INSIGHT ON THE EVOLUTION OF OCCATOR CRATER ON CERES FROM THE PROPERTIES OF CARBONATES, PHYLLOSILICATES, AND CHLORIDES

A. Raponi[a], M.C. De Sanctis[a], F.G. Carrozzo[a], M. Ciarniello[a], J. C. Castillo-Rogez[b], E. Ammannito[c], A. Frigeri[a], A. Longobardo[a], E. Palomba[a], F. Tosi[a], F. Zambon[a], C.A. Raymond[b], C.T. Russell[d].

[a] INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Via del Fosso del Cavaliere, 100, I-00133 Rome, Italy;
[b] NASA/Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, United States;
[c] Italian Space Agency (ASI), Via del Politecnico snc, I-00133 Rome, Italy;
[d] Institute of Geophysics and Planetary Physics, University of California at Los Angeles, 3845 Slichter Hall, 603 Charles E. Young Drive, East, Los Angeles, CA 90095-1567, United States.

Introduction: NASA's Dawn spacecraft [1] arrived at dwarf planet Ceres. Data from the Visible and near-InfraRed imaging spectrometer (VIR) [2] shown that Ceres' surface presents ubiquitous absorption bands at 2.7 µm (OH stretching) and 3.1 µm related to Mg-phyllosilicates and NH_4-phyllosilicates, respectively [3]. The thermally-corrected spectra of reflectance shows several distinct absorption bands at 3.3-3.5, and 3.95 µm, due to the presence of Mg-Ca carbonates [3].

Although the spectral properties of Ceres' surface are quite uniform, there are several peculiar areas with brighter material where significant differences in spectral parameters have been detected. The features that stand out from the surrounding terrains are the bright areas, called "Cerealia Facula" and "Vinalia Faculae," in the 92-km-diameter Occator crater (15.8-24.9 °N and 234.3-244.7 °E). Their albedo is 5-10 times higher than the average surface [4]. Bright material in the faculae has many spectral differences (band center shifts of absorptions at 2.7 and 3.95 µm toward longer wavelengths, and the emergence of the 2.2 µm absorption band) with respect to the crater floor, which correspond to compositional differences. Unlike the average Ceres surface that contains a dark component, Mg-Ca-carbonate, Mg-phyllosilicates, and NH_4-phyllosilicates, the faculae contain mainly Na-carbonate, Al-phyllosilicates [5], and NH_4-chloride, whose presence has been established unambiguously thanks to high spatial resolution data analysed in the present work [6].

Methods: We implemented a proper algorithm in order to remove the thermal emission [6]: the measured radiance is modeled as the sum of the solar radiance reflected by the surface and the thermal emission of the surface, then the latter is removed.

We analyzed absolute signal levels, spectral slopes, and band area of the main absorption bands of the spectra over the whole crater. Moreover, the abundances and grain sizes of the main minerals identified as components of the Occator surface materials have been retrieved from a quantitative analysis by means of the Hapke radiative transfer model [7]. Example of best fit are shown in Fig. 1.

Results: From spectral analysis and spectral modeling, we detect very peculiar ejecta in the north-eastern part of the crater, which shows a larger abundance of all minerals identified on the average surface of Ceres (Mg-phyllosilicates, Mg-Carbonates, NH_4-phyllosilicates), and smaller grain size (see Fig. 2) [6].

The spectral analysis of the floor near the faculae reveals material that has intermediate properties between bright material and average regolith, pointing to bright material deposition events older than the faculae formation, partially buried by lateral mixing. However, a significant difference with respect to the faculae material is represented by the larger grain size in the entire crater floor. The larger grain size would point to slower cooling conditions, in which larger grains can grow, for example in a melt reservoir. Contrarily, a fast cooling should have taken for the bright material of the faculae, for which smaller grains have been modeled. For this reason, the deposition event of floor material could have been very close to the impact event, unlike the more recent faculae formations.

The specific analysis performed for the faculae has highlighted differences between the Cerealia and Vinalia areas for both mineralogy and morphology. The composition of the Vinalia Faculae presents lower abundances of all components found on Cerealia facula: Na-carbonate, NH_4Cl, Al-phyllosilicates.

Notable differences in the mineralogy are also observed across Cerealia Facula. The mineral distribution does not seem homogeneous, and it is not perfectly correlated to the brightness of the surface, revealing peculiar regions inside the Facula. From the band area map of the ammonium chloride (at 2.2 µm) in Cerealia Facula, we identified a region with higher concentration of that mineral than the average trend, suggesting different emplacement events (see Fig. 3) [6].

Conclusions: The overall analysis performed in this work suggests the following evolution for the Occator crater: 1) Heterogeneous composition in the deeper layers was preexistent to the impact event in the entire area of the crater. In particular, we can infer the presence of regions with a higher content of phyllosilicates, carbonates, and a reservoir of a material darker and redder than the average surface, which produced the north-eastern ejecta; 2) The impact event produced a slight depletion of OH^- and NH_4^+ in the crater floor, and the melted material on the crater floor favored the growth of larger grains because of the slow cooling; 3) The faculae are likely to be formed more recently on the basis of their very different composition, which has not experienced any significant lateral mixing, and on the basis of the smaller grains pointing to faster cooling. Following this argument, Cerealia Facula appears to be more recent than Vinalia Faculae, and/or the emplacing mechanism should be different; 4) Different bright material deposition events would have occurred within Cerealia Facula, on the base of its heterogeneous composition that potentially points to an evolution of the composition in the source chamber [6].

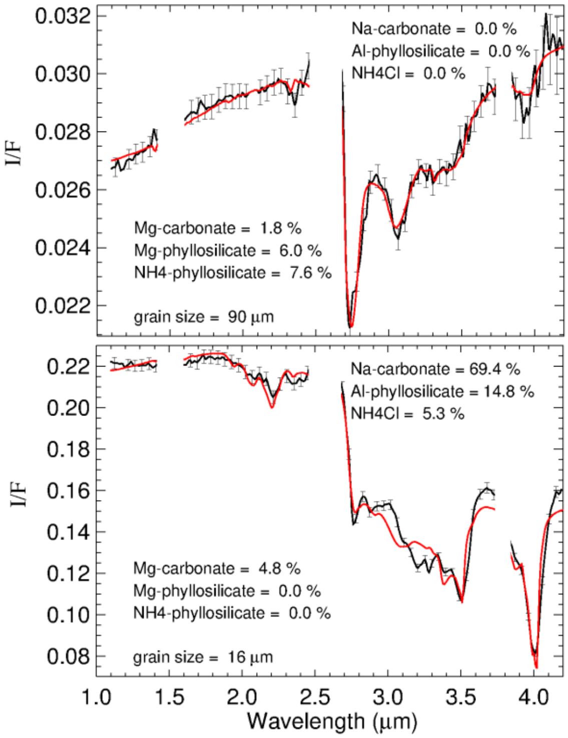

Figure 1. Two examples of best fit measured spectra: crater ejecta (upper), and Cerealia Facula (lower). Error bars include poissonian noise and calibration uncertainties.

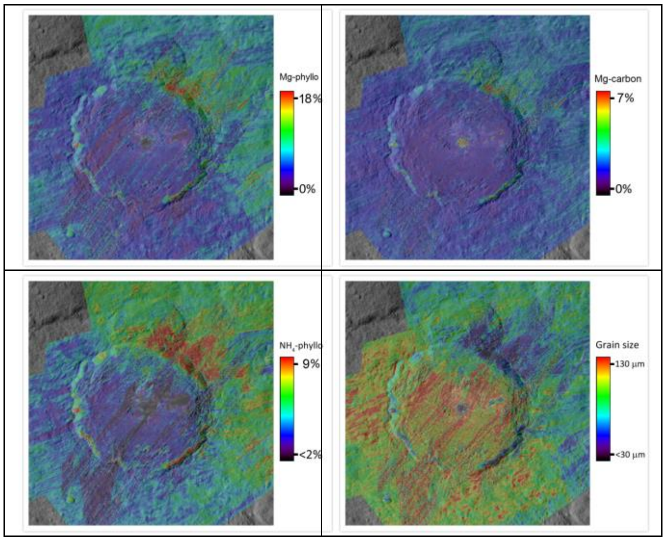

Figure 2. Abundance maps of Mg-phyllosilicate, NH_4-phyllosilicate, Mg-carbonate, and grain size as retrieved with the Hapke model.

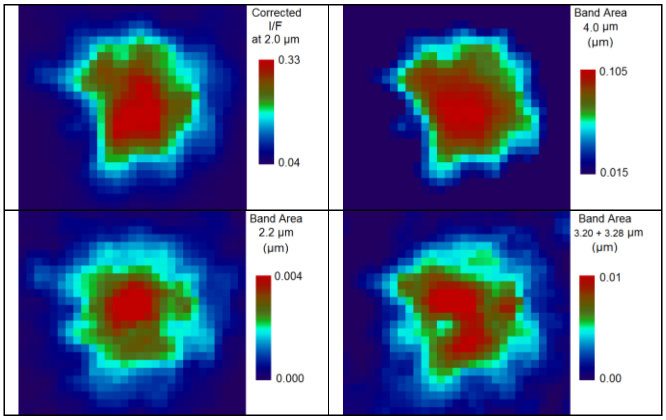

Figure 3. Cerealia Facula maps for different parameters as described in the panels.

References: [1] Russell, C. T.; Raymond, C. A. Space Science Reviews, 163, 3-23, 2011. [2] De Sanctis et al., Space Sci Rev. 163, 329-369, 2011. [3] De Sanctis et al., Nature 528 (7581), 2015. [4] Ciarniello et al. Astron. Astrophys. 598, 2017. [5] De Sanctis et al., Nature 536 (7614), 2016. [6] Raponi et al., Icarus 2018. [7] Hapke, 1993, 2012.