EPSC Abstracts
Vol. 17, EPSC2024-646, 2024, updated on 25 Mar 2025
https://doi.org/10.5194/epsc2024-646
Europlanet Science Congress 2024
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Spectral properties of pyroclastic deposits on Mercury over space and time

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Explosive volcanic activity on Mercury extended after the end of the widespread effusive volcanism era (Jozwiak et al., 2018). Understanding the precise timing of explosive eruptions has significant implications for the volatile content and thermal evolution of the planet. However, the age of individual pyroclastic deposits remains largely debated and is difficult to assess using crater counting (e.g. Luchitta and Schmitt, 1974). An individual analysis of a selection of faculae has highlighted the spectral diversity across and within deposits (Barraud et al., 2021, Besse et al., 2020). In this work, we constrain the link between the variability in spectral properties across deposits and deposit age. Additionally, we explore the spatial variability in spectral properties inside deposits, and the relationship of this variability to the timing of eruptions inside individual faculae. A combination of morphologic analyses based on MESSENGER/MDIS images and spectral data from MESSENGER/MASCS is analyzed to this end, utilizing a deep learning approach.

We analyze the relationship between the morphological degradation of the vents (physical depressions) and the spectral changes in the associated deposits (faculae). This study shows a correlation between the deposit spectra and vent degradation, characterized by a rapid initial darkening of the deposit and spectral flattening over time, followed by stabilization. The deposits with heavily degraded vents reach the properties of the local background terrain, rendering old deposits spectrally undetectable. To explain these temporal variations in spectral properties, we propose three potential processes: space weathering, mixing with the underlying terrain, and changes in erupted pyroclast size. Space weathering acts “fast”: spectral changes induced by nanophase iron accumulation produced by space weathering on the Moon saturate after ~1 Ga (Tai Udovicic et al., 2021). If a similar mechanism is responsible for most of the spectral modifications observed over time, then a large part of explosive eruptions detected on Mercury could be significantly younger than previously expected.

To explore the relative timing of vents within the same facula, we examine the variability of spectral properties inside the deposits. Using outlines defining the vent profile and the deposit extent defined by Leon-Dasi et al. (2023), we extract the evolution of spectral properties in the direction locally perpendicular to the vent. Using these data, we study (1) the rate of change of spectral properties, (2) the symmetry of the deposit, and (3) the contribution of each vent to the spectral variability. This analysis benefits from leveraging the deep learning-based data reduction performed by Leon-

Dasi et al. (2023), which results in a set of latent dimensions integrating spatial and spectral information. Using such latent dimension has proven to highlight the pyroclastic deposits and reduce the spatial noise more effectively than using single MASCS-derived spectral parameters. From a preliminary analysis, we find a trend between the rate of change of the spectral variations across the deposits and the deposit age. Older deposits appear to present slower-changing spectral properties, which is consistent with deposit erasure over time through various space weathering processes. Within multi-vent faculae, we find spatial variations in the association between spectral signatures and different vents—this implies that eruptions within a single facula were separated in time. Overall, this research provides further insight into Mercury’s volcanic history and the processes that have shaped its surface over time.