MINERALOGY ASSEMBLAGES OF THE ROCK DETECTED AT CHANG'E-4 LANDING SITE BY VISIBLE AND NEAR-INFRARED IMAGING SPECTROMETER ABOARD YUTU-2.

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Introduction: Exploration of the mafic anomaly in South Pole-Aitken (SPA) basin on the Moon provides important insights into the composition of the lunar interior and, specifically, the makeup and processes associated with formation of SPA [1]. The landing of Chang'e-4 (CE-4) and deployment of the Yutu-2 rover on the discontinuous ejecta from Finsen crater deposited in Von Kármán crater enabled in-situ measurements of the unusual mineralogy in the central portion of the SPA basin using the visible and near-infrared imaging spectrometer (VNIS) [2-4].

For the 12 lunar days on lunar farside surface until Dec., 4, 2019, Yutu-2 had traversed more than 345 m (Fig. 1a). In this study, we focus on the mineral assemblages and composition of one lunar rock detected on the third lunar day (Fig. 1b,c). Using the data acquired by VNIS (Fig. 1d,e), we employ both the modified Gaussian model (MGM) deconvolution and Hapke radiative transfer model to obtain quantitative mineralogical information to provide a more robust result for the mineralogy of the CE-4 landing site.

Data processing and calibrations: The VNIS collected hyperspectral VNIR (visible and near-infrared) images (450–950 nm) and point SWIR spectra (900–2400 nm) for fourteen detection targets during the first three lunar days of the CE-4 mission. The VNIS raw data were processed to level 2B radiance through a series of processing pipelines [5]. The level 2B VNIS radiance data were further processed (e.g., photometric correction [6]) to extract diagnostic absorption characteristics and identify the surface mineralogy of exploration sites in this work.

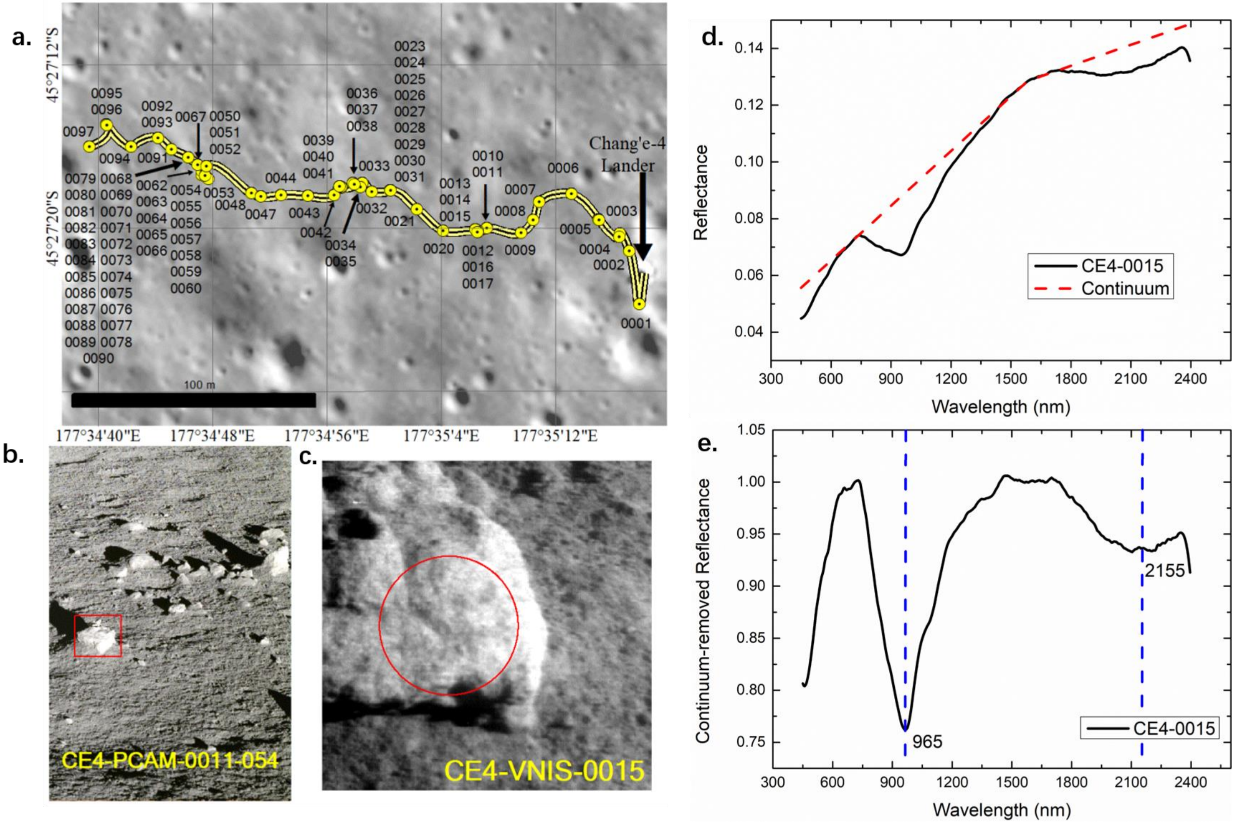

Figure 1. Geologic context of Yutu-2 traverse route and the in-situ spectra collected for the rock shown in (c). (a) Yutu-2 rover traverse map; (b) PCAM images of the rocks found on the third lunar day; (c) Micro-image taken by VNIS; (d) Spectra and continuum of VNIS spectra (CE4-0015); (e) Continuum–removed spectra of CE4-0015.

Spectral properties of the rock: From the VNIS spectral data (Fig. 1e), the mafic components of this rock exhibit absorption features at 965 nm and 2155 nm, indicating the Ca- and Fe-rich nature of the pyroxene, consistent with the observation by the Moon Mineralogy Mapper (M^3), i.e., Ca-Fe-rich mafic non-mare materials ejected from Finsen crater [1, 4].

Mineral chemistry and mineral modes based on VNIS spectra: To estimate the average composition of minerals contributing to the spectra, we first apply the modified Gaussian model (MGM, Fig. 2a) to deconvolve the spectral bands [7-9] using mixtures of three endmembers, high-Ca pyroxene (HCP), low-Ca pyroxene (LCP) and olivine. The HCP/LCP ratio is estimated to be 0.65 based on the strength of 1 and 2 μm absorption features. The olivine proportion, however, is difficult to estimate based on the absorption features [7]. MGM results suggest olivine should be abundant in this rock. When overlain with the absorption centers of HCP and LCP with laboratory and CE-3 spectral data of pyroxenes (Fig. 2b), we find they belong to more Fe- and Ca-rich mineral members (pyroxene).

For quantitative estimates of mineral assemblages and mineral chemistry, a lunar spectral mineral lookup table (LUT) was constructed based on a Hapke radiative transfer model [10, 11]. The modeled spectra of CE4-0015 show a good match with the observed spectra as indicated in Fig. 2c. The mineral proportions of HCP, LCP, olivine (OL) and plagioclase (PLG) are *7:15:13:65*. The mineral chemistries of HCP, LCP, and olivine are in Fig. 2d. In brief we find that the MGM and Hapke modeling results are consistent for the mineral modes and chemistries.

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References: [1] Moriarty et al., (2018), JGR, 123, 729-747. [2]Wu et al., (2017), J. Deep Space Explor., 4(2):111-117.[3] Huang et al., (2018), JGR, 123, 1684–1700. [4] Ling et al., (2019), PSS, 104741. [5] He et al., (2014), Res. Astron. Astrophys. 14, 1567–1577.[6] Qi et al., (2020), 51th LPSC, this volume. [7]. Ling, et al.,(2015), Nat. Comm. 6:8880. [8] Sunshine et al., (1993), JGR, 98, 9075–9087. [9] Sunshine et al., (1998), JGR,103, 13675–13688. [10] Lucey et al., (2004), JGR, 31, L08701.[11] Lemelin et al., (2015), JGR, 120, 869-887.

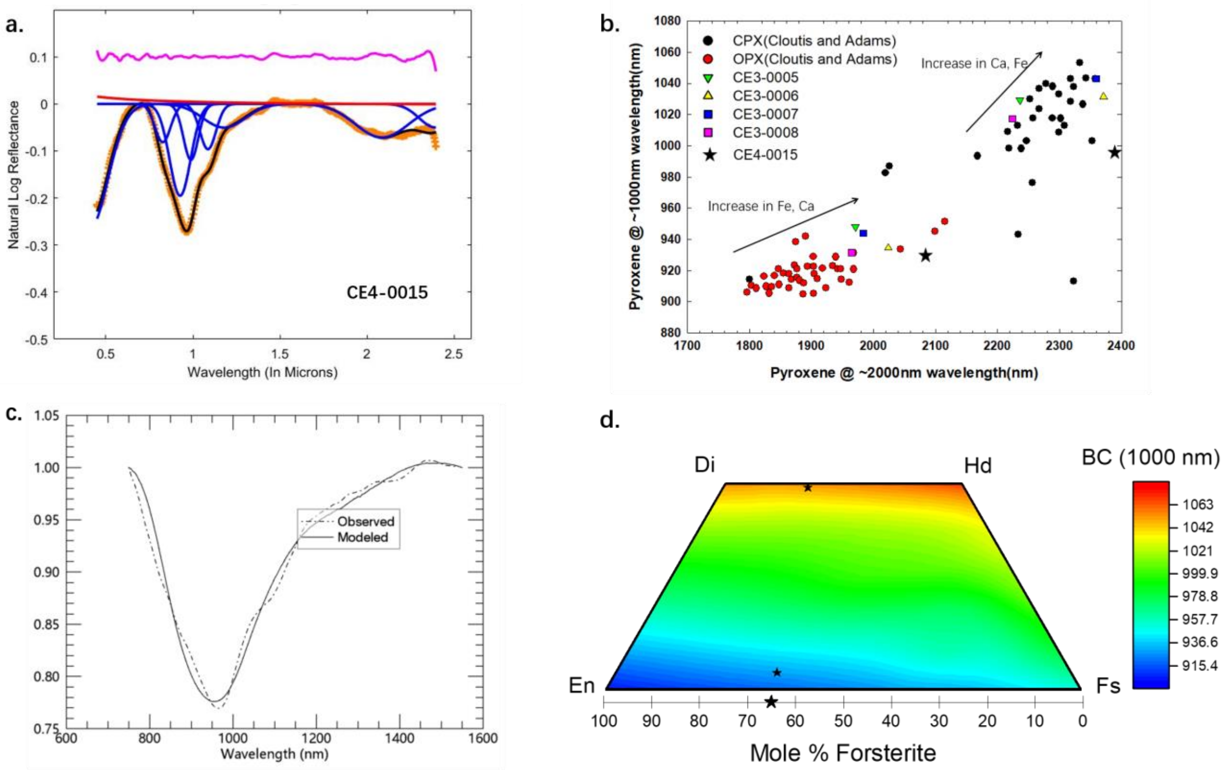

Figure 2. Spectral deconvolution of the VNIS spectra of the lunar rock (CE4-0015). (a) Modified Gaussian Model (MGM); (b) Pyroxene VNIS peak positions of the CE-4 rock from MGM; (c) Hapke radiative transfer model; (d) Mineral chemistries of pyroxene and olivine from Hapke radiative transfer model.