LAYERING AND THICKNESS OF BASALTIC LAVA FLOWS IN MARE HUMORUM: NEW SPECTRAL ANALYSIS OF MULTIBAND IMAGER DATA OF KAGUYA (SELENE). N. Kubo[1], N. Namiki[2], M. Ohtake[3], A. Yamaji[4], J. Haruyama[3], T. Matsunaga[5], [1]Univ. Kyushu (6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan, sp00888769@gmail.com), [2]PERC/Chitech, [3]ISAS/JAXA, [4]Univ. Kyoto, [5]NEIS.

Introduction: Areal distributions of mare basalts of the Moon have been well known. They appear mostly on near side and cover with 17 % of the lunar surface. In contrast, basalt thickness has been poorly constrained despite that the thickness is crucial on estimating size and nature of magma source [1], tectonics of lithosphere, and structures beneath mascon basin [2]. Further, if thickness of each lava flow in layered mare basalt is determined, volcanic history of maria will be strongly constrained [e.g., 3, 4].

Previously basalt thickness has been estimated by using two different methods. De Hon [5] estimates the thickness using craters that were partly buried by lava flows, and proposed a map of basaltic lava flows first time. In his work, two assumptions are made. First, depth of crater follows simple scaling law. Second, craters are older than eruption of basalts. Otherwise the thickness is likely overestimated by this technique [6]. On the other hand, Budney and Lucey [7] proposed a new map from spectral analysis of Clementine UVVIS data. A sufficiently large impact excavates highland materials that are covered by mare basalts. They identify boundary between highland material and mare basalt in ejecta blanket. By measuring radial distance of this boundary and taking an experimentally determined of mixing ratio of target materials ejected from different depths with radial distance, mare thickness are estimated [7]. Their new map reveals that thicknesses of lava flows are thinner by a factor of 2 than that of [5]. New estimates by [7] are likely influenced by low resolution of spectral images (a few hundred meters per pixel), a small number of spectral band (five), and most significantly an identification of boundaries between highland material and mare basalt that are usually obscured by local mixing of ejecta.

In this study, we use spectral images taken by Multiband Imager (MI) onboard Kaguya to constrain mare basalt thickness independently. MI covers a spectral range from 415 to 1550 nm with 8 bands in VIS and NIR, and has a spacial resolution of 20 m/pix in VIS, 62 m/pix in NIR bands [8]. We note that, as for the number of spectral bands, MI never matches Moon Mineralogy Mapper (M^3) on Chandrayaan-1 that has 261 bands in a wide range of wavelength (430 to 3000 nm), however, the spacial resolution of MI is higher than M^3 (70 to 140 m/pix). Further, MI provides not only spectral images but also topographic model obtained from stereoscopic views of images in different bands. Taking these advantages, we examine crater interiors aiming to identify thickness of basaltic lava flows directly. For a comparison of our results with previous estimates [5, 7], we study Mare Humorum (24.4 ° S, 38.6 ° W, 425 km in diameter).

Methods: In order to distinguish mare basalt and highland material in the interior of crater, we carry out two independent analyses, that is, a decomposition of end-members [e.g., 7] and a caluculation of FeO content [9]. At first, we determine three spectra of end-members, fresh highland, fresh mare, and mature mare, respectively, following [7]. In order to reduce an effect of space weathering, previous study normalizes spectrums relative to 750 nm [7]. Instead, we draw continuum taking 750 and 1550 nm reflectance, and calculate absorption depths of five band (900, 950, 1000, 1050, and 1250) from the continuum [e.g., 10]. Reflectance at 415 nm corresponds to the absorption of ilmenite which is of little use for this study, so this band is not included in this analysis. We then compute relative abundances of three end-member components for each pixel in the same manner as least square fitting. Second, we calculate FeO content following [9]. Because highland material has lesser FeO content than mare material, we can distinguish highland material from surrounding mare basalt by using FeO map subsidiary. When highland materials are identified in the interior of crater, an elevation of the boundary between underlying highland material layer and overlying mare basalt layer is measured with respect to rim altitude by using topographic model. We apply this technique to 31 fresh craters in a list of 44 craters given by [7] to estimate thickness of lava flows. The rest 13 craters are not taken into account because of degradation of crater walls.

In order to distinguish multi-layers of basaltic lava flows in the wall of craters, we use a scatter map of absorption depths. Especially, absorption depth of plagioclase at 1250 nm turns out of to be useful in identifying layers of different types of basalts. Based on maps of lava flow units proposed by [11], we determine spectra of end-members of different surface units in [11] by taking small fresh craters which are less than 1 km in diameter. Next, we compare these spectra with that of upper layer on crater walls to confirm this layer to be the same as lava flow in the surroundings. Then, by using topographic model, we can examine thickness of upper layer. We find three craters which have layering structure, that is, Liebig FA (Tab. 1-8), Gassendi J1

(20.4 ° S, 35.5 ° W, 2.5 km in diameter), and Gassendi J2 (20.1 ° S, 35.4 ° W, 2.1 km in diameter).

Results: According to [7], 15 craters are suggested to have penetrated mare basalt at the surface. In Table 1, our estimates of lava flow thickness of 11 craters are listed, and for a comparison, estimates by [7] are shown, too. Four craters are eliminated because either crater's walls have degraded or the crater locates outside of the mare. We find that thicknesses of 7 craters are from 1 to 1.5 times greater than the estimates of [7]. On the other hand, highland materials are not identified in Liebig FA and Gassendi L (Tab. 1-9). Neither we can estimate basalt thickness of Doppelmayer T (Tab. 1-10) and Gassendi O (Tab. 1-11), because ejecta of highland materials are concentrated in quadrant of ejecta blanket. It is possible that these carters formed over irregularly shallow peaks of basin floor such as local mounds and basin inner rings.

Our estimates are limited in periphery of the Mare Humorum. In the periphery, the mare basalt is thin, therefore craters of 5 to 10 km in diameter are able to penetrate mare basalts at the surface. In contrast, lava thickness at the center of Humorum is unbounded by our technique. This is because craters in the Humorum basin are not large enough to penetrate lava flows at the center of Humorum. Our estimates of basalt thicknesses for 7 craters are greater than estimates by [7], but are consistent with [5]. A discrepancy between our results and those of [7] could be attributed to an identification of boundary in ejecta blanket between highland materials and mare basalts. For example, Hippalus A (Tab. 1-1) is proposed by [7] that the boundary exists at 3 radii from the crater rim, while our end-member analysis suggests the boundary at 1 radius. This difference results from whether reflectance or absorption depth is adopted for decomposition of end-members. Because absorption depth is less affected by space weathering than reflectance, our estimates are likely plausible. It is also possible that we overestimate basalt thickness because we ignore vertical extensions of layers by impact.

Liebig FA appears to have two layers in crater interior at single band (Fig. 1-a). Liebig FA lies on H5 unit [11], and spectra of upper layer agree with end-member of this unit. On the other hand, spectra of lower layer correspond to H7 unit (Fig. 2) is older than H5 as indicated by [11]. We thus estimate thickness of H5 unit at this location to be from 380 to 420 m. Gassendi J1 and J2 lie close each other, and also show two layers in crater interior. These craters lie on H8 unit [11] which is proposed to be a flow from Oceanus Procellarum and is younger than other flows on Humorum. Taking estimated thickness of upper layers, we conclude that thickness of H8 unit is from 120 to 250 m.

References: [1] Hiesinger H. and Head J.W. (2006) in New Views of the Moon, 721 pp. [2] Namiki N. *et al.* (2009) Science, 323, 900-905. [3] Hiesinger H. *et al.* (2002) GRL, doi:10.1029/2002GL014847. [4] Morota T. *et al.* (2009) GRL, doi:10.1029/2009GL040472. [5] De Hon R.A. (1977) PLPSC, 8, 633-641. [6] Horz F. (1978) PLPSC, 9, 3311-3331. [7] Budney C.J. and Lucey P.G. (1998) JGR, 103, 16855-16870. [8] Ohtake M. *et al.* (2008) EPS, 257-264. [9] Lucey P.G. *et al.* (1998) JGR, 103, 3679-3699. [10] Ohtake et al. (2009) Nature, 461, 236-240. [11] Hieginger H. (2000) JGR, 105, 29239 – 29275

Table 1. Estimates of basalt thickness in Mare Humorum.

Crater Name Diameter (km)	Lat. (° S) Long.(° W)	**Baslt Thickess**	
		[7]	This work
1 Hippalus A 7.6	23.77 32.77	200-400	500
2 Gassendi OA 4.5	21.20 34.35	150-250	300
3 Kelvin D 6.0	27.92 34.30	0-100	0-60
4 Liebig F 8.7	24.65 45.67	0-50	170-250
5 Vietello E 7.0	29.13 35.67	100-300	220
6 Doppelmayer S 4.4	28.12 43.60	150-250	240
7 Doppelmayer S1 4.2	27.82 44.75	50-150	160
8 Liebig FA 3.6	24.80 44.95	250-350	>380
9 Gassendi L 4.4	20.37 41.63	350-550	>590
10 Doppelmayer T 3.0	25.97 43.20	150-50	NA
11 Gassendi O 10.8	21.92 35.00	300-700	NA

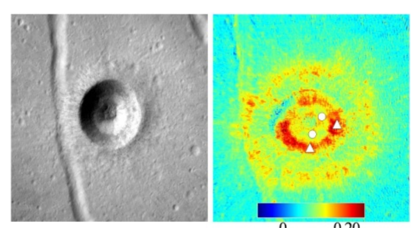

Figure 1. Liebig FA. (a) 1000nm image.
(b) Absorption depth at 1250 nm.

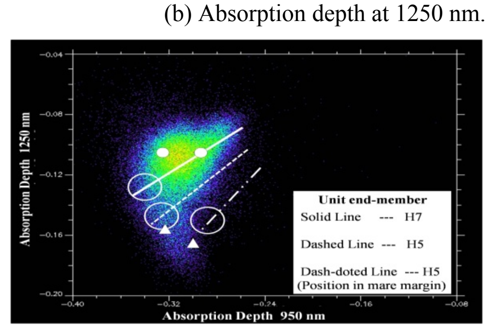

Figure 2. Scatter of absortion depth in Liebig FA interior.