EPSC Abstracts
Vol. 13, EPSC-DPS2019-1185-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Evolution of Occator Crater from Dawn XM2 data

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Abstract

During its second and final extended mission (XM2) the Dawn spacecraft obtained observations at altitudes as low as 35 km over a longitudinal sector that encompassed Occator crater. In-depth analysis of that dataset has led to a better understanding of the formation of Occator Crater, the host of the brightest faculae found on Ceres. Combined with the extensive dataset returned throughout the Dawn mission, new insights gained at Occator provide a foundation for predicting consequences of large impacts into the icy moons in anticipation of future mission observations.

1. Introduction

During Dawn's XM2, considerable work and ingenuity by the Dawn Flight team produced an eccentric orbit with periapsis lower than 50 km, enabling the spacecraft framing camera (FC), visible and infrared and mapping spectrometer (VIR), gamma ray and neutron detector (GRaND) and gravity science to achieve measurements with a spatial resolution at least 7x better than obtained during the prime mission. Dawn's XM2 was in part driven by the requirements to map Ceres' elemental composition at the scale of geological units and image the floor of Occator and Urvara craters. The flight team designed a resonant eccentric orbit that allowed repeated observations of a longitudinal sector covering the two craters for more than 110 orbits. Periapses as low as 30 km yielded FC imaging of the Occator faculae with a spatial resolution of ~3 m/pix, GRaND mapping with a footprint of ~50 km (full-width-at-half-maximum), gravity data with a half wavelength of 37-50 km, and fine sampling of the Occator faculae with VIR. This new dataset has led to new constraints on the Occator faculae evolution and the Occator crater setting: the ~550 km wide Hanami Planum.

2. Geology of Occator's Floor

High-resolution imaging has led to a better understanding of the stratigraphic relationships between geological units found across the floor of Occator and thickness estimates for the bright deposits [1]. The faculae were emplaced via 'brine effusion': flows and ballistic deposits from numerous localized brine sources in a hydrothermal system under the control of fracture networks and hydrologic gradients. The central pit formed early, before the majority of faculae emplacement. Brine availability varied on short spatial scales and the system was brine-limited in places. Revised estimates for the relative ages of the faculae and lobate material [2] indicates protracted activity until recent time. The high-resolution images also revealed mounds testifying to the existence of a complex hydrological network below the crater floor [3] and a variety of flow features, troughs, and periglacial landforms [3,4,5]. Analysis of fractures on top of the Cerealia tholus (Fig 1) indicate extensive stress associated with a volume change of 5-10%, consistent with the change expected from the freezing of a water-dominated reservoir [3]. Lastly, high hydrogen content detected by GRaND at lobate flows in the eastern floor region are evidence for abundant ice excavation and redistribution by the Occator-forming impact [6].

3. Shallow or Deep Source?

The faculae and many of the floor features result from impact-induced melting of a crust dominated by ice with salts and silicates [7]. However, models so far predict only short-lived impact-produced melt chambers, at most 9 My [8], whereas the activity has been ongoing for ~20 My at Occator based on crater-age dating [2]. A likely explanation is that abundant salts in Ceres' lower crust [9] decreased the eutectic temperature, establishing a long-lived thermal connection [8, 10] between the impact melt chamber and a ~50-km deep brine reservoir suggested from global topography relaxation observations [11]. The subsurface hydrological networks inferred from surface morphology combined with high-resolution topography and gravity data of Occator and its surrounding [9] further reveal the role of impact-produced fractures in creating a complex network of channels. Impact simulations indicate these fractures could potentially connect with the existing fracture network, in particular the large Samhain Catenae [10,12].

4. Implications for Icy bodies

By analogy, large impacts in icy shells, especially if they are relatively thin (a few 10s km) could connect a deep ocean to a local melt chamber. Impact simulations [7] indicate a significant fraction of the impactor may be retained in the melt chamber. The geochemical characteristics of the resulting reservoir, which combines a crustal component, oceanic component, and exogenic material could have important implications for astrobiology [13]. Intercomparison with images returned by the upcoming Europa Clipper and JUICE missions will further our understanding of the role of impact-produced heat and damage in driving local geological activity and introducing heterogeneities in icy crusts.

5. Summary and Conclusions

The Dawn XM2 data have yielded new insights into the evolution of a large crater in an ice-dominated crust. The results demonstrate the critical role of brines and hydrates in maintaining long-lived liquid reservoirs in icy bodies. They also highlight the role of impacts as transient sources for heat-starved bodies such as Ceres.

Acknowledgements

Part of this work is being carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract to NASA. Government sponsorship acknowledged.

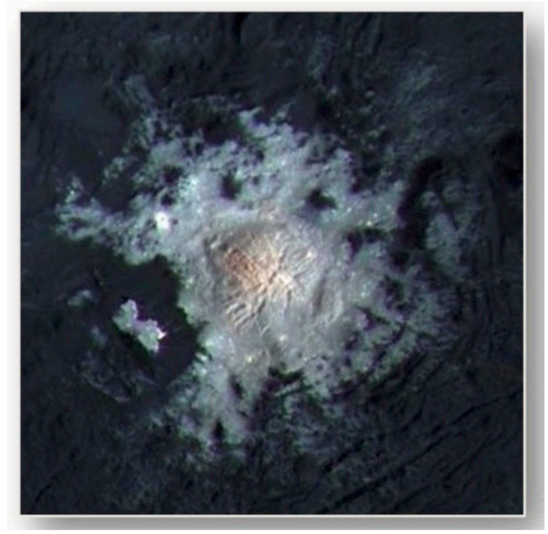

Figure 1: FC color mosaic of Cerealia Tholus, the dome within the brightest region of Ceres, Cerealia Facula at the center of Occator crater.

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