DIFFERENTIATION OF BASALTIC LAVA AT CHANG'E-3 LANDING SITE Zongcheng Ling[1,2], B. L. Jolliff[2], Jiang Zhang[1], Bo, Li[1], Lingzhi Sun[1], Jianzhong Liu[3] [1]Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, Shandong University, Weihai, 264209, China; [2]Dept Earth & Planetary Sciences and McDonnell Center for the Space Sciences, Washington University in St. Louis; [3]Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, China (zcling@sdu.edu.cn).

First ground truth after Apollo and Luna missions: China's Chang'e-3 conducted the first lunar surface landing and roving mission after some forty years. Based on the returned wealth of data from four payloads aboard Yutu rover, i.e., Panoramic Camera (Pancam), Lunar penetrating radar (LPR), Active Particle-induced X-ray Spectrometer (APXS) and Visible and Near-IR Imaging Spectrometer (VNIS), researchers have advanced our knowledge of the structural, composition, and mineralogy of specific lunar young volcanism [1-6]. Recently, we combined APXS and VNIS data of Yutu rover, derived self-consistent and well-correlated compositional and mineralogical information of the lunar regolith derived from rocks freshly excavated by Zi Wei crater, and discovered a new type of lunar basaltic rock that differs from basalts returned by the Apollo and Luna missions as well as lunar meteorites [7]. Elemental concentrations, mineral modes and mineral chemistries of the Chang'e-3 landing site are consistent with remote sensing, but more accurate with high spectral and spatial resolution, thus making this landing site a good calibration site for the lunar remote sensing studies.

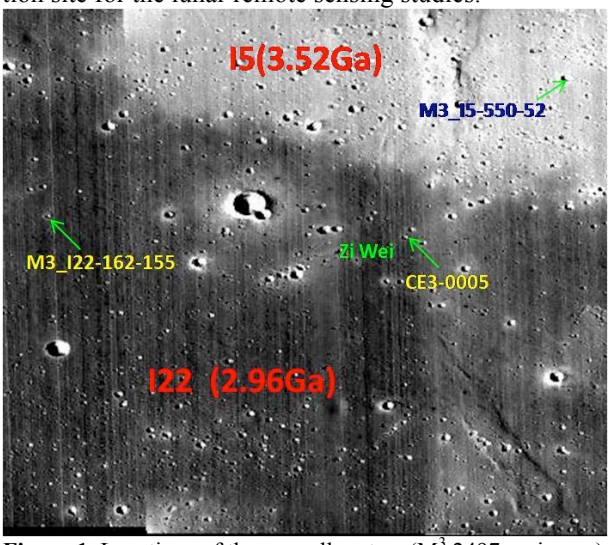

Figure 1. Locations of three small craters (M^3 2497nm image)

In a previous study [7], we found two types of rock, one is light-toned, the other, dark-toned. The chemistries of these two kinds of rocks may be related to the two groups of Yutu measurements (i.e., CE3-0005 and -0008, CE3-0006 and -0007), but do not totally account for difference in these measurements. The origins of these two types of rock still need further investigation. Here we employ orbital hyperspectral imaging data from Chandrayaan-1's Moon Mineralogy Mapper (M^3) to evaluate the spectral and compositional variations of the two basaltic units (I5 and I22, shown in Fig. 1), near the Chang'e-3 landing site, to determine whether the two types of rock originate from a physical mineral mixture or chemical differentiation mechanism. We also use the in-situ Pancam color images (with RGB bands) from the Yutu rover to further investigate these two rock types.

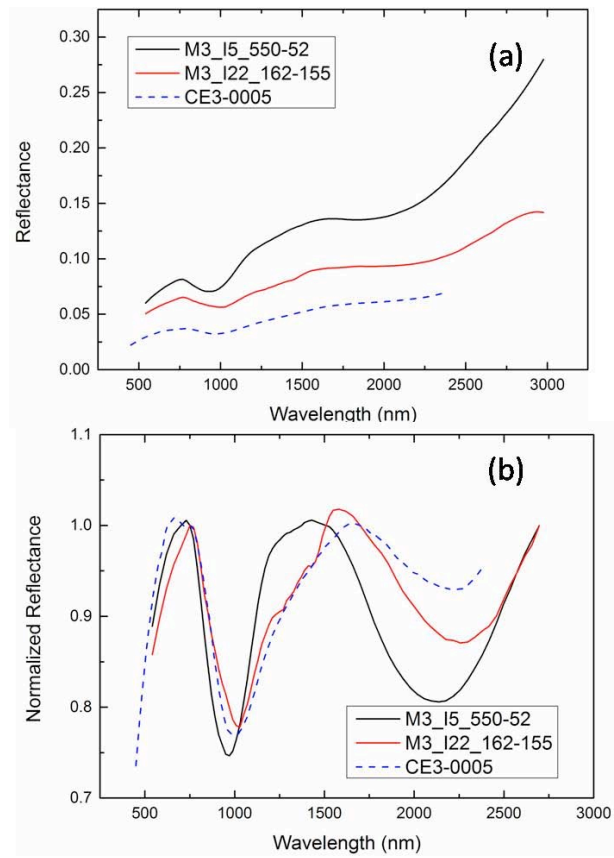

Figure 2. Visible-near-infrared spectra of three craters Orbital observed spectral properties of two basaltic units.

In order to decrease space weathering effects on the spectral data, we extract spectra of the small, young craters of similar sizes to Zi Wei crater (~450 m). Fig.1 shows the locations of three small craters for which we selected representative spectra of the two basaltic units (i.e., I22 and I5). The spectra are given in Fig. 2. The typical M^3 data of young basaltic unit I22 (i.e., 2.96 Ga, M3_I22-162-155) is very similar to the ground truth spectra (CE3-0005) taken by the visible near-infrared imaging spectrometer (VNIS) aboard Yutu rover. However, the spectra taken from the older I5 unit (i.e.,

3.52 Ga, M3_I5-550-52) show distinct features from the other two, i.e., 1- and 2-μm features are shifted to lower wavelengths, implying its pyroxene is lower in Fe and Ca, and enriched in Mg. The ~1.25 μm spectral feature (in Fig. 2b) of the I5 unit is negligible, suggesting it has little or no olivine.

Modified Gaussian Modeling (MGM) deconvolution is conducted for the M^3 spectral data [7]. The derived peak positions of High-Ca (HCP) and Low-Ca (LCP) pyroxenes of I5 units (M3_I5-550-52) are: HCP (1.0 μm, 2.2 μm) and LCP (0.89 μm, 1.9 μm), and the volume ratio (HCP/LCP) is 1.7. The pyroxene and olivine chemistries derived from M3_I22-162-155 are very similar to the mineral chemistries measured by Yutu rover (see [7]). The derived olivine peak positions (0.87 μm, 1.0 μm, 1.25 μm) of M3_I22-162-155 yield Fo ~50 and the volume ratio (HCP/LCP) is 1.9.

In-situ observations of the two types of rock: Here we consider the images taken by Pancam on the Yutu rover. The Pancam has three filters (RGB) to take color images along the traverse route. Fig. 3 shows the Pancam view at the CE3-0008 site, observing across the Zi Wei crater. As indicated by decorrelation stretched (DS) images, the two types of rock are more easily discriminated. One comprises bluish rocks/boulders (the dark-colored rock), the other comprises the light-toned boulders. As shown in Fig. 3, we find that there are many bluish boulders on the inner rim of Zi Wei crater. Considering their lower abundance appearance on the ground traversed by Yutu (e.g., the four detection sites), we infer that this bluish rock likely comes from a deeper part of the basaltic unit at the Chang'e-3 landing site (I22).

Although the three bands of Pancam have not been calibrated to the radiance values, their DN values could be used as guide for their spectral variance. We find that the three bands of the bluish rock are flat in the 360-780 nm spectral range. According to experimental results on olivine and pyroxene, considering the ilmenite proportions are similar among the four sites investigated by Yutu [7], the flat spectral slope in the visible region for the fresh exposed rocks would indicate higher Mg# for the mafic minerals. Thus we think that the dark-toned rock tends to be more Mg-rich.

Referring to the origin of these two types of rock, we need to determine if the cause is mineral mixing (upper unit and lower unit) or differentiation of the proto-lava of the basalt at the Chang'e-3 landing site. We can exclude the mineral mixing mechanism for the following three reasons: 1. The dark-toned rock has a high Mg# with higher olivine content; 2. The light-toned rock is lower in Mg# with a lower olivine content; 3. The northern I5 unit rock is higher in Mg# but poorer in (or lacks) olivine.

We prefer the explanation that these two types of rock result from differentiation (fractional crystallization) of the basaltic lava. We reason that the lower part of the basaltic unit is more Mg-rich and earlier crystallized. In addition, we find that most of the bluish rock around or inside the crater are columnar jointed (with elongate sharp edges). Temperature gradients and compositional differences between the upper layer and lower layer may lead to the formation of columnar jointing for this type of basalt.

Conclusions and future work: Although orbital observations of the young lunar basalt unit (I22) at the Chang'e-3 landing site appear homogenous, in-situ detection by Yutu suggests that the basaltic lavas experienced chemical differentiation. In-situ measurements by Yutu provide new insights for the crystallization processes of these rocks. For future study, we will concentrate on the chemical variations and distributions, with intent to better understand the record of late-stage volcanism on the Moon.

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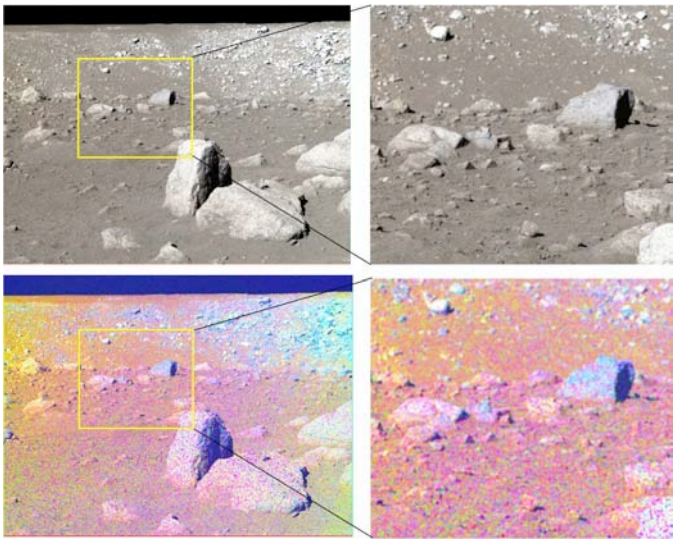

Figure 3. Pancam and decorrelation stretch images of the rims of Zi Wei crater