EPSC Abstracts
Vol. 12, EPSC2018-806, 2018
European Planetary Science Congress 2018

Spectral analysis of Ceres subsurface

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Abstract

The dwarf planet Ceres is a heavily cratered rocky body and complex craters with a central peak are present on its surface. The material composing the central peaks is the geological unit termed *crater central peak material* (ccp) and corresponds to subsurface rock emergent as consequence of significant impact event. Mineralogical investigation of Ceres subsurface (within a depth of about 22 km) was performed by means of spectral data of 32 ccps, acquired by VIR spectrometer onboard the NASA Dawn spacecraft. Mg-phyllosilicates, NH_4-phyllosilicates and Mg/Ca-carbonates compose both the Ceres subsurface and surface, but their abundances in ccps vary with latitude and depth of excavation.

1. Introduction

The NASA Dawn mission has explored the dwarf planet Ceres since March 2015 and the mineralogical composition of Ceres surface has been obtained by means of spectral data acquired by the Visible and Infrared Mapping Spectrometer (VIR): absorption bands at 2.7-, 3.1-, 3.4- and 4.0-µm in reflectance spectra revealed a surface composition made of Mg-phyllosilicates, NH_4-phyllosilicates, Mg/Ca-carbonates and a dark featureless component, which reduces the albedo [1]. Na-carbonates have been detected in Occator'sfFaculae [2] and in other localized areas of Ceres, such as in the ejecta and floors of Kupalo and Haulani crater [3]. Organics occur on the peak, floor and ejecta of Ernutet crater, as detected by the prominent 3.4-µm absorption band, connected to the C-H bonds of aliphatic organic compounds [4].
To investigate the mineralogical composition of Ceres subsurface we examined the spectral properties of the geologic unit identified as *crater central peak material* (ccp) [5], subsurface rocks exhumed during the formation of large impact craters [6].

2. VIR data

The Dawn spacecraft performed mapping orbits with decreasing altitude from the Ceres surface and VIR spectrometer acquired reflectance spectra in the 0.25-5.1 µm spectral range with increasing spatial resolution. In particular, in the HAMO (High-Altitude Mapping Orbit) phase the spacecraft was at an altitude of 1470 km and VIR acquired spectra with a spatial resolution of 360-400 m/pixel; during the LAMO (Low-Altitude Mapping Orbit) phase the minimum altitude of 385 km was reached and spectral data were acquired with a spatial resolution of 90-110 m/pixel. Data from these two orbital stages were used for this work.

3. Data selection and parameters

Central peaks of complex craters identified from the geological maps of Ceres [5] and observed by VIR data with high spatial resolution, i.e. acquired during the HAMO and LAMO phase, were selected. In total, 32 ccps were analysed, by defining a square-shaped area around each peak. For each ccp, mean values of 2.7-, 3.1-, 3.4- and 4.0-µm band depths and band centers were computed [7], as well as spectral slope estimated between 1.2 and 1.9 µm. Furthermore, the elevation of each crater's peak with respect to the ellipsoidal shape model of Ceres was retrieved and we estimated the subsurface depth from where ccp originated, by subtracting from the maximum elevation a tenth of crater's diameter containing the peak [8].

4. Spectral investigation of ccps

According to our results, the mineralogical composition of the Ceres subsurface reflects the surface, i.e. a mixture of Mg/Ca-carbonates, NH_4-phyllosilicates, Mg-phyllosilicates and a dark component, but particular trend is observed with higher latitudes and with increasing depth of excavation. For ccps, the 2.7- and 3.1-µm band depths correlate, as observed for the entire Ceres surface [9], i.e. Mg-phyllosilicates and NH_4-phyllosilicates are strongly correlated for the subsurface materials. Furthermore, the abundance of Mg-phyllosilicates and NH_4-phyllosilicates increases in poleward subsurface deposits, as shown in Figure 1. This trend can be due to the fact that the OH group (responsible for the 2.7-µm band) and ammonium-bearing clays (responsible for the 3.1-µm band) are more prominent.

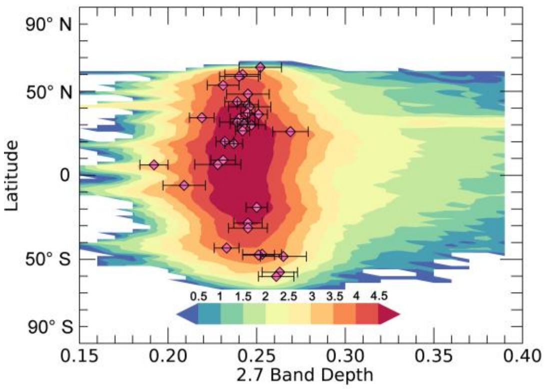

Figure 1: Scatterplot of 2.7 µm band depth of ccps as a function of latitude (magenta diamonds) superimposed on the density plot representing the Ceres surface. Differently from the behavior of Ceres surface, band depths of ccps are stronger at higher latitudes. The Color bar refers to the density of pixels forming the density plot, expressed in logarithmic form, where lower values are represented by blue color and higher values by red color.

The 3.4- and 4.0-µm bands, associated with carbonates, show different trends when compared with the other parameters: the 4.0-µm spectral feature is weakly correlated with 3.1-µm band, while the 3.4-µm band is strongly correlated with spectral features diagnostic of NH_4-phyllosilicates. The 3.4-µm band depth increases at poleward latitudes (as do the 2.7- and 3.1-µm bands, which are features diagnostic of phyllosilicates) while the 4.0-µm band does not show any significant latitudinal trend.
The 3.1- and 3.4-µm band depths show an increase at increasing depth of excavation and show a strong correlation (Figure 2); the 2.7- and 4.0-µm band depths are weakly correlated with excavation depth. This mean that NH_4-phyllosilicates seem to be more concentrated in ccps excavated from greater depth. The 3.4-µm band depth shows a similar trend to the phyllosilicates' bands and in particular to the 3.1-µm band (associated to ammoniated phyllosilicates): in fact, such a spectral feature is not only due to carbonates, but NH_4-phyllosilicates and organics also contribute or affect to its shape and strength.
Furthermore, 3 ccps, i.e. Haulani, Ikapati and Ernutet are composed of Na-carbonates and Mg/Ca-carbonates, in addition to phyllosilicates and dark material, exhumed from a depth of about 6-9 km.

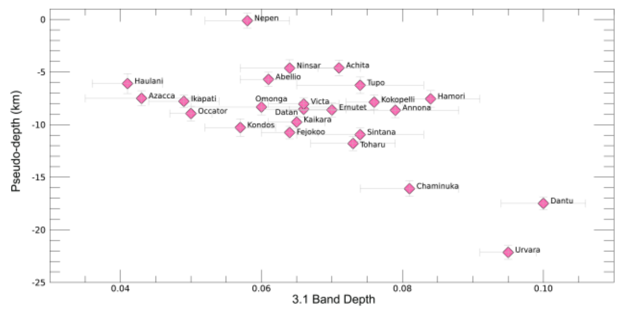

Figure 2: Scatterplot of 3.1 µm band depth of ccps as a function of excavation depth (magenta diamonds).

Acknowledgements

VIR is funded by the Italian Space Agency–ASI and was developed under the leadership of INAF-Istituto di Astrofisica e Planetologia Spaziali, Rome-Italy. The instrument was built by Selex-Galileo, Florence-Italy. The authors acknowledge the support of the Dawn Science, Instrument, and Operations Teams.

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