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Spectral characteristics of 121 impact craters on Mercury

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Abstract

We have characterized the spectral reflectance of geological units associated with 121 complex impact craters on Mercury. To do so, we have combined Mercury Atmospheric and Surface Composition Spectrometer (MASCS) Visible and Infrared Spectrograph (VIRS) data with Mercury Dual Imaging System (MDIS) images, both acquired from orbit by the MESSENGER spacecraft.

1. Introduction

Through 2013, the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) instrument on the Mercury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft collected more than 4 million surface reflectance spectra of Mercury that provide nearly complete global surface coverage. Building on local studies of the Kuiper and Waters craters [1-2], we describe a procedure that exploits geologic mapping as a tool to retrieve supervised spectra within a number of mapped geologic units to inter-compare units and spectral characteristics across many craters simultaneously. This work is complementary to the unsupervised classification of MASCS data, which is providing valuable information on the spectral properties of Mercury's surface at global scales [3-8].

2. Methods of analysis

For our study, we mapped only relatively fresh impact craters characterized by a complex morphology and a diameter between 10 and 100 km. For each impact crater, we mapped as independent geological units the central peak, floor deposits, wall deposits, and exterior deposits at 1, 5 and 10 crater radii outward of the crater rim. We used the DLR database of MASCS Visible and Infrared Spectrograph (VIRS) spectra to retrieve all observations within each geological unit mapped for the 121 impact craters. The spectra were normalized at 700 nm wavelength to provide a first-order correction for phase-angle effects [3-8].

We have considered two selection approaches. In the first, we included all reflectance observations, even those shared among units for multiple craters. In the second approach, we excluded all spectra from areas that spanned multiple units. This dual approach allows us to study the influence of the areas of overlap and thereby quantifies the effect of mixing of ejecta deposits from different craters.

3. Initial results

We have focused on the first selection approach to date. Initial results indicate that central peaks display a greater range of spectral slopes, and exterior units are spectrally more homogenous (Fig. 1).

From a comparative analysis of the spectral slopes of central peaks and areas external to the craters, we observe three different outcomes: (1) central peaks with steeper spectral (redder) slopes than the exterior deposits (Fig. 2a), (2) central peaks with spectral slopes similar to those of the exterior units, and (3) central peaks with shallower spectral (bluer) slopes than the exterior deposits.

Following the general assumption that central peak material originates from greater depth than other crater deposits, outcomes (1) and (3) could indicate layering of crater target material [9-11]. We also consider the general assumption that, given two materials with a similar composition, space weathering has reddened the spectrum of the more mature material [12]. By this reasoning, spectra of central peaks might be expected to be less steep than spectral slopes in areas far from the crater rim. We observe several examples, however, where the central peak has a spectral slope that is steeper than (Fig. 2a) or similar to (Fig. 2b) those of distal exterior deposits. We therefore conclude that the observation of central peaks with redder spectral slopes than surrounding terrain is an indicator of compositional heterogeneity in the target area [9-10]. For craters with central peaks that display shallower spectra than distal exterior areas (Fig. 2c), in contrast, either space weathering or compositional heterogeneity may be indicated.

4. Outlook

Although analysis is still underway, initial results from the first selection approach show that the methodology developed here provides a tool for identifying the presence of compositional heterogeneity between central peaks and surrounding terrain for a number of complex impact craters on Mercury. Results from this study should provide a useful platform for future investigations that aim to reconstruct the global stratigraphy of Mercury from MASCS and Mercury Dual Imaging System (MDIS) datasets.

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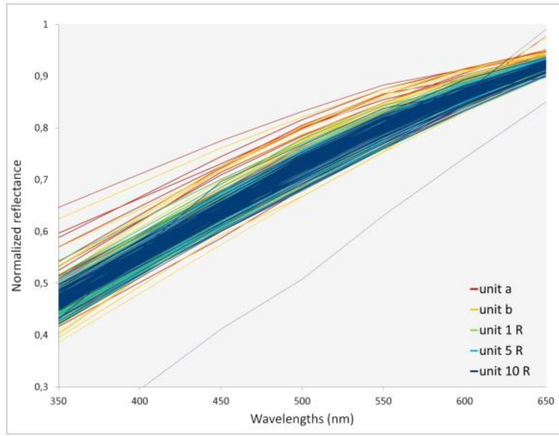

Figure 1. Normalized spectra for each unit mapped over the 121 selected impact craters. Spectra are derived from all MASCS observations, even those for areas affected by multiple craters. Unit a (red): central peaks. Unit b (orange): floor deposits. Unit 1 R (green): deposits at 1 crater radius from the crater rim. Unit 5 R (light blue): deposits at 5 radii from the crater rim. Unit 10 R (dark blue): deposits at 10 radii from the crater rim.

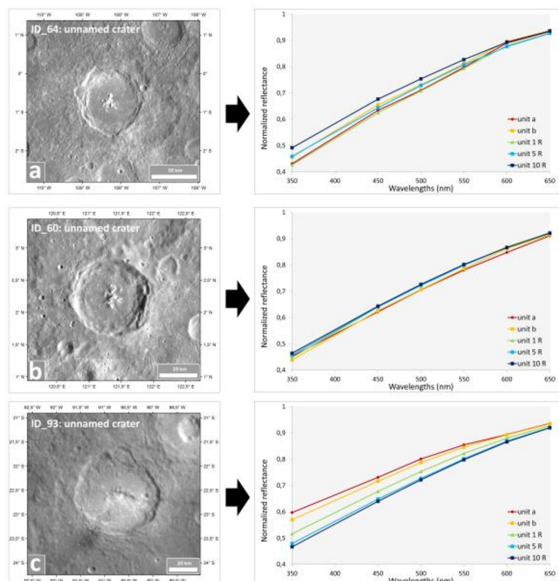

Figure 2. Three example craters displaying the three different outcomes we observe globally. (a) Unnamed crater (0.7°N; 251.7°E), 71.5 km in diameter, displays a central peak with a spectral slope steeper than the exterior deposits. (b) Unnamed crater (2.2°N; 121°E), 51 km in diameter, displays a central peak with a spectral slope similar to those of the exterior deposits. (c) Unnamed crater (21.3°S; 283.4°E), 43.8 km in diameter, displays a central peak with a spectral slope shallower than those of the exterior deposits.