GEOLOGIC DISCOVERIES IN MARIA BASALTIC FLOW AS REVEALED BY CE-2'S MICROWAVE OBSERVATION. Y. C. Zheng[1,2], Y.C. Zhu[1], K. T, Tsang[2] and K. L. Chan[2], [1]A20, Datun Rd. Chaoyang, Beijing, National Astronomical Observatories, CAS, China (zyc@nao.cas.cn and mayczheng@ust.hk); [2]Dept. Math., The Hong Kong Universty of Science and Technology, Hong Kong (k2tsang@gmail.com and maklchan@ust.hk).

Introduction: The eruption periods, the path and composition characteristics of magma flow filling the maria basin are important topic about the geologic evolution of the moon. Here we show the new geologic discoveries about maria basaltic flow as revealed from China's CE-2's four channels microwave observation of the Moon.

Instrument and Data: CE-2, launched in 1st, Oct, 2010, is the second lunar mission in China, marked as the beginning of soft-landing stage of China's Lunar Exploration Program [1]. Microwave radiometer (MRM) is the common instruments on board CE-1 and -2. It made the orbital passive microwave remote sensing of the complete Moon from the circular lunar orbit. The science goal of CE-2's MRM is to measure the brightness temperature (TB) of the lunar surface, from which to retrieve the physical properties of the lunar regolith layer. The instrument is composed by four channels receivers, which worked at 3.0, 7.8, 19.35, 37.0GHz, respectively. Every channel contained the branch of calibration, including cold space antenna and hot matching load, and the branch of observation. Two point calibrating method, observation of cold space as low end and measurement of hot load as high end, was applied to derive TB data of the lunar surface [2].

Compared with CE-1's observation [3], CE-2's MRM have made significant improvement: (1) Benefited from the lower orbital altitude of CE-2 (about 100km), the spatial resolution of CE-2's TB data sets has been improved by a factor of four. (2) Mounting direction of the calibration antenna for the 3GHz channel was installed with a 15° deviation from X axis to Z axis. As a result, the quality of calibration of low temperature end would be improved. (3) CE-2's MRM instrument measured TB of the moon in the complete lunation.

Methods and Results: CE-1's MRM measured TB during lunar hour angle [3], h=-0.86~0.67 (8:43 ~ 14:34 in 24 hours) in the day, h=2.28~-2.48 (20:42 ~ 2:32) in the night. Therefore, CE-2's TB data is much more useful for us to study the heating and cooling of lunar surface in a lunation period.

Brightness temperature model. TB of the Moon is decreased from the equator to the poles and sinusoidal variation in a lunation. We constructed the 4th order spherical harmonics model (TB_{model}, Fig. 1) fitted by CE-2's TB data in the region with -60°< latitude < 60°. These models are significant to remove the latitude and diurnal effect in TB measurements (Fig.2). It is helpful to find much detail geologic characteristic in the microwave observation of the moon.

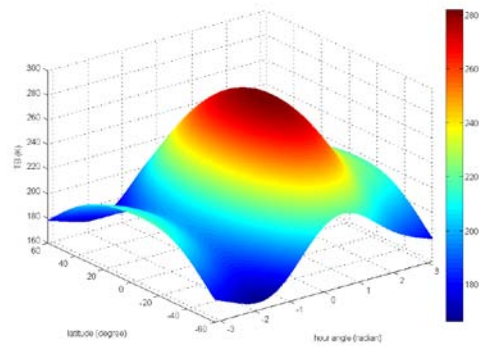

Fig.1. 4th order spherical harmonics model (TB_{model}) fitted by CE-2's 37GHz TB data in the region with -60°< latitude < 60°.

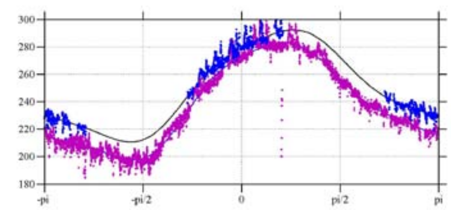

Fig.2. TB variation in a lunation period for 37GHz TB data at latitude belts 0±0.1°. Red points are CE-2's TB data and blue points are CE-1's TB data. x axis is hour angle and 0 means lunar noon.

Microwave map of the moon at lunar noon and midnight. With application of TB_{model}, all TB data measured in CE-2's life span could be normalized into a certain local moment. We constructed the daytime and nighttime microwave maps for the four frequency channels with $\tau = (TB-TB_{model})/TB_{model}$) (Fig. 3). The warmer areas were shown in brighter and the colder areas were shown in darker.

From a global point of view, the maria are much warmer than highlands during lunar daytime in microwave observation. The hottest area are located in a craw crap region composed by the eastern and southern parts of Oceanus Procellarum and the western part of Mare Imbrium, in addition to all of Mare Tranquillitatis and parts of Mare Foecunditatis. However, the hottest regions in lunar daytime became into the colder in nighttime. It suggested that the surface material in these maria could be heated quickly after sunrise and be cooled quickly after sunset. Otherwise, the surface materials in other maria are heated slowly in daytime and cooled slowly in nighttime.

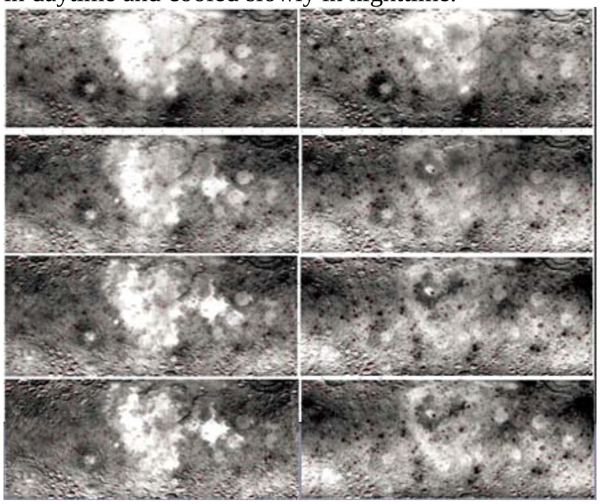

Fig.3. Microwave map of the Moon at noon (left pannels) and midnight (right pannels). From upper to down are τ-map for 3, 7.8, 19.35 and 37GHz observation respectively. $\tau = (TB-TB_{model})/TB_{model}$).

RGB maps of CE-2's microwave observation. In order to distinguish the maria basalts clearly, we constructed the RGB maps of CE-2's microwave observation. Fig. 4 is composed by three color, red, green and blue, where R is $(T4_{day} - T4_{nig})/(T4_{day} + T4_{nig})$, G is $T4_{day}$, and B is $T4_{nig}$. $T4_{day}$ and $T4_{nig}$ are the normalized 37GHz daytime and nighttime TB value by using TB model shown in Fig. 1. Three bands value of R, G, B were all normalized into the limitation of 0~1.

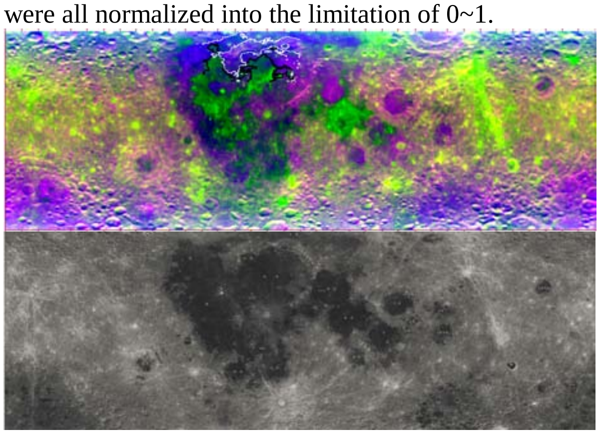

Fig. 4. RGB map of the CE-2's microwave observation (upper) and CE-2's visible image (down).

From Fig. 4, we could observe that the maria basalts have different performance in CE-2's microwave observation. The maria materials could be distinguish into three types: (I) represented in the *crab craw* region and all of Mare Tranquillitatis and parts of Mare Foecunditatis, which are shown in bottle-green. (II) represented in the northern and western parts of Oceanus Procellarum, Mare Frigoris, Mare Humorum and Mare Nubium, which are shown in blue. (III) represented in Mare Serenitatis, Mare Crisium and other maria, which are shown in purple.

Lave flow in Mare Imbrium. From Fig. 5, we could observe that the 37GHz microwave map of the *crab craw* region in Mare Imbrium (bottle-green, Fig. 5F) are consistent with Clementine's false color image (light blue, Fig. 5B), coincided perfectly with TiO_2 content higher than 9 wt.% (red and yellow, Fig. 5C) and FeO (red, Fig. 5D). It suggested that the performance in microwave observation are resulted from the high content of ilmenite. The ilmenite has higher loss tangent than other minerals, i.e. pyroxene, olivine, feldspar in basalt. The high lossy materials lead to shallow penetration depth of microwave radiation. The TB in these region are controlled by the surface properties.

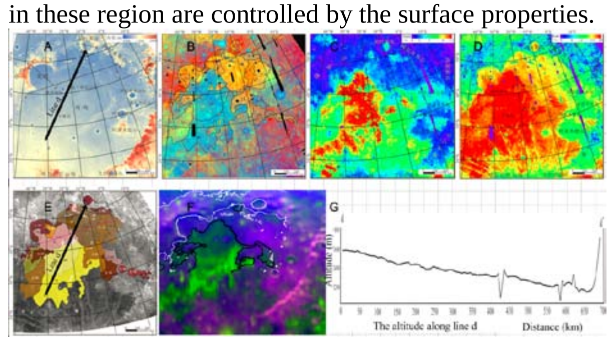

Fig. 5. The lava flow in Mare Imbrium. A. CE-1's topography data; B. Clementine's false color image; C and D. TiO_2 and FeO abundance; E. Geologic ages; F. 37GHz RGB image. G. Altitude.

Along the line d in Fig. 5A and 5E, the altitude is decreased from the southwestern to northwestern (Fig. 5G). It shows a clear path of high titanium basalt magma flowing from the southwestern to northwestern in Mare Imbrium. The source of lava flow might be located in the high altitude region near crater Aristarchus and crater Copernicus. It flew northwest-ward into the northern part of Oceanus Procellarum, flew southward into the southern part of Oceanus Procellarum, and flew northeast-ward into the Mare Imbrium.

Combined with the geologic age calculated from crater density (Fig. 5E), we could find that the high-Ti basaltic magma were erupted into Mare Imbrium younger than 26.5 Ga and lasted to 19.1Ga (yellow, Fig. 5E) in Eratosthenian period. Whereas the other basaltic magma in Mare Imbrium were filled in older age than 31.9 Ga and lasted to 35 Ga, in later Imbrian period.

References: [1] Zheng, Y. C., Ouyang, Z. Y., Li, C. L., et al. (2008) *PSS, 56,* 881–886. [2] Wang, Z. Z. *et al.* (2010) *Sci. China (D), 53,* 1392–1406. [3] Zheng, Y. C. *et al.* (2012) *Icarus, 219,* 194–210.

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