THE THICKNESS OF LATE STAGE BASALTS IN MARE IMBRIUM. Y. Chen[1] , Y. Z. Wu[1], Z. C. Wang[2] , X. W. Zhang[1], X. Tang[1], X. M. Zhang[1], [1] School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing, 210023, China (chenyuan_chy@qq.com), [2]School of Earth Sciences and Engineering, Nanjing University, Nanjing, 210023, China.

Introduction: The basaltic volcanism is one of the most important geologic process on the Moon. As lunar basalts were formed from the partial melting of mantle materials, the volume of basalts reflects the size and the melting degree of source region. The erupted volume of mare basalts can be determined by combining areal coverage with thickness of basalts [1]. Although the areal extent of lava flows can be easily determined, the evaluating of their thickness is more difficult [2].

Previously, the estimations of thickness were carried out from two approaches: direct detection and indirect inference. Researches obtained the exact thickness of basalts by gravity [3], seismic data [4] and ground probing radar on Apollo 17 [5] and Chinese Chang'E-3(CE-3) [6]. However, the direct detections are limited by spatial coverage. The indirect inferences were based on orbital remote sensing data. De Hon [7] measured plenty of partly buried craters to estimate the thickness of mare. This method, however, can only be used to evaluate lavas after the formation of craters. The spectra of craters which penetrated through mare basalts were used to identify the boundary of mare and highland materials (can also be uppermost and underlying lava flows) in ejecta blanket, then the thickness of basalts was inferred with radial distance [1, 2, 8].

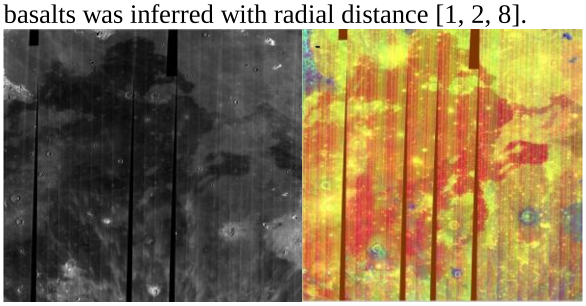

Fig.1 (a) Eratosthenian mare deposits in the Imbrium basin appear dark at 2μm in this M^3 mosaic. **(b)** Eratosthenian flow units within the Imbrium basin appear red in this M^3 color composite, however Imbrian flow units show yellow.

Mare Imbrium, which located in the western nearside mare, is the second largest mare on the Moon. In this study, we mainly used Moon Mineralogical Mapper (M^3) global mode spectral data to constrain the thickness of young lava flows in Mare Imbrium. Previous studies have shown that these lava flows, which are rich in olivine [9], erupted during Eratosthenian age [10].The spectra of Eratosthenian basalts are quite different from those of the underlying pyroxene-rich basalts(Fig. 2). This difference is the basis to discriminate the uppermost and underlying basalts, hence the thickness of Eratothenian basalts could be assessed. Eratosthenian deposits in the Imbrium basin appear dark in M^3 mosaic of 2μm (Fig.1a) and red in the M^3 integrated band depth color composite (IBD) (Fig.1b).

Data: M^3 (~140m/pixel) and Lunar Orbiter Laser Altimeter (LOLA) DEM datasets (~30m/pixel) were used to estimate the thickness of the late stage basalts in Mare Imbrium.

Methods: To estimate the thickness of basalts, M^3 spectra were extracted from small craters to determine whether the craters were penetrated through the young uppermost basalts. "Penetrating" craters excavated underlying basalt, then old low-Ti material was redeposited interior of crater and around the rim [8]. The spectra of old low-Ti basalts display both 1μm and 2μm absorptions, indicating the basalts are rich in pyroxene. On the contrary, young high-Ti basalts show stronger 1μm absorption with a distinct secondary feature around 1.25μm, and very weak 2μm absorption, indicating the basalts are rich in olivine (Fig.2). The thickness of the Eratosthenian lava flows was constrained to the depth between the deepest "non-penetrating" crater and the shallowest "penetrating" crater. In areas where have no or few "non-penetrating" craters, the depth of excavation (Hexc) of "penetrating" craters provides a maximum thickness. The thickness of basalts was constrained by the Hexc of small craters according to the equations of Melosh [11]:

$$H_{exc} \approx 0.084 * D_{rim}.$$

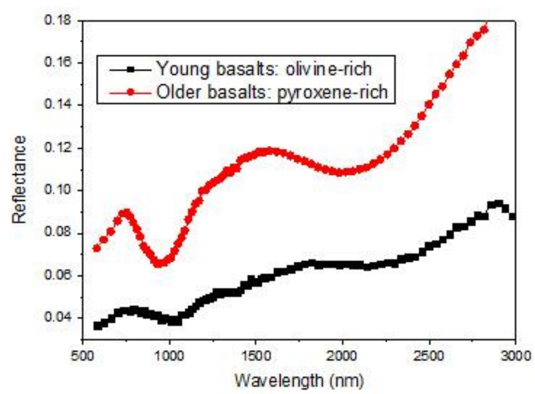

Fig.2 M^3 spectra of Eratosthenian and Imbrian basalts in Mare Imbrium.

Crater diameter (D_{rim}) was measured from four directions (N/S, W/E, NE/WS, NW/WE) on the mosaic of Lunar Reconnaissance Orbiter Wide Angle Camera (LROC WAC) and Narrow Angle Camera (LROC NAC).

Moreover, some very young lava fronts can be clearly seen in the M^3 thermal bands. The traces could be used to confirm the boundary thickness of lava flows. LOLA DEM data was used in ArcGIS to derive elevation curves, hence the height of these lava fronts could be acquired. The height of lava fronts was measured in CorelDraw. During the performance, the elevation curve was overlaid on the local background image, then the variation of height could be determined (Fig.3).

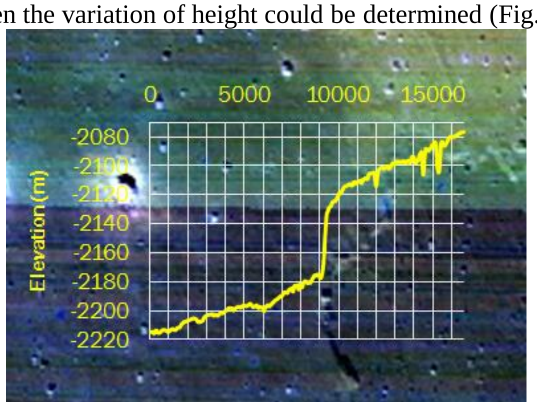

Fig.3 Measurement of height of lava fronts using LOLA DEM data in CorelDraw.

Results: The Eratosthenian deposits in Mare Imbrium have been divided into three phases: phase I (3.0 ± 0.4 Ga.), phase II (2.7 ± 0.3 Ga.) and phase III (2.5 ± 0.3 Ga.) [9]. The young basalts in Mare Imbrium were generally divided into two parts: northern Imbrium and southern Imbrium. The northern young basalts erupted just during phase I, while the southern deposits included all the three stages.

Forty "penetrating" craters and thirty-six "non-penetrating" fresh craters were extracted from the North. Apart from fifty-two "penetrating" craters and ten "non-penetrating" fresh craters, twenty-three lava fronts were picked out from the South. The method of inverse distance weighted was performed in ArcGIS to establish the distribution of basalts thickness. The high resolution raster map of the thickness of the Eratosthenian basalts (Fig.4) was produced by combining the estimated thickness using the crater excavation method and the height of the lava fronts derived from LOLA DEM.

As shown in Fig.4, the estimated thickness of young high-Ti basalts in northern Imbrium varies from ~15.65 m to ~43.72 m. Besides, it also displays the apparent decreasing of the thickness from NE to SW. The average thickness of northern young basalts is ~29.12 m. Flow thickness and areal extent indicate that ~3.26×10^3 km^3 of mare material covering an area of ~1.12×10^5 km^2 was deposited in the northern Imbrium.

The distribution of thickness in southern Eratosthenian basalts is more complex. The estimated thickness appears the maximum in the middle, then it decreases towards north and south separately. Moreover, the thickness, which derived by crater excavation and the height of the lava fronts, ranges from 12.85 m ~38.26 m in the south. The average thickness of southern young basalts is ~22.7 m, which suggests that young basalts in the south are thinner than those in the north. The areal extent of southern lava flows was estimated to be ~2.48×10^5 km^2. Combining with the thickness of flows, about 5.63×10^3 km^3 of basalts were deposited during Eratosthenian age.

Hiesinger et al. reported that the thickness of six flow units in Imbrium are average ~32–50 m (+11/-5 m) using the shape of crater size-frequency distribution (CSFD) curves [12]. While our work indicate a thickness of 15.65 m ~ 43.72 m in the north, 12.85 m ~38.26 m in the south, which is thinner than Hiesinger's estimation.

Summary: This study produced the high resolution map of the thickness of young high Ti basalts in Mare Imbrium using M^3 combined LOLA DEM data.The thickness of Eratosthenian basalts are thinner than which found in previous results. Future work should include more details of the division of basaltic units in the southern Imbrium, and the evaluating volume of each unit.

Reference: [1] Budney C. J. and Lucey P. G. (1998) *JGR, 103*: 16855–16870. [2] Kubo N. et al. (2010) *LPSC XLI*, abstract 1915. [3] Cooper M. R. and Kovach R. L. (1974) *RG, 12*: 291–308. [4] Maxwell T. A. and Phillips R. J. (1978) *GRL, 5*: 811-814. [5] Porcello, L. J. et al. (1974), *IEEE Proceedings, 62*: 769–783. [6] Yan S. et al. (2014) *RAA, 14*: 1623–1632. [7] De Hon R. A. (1977) *PLPSC X*, 2935–2955. [8] Weider S. Z. et al. (2010) *Icarus, 209*: 323–336. [9] Wu Y. Z. et al. (2015) *LPSC XLVI*, this abstract. [10] Schaber G. G. (1973) *LPSC IV*: 73–92. [11] Melosh H. J. (1989) *Impact Cratering, A Geologic Process.* 245 pp. [12] Hiesinger H. et al. (2002) *GRL, 29(8)*: 89-1–89-4.

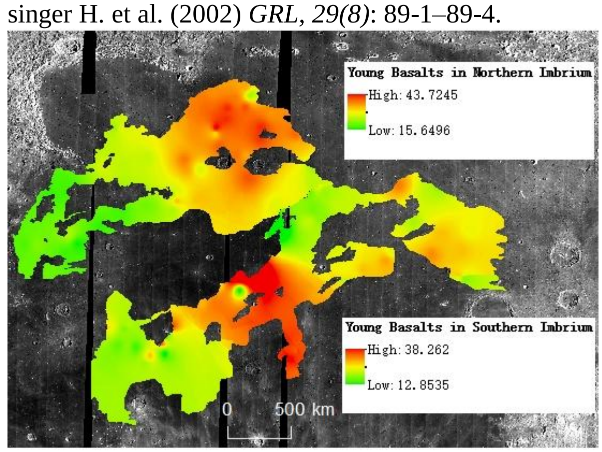

Fig.4 Raster map of estimated thickness (m) of young Ti-rich basalts in Mare Imbrium.