MINERALOGY AND CHRONOLOGY OF YOUNG MARE VOLCANISM IN THE PROCELLARUM KREEP TERRANE. Yuqi Qian[1] (yuqi_qian@cug.edu.cn), Zhenbing She[1], Qi He[1], Long Xiao[1], Zaicong Wang[1], James W. Head[2], Lingzhi Sun[3], Yiran Wang[4], Bo Wu[4], Xiang Wu[1], Biji Luo[1], Kenan Cao[1], Yiheng Li[1], Mingtan Dong[1], Wenlei Song[5], Fabin Pan[1], Joseph Michalski[6], Binlong Ye[6], Jiawei Zhao[1], Siyuan Zhao[1], Jun Huang[1], Jiannan Zhao[1], Jiang Wang[1], Keqing Zong[1], and Zhaochu Hu[1], [1]School of Earth Sciences, China University of Geosciences (Wuhan), [2]Department of Earth, Environmental and Planetary Sciences, Brown University, [3]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, [4]Department of Land Surveying & Geo-Informatics, The Hong Kong Polytechnic University, [5]Department of Geology, Northwest University, [6]Department of Earth Sciences and Laboratory for Space Research, University of Hong Kong.

Introduction: The young mare basalts are the products of recent lunar volcanism, with low to intermediate titanium and high iron abundance. They are mainly distributed in the center of the Procellarum KREEP Terrane (PKT), where volcanic activity may be extended by elevated heat-producing elements and volcanism was active until ~1.2 Ga [1,2].

To understand the nature and evolution of young lunar volcanism, determining their composition and chronology is crucial. The young basalts were proposed to be rich in olivine based on their strong and broad 1 μm spectral feature [3-5]. In addition, the olivine abundance of these young basalts varies stratigraphically, with younger flows tending to have higher abundances [4, 5].

These young basalts had not been visited by previous missions. Thus, our understanding relied solely on remote sensing techniques, which lack ground truth verification. Recently, the young basalts were first investigated in-situ by Chang'e-3 (CE-3), and then sampled by Chang'e-5 (CE-5) (Fig. 1), which has provided significant ground truth to constrain the mineralogy, chronology, and evolution of the young basalts in the Procellarum KREEP Terrane.

Data and Method: The CE-3 Yutu rover carried a Visible and Near-infrared Imaging Spectrometer (VNIS, 450-2400 nm) and an Active Particle-induced X-ray Spectrometer (APXS); the CE-5 lander carried a Lunar Mineralogical Spectrometer (LMS, 480-3200 nm). The CE-3 VNIS and CE-5 LMS in-situ data were used to analyze the spectral characteristics of the young basalts. In addition, the CE-3 APXS data, the laboratory Raman spectroscopy, TIMA EDS analysis, and electron probe measurements of the CE-5 returned soil were used to constrain its mineral abundance and composition of the constituent minerals.

To further investigate the mineralogy and chronology of the young basalts globally, Moon Mineralogical Mapper (M^3, 430-3000 nm) spectra of 1,741 small fresh craters were extracted within the young mare region and were then unmixed by the lookup table technique [6] and finally interpolated using the Kriging method (Fig. 1).

The lunar chronology function was calibrated by the CE-5 basalt age (~2.0 Ga) in the less constrained range of the function between 1.0-3.0 Ga for the first time [7]. The new function is a significant step in updating the ages of the young basalts because all of their ages are within this range [2]. Therefore, we counted the impact craters within the young mare region using an automatic method via active machine learning [8]. Model ages of 30 mare units subdivided based on multisource data were then obtained on the basis of the new chronology function (Fig. 2). Finally, the relationship between their composition and ages were analyzed.

Results and Discussion: We found that the CE-3/CE-5 basalts have a broad 1 μm absorption from the in situ spectral data as the same as the previous observations of the young basalts [3-5]. However, CE-3 APXS data and laboratorial investigation of CE-5 samples indicate that olivine is not abundant (<10%) in CE-3/CE-5 basalts. The misinterpretation of high olivine abundance in previous studies [3-5] may be due to the special composition of pyroxene, with half of Fe^{2+} siting at the M1 site of pyroxene. In addition, according to the obtained mineral abundance maps of young basalts (Fig. 1), we found the mineralogy of young basalts are not homogeneous; U3 and U22 are two most distinctive regions with highest and lowest olivine abundance respectively.

Based on the new model ages of young basalts obtained, we found that the unit on which CE-5 landed (U2) has an age of ~1.95 Ga, consistent with the isotopic ages of the samples. The youngest unit among all young basalts is located to the northeast of Kepler crater, with an age of ~1.19 Ga (U17). Mare basalts with ages of ~2.0 Ga are widespread in the center of the PKT including U2 where CE-5 landed, indicating mare volcanism is still active at ~2.0 Ga in the PKT and an additional heat source or mechanism may be needed at that time. When considering the composition and ages of the young basalts together, the younger basalts tend to have higher abundance of TiO_2, but no clear trend of olivine.

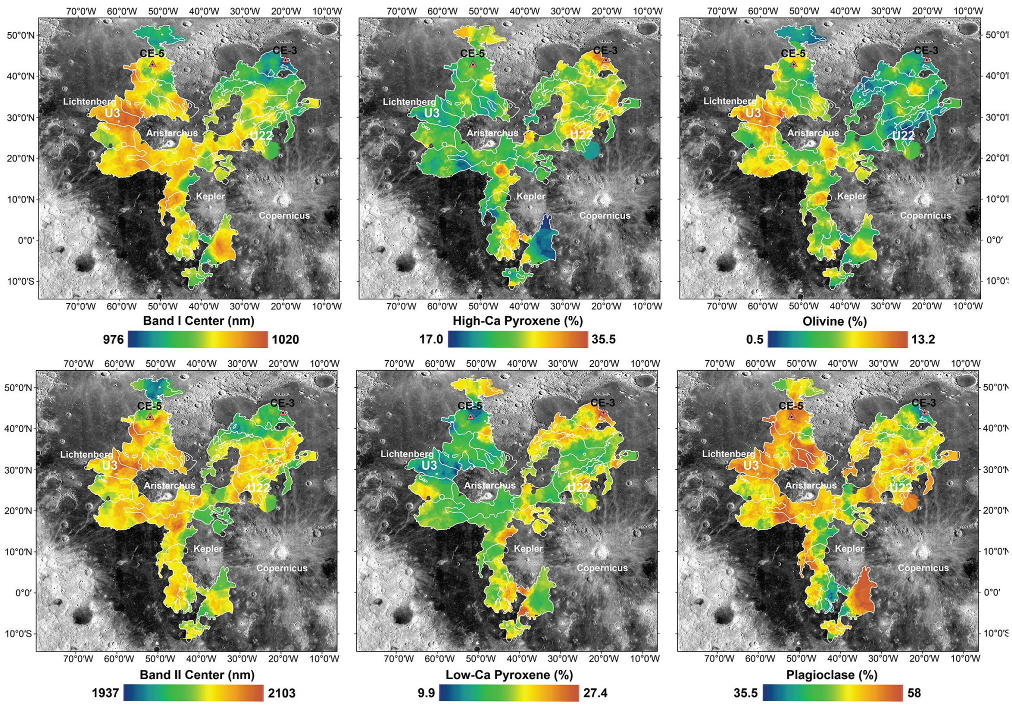

Fig. 1 Mineralogy of young mare basalts in the Procellarum KREEP Terrane based on Moon Mineralogy Mapper spectra of small fresh craters.

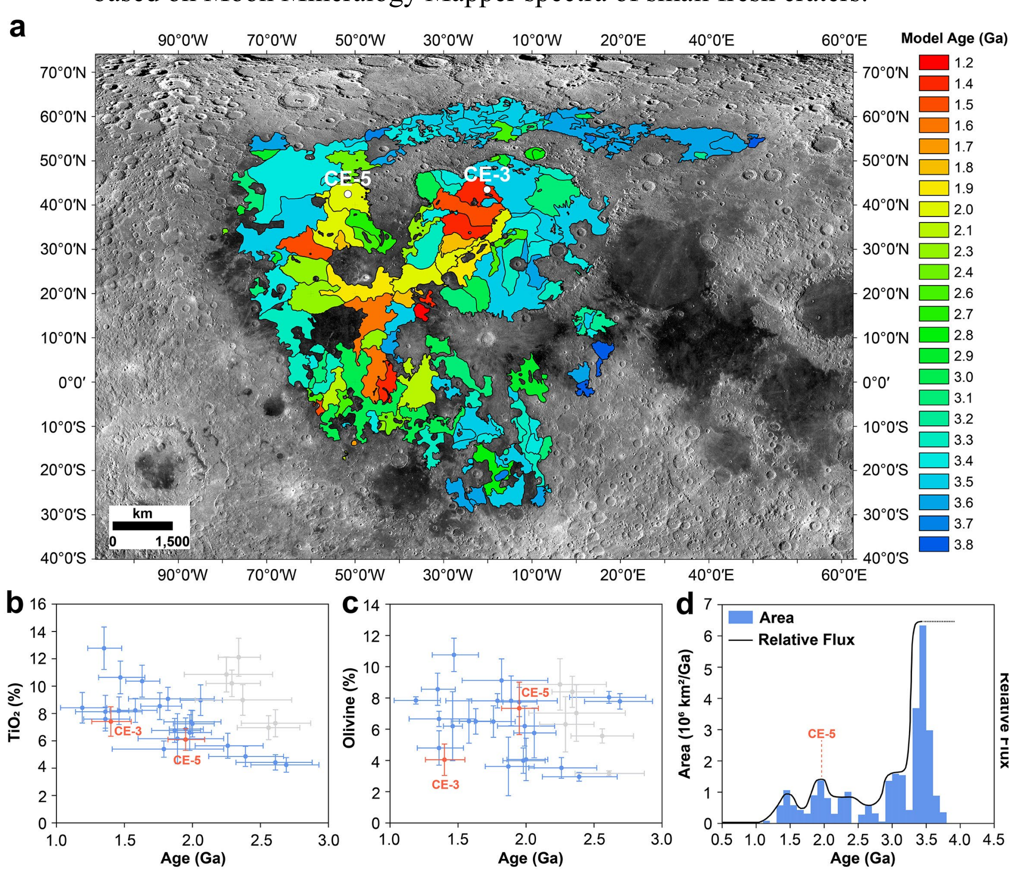

Fig. 2 Chronology and evolution of young mare basalts in the Procellarum KREEP Terrane.

Future Exploration: Two distinct young mare regions were identified within the PKT, i.e., U3 and U17, with highest olivine abundance and youngest age. We propose that they should be listed as high priority sample-return targets for future missions to understand late lunar thermal history.

References:

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