High Calcium Pyroxene and Plagioclase Minerals from the lunar crust identified along the path of Chang'E-4 Rover.

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Summary: So far, Chang'E-4 rover has operated for over 1 year, and moved for a distance of over 300 meters in the Von Karman Crater at the lunar farside. Along the whole path, two types of composites along the path until to end of the year 2019 have been identified. One is a composite of high-calcium pyroxene and plagioclase as two main end-members, and the other is that of low pyroxene and plagioclase, which both mean that the materials along the path is most probably originated from the ***lunar lower crust, not from mantle***. Through detailed analysis, no olivine has been discovered along the path until now. For accurate analysis, we also corrected the difference between two coordinate systems for the CE4 (abbrevation for Chaneg'E-4, and in the rest of the abstract) rover and the LROC to comparison in worldwide, and we designed an algorithm for accurate radiance correction.

Introduction: In-situ sampling and/or acquiring spectral properties of materials on planetary surface is essntial to understanding of remote sensing data sets. Until last year, there no materials from lunar farside acquired. Mantle materials probably have excavated in Aikten basin at the lunar farside. The successful landing of CE4 rover in the Aitken basin make some true of searching for and knowing the deep material of the Moon and possible mantle materials, which is one of key objectives for this mission.

Instruments and Data Sets: CE4 misson composes of a lander and a rover. Of all payloads on the rovers, Panoramic Camera (**PCAM**), lunar penetrating radar (**LPR**) and visual and infrared spectrometer (**VNIS**) are applied for detections of materials. VNIS consists of 'VIS' in visual bands of 450~950 nm (100 bands), and of 'SWIR' part in infrared bands of 900~2400nm (300 bands). The same interval of 5 nanometers is officially applied for the two components. The resolutions of two spectrometers are 2.4~6.5nm for VIS, and 3.6~9.6nm for SWIR, separately. The 256x256 pixels for one VIS image and one only circle point for SWIR data, which located at the center(at the x=128, y=128 pixel) of the responding VIS image. All data sets will open for the public. Link to http://moon.bao.ac.cn/pubMsg/detail-CE4.

Data Pre-Processing: (1) **Location Correction.** There is some difference in the two coordinate of CE4 and LROC. To acquire accurate position of the rover and to realize the geological setting around, we converted the original latitudes and longtitudes of each site in CE4 coordinate system into the LROC's (fig.1) at the accuracy of 2-3m. The each site with 4-digit number same to the last 4 digits of each SWIR data file presented in fig.1. For convience, the number is shortened into 2 digits. The data in 0000 number stands for the landing sites (Di et al., 2019). All data before Oct 1 2019(which equals to 10 daytime on the Moon) in total of 61 sites have been processed, and been marked in the fig.1. (2) **Radiance Correction.** To acquire high accurate reflectance, we design a specific algorithm using correction of high accurate solar spectrum and geometry of the sensor to calculate reflectance in accuracy of less than 3%.

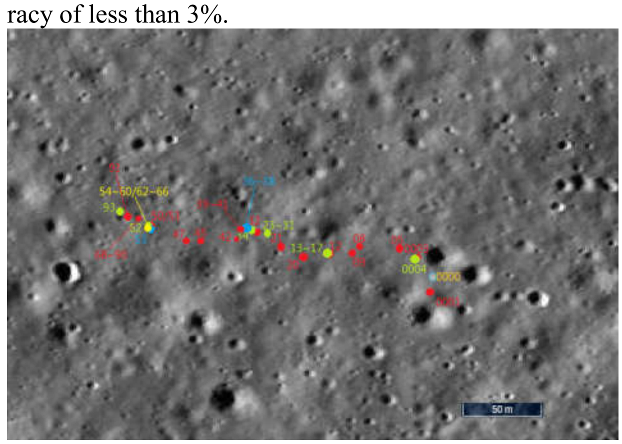

fig.1 At the total of 61 sites are placed in the LROC coordinate. (scale is presented at right bottom)

Results: All data sites are divided into two groups based on geological setting (fig.1) and their reflectance analyzed in the following. Prior to 42(included), one unifed type consisting of three end-memeber materials has been identified, and the rest presented into the other group consisting of only two end-members. The reflectances in figure 2 apparently presents two distinct types of materials(like 40, 41, 42 for one group, and 45, 47 for the other). After carefully analysis based on MGM unmixing method (Sunshine et al., 1990), we acquired end-members for the two groups (fig.3 and 4).

The absorption at 2.35um in the fig3 typically presents for high-calcium pyroxene(Cpx). The carefully analysis demenstrates that the absorption at around 1.24um stands for the plagioclase and that at 1.13um and 1.0um stand for a composite of opx(low-calcium pyroxene) and cpx, of which the later composed the large partition of the materials. Through careful analysis on (1) centres of absorption bands and (2) many properties of amount of minerals (from RELAB libary) (Adams and Goullaud, 1978; Cloutis and Gaffey 1991; Sunshine and Pieters 1998; Klima et al., 2011), we rejected olivine mineral in the first group. In the other areas with sites after 42, the other group consisting of two end-members identified (fig.4). Plagiclase (at absorption of 1.25um) was still identified in this group, and orthopyroxene (at absorption of 0.96, 1.1, and 1.92um) not clinopyxene was identified(fig.4).

Conclusion: In particular, on the basic of minerals identified, we have discovered mafic rocks consisting plagioclase and high-calcium pyroxene, which probably originated from lunar lower crust, not from mantle. Small quantities of low-calcium pyroxene were also identified along the path. There is no olivine minerals identified at the both of groups.

Acknowledgements: We appreicate data providers and specialists in CNSA and NSSC for their supports on the data and instruments calibrations.

Reference: [1] K Di et al., 2019, J of Remote Sensing; [2] Sunshine et al., 1990; [3] Adams and Goullaud, 1978; [4] Cloutis and Gaffey 1991; [5] Sunshine and Pieters 1998; [6] Klima et al., 2011

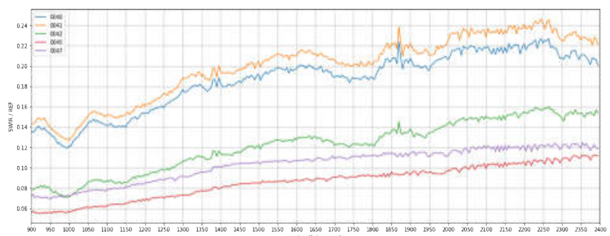

fig.2 Spectrums at SWIR bands for each sites of 40, 41, 42, 45, 47. One gruops with number prior to 42 are presented distinct absorption features to the other.

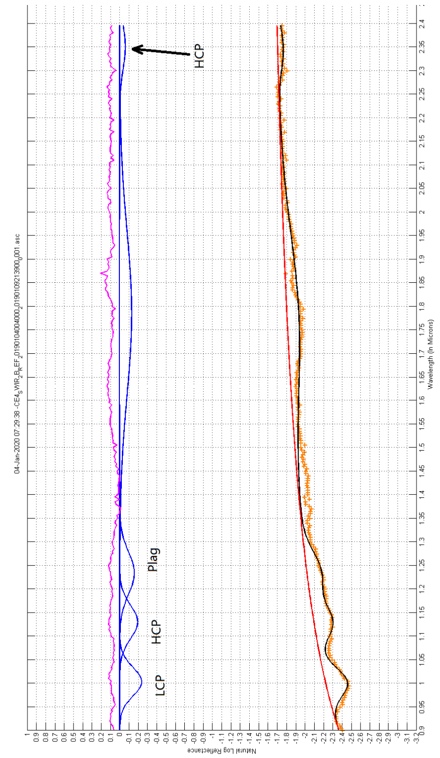

fig.3 Unmixing of end-member for the No.5 site. (Cpx, Pl and Opx identified)

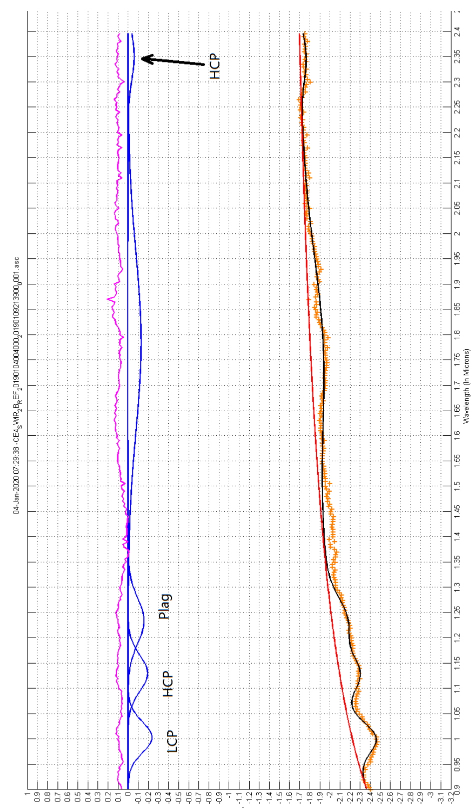

fig.4 Unmixing of end-member for the No.58 site. (Opx and Pl identified)