MARE VOLCANISM ON THE FARSIDE AND IN THE ORIENTALE REGION OF THE MOON. T. Morota[1], J. Haruyama[1], M. Ohtake[1], T. Matsunaga[2], Y. Yokota[1], C. Honda[3], T. Sugihara[4], J. Kimura[5], Y. Ishihara[6], T. Kawamura[1], A. Iwasaki[7], K. Saiki[8], and H. Takeda[9], [1]Institute of Space & Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara 229-8510, JAPAN (morota@planeta.sci.isas.jaxa.jp), [2]NIES, [3]Univ. Aizu, [4]JAMSTEC, [5]Hokkaido Univ., [6]NAOJ, [7]Univ. Tokyo, [8]Osaka Univ., [9]Chiba Inst. Tech.

Introduction: Dating of lunar mare basalts is necessary for understanding the volcanic history of the Moon. A considerable number of nearside maria have been dated by using image data from Lunar Orbiters and Apollo missions [e.g., 1–6]. These studies revealed that the largest number of mare basalts formed in the Late Imbrian Epoch at 3.2 to 3.8 Ga, and that mare volcanism lasted until the Eratosthenian Period [1] or even until the Copernican Period [2, 4], suggesting that the total duration of volcanism was 1.5 to 3.0 Ga.

Prior to the SELENE (Kaguya) mission, accurate age determinations of most maria on the farside had not been performed because of the lack of high-resolution images. Therefore, a systematic, high-resolution mapping of the entire lunar surface, particularly the farside, is a primary objective of the SELENE mission. The SELENE Terrain Camera (TC) has obtained high-resolution (10 m/pixel) images of most areas of the lunar farside at solar elevation angles lower than 10˚. Using the images, Haruyama et al. [7] carried out crater counts in farside mare deposits within the South Pole-Aitken (SPA) basin and Mare Moscoviense, and found that mare volcanism on the lunar farside lasted ~2.5 Ga, longer than was previously considered.

Here we performed new crater counts in mare deposits on the farside, which had been previously undated, and in the Orientale region, using new images obtained by TC. The mare deposits include Mare Orientale (19˚S, 93˚W), Lacus Veris (17˚S, 86˚W), Lacus Autumni (10˚S, 84˚W), Lacus Luxuriae (19˚N, 176˚E), and mare deposits in Buys-Ballot (21˚N, 175˚E), Campbell (45˚N, 152˚E), Kohlschütter (15˚N, 154˚E), and Tsiolkovsky (21˚S, 129˚E). Based on our new crater counts, we will discuss how long mare volcanism was active on the farside and in the Orientale region. We will also discuss whether a difference existed in the durations of mare volcanisms within the SPA basin and in the central region of the northern farside, i.e., the so-called Feldspathic Highland Terrane (FHT) [8], which corresponds to the highest parts of the topography and the thickest parts of the lunar crust.

Technique of Age Determination: Crater counting is a well-established technique for deriving the relative and absolute ages of planetary surfaces [e.g., 3, 4, 6, 9–11]. Based on the simple idea that older surfaces accumulate more craters, we can infer the relative and absolute ages by measuring the crater size-frequency distribution (CSFD) with image data.

We used the production function polynomial and the cratering chronology model proposed by Neukum and Ivanov [9] to obtain the absolute model age from the CSFD measurement. We also adopt their chronostratigraphic system [9], with the Nectaris basin being 4.1 Gyr old, and the Imbrium basin being 3.91 Gyr old. The Eratosthenian system started 3.2 Gyr ago, and the Copernican system began 1.5 Gyr ago.

Results and Discussion: Table 1 lists model ages of the mare deposits investigated in our study. The model ages range from 3.75 to 2.1 Gyr (i.e., from the Late Imbrian Epoch to the Eratosthenian Period). The oldest basalt was found in Lacus Luxuriae and Lacus Veris as layers buried by later flows, and in the southwestern part of Mare Orientale. The youngest basalt occurs in the southeastern part of Mare Orientale.

Duration of Mare Volcanism. Figure 1A presents the frequency distribution of model ages for all investigated mare deposits in the Orientale region and on the farside. This suggests that most lava flows in these regions formed in the Late Imbrian Epoch at 3.2 to 3.8 Ga, indicating good agreement with radiometric ages for basaltic rocks returned from the nearside and model ages for nearside lava flows determined with crater counts [1–6]. However, some deposits indicate younger model ages. Thus, we conclude that mare volcanism in these regions continued until ~2.0 Gyr ago. The onset of mare volcanism on the farside and in the Orientale region is not well understood, even though our results indicate that mare volcanism began at least as early as 3.9 Gyr ago, for a total duration of ~1.9 Gyr.

Comparison of the SPA and the FHT. Figures 1B and 1C present histograms of model ages for mare deposits in the FHT and in the SPA [7], respectively. We found that the shape of the frequency distribution of mare basalts in the FHT is very similar to that in the SPA basin; the histograms have a peak at ~3.5 Gyr, and expand to ~2.5 Gyr. However, it must be noted that some cryptomaria exist within the SPA basin [12], implying that mare volcanism in the SPA basin may have started prior to that in the FHT, though the volumes of the cryptomare deposits are not so large.

The effects of large impacts on the thermal evolution of the mantle have been proposed as one mechanism of forming lunar basalts [e.g., 13–15]. A recent version of the mechanism, related to the mantle convection triggered by impact-induced thermal perturbations [15], requires that the SPA basin formation impact generates a substantial amount of melting in the mantle, which does not seem to be compatible with the minor amount of mare and cryptomare deposits filling this basin. Furthermore, the impact-induced convection model requires a long duration of mare volcanism for the SPA basin [15]. This is also incompatible with our result, which indicates no difference in the timing and the duration of mare volcanism inside and outside the SPA basin. Thus, it is probable that the SPA basin formation impact had a minor effect on the formation of mare basalts in the region.

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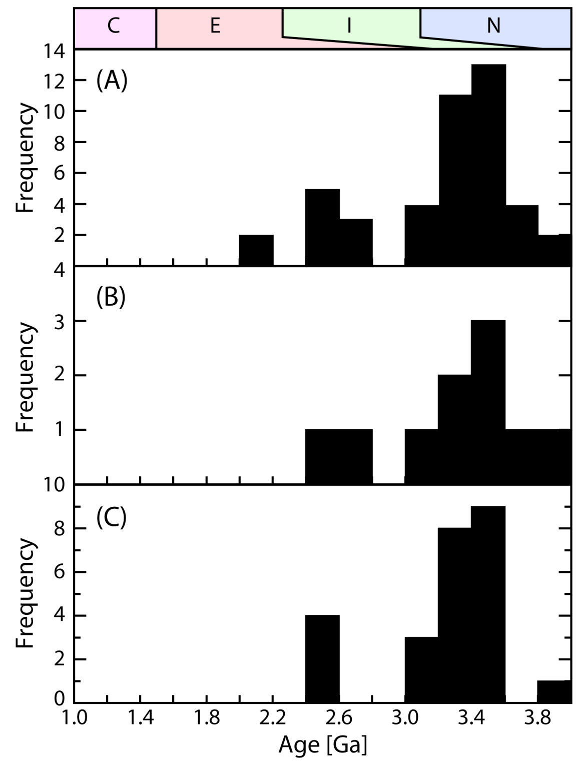

Fig. 1. Histogram of the model ages of mare deposits (A) on the farside and in the Orientale region, (B) in the FHT, including those in Mare Moscoviense [7, 20], Lacus Luxuriae, Buys-Ballot, Campbell, and Kohlschütter, and (C) in the SPAT [7]. C – the Copernican System. E – the Eratosthenian System. I – the Imbrian System. N – the Nectarian System.

Table 1. Model ages of the mare deposits on the farside and in the Orientale region.

Mare Deposit		Model Age [Ga]	Corrected Model Age[a] [Ga]	Other Studies[b] [2]	[16]	[17]	[18]
Lacus Luxuriae	N	3.28 (+0.06/-0.08)	3.29 (+0.06/-0.08)		Im		
		3.68 (+0.07/-0.12)	3.68 (+0.07/-0.12)				
	S	3.46 (+0.03/-0.04)	3.46 (+0.03/-0.04)		Im		
		3.67 (+0.06/-0.10)	3.67 (+0.06/-0.10)				
Buys-Ballot		3.22 (+0.10/-0.18)	3.23 (+0.10/-0.18)		Im		
Campbell		2.72 (+0.24/-0.29)	2.84 (+0.21/-0.30)	Im	Im		
Kohlschütter		3.03 (+0.24/-0.56)	3.13 (+0.19/-0.52)		Im		
Tsiolkovsky	S	2.71 (+0.31/-0.41)	2.95 (+0.23/-0.42)	Im			
Mare Orientale	SE	2.73 (+0.24/-0.28)	2.44 (+0.24/-0.26)	Im		≤3.45	3.45 (+0.05/-0.12)
	SW	3.75 (+0.03/-0.04)	3.73 (+0.03/-0.03)	Im			
Lacus Veris	N	2.70 (+0.24/-0.27)	2.40 (+0.24/-0.25)	Im		~3.45	3.50 (+0.05/-0.08)
		3.32 (+0.10/-0.26)	3.21 (+0.14/-0.42)				
	S	2.14 (+0.42/-0.47)	1.90 (+0.37/-0.42)	Im		2.29 (+0.51/-0.55) ?	3.50 (+0.05/-0.08)
		3.75 (+0.08/-0.20)	3.73 (+0.08/-0.22)				
Lacus Autumni		2.08 (+0.53/-0.54)	1.84 (+0.48/-0.48)	Im		2.85 (+0.28/-0.57)	2.85 (+0.37/-0.67)

[a] Model age corrected for the apex-antapex cratering asymmetry using an equation of Galant et al. [19].
[b] Im – Imbrian mare material.