YOUNG RESURFACING EVENTS AT CERES' OCCATOR CRATER CAUSED BY DEPOSITION OF CRYOVOLCANIC MATERIAL OR SEISMIC SHAKING?

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Introduction: With its faculae (bright spots) Occator crater is one of the most interesting and extensively investigated geologic features of dwarf planet Ceres. Since their first discovery by the DAWN mission [1] a possible cryovolcanic origin of Occator's faculae has been heavily debated in the science community [2-7]. Spectral analyses indicate that the bright material of the faculae is dominated by sodium carbonate [8], and is thought to originate from brines emplaced by flows [5], or salt-rich water fountains [6], or a combination of both [9]. In addition to the faculae, the floor of Occator crater has been modified by different types of lobate materials [3, 4] and 4 different sets of fractures [10]. Similar to the origin of the faculae, the origin of some areas of the lobate material seem to be worthy of further discussion. Currently all lobate material is expected to be caused by solidified impact melt [e.g. 4], which is inconsistent with recently identified resurfacing events affecting some lobate material units [11] and ages of floor units derived by [2]. 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 [10]. Based on stratigraphic relationships, the majority of these fractures is interpreted to be younger than the crater floor material as well as the bright materials, forming the faculae [12]. Based on crater size-frequency distribution (CSFD) measurements on Dawn's Low Altitude Mapping Orbit data (LAMO: ~35 m/px), [2, 11] found young resurfacing events at the floor of Occator crater and the faculae, which they interpreted to represent young cryovolcanic activity < 10 Ma ago. With the latest data from Dawn's XM2 Orbit such resurfacing events can be found at multiple location at the crater floor [11]. As many of these young resurfacing events seem to be connected to the young fractures, the question arises, whether these resurfacing events are caused by the deposition of cryovolcanic material, or if seismic shaking related to the formation or reactivation of the fractures are responsible for the resurfacing events visible in the CSFD measurements.

Data and Methods: To answer this question, we performed CSFD measurements on 7 different counting areas spread over the crater floor and crater rim (Fig. 1). To derive absolute model ages (AMAs) from these measurements, the lunar-derived (LDM) chronology and production functions from [13] have been used. We used the LAMO Occator Framing Camera (FC) mosaic (~35 m/px) produced by the DLR as a base map, and individual FC images from the XM2 Orbits with resolutions of up to ~3 m/px for the CSFD measurements.

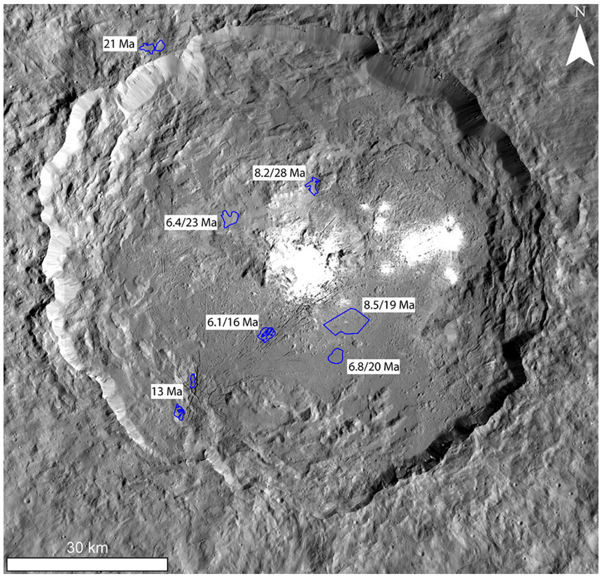

Figure 1: Overview of the counting areas in and around Occator crater with the LAMO mosaic as a base map. White boxes show derived absolute model es. Two slash-separated numbers indicate a surface formation age at the time of the higher age and a resurfacing event that ended at the time of the younger age.

Results: To evaluate the influence of potential seismic shaking due to the formation of the fractures at the southern crater floor, we specifically chose counting areas on geologic units with different texture und varying distances to the fractures. For a smooth pond-like unit close to the northern crater rim, which is part of the ejecta blanket, we obtained an AMA of ~21 Ma by fitting craters > 70 m (Fig. 2). This AMA is similar to the AMA of Occator derived by other studies [e.g., 2, 14]. In contrast, other pond-like features with a similar smooth texture at the northern crater floor which have been mapped as smooth lobate material by [4], show resurfacing events at ~6.4 Ma and ~8.2 Ma in addition to older background AMAs of ~23 Ma and

~28 Ma. The two background ages are within their uncertainties similar to the AMA of the ejecta, as the error bars are relatively large, due to a small number of fitted craters. In addition to the northern smooth lobate material, we also chose two counting areas at the southern smooth lobate material, one close to the fracture system, and one more distant to any fractures. Both areas show a young resurfacing event and an older background AMA similar to the counting areas of the northern smooth materials. The unit directly located at the fractures shows a background AMA of ~16 Ma and a resurfacing event at ~6.1 Ma, while the other southern smooth material shows a background AMA of ~20 Ma and a resurfacing event at ~6.8 Ma. Thus, the counting area on the fractures shows slightly younger AMAs for the resurfacing event, as well as for the background AMA, than the counting area of the other lobate smooth materials. The counting area for the hummocky crater floor which is located north of the southern smooth lobate materials, also shows a young resurfacing event and a background AMA (~19 Ma) similar to that of the crater formation. However the resurfacing event for this unit is with ~8.5 Ma the oldest of all young resurfacing events discovered during this study. In contrast, the counting area located at the center of the domal uplift and starting point of the southern fracture system does not show a young resurfacing event, but a generally young AMA of ~13 Ma. This area is part of the crater terraces, and thus should show similar AMA as the ejecta blanket, as these terraces might have formed shortly after the impact.

Discussion: We know from the Moon, that seismic shaking during the formation or reactivation of lunar scarps can destroy a significant number of craters with diameters of several tens of meters causing younger AMAs [15]. Similar effects can been seen at areas close to the southern fracture system. These areas (Fig. 2b,c) generally show younger AMAs. However, the resurfacing events visible at multiple areas and units with different textures all over the crater floor do not seem to be caused by seismic shaking. Moreover, these resurfacing events seem to be directly linked to the deposition of material at the crater floor, as also areas distant to large fractures show similar young resurfacing events. In addition, crater terraces which do not show any signs of late stage deposition do not show such resurfacing events in the CSFD measurements even in areas of heavy fracturing, like at the center of the domal uplift at the southern crater terraces (Fig.2b).

Conclusions: Seismic shaking due to the formation or reactivation of the fracture systems does not directly cause the resurfacing effects visible in the CSFD measurements, but it seems to affect the CSFDs in general. In particular, areas at or close to the fractures appear to be generally younger which might be an indication for the removal of craters by seismic shaking. However, the strong resurfacing effects visible at multiple locations within Occator crater are not caused by seismic shaking as these resurfacing effects can also be observed at areas of the northern part of the floor, where fractures seem to be absent.

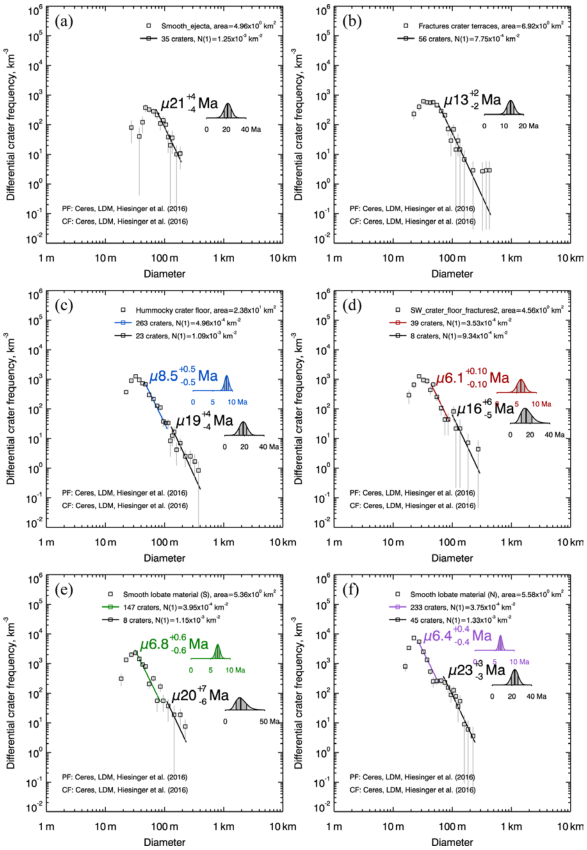

Fig. 2: CSFD plots of (a) the smooth ejecta pond, (b) fracture center, (c) the hummocky crater floor, (d) the smooth crater floor at the southern fracture system, (e) the southern smooth lobate material distant to the fractures, (f) the northern smooth lobate material.

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References: [1] Russell et al. (2016) *Science, 353,* 1008-1010. [2] Nathues et al. (2019) *Icarus,* , 320, 24-38, and references therein. [3] Scully et al. (2019a) *Icarus,* 320, 213-225. [4] Scully et al. (2019b) *Icarus,* 320, 7-23, and references therein. [5] Schenk et al. (2019) *Icarus,* 320, 159-187. [6] Ruesch et al. (2019) *Icarus,* 320, 39-48. [7] Quick, L. C., et al. (2019) *Icarus,* 320, 119-135. [8] De Sanctis et al. (2016) *Nature*, 536. [9] Nathues et al. (2017) AJ, Vol.153. [10] Buczkowski et al. (2019) *Icarus,* 320, 49-59. [11] Nathues et al. (in review). [12] Pasckert et al. (2019) LPSC50 #2308. [13] Hieisnger et al. (2016) *Science*, 353, 6303. [14] Neeseman et al. (2019) *Icarus*, 320, 60-82. [15] van der Bogert et al. 2018, *Icarus*, 306, 225-242.