MINERALOGICAL VARIATION AND ANALYSIS OVER WESTERN OCEANUS PROCELLARUM INVESTIGATED USING MOON MINERALOGY MAPPER (M^3) DATA. C. Wang[1,2], R. H. Shi[1,2] , W. Gao[1,2] and Y. Z. Wu[3]. [1]School of Geographic sciences, East China Normal University, Shanghai 200241, China (wangchaoecnu@gmail.com), [2]Branch of Data Application System, Center of Space Exploration, Ministry of Education, East China Normal University, Shanghai 200241, China, [3]School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210093, China.

Introduction: Oceanus Procellarum is the largest mare on the Moon. It encompasses the most widespread continuous deposits of mare basalts. Its origin and evolution are poorly constrained since its complex. Lunar compositional information can be important clues for understanding of Moon's origin and evolution [1]. Olivine and pyroxene are abundant and easily recognized in the basalts with remote sensing due to their characteristic absorption features around 1000 (BI) and 2000 nm (BII) [2]. In this paper, the mineralogical variations of western Oceanus Procellarum were presented through the analysis of the spectra from Moon Mineralogy Mapper (M^3) data. The relative concertration of olivine and pyroxene were derived and were utilized to explore the possible connections between spectral performances and the ages and basalt types of the studied basaltic units.

Data and methods: The hyperspectral instrument M^3 onboard Chandrayaan-1 images the Moon with a spectral coverage from ~430 to 3000 nm, which is very useful for mapping the lunar materials. The M^3 data between different optical periods were obtained under different imaging conditions. To avoid possible errors caused by the optical periods, only the OP1B data were used in this study.

The study area (Fig. 1) was separated into eleven units using the Integrated Band Depth (IBD) and albedo information. To reduce the disturbulences from space weathering and possible noise, the spectra from fresh caters with diameter smaller than 1000 m were extracted.

Several spectral parameters, band absorption centers in BI and BII, band absorption width in BI and the band absorption area ratio (BAR, BII area/BI area), were calculated for each spectra. All the spectral parameters were derived after removing the continuum associate with each spectra. For the purpose of removing the continuum, firstly, a continuum composed of two-part straight line across BI and BII was defined. For the first-part continuum of BI, the two tangency points were obtained using convex hull method. And for the second-part continuum of BII, the first tangency point was also obtained by convex hull method. The second tangency point was fixed at 2497 nm due to the thermal problem in M^3 data. After the continuum determined, the continuum removed spectra was calculated through diving the reflectrance spectra by the continuum.

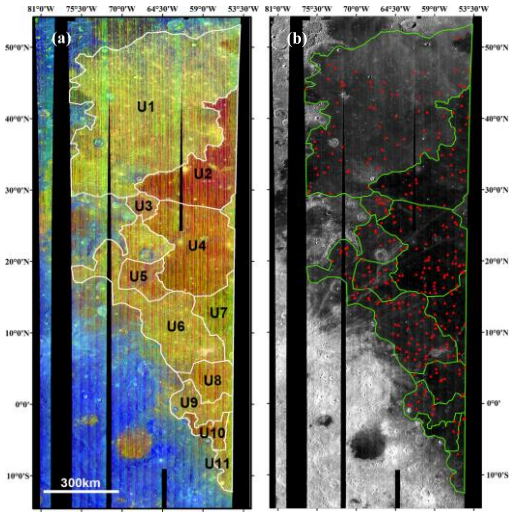

Fig. 1. IBD color composite (left; assigned red for 1 μm IBD, green for 2 μm IBD, blue for reflectance at 1578 nm) and albedo (right, M^3 1578 nm) images of the study area. The selected fresh craters were marked as the red solid triangles.

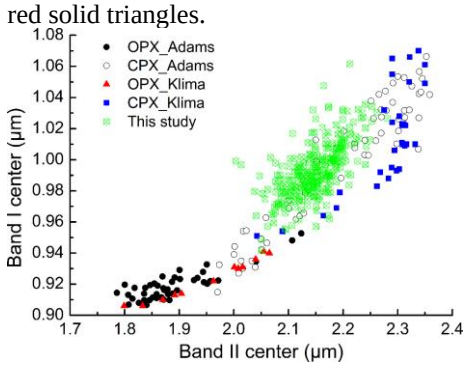

Fig. 2. Band I and II centers of the fresh craters compared with natural pyroxenes measured by [2, 6] and synthetic pyroxene from [7].

Spectral units: The boundaries of the eleven units were shown in Fig. 1 (left pannel) as white outlines. In the IBD color composite, the units with strong BI and relatively weak BII absorption appear red. The units with both strong BI and BII absorption yield green and the highland with weak mafic absorption is blue. U1, U6, U7, U9 and U11 display yellow/green hues and U2, U3, U4, U5, U8 and U10 are relative redder. Among these units, U2 is the reddest and U7 is the

greenest. This phenomenon illustrates the difference of the BI and BII absorption among the eleven units.

Spectra analysis: The paramenters derived from aveaged spectra of each unit were calculated and list in Tab. 1. All the eleven units have a apparent and asymmetrical BI absorption, but the depths of BII varies from unit to unit. U1 has the strongest absorption of BI and BII. U2 has the widest absorption width of BI. The albedo of each unit is highly correlated to the absolute ages from [4]. The absolute model ages of U1, U3, U6 and U9 are approximately ~3.5 Ga. U2, U4, U7 and U11 are younger than U1, U3, U6 and U9, with a difference of ~1.0 Ga. The albedo reduces with decreasing model ages, i.e. the youger the basalt is, the darker the albedo is.

The studied basaltic layers are composed of the materials mixing by olivine and pyroxene. The BI and BII centers of each fresh crater were shown in Fig. 2. The Band I centers of the studied craters mainly concentrated in 0.97~1.02 μm and Band II centers mainly located in 2.05~2.16 μm. This illustrates that the pyroxene in these layers appears low- to moderate-Ca feature. There are also some craters whose BI centers are larger than 1.01 μm and BII centers are larger than 2.20 μm. These plausible "high-Ca pyroxene" features were considered to be induced by olivine rather than pyroxene due to their very small BAR values. Figure 3, plot of BAR versus BI centers, provides the information about the relative abundance of olivine and pyroxene within the layers. Meanwhile, the width of BI varies consistent with the trend of the Ol-Opx mix line described in [5]. This illustrates the olivine-pyroxene mixture of the basalts. Therefore, the BI width could also be a indicator for estimating the relative abundance of olivine and pyroxene.

Summary: In the western Oceanus Procellarun, the olivine and pyroxene dominated layers exist with a obviously spectral features which has a correlation with the ages, basaltic types and mineral relative concentration. The units in this study can de divided into two groups, i.e. pyroxene-rich and olivine-rich layers. U1, U6, U7, U9 and U11 are the first group, these pyroxene-rich layers display yellow/green hues in the IBD map due to their apparent pyroxene absorption features. U2, U3, U4, U5, U8 and U10 are the second group. These olivine-rich layers are redder in IBD map because of their obvious absorption features of olivine. The first group, the basalt type defined as mISP [8], is mostly low- to moderate-Ca pyroxene dominated layers. The basaltic types of the second group are various (Tab. 1). The concentration of olivine of second group is higher than that of the first group. U1, U6 and U9 formed very early (3.0~3.5 Ga), and were not affected by the late stage volcanism. With a contrast, U2, U3, U4 and U5 were produced during the late stage lunar volcanism. For mostly units in this study, the pyroxene dominated layers are brighter than the layers which are dominated by olivine. While U3 and U7 are the exceptions. U3 is much more complex than other units in the second group. It is a olivine-rich layer, which is similar to other units in the second group. But it is as bright as U6 (the first group). And its age was reported older than ~3.0 Ga. This age is close to the ages of the first group. U7 is spatialy contiguous to U4. Its albedo is similar to U4, which might suggest that their ages are very close. But the spectral feature of U7 is very different from U4. Many spectra in U7 show high pyroxene concentration and much difference to U4.

References: [1] Cintala M. J. and Grieve R. A. (1998) *Meteoritics & Planet. Sci., 33*, 889-912. [2] Adams J. B. (1974) *JGR, 79*, 4829-4836. [3] Staid M. I. et al. (2011) *JGR, 116*, E00G10. [4] Hiesinger H. et al. (2003) *JGR, 108*, 5065. [5] Gaffey M. J. et al. (1993) *Icarus, 106*, 573-602. [6] Cloutis E. A. and Gaffey M. J., (1991) *JGR, 96*, 22809–22826. [7] Klima R. L. et al. (2011) *JGR, 116*, E00G06. [8] Pieters C. M. (1978), *LPSC IX*, 2825-2849.

Tab. 1. Statistic of the mean spectra of the 11 units

	BI depth (%)	BII depth (%)	BI width (nm)	Albedo	Basalt type[8]	Group No.
U1	31.4	15.4	558.94	0.104	mISP	1
U2	22.8	7.1	668.72	0.085	HDSA /hDSA	2
U3	26.8	8.1	648.76	0.096	mISA	2
U4	25.6	8.6	648.76	0.084	HDSA /hDSA	2
U5	29.1	12.1	608.84	0.092	mISA	2
U6	30.8	14.5	558.94	0.098	mISP	1
U7	25.9	13.0	538.98	0.080	-DSP	1
U8	28.2	12.6	588.88	0.085	mDSP	2
U9	29.2	12.4	558.94	0.095	mISP	1
U10	28.1	11.9	558.94	0.086	mDSP	2
U11	28.7	14.8	538.98	0.079	mISP	1

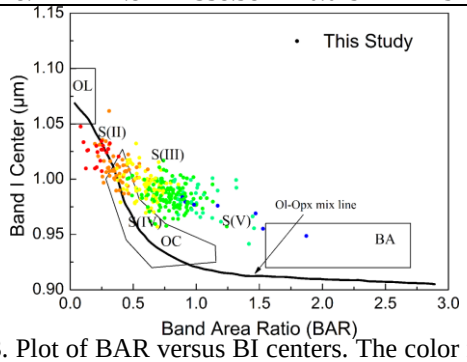

Fig. 3. Plot of BAR versus BI centers. The color represents the absorption width in BI. Three polygons representing different minerals from [5] are also drawn on this plot.