EPSC Abstracts
Vol. 13, EPSC-DPS2019-78-2, 2019
EPSC-DPS Joint Meeting 2019

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

Experimental evidence for the nature of Ceres blue material

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Abstract

The ejecta of young impact craters on Ceres are "blue", exhibiting a negative spectral slope in the visible and near-IR wavelength range, for reasons yet unknown. We have performed an experiment with Ceres analogue material to support the hypothesis that the blue color naturally results from the dehydration of phyllosilicate-rich ice particles, which are expected to form upon impact.

1. Blue material

Blue material on Ceres is associated with fresh impact craters and characterized by a negative visible spectral slope. Observations by the VIR imaging spectrometer aboard the Dawn spacecraft reveal the ubiquitous presence of Mg- and NH_4-bearing hydrated minerals such as phyllosilicates [1, 2]. Water ice is not stable on the surface of Ceres, but seems to be abundant in the sub-surface at variable depth depending on latitude [3]. Blue material is found in and around fresh impact craters. The false-colour map in Fig. 1 based on Dawn framing camera images shows the spatial distribution of blue material. The blue colour fades into the background over the course of a few million years, for reasons unknown [5].

It has been suggested that the blue colour results from the presence of very small phyllosilicate particles [6]. Very small (sub-micron) particles may contribute to the blue slope in the visible range in the spectra of certain moons of Saturn through Rayleigh scattering [7]. However, it is not clear how comminution would be achieved in the blue Ceres ejecta, other that it must be the result of impact, nor why such small particles would disappear over time. On the other hand, a sub-micron structure could arise naturally in the ejecta of young craters as a result of sublimation of phyllosilicate-rich ice particles, formed by the impact mixing phyllosilicates on the surface with subsurface water ice [4]. Formation of such a phyllosilicate matrix with a highly complex structure was demonstrated in laboratory experiments (Fig. 2) [8]. The matrix may then be destroyed over time by space weathering, leading to the fading of the blue color.

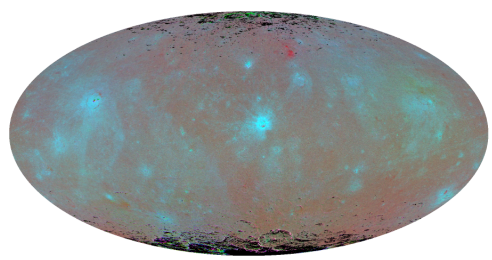

Figure 1: Global map of Ceres in Mollweide projection centered on 0° longitude. The ratios 965 nm/749 nm, 555 nm/749 nm, and 438 nm/749 nm are in the RGB color channels. Figure from [4].

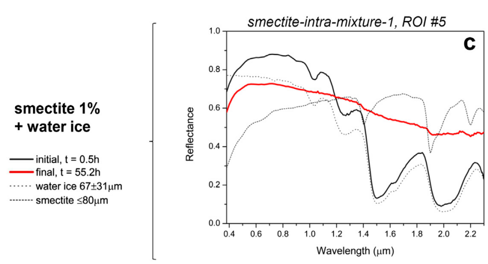

Figure 2: The spectrum of smectite changes fundamentally after incorporation into ice particles and sublimation. Compare the original spectrum ("smectite $\leq$ 80 μm") with that of the sublimation residue ("final, t = 55.2 h"). Figure from [8].

2. Experimental investigation

The nature and origin of Ceres blue material have thus far been a mystery. We test the hypothesis that the blue colour is a natural consequence of the dehydration of ammoniated phyllosilicates in the ejecta of fresh impact craters [4]. By experimentally dehydrating particles composed of a mixture of water ice and Ceres analogue material we expect to induce a blue spectral slope, thus demonstrating the plausibility of the proposed mechanism to explain the blue colour on Ceres. The analogue material used in this experiment is a mineral mixture containing a NH_4-smectite that closely mimics the composition and the spectral properties of the average Ceres surface [9, 10].

The experiment is carried out in the Cold Surfaces Spectroscopy facility of the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) in France as described in [8]. The first step is to mix 1wt% sample material with water. The liquid mixture is nebulized using ultrasound to produce droplets that are frozen in liquid nitrogen, resulting in the formation of spherical water ice-grains with a diameter of 67 ± 31 µm. The ice particles are collected and deposited by sieving in a cylindrical sample holder and placed in a cold chamber. In here, the sample is maintained under high vacuum (10^{-6} bar) at 173 K to allow the ice to sublimate. This temperature is in the range of those experienced on Ceres (130-200 K). After several days of sublimation, a dry porous residue is expected to remain. We determine the spectrophotometric properties of the sample material both before and after the sublimation experiment. We will qualitatively compare our experimental results with Dawn FC colour data [4]. Furthermore, we will uncover any spectral changes in the near-IR and compare to VIR observations of blue material [6].

3. Conclusions

Our experiment addresses one of the long-standing, unresolved questions resulting from the Dawn mission to Ceres: the origin of the blue colour of fresh material. We aim not only to connect the fate of phyllosilicates on the surface of Ceres with that of the water ice below and confirm a new and unexpected role of space weathering, but may also confirm the hypothesis of the occurrence of Rayleigh scattering inside planetary regoliths [7]. At the time of writing, the experiments have just been completed and data analysis has commenced. We will report on the results in the meeting.

Acknowledgements

Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

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