GLOBAL DISTRIBUTION OF AREAS WITH FEATURELESS SPECTRA ON THE MOON: ERODED LUNAR PRIMORDIAL CRUST?

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INTRODUCTION

Global distributions of exposure sites of various lunar major minerals have been revealed from the global survey using the spectral data obtained by Spectral Profiler (SP) onboard SELENE/Kaguya [e.g., 1-4]. These studies are conducted based on the diagnostic absorption bands of 1 μm and 2 μm. On the other hand, it has been reported that several sites on the Moon exhibit no absorption bands for 1 μm and 2 μm (hereafter featureless (FL) spectra) [e.g., 5,6]. For the interpretations for the origin of FL spectra, we need to understand the global occurrence trends of FL points on the Moon. Thus, we conducted the global survey using SP data to reveal the global distribution of FL points.

RESULTS

SP has obtained continuous spectral reflectance data for about 70 million points (0.5 by 0.5 km footprint) on the Moon in wavelength $\lambda = 0.5$-$2.6\,\mu$m and a spectral resolution of 6-8 nm [7,8]. Analyzing the 70 million spectra with the global survey algorithm used in [2-4], we identified the spectra whose absorption depths at wavelengths λ_d are less than the critical depth d_c. We used $d_c = 0.01$ for $\lambda_d = 0.93$, 0.98, 1.05, and $1.25\,\mu$m and $d_c = 0.03$ for $\lambda_d = 2.00\,\mu$m. Applying the algorithm to all the SP data, we found 244 points of FL spectra.

Fig. 1 shows example of the FL spectra (A, B, and C). For a comparison, the spectra for olivine-rich site (F)[3], purest anorthosite (PAN) site (D)[2], and Mg-spinel-rich site (E)[8] are plotted. The FL spectra show a smooth feature for $\lambda > 0.7\,\mu$m as compared to those of the other lunar minerals. The typical spectra for the mixing layers in the highlands, which are affected by space weathering and/or soil developments, are also plotted (G, H, and I), where we can see a discernible 1 μm band in $\lambda \sim 0.9$-$1.0\,\mu$m. Thus, the FL spectra are different from those of the mixing layers. Indeed, the discernible 1 μm band features are used for the interpretation of LCP-dominant spectra for the mixing layers [9].

Fig. 2 shows the global distribution of FL points. The detection points are clustered into several local areas. They are associated in the major lunar impact basins in the Feldspathic Highlands Terrane (FHT) region: e.g., the Orientale, Moscoviense, Freundlich-Sharonov, Dirichlet-Jackson, Hertzsprung, Korolev, Humboldtianum, Lorentz, Birkhoff, Coulomb-Sarton, and Keeler-Heaviside basins. Note that these impact basins are also PAN-bearing sites [1,2]. In addition, the FL spectra are found at large, prominent impact craters: e.g., Debye, D'Alembert, and Fowler craters. These craters are also the PAN-bearing sites [1,2]. Thus, the occurrence of the FL points are always associated with the PAN. On the other hand, there is no FL point inside the Procellarum KREEP Terrain (PKT) and South-Pole Aitken (SPA) basin. Furthermore, we can also see in Fig. 2 that there is an asymmetric distribution of the FL points between the nearside and farside of the Moon. Even the highlands in the nearside (e.g. around Tycho crater) does not possess FL point.

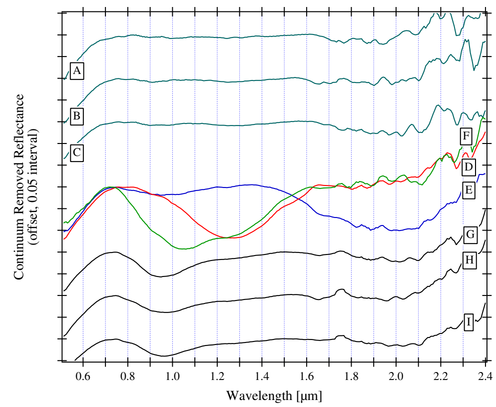

Figure 1: The continuum-removed reflectance spectra measured by SP in several FL points in (A) Moscoviense, (B) Humboldtianum, and (C) Freundlich-Sharonov basins. For a comparison, the spectra for olivine-rich site (F, green), PAN site (D, red), and Mg-spinel-rich site (E, blue) are plotted. In addition, the typical spectra for the mixing layers in the FHT near (G) King, (H) Jackson, and (I) Lentz craters are also plotted.

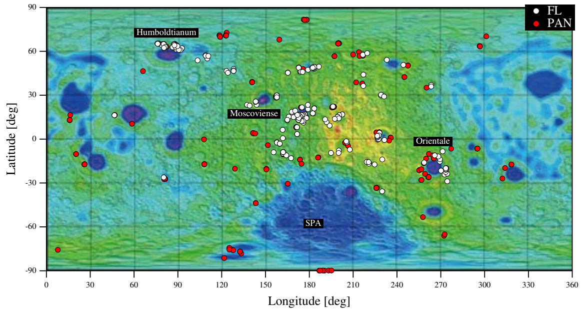

Figure 2: The global distribution of FL points. For a comparison, the data of PAN points by [2] are plotted. The background is the total crustal thickness map [12].

Fig. 3(a) shows the local distribution in the Orientale basin. The FL points are distributed along the peak rings of this basin. The PAN points are also distributed along the peak rings. We can also see that most of the FL points are distributed in the eastern half of the peak rings, while most of the PAN are found in the western half. On the other hand, there are no FL nor PAN points in its central region. Fig. 3(b) shows the FL and PAN points in the Hertzsprung basin. They are distributed along the peak rings, while the center region of this basin does not possess FL and PAN points. The same distribution pattern was observed at the other basins.

In a local scale, they are distributed around the rims or ejecta deposits of fresh impact craters. Fig. 4(a) shows the local distribution of FL points around Hayn crater located at the outer region of the Humboldtianum basin. The FL points are distributed on the rim and ejecta deposits of the Hayn crater, while they are not found inside this crater. (Since the FL points are found at various observational timings, the lack of the FL points inside the crater is not due to shadow.) The previous survey [2] also found the PAN points around the rim. Fig. 4(b) shows the FL points in the Debye crater. There is a 10-km sized fresh crater inside the Debye crater, where many PAN points are distributed. On the other hand, FL points are distributed around the fresh crater.

DISCUSSION

What produced the FL points on the Moon? In general, the absorption depth would be affected by space weathering, the grain size in regoliths, and geometrical conditions (e.g., phase angle) [10]. In addition to these effects, PAN could be an important factor for the occurrence of the FL, because our data showed that most of

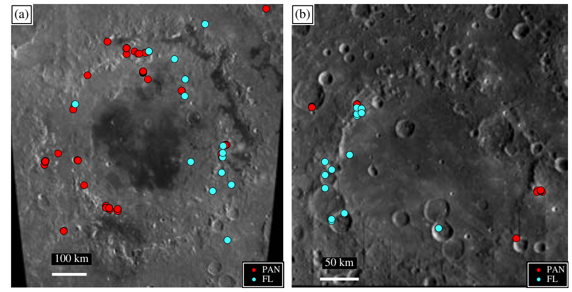

Figure 3: The close-up images of the FL points in (a) Orientale and (b) Hertzsprung basins. Light blue and red circles indicate the FL and PAN points, respectively [1,2]. The background map is obtained by Terrain Camera (TC) onboard SELENE.

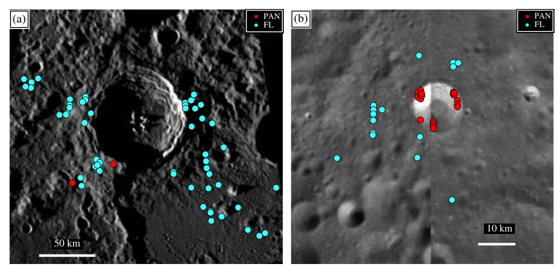

Figure 4: The close-up images of the FL points in (a) Hayn and (b) Debye craters.

the FL points are associated with the PAN. Thus, we propose three possible origins: shocked plagioclase [5,6], the PAN with small iron particles by space weathering [11], or the deposition of fine grains of PAN as seen in Swirl. Whatever the origin for the FL is, the excavation of the primordial PAN layer in the lunar crust by the basin formations [2] could be related to the occurrence of the FL, because the FL points are limited to the concentric regions of the major impact basins in the highlands. Our new data may provide a new observational evidence of eroded lunar primordial crust.

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