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Initial identification of candidate lunar mantle-derived mafic materials based on Chang'E-4 spectroscopic data

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Abstract

The first lunar far side soft lander of human beings, Chang'E-4 (CE-4) has successfully landed in Von Kármán crater of South Pole-Aitken basin (SPA) of lunar far side on January 3, 2019. As the largest and oldest impact structure on the lunar surface, SPA can potentially penetrate through the crust and exhume the mantle material. Here we reported on the initial data processing and interpretation results of the Yutu-2 Visible and Near-Infrared Spectrometer (VNIS) data, which interpreted to represent the presence of low-Ca (ortho) pyroxene and olivine, candidate lunar mantle materials. We will focus on these materials to understand their geologic context, origin and abundance as the continued exploration by the Yutu-2 rover.

1. Introduction

The initial composition and structure of the lunar mantle remain unknown [1-4]. Recent developments of impact-basin models [5-6] show that the SPA event should have penetrated to the lunar mantle and excavated mantle materials. However, the absence of abundant olivine in the SPA interior remains difficult to explain. Chang'E-4 has successfully landed in the Von Kármán crater of the SPA basin at 10:26 (UTC+8) on 3 January 2019, and the landing site is considered to have high likelihood of sampling lunar-mantle materials [7]. As the only payload designed for minerals identification and interpretation, the VNIS onboard the Yutu-2 rover enabled the first in situ reflectance spectrum measurements of the far side of the Moon. It will help to constrain the composition and origin of the landing site's materials.

2. VNIS description

The VNIS spectral range covers from 450nm to 2,400 nm and consists of one hyperspectral imaging detector (VIS/NIR; 450–950 nm) and one single-point spectrometer (SWIR; 900–2,400 nm). The single-point SWIR spectrometer has a circular field of view, the center of which corresponds to (X98, Y128) of the VIS/NIR image, and The radius of the circle covers 53.8 pixels of the VIS/NIR image. The technical characteristics of the Chang'E-4 VNIS are consistent with those of Chang'E-3 [8-9].

3. Data processing and spectral deconvolution methods for VNIS

The data processing of VNIS began with level 2B data, which underwent dark-current subtraction, scattering-background correction, flat-field, instrument temperature corrections, and radiometric and geometric calibration [10]. First, the radiance data were divided by the solar irradiance, multiplied by π, and further divided by the cosine of the incident angle to obtain the reflectance factor (REFF). Second, for each detection point, the reflectance spectra (450–950 nm) of 9,082 pixels from the circle of SWIR field of view were averaged to obtain one spectrum (450-950 nm), which was then connected with the point spectrum (900–2,400 nm) measured in the same circular area. Finally, the continuous spectra were smoothed using the Savitzky–Golay method [11-12]. The Modified Gaussian Model (MGM) was also used to deconvolve the VNIS spectra to constrain their mineral composition [13-14].

4. Conclusions and discussion

The radiance spectra of the two detection points adjacent to the lander (Detection points A and S1) collected during the first lunar day were analyzed. After removal of the continuum, the positions of the 1-μm and 2-μm absorption bands of the two spectra were identified through parabola fitting. Results show that the positions of the 1-μm band for Point A and Point S1 are 949.2 nm and 995.1 nm, and those of the 2-µm band are 1,985.9 nm and 1,984.9 nm. The 1-µm and 2-µm absorption-band center of the two Chang'E-4 spectra move to shorter wavelengths, showing spectral features of low-Ca pyroxene (LCP) and olivine. The overall spectral shape and absorption-band positions are more similar to those of lunar highland materials and are enriched in mafic components distinct from mare basalt.

Four different groups of mineral combinations were used in the MGM deconvolution: (1) LCP, HCP and olivine (OL); 2) LCP, HCP and plagioclase (Plag); 3) LCP and Plag; 4) LCP and OL. Results show that the reflectance spectra of points A and S1 can be accurately fitted by the mineral combination of LCP+HCP+OL, which has the lowest root-mean-square (r.m.s.) deviation. Further analysis on the deconvolved 1-µm band depth of LCP, HCP and OL suggests that for point A LCP:HCP:OL is 42%:10%:48%, with the highest abundance being OL, followed by LCP and the lowest abundance being HCP. MGM deconvolution of point S1 indicates that LCP:HCP:OL is 38%:7%:55%. Point S1 is dominated by LCP and OL and possesses a greater abundance of OL than point A and a very small amount of HCP.

The results imply that the Chang'E-4 landing site is characterized by mafic components that are dominated by LCP and olivine, with a very small amount of HCP, suggesting the presence of deep-seated material from the upper mantle [6], rather than the surface mare basalts on the floor of the Von Kármán crater.

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