

## Laccolithic “Pingo” & Hydrothermal Origins for the Central Features of Occator Crater, Ceres

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### Abstract

Dawn mapping of Occator crater Ceres indicates that the carbonate-rich deposits at its center are related to formation of the central pit and central dome within it. Spatial associations indicate that the deposit may have been associated with discrete venting sources, at least at several sites, and that the dome formed after the deposit was (mostly) in place. The dome was probably formed by laccolithic-style inflation from below, perhaps due to the forced migration of water-rich fluids toward the center (and the sources of the deposit) followed by freezing.

### 1. Introduction

The carbonate deposits at Occator crater, Ceres, are spatially and temporally associated with the central structure of that 92-km diameter fresh complex impact crater. The deposits lie within a 10-km wide central pit featuring a fractured central dome. Here, in advance of extended mission mapping, we examine the morphologic evidence in support of an origin related to hydrothermally driven deposition of carbonates and subsequent inflation of the central dome from beneath.

### 2. Origins of Cerealia Facula

Hydrothermal venting of mineral-rich fluids at the center of Occator (and presumably other large craters in the past) on Ceres has been proposed for the bright materials on Occator (e.g., 1, 2, 3). These fluids would be driven by the decay of residual heating in the center of the crater (4).

The process(es) of emplacement of the carbonate-rich deposits at Occator are fundamental and yet very poorly understood in the current 35-m resolution images. No obvious central vent has been identified. Bright material extends up the inward-facing walls of the central pit, forming tendrils or lobate extensions.

In numerous locations in the western quadrant (though not all), bright material clearly extends downslope from several elongate ridge-like dark features (Fig. 1). In another location part way up the sides of a steep-sided plateau (Fig. 1), bright material also appears to emanate from a row of dark spots. Both examples suggest outflow from one or more specific horizons. These are the best candidates for the formation of carbonate deposits from the outflow of fluids from discrete sources.

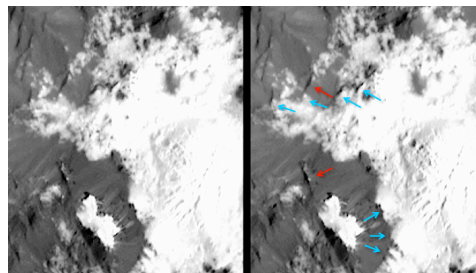


Figure 1: Enlargement and contrast enhancement, highlighting narrow ridge-like structures (blue arrows) and dark spots along outer edge of the bright materials along western margins of Cerealia Facula; candidate vent sources for hydrothermal venting. Resolution ~35 m/pixel.

### 3. Origins of the Central Dome

The timing of the formation of the dome in Occator is key to understanding the sequence of events. The fracture network on its surface (Fig. 2) occurs only on the dome itself and does not (with rare exception) extend up onto the pit walls. Similarly, the southern flank of the dome is also stratigraphically contiguous with bright deposits on the pit walls. The northern contact between dome and pit is more complex but does not appear to require different materials. These suggest that doming occurred after Cerealia Facula was (mostly) emplaced, that doming was limited to a

small area only 3-4 km wide, and that doming was not the result of extrusion of new material.

The stratigraphy of the central dome suggests that a laccolith model is most likely for the dome. Laccoliths can form from intrusion of new material in one location. The material can be in the solid or liquid state. The most common examples include magma bodies, salt domes and pingos. Fracturing of overburden rocks can often produce fracture patterns (5) very similar to those observed at Occator.

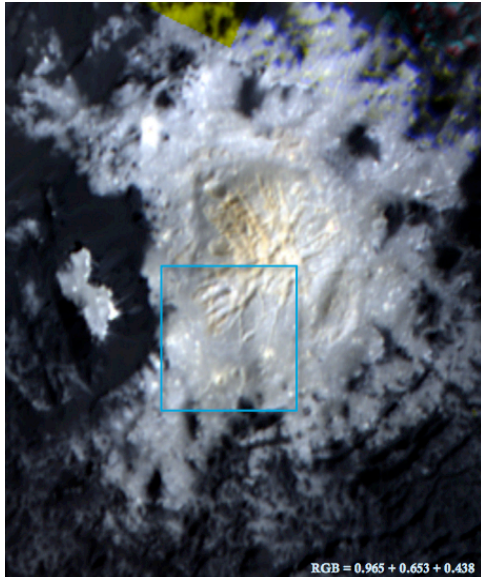


Figure 2: Fractured central dome, Occator crater. Box highlights transition from dome to central pit wall, with no apparent break in stratigraphy.

Without direct observations of the intruding material we are forced to speculate regarding candidate dome-forming processes and materials. Calculations indicate that temperatures above melting point of water are probable beneath the crater (4). Mineral-rich fluids can then be formed by mixing or leaching of more rocky materials by water, followed by migration towards the warmest surfaces (i.e., the center) (e.g., 9). Salt domes are one candidate but they tend to be rather dry.

Pingos are domical polar features formed in permafrost zones experiencing diurnal or seasonal

freeze-thaw cycles (6) (7). These cycles allow or even force the migration of liquid water to local topographic or structural deviances, where it accumulates as part of the freeze-thaw cycle. On Ceres, this could be driven as well by the radially inward freezing cycle beneath crater floor, centered on the region of the central pit where the bedrock is most fractured (8) and topography is lowest.

## 4. Summary and Conclusions

Analysis of Dawn imaging points to hydrothermal outgassing of mineral-rich fluids from the beneath the central pit of Occator crater. The dome on the floor of the pit suggests a complex process of either freezing of water-rich fluids beneath the dome or intrusion of water-rich materials that subsequently froze. The volume of the dome is on the order of  $2.75 \text{ km}^3$ , indicating that the amount of mobilized fluids was limited.

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