Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany ([jhpasckert@uni-muenster.de](mailto:jhpasckert@uni-muenster.de)); <sup>2</sup>NASA JPL, California Institute of Technology, Pasadena, California, USA; <sup>3</sup>School of Earth & Space Exploration, Arizona State University, Tempe, Arizona; <sup>4</sup>JHU-APL, Laurel, Maryland, USA; <sup>5</sup>MPI for Solar System Research., Göttingen, Germany; <sup>6</sup>DLR, Berlin, Germany.

**Introduction:** During its mission at dwarf planet Ceres, the Dawn spacecraft [1] obtained a variety of datasets from different orbits, including image data (FC [2]) spectral data (VIR, [3] / GRaND, [4]), and gravity data [5]. After 3 years of Ceres exploration, the Dawn mission successfully ended on Oct. 31<sup>st</sup>, 2018 in its second and final extended mission phase (XM2), after having depleted all its hydrazine propellant. During the mission, Occator crater and its bright material deposits, which cover parts of the crater floor, turned out to be one of the most spectacular and interesting geologic features on the surface of Ceres. Thus, Occator crater and its faculae (bright deposits) have been investigated in great detail using datasets from the Low Altitude Mapping Orbit (LAMO: ~35 m/px) [e.g., 6-10]. During the final XM07 Orbit, Dawn's Framing Camera (FC) achieved a significantly higher image resolution (up to ~3 m/px) than previously obtained, enabling us to map small-scale geologic features of Occator's faculae, in particular Cerealia Facula, in high detail. Here we report on our geologic map (1:10,000) of Cerealia Facula, which is located in the center of Occator crater.

**Geologic Setting and Previous Work:** Occator crater is a ~92 km diameter complex impact crater located in Ceres' northern hemisphere (20°N, 239°E). Cerealia Facula is located in the center of Occator crater within a central pit hosting a ~550 m high dome [6-9] with a crisscrossing radial fracture system. In addition to the radial fractures, we identified a tongue-shaped hummocky area, where material might have moved or collapsed. Spectral analyses indicate that the bright material of the faculae is dominated by sodium carbonate [11], and is thought to originate from brines emplaced by flows [9], or salt-rich water fountains [10], or a combination of both [13]. Whether these brines are cryovolcanic in origin, or formed due to the impact, is still under debate [6-10]. In addition to the faculae, the floor of Occator crater has been modified by different types of lobate materials [7, 8] and 4 different sets of fractures [12]. Similar to the origin of the faculae, the origin of the lobate material is also under debate (impact related [e.g., 7] or cryovolcanism [6, 13]). The most important fracture systems for understanding the formation of Cerealia Facula are the concentric and radial fractures around the central pit, and cross-cutting fractures in the lower part of the southwestern wall. The latter are

thought to originate from domal uplift due to a putative cryomagmatic laccolith [12]. The concentric fractures surrounding the southern part of the central pit, and the edge of Cerealia Facula, are thought to have formed during central pit formation [8, 9, 12]. Although a central peak is missing today, the eastern and western edges of the central pit are relatively high topographic rises and are probably remnants of an initial central peak [8, 13].

**Geologic Units:** Based on Dawn's XM07 orbit FC data, we identified and mapped three different types of bright material based on their relative brightness (weathered bright material, fresh bright material, mixed material). In addition, we subdivide Cerealia Facula into a continuous and a discontinuous part. While most of the slopes surrounding Cerealia Facula exhibit talus material, one relatively flat elevated area (nicknamed the 'mesa'), located in the western pit, rises about 1 km above the lowest area of the central pit. This elevated area is covered with a bright material layer and displays a strongly sloped eastern scarp where freshly exposed bright material moves downslope, forming striking flows. These bright landslides darken while moving downward since they mix with the underlying dark talus material, probably implying that these features are granular flows and not viscous.

Weathered Bright Material/Fresh Bright Material/Mixed Material: Typical bright material is characterized by a significantly higher reflectance than the surrounding darker crater floor material, but seems to be slightly weathered. Fresh bright material shows the highest reflectivities of all bright material on Ceres and can be found at young impact craters at Cerealia Facula and on scarps of the mesa. Mixed material is a mixture of dark talus material and bright material, is mostly associated with mass wasting features, and can be found at the base of slopes. While most of the inner part of Cerealia Faculae is covered by a continuous deposit of bright material, the outer discontinuous part shows patches of bright material separated by darker crater floor material or broad, dark fractures. The density and size of the bright patches seem to decrease with distance from the center, which could be an indication for an eruptive origin of the bright material.

Talus Material (smooth/rigid): The smooth talus material generally has a smooth appearance and occupies most of the steep slopes (>30°) of the remnants of the

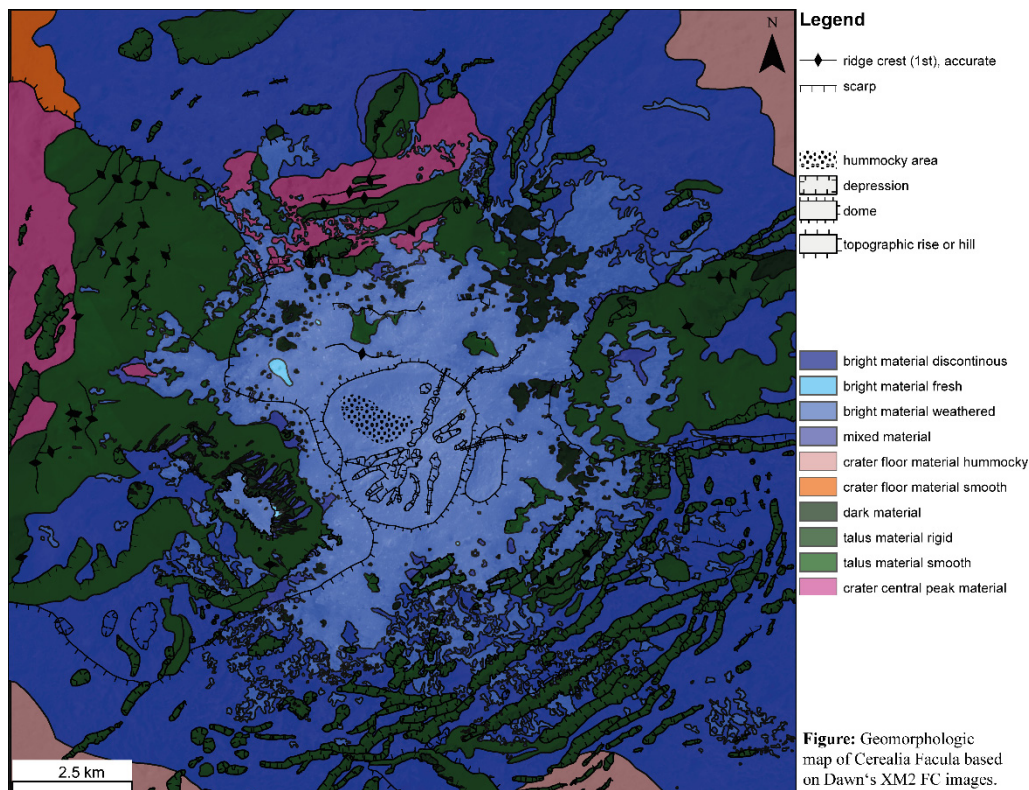
central peak and of the broad fractures at the southern edge of Cerealia Facula. The smooth talus material is mostly darker than the bright material. Rigid talus material is composed of relatively competent blocks and is located at the mesa and at the steepest slopes at the top of some scarps.

**Stratigraphy:** Based on our geologic map we propose that the central bright deposit has been emplaced prior to the concentric fracture system at the southern and southeastern edge of Cerealia Facula. Our conclusion is based on the observations that the concentric fractures cut through the bright material (and is based on the interpretation that all the bright material formed at the same time), and slopes that would have been covered by bright material during a potential eruptive event, mostly contain dark material. In contrast, the crisscrossing fractures at the dome's crest, are covered completely by bright material. Consequently, these fractures might be older than the emplacement of the bright material. Alternatively, the emplacement of the bright material might have occurred episodically during the formation of the radial fractures. A second alternative interpretation is that the dome itself is made out of bright material, implying that the fractures could be younger than the bright material. The outcome of this is that the thickness of the bright material is very heterogeneous, as most of the steeper slopes within Cerealia Facula show darker material from the initial/underlying surface, implying that the bright material is mostly a thin coating on top of

the darker crater floor and remnant central peak material. Our crater size-frequency measurements show that the bright material seems to be significantly younger ( $< 10$  Ma) than the impact crater ( $\sim 21$  Ma) itself, which might imply that the concentric fracture system, which is younger than the main bright material deposit, might not have been formed shortly after the crater formation, or that the pit forming process is still ongoing. Another implication of the bright material being  $< 10$  Myr old may be that the dome is very young, or at least the dome-forming process occurred very recently. In conclusion, such a young formation age of the bright material might favor a cryovolcanic origin of the Cerealia Faculae, as the heat from the impact may have already dissipated such a long time after the impact.

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**References:** [1] Russell et al. (2016) *Science*, 353, 1008-1010. [2] Sierks et al. (2011) *Space Sci. Rev.* 163. [3] De Sanctis et al. (2011) The Dawn Mission to Minor Planets 4 Vesta and 1 Ceres. [4] Prettyman et al., 2011) *Space Sci. Rev.* 163. [5] Park et al. (2016) *Nature*, 537. [6] Nathues et al. (2019) *Icarus*, in press, and references therein. [7] Scully et al. (2019a) *Icarus*, in press. [8] Scully et al. (2019b) *Icarus*, in press, and references therein. [9] Schenk et al. (2019) *Icarus*, in press. [10] Ruesch et al. (2019) *Icarus*, in press. [11] De Sanctis et al. (2016) *Nature*, 536. [12] Buczkowski et al. (2019) *Icarus*, in press. [13] Nathues et al. (2017) *AJ*, Vol.153.



**Figure:** Geomorphic map of Cerealia Facula based on Dawn's XM2 FC images.