THE RELATIONSHIP BETWEEN THE ABUNDANCE OF RADIOACTIVE ELEMENTS AND ERUPTION AGES OF LUNAR MARE BASALTS IN THE PROCELLARUM KREEP TERRANE.

Y. Hirai[1], Y. Karouji[2], M. Hareyama[2], H. Nagaoka[1], Y. Fujibayashi[1], S. Kamata[3], T. Morota[4], S. Kobayashi[5], N. Hasebe[1], [1]Research Institute for Science and Engineering, Waseda University, Tokyo, 169-8555, Japan (cosmos-yutaka.h@fuji.waseda.jp), [2]Japan Aerospace Exploration Agency, [3]The University of Tokyo, [4]Nagoya University, [5]National Institute of Radiological Sciences.

Introduction: Investigation for the timing and duration of mare volcanism on the Moon is essential for understanding thermal evolution of basaltic magmatism. By using data of crater size frequency newly measured by the Terrane Camera (TC) [1] onboard Kaguya, Morota et al. [2] reported the eruption ages of mare basalt units in the Procellarum KREEP Terrane (PKT) [3] and found the youngest mare basalts around its central region. In addition, Kaguya Gamma-Ray Spectrometer (KGRS) [4] confirms that the radioactive elements such as potassium (K) and thorium (Th) are relatively abundant in the PKT region [5, 6].

The radioactive heating produced by the decay of the radioactive elements in KREEP may affect the volcanic activities in the PKT [e.g., 2, 7]. Some relationships between the abundance of the KREEP and eruption ages of mare basalts are expected [e.g., 8]. Studies of lunar basaltic meteorites indicate that there are good correlations between the contents of the radioactive elements (K, Th) and crystallization ages among them (Fig. 1). This correlation suggests that the source regions of young magma need to contain a grater abundance of heat-producing elements to offset cooling associated with heat loss of the Moon through time [8]. Therefore, it is important to investigate the relationship among abundance of heat-producing elements and ages of mare basalts. However, ages of lunar basaltic meteorites are around 3.0 to 4.0 Ga, although the youngest ages of mare basalt units were estimated around 1.5 Ga by recent remote sensings [2].

In this study, we estimate the abundance of radioactive elements in each of mare basalt units by KGRS data, and investigate the relationship between the abundance of radioactive elements and the eruption ages.

Data and Analysis Method: We used the gamma-ray data obtained by the KGRS at the low altitude (50 ± 20 km) during February and May, 2009. The gamma-ray counts observed by the KGRS were integrated on each of basalt units which were defined by previous studies [e.g., 11].

The spatial resolution of KGRS is 67 km at the low altitude [12]. Thus, when the size of basalt unit is much smaller than the spatial resolution of the KGRS, it is difficult to estimate the composition in the unit because the gamma-ray coming from the outside region strongly contributes its intensity of gamma-ray. It is also difficult to estimate its composition of the units located close to the high-Th region (e.g., Aristarchus, Fra Mauro). Therefore, the units which are much smaller than the spatial resolution of KGRS and units located near the high-Th region were excluded for our analysis.

The peak fitting method was applied for each spectrum to estimate the intensity of K gamma-ray peak. The peak at 1461 keV (^{40}K; Fig. 2) was used to estimate the intensity. The model ages of each mare basalt unit are derived by [e.g., 2, 11].

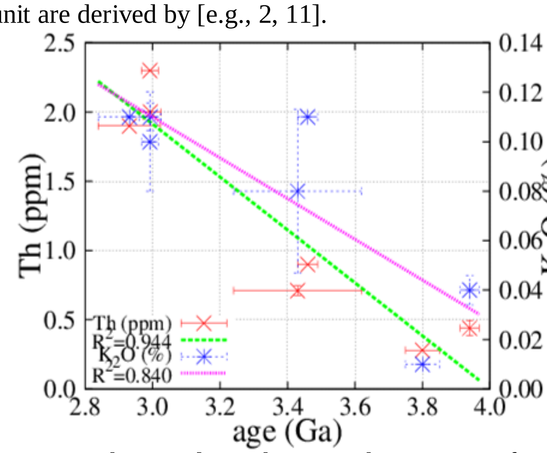

Figure 1: The correlation between the contents of K_2O (%), Th (ppm), and crystallization ages (Ga) among the lunar basaltic meteorites. The crystallization ages and those errors were determined by past studies using Sm-Nd isotopic analysis [e.g., 9]. The chemical compositions of the meteorites are from previous studies [e.g., 10].

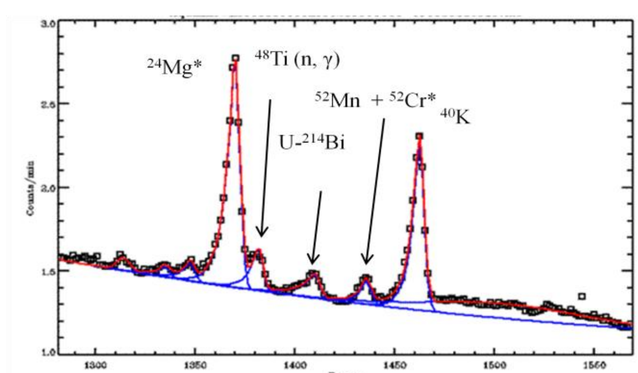

Figure 2: The energy spectrum of gamma-ray around the peak of K (1461 keV) observed by KGRS.

Results: We investigated the units in Oceanus Procellarum, Mare Imbrium, and Mare Frigoris in this work. Fig. 3 shows the distribution map of K counting rates on each basalt unit in the PKT region. The relationship between the counting rates of K and model ages of the units are shown in Fig. 4.

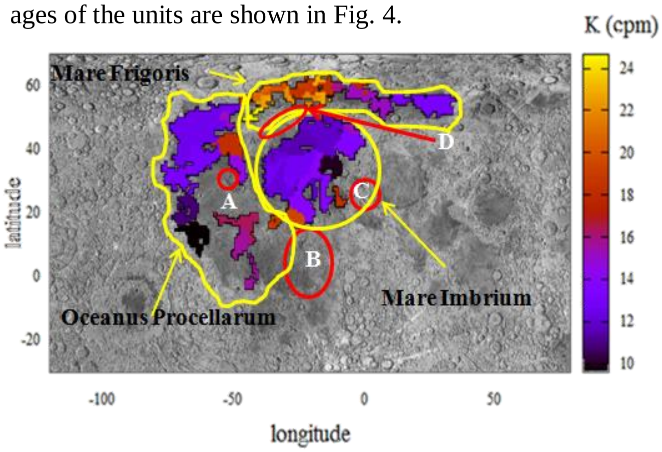

Figure 3: The distribution map of counting rates of K (cpm) in each basalt unit in the PKT. The red circle represents the high-Th region. A: Aristarchus, B: Fra Mauro and Copernicus, C: Aristillus, D: Montes Jura.

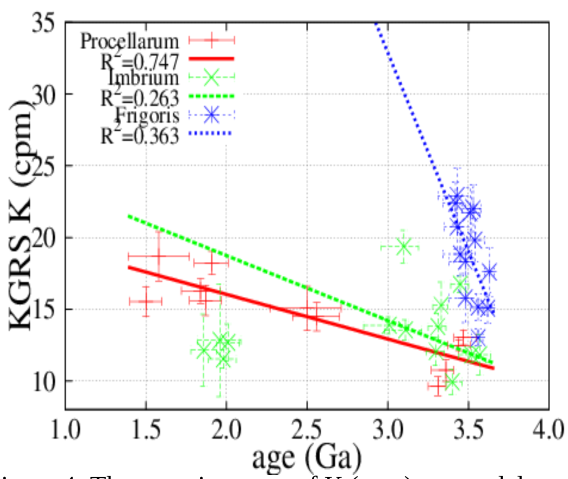

Figure 4: The counting rates of K (cpm) vs. model ages (Ga) in Oceanus Procellarum, Mare Imbrium, and Mare Frigoris. The vertical and horizontal error bars are statistical errors of counting rates of K and model ages [e.g., 2, 11], respectively.

Oceanus Procellarum: We investigated 11 units in Oceanus Procellarum. The relationship between the counting rates of K and model ages in Oceanus Procellarum is shown by red in Fig. 4. The coefficient of determination (i.e., R^2) is larger than 0.7, indicating a clear correlation between the abundance of K and model ages.

Mare Imbrium: 14 units were investigated in Mare Imbrium. The green points and line in Fig. 4 show the results for units of Mare Imbrium and their liner regression line, respectively. In Mare Imbrium, there are two clusters of ages of mare units from 3.5 Ga to 3.0 Ga and from 2.0 Ga to 1.5 Ga. The K abundance of old erupted units is scattered, though that of new erupted units is low and converged.

Mare Frigoris: We selected 13 units to investigate in Mare Frigoris. The relationship between the counting rates of K and model ages in Mare Frigoris is shown by blue in Fig. 4. It shows that the mare eruption occurred in short period (around 3.5 Ga) in Mare Frigoris. The K abundance of Mare Frigoris is scattered among short period.

Summary and Implications: We investigated the relationship between the counting rates of K and eruption ages among mare basalt units in Oceanus Procellarum, Mare Imbrium, and Mare Frigoris. The good correlation between the K abundance and eruption ages in Oceanus Procellarum is found, though significant relationships in Mare Imbrium and Mare Frigoris cannot be recognized.

The correlation in Oceanus Procellarum is similar to that for the lunar basaltic meteorites (Fig. 1). This correlation may suggest that the source regions of young magma need to contain a grater abundance of heat-producing elements to offset cooling associated with heat loss of the Moon through time [8]. On the other hand, in Mare Frigoris and the old eruption units (around 3.2 Ga) in Mare Imbrium, the eruption occurred in short period (around 3.0-3.6 Ga), though the period of mare volcanism in Oceanus Procellarum is long (around 1.5- 3.5 Ga). Thus, the mechanism of mare volcanism in these regions might be different from that of Oceanus Procellarum. We should discuss the mechanism of the young eruption in Mare Imbrium (around 2.5 Ga) in future. In addition, we will investigate the relationship between other radioactive elements such as Th, U and eruption ages in all basins in the PKT as a future work.

References: [1] Haruyama J. et al. (2008) *Earth Planets Space, 60,* 243–255. [2] Morota T. et al. (2011) *Earth Planet. Sci. Lett., 302,* 255–266. [3] Jolliff B. L. et al. (2000) *JGR, 105,* 4197-4216. [4] Hasebe N. et al. (2008) *Earth Planets Space, 60,* 299-312. [5] Kobayashi S. et al. (2010) *Space Sci Rev, 154,* 193-218. [6] Yamashita N. et al. (2010) *Geophys. Res. Lett., 37,* L10201. [7] Wieczorek M. A. and Phillips R. J. (2000) *JGR, 105,* 20,417-20,430. [8] Borg L. E. et al. (2004) *nature, 432,* 209-211. [9] Borg L. E. et al. (2009) *GCA, 73,* 3963-3980. [10] Fagan T. J. et al. (2003) *Meteoritics & Planet. Sci., 38,* 529-554. [11] Hiesinger H. et al. (2003) *JGR, 108,* 5065. [12] Yamashita N. et al. (2012) *Earth Planet. Sci. Lett., 353-354,* 93-98.