Evolution of volcanism on Mercury using spectroscopy

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Introduction

Volcanism was a major process on Mercury and modeled the formation of the secondary crust. 27% of the surface is covered by smooth plains[1], mostly volcanic, whose spectral [2] and compositional [3] properties are heterogeneous. The well-preserved Caloris basin is one of the most important geological features on Mercury associated with smooth plains: Caloris Planitia and the circum-Caloris smooth plains, respectively called interior and exterior plains. The interior plains have a high reflectance that increases with wavelength and is associated with the High-reflectance Red Plains (HRP) spectral unit. The exterior plains are bluer and have a lower reflectance and belong to the Low reflectance Blue Plains (LBP) [1]. The formation of large impact basins can bring to the surface deep material sampling the earliest carbon rich crust now buried under the secondary magmatic crust. This deep excavated material is at the origin of the Low Reflectance Material (LRM) spectral unit [4]. The interior and exterior plains appear to be both set up by an effusive volcanism after the formation of the basin although the timing of their establishment and the understanding of their spectral differences remain debated [5]. Lavas on Mercury are characterized by a high content of MgO showing that they vary from mafic to ultramafic with the possibility to find more silica or alkaline igneous rocks. The Caloris basin exemplifies of this compositional diversity with exterior plains composed of a more ultramafic lava, richer in Mg and poorer in Al than the interior plains [2]. An exhaustive spectral study of Caloris is proposed with the aim of improving our understanding of the setting up of volcanic smooth plains and the origin of spectral and compositional disparities.

Relative timing between volcanic plains associated with the Caloris basin

MASCS data analysis

We created spectral maps using multispectral images obtained by the Mercury Dual Imaging System (MDIS/MESSENGER) and spectral observations acquired by the Mercury Atmospheric and Surface composition Spectrometer (MASCS/MESSENGER). MASCS data are contained in the MeSS (Mercury Surface Spectroscopy) database [6] as well as several spectral parameters and observation conditions. We carried out a spectral characterization of HRP, LBP and LRM units filtering the data and using spectral parameters (reflectance, slopes, reflectance ratio, curvature, uv_downturn). This characterization was then used to map the different spectral units within and around the Caloris basin.

Results and discussion

Our spectral characterization distinguishes the interior from the exterior plains of the Caloris basin. Focusing on Atget crater located in the interior plain, we can see that there are footprints associated with LRM in the center surrounded by LBP and HRP (Figure 1). This arrangement of Atget deposits provides information on the stratigraphy under the crater and therefore the Caloris basin. The closer to the center of the crater the ejecta

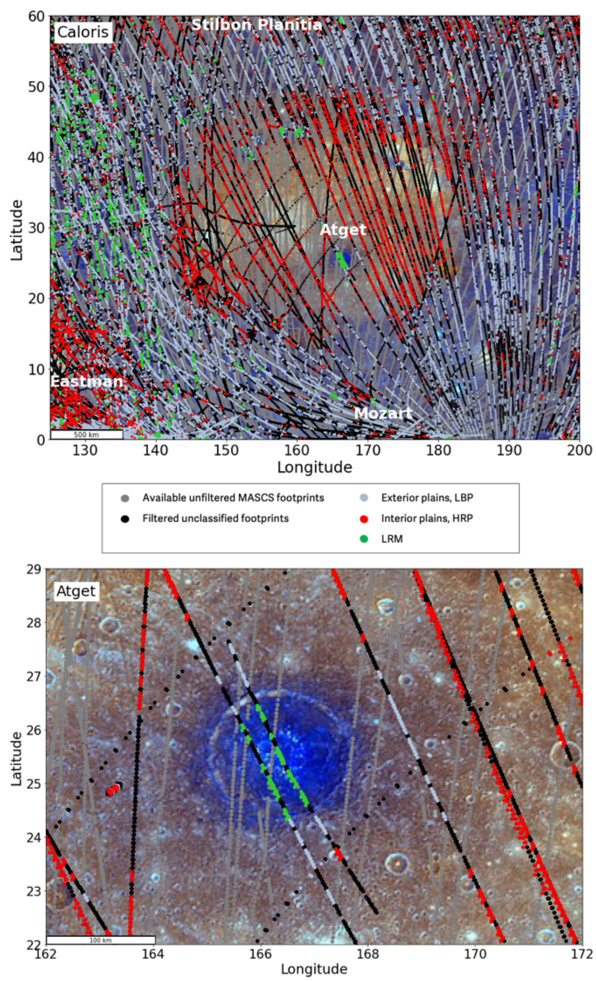

Figure 1 : Spectral mapping of Caloris and Atget

is, the deeper/older the source of the deposit is. We propose that the exterior plains were emplaced before the interior plains with an evolution of the deep melting conditions through time as the origin of their spectral and compositional differences [7]. This implies that the Caloris basin was filled by two distinct volcanic events.

Nature and evolution of lava over time

Remote sensing reflectance spectroscopy was used to study Mercury's surface but space weathering by solar wind complicates the interpretation of reflectance spectra. A better understanding of space weathering is essential to better constrain the nature of volcanic units on Mercury including smooth plains related to the Caloris basin. Mg rich terrestrial rocks such as boninites, basaltic komatiites and komatiites represent good analogues for Mercury's surface composition[8][9][10][11]. The Mg content in these rocks varies increasing from boninite to komatiite.

To better constrain the nature, evolution of lavas over time and spectral properties of the surface including effects of space weathering, we propose to study terrestrial komatiite, basaltic komatiite and boninite exposed to simulated solar wind.

Laboratory irradiation campaign

Pellets of boninite, basaltic komatiite and komatiite were prepared by pressing ~270 mg of powder with a grain size < 36 µm representative of Mercury's surface [12]. Ion irradiation was performed with SIDONIE isotope separator in IJCLab, Orsay, using He^+ ions at 20 keV [13] reaching a final dose at 1.10^{17} ions cm^{-2}. Bidirectional reflectance spectroscopy was performed in the VIS (0.4-1.05 µm) to NIR (0.9–2.5 µm) using INGMAR set up (IrradiatioN de Glaces et Météorites Analysées par Réflectance VIS-IR, IAS-CSNSM/Orsay). Spectra were collected with e=15° and illumination angle i=15° (α=20°) in the VIS and i=20° (α=15°) in the NIR.

Preliminary results and perspectives

The preliminary comparative study of boninite, basaltic komatiite and komatiite shows a different absolute reflectance increasing from boninite to komatiite (Figure 2). Globally, after irradiation spectral features in the VIS are modified and the absolute reflectance in the NIR is reduced. However, the impact of irradiation on the spectra is not the same according to the composition of the sample.

We plan to expose our irradiated Mercury volcanic surface analogues to Hermean high temperatures in order to better constrain the effects of temperature and irradiation on the spectral properties.

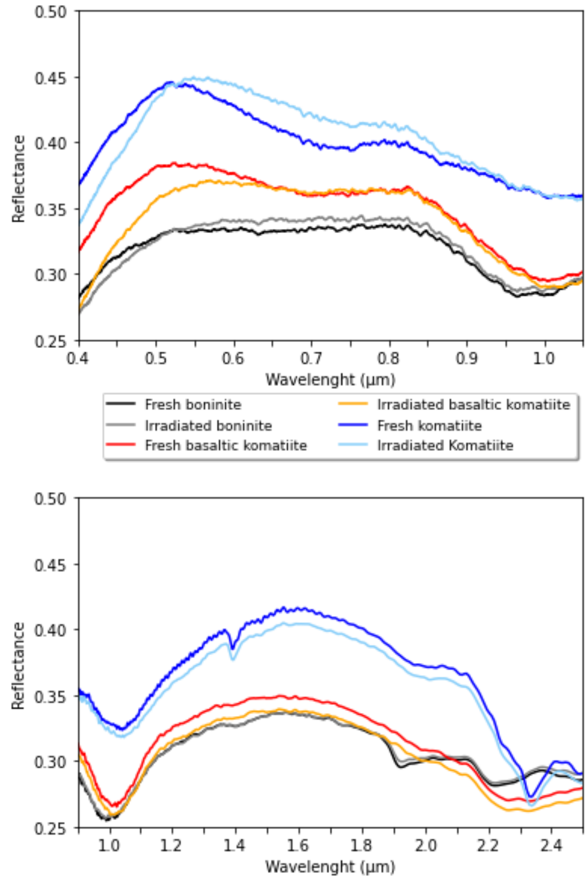

Figure 2: Visible and near-infrared reflectance spectra

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