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Shallow crustal composition of Mercury as revealed by spectral properties and geological units of two impact craters

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ABSTRACT

We have performed a combined geological and spectral analysis of two impact craters on Mercury: the 15 km diameter Waters crater (106°W; 9°S) and the 62.3 km diameter Kuiper crater (30°W; 11°S). Using the Mercury Dual Imaging System (MDIS) Narrow Angle Camera (NAC) dataset we defined and mapped several units for each crater and for an external reference area far from any impact related deposits. For each of these units we extracted all spectra from the MESSENGER Atmosphere and Surface Composition Spectrometer (MASCS) Visible-InfraRed Spectrograph (VIRS) applying a first order photometric correction. For all the mapped units, we analyzed the spectral slope in two wavelength ranges, 350–450 nm and 450–650 nm, and the absolute reflectance in the 700–750 nm range. Normalized spectra of Waters crater display a generally bluer spectral slope than the external reference area over both wavelength windows. Normalized spectra of Kuiper crater generally display a redder slope than the external reference area in the 350–450 nm window, while they display a bluer slope than the external reference area in the 450–650 nm wavelength range. The combined use of geological and spectral analyses enables reconstruction of the local scale stratigraphy beneath the two craters, providing insight into the properties of the shallower crust of Mercury. Kuiper crater, being ~4 times larger than Waters crater, exposes deeper layers with distinctive composition, while the result for Waters crater might indicate substantial compositional homogeneity with the surrounding intercrater plains, though we cannot exclude the occurrence of horizontal compositional heterogeneities in the shallow sub-surface.

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1. Introduction

The Mariner 10 mission unveiled the general morphology of Mercury, allowing a first geologic mapping of its surface. The MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) mission went farther, providing more detailed information through the combination of morphology and spectral analysis. The goal of this work is to reconstruct the local stratigraphy beneath the two craters using a geologically supervised spectral analysis. This technique, combining spectral analysis and geologic interpretation, can serve as a tool for identifying vertical and horizontal heterogeneities in the crust of Mercury, allowing the reconstruction of the local scale stratigraphy beneath the surface indeed. Impact craters can open a window into the shallow crust of Mercury, as they excavate materials from depth. The spectral properties of these materials can reveal vertical or horizontal compositional heterogeneities in the shallow crust, although these compositional differences may be obscured by several factors, including space weathering, impact metamorphism, and differences in grain size. This study provides a local scale characterization of two impact craters of Mercury, the 15 km diameter Waters crater (106°W; 9°S) and the 62.3 km diameter Kuiper crater (30°W; 11°S). We analyze and compare the spectral character of central peaks, internal deposits, impact melts and the fresh ejecta of both craters in function of the spectral properties of a region mapped as intercrater plains by Mariner 10 authors (i.e., De Hon et al. 1981; King and Scott, 1990).

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2. Background

2.1. Geology of Mercury after the Mariner 10 mission

The Mariner 10 spacecraft imaged approximately 40% of the surface of Mercury at a resolution more or less comparable to that of Earth-based observations of the Moon (Murray et al., 1974). In the mid-1970s, Mariner 10 science team members identified and divided Mercury's surface into morphologic and physiographic units such as intercrater plains, heavily cratered terrain and smooth plains (e.g., Trask and Guest, 1975; Gault et al. 1975; Trask, 1976; Strom, 1977; Kiefer and Murray, 1987; Spudis and Guest, 1988). Intercrater plains and heavily cratered terrain represent the oldest units of Mercury and their origins and chronostratigraphic relations have been studied by various authors (e.g., Strom, 1977; Trask and Guest, 1975; Trask and Strom, 1976).

In contrast to the intercrater plains, the smooth plains are characterized by a relatively low density of impact craters and by a smoother surface morphology. In accordance with the studies of Leake (1982), smooth plains have been interpreted by Mariner 10 geologic mappers to be stratigraphically younger than the intercrater plains (i.e., Schaber and McCauley, 1980; De Hon et al., 1981; Guest and Greeley, 1983; Grolier et al., 1660; King and Scott, 1990).

Intercrater plains, heavily cratered terrains and smooth plains were all plausibly emplaced during a very early phase of Mercury's surface history. The most recent chronostratigraphic periods, the Mansurian (which began between 3.0 and 3.5 Ga) and the Kuiperian (1.0 Ga), are mainly characterized by the emplacement of impact craters and related material (Spudis and Guest, 1988).

2.2. MESSENGER's studies

Data acquired by the MESSENGER spacecraft have allowed key questions such as the origin of smooth plains to be revisited. The MDIS instrument has imaged 100% of Mercury's surface at a spatial resolution better than 200 m/pixel. Coupled with new spectra

Table 1
MDIS color units (in the center) are compared with global units defined on the basis of geologic interpretation (on the left) and with MASCS VIRS spectral units (on the right). The correspondence is not total, but in some cases the overlap is possible.

GLOBAL GEOLOGIC UNITS (Mancinelli et al., 2014)	MDIS COLOR UNITS (Robinson et al., 2008; Denevi et al. 2009, 2013; Ernst et al., 2010)		MASCS VIRS UNITS (Izenberg et al., 2014)
Smooth Plains	Smooth Plains	High Reflectance Red Plains (HRP)	Average
		Intermediate Plains (IP)	
		Low Reflectance Blue Plains (LBP)	
Intercrater Plains (IP)	Intermediate Terrain (IT)		
	Low Reflectance Material (LRM)		Dark Blue
Bright Intercrater Plains (BIP)			
	Bright Crater-Floor Deposits (BCFDs)		Bright
	Pyroclastic Deposits		Red
Odin Formation	Odin Formation		
Caloris Rough Ejecta (CRE)			
Dark Material (DM)			
Ejecta Material (EM)			
	Red Material (RM)		
	Immature Ejecta		

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