THE LOWEST THORIUM REGION ON THE LUNAR SURFACE IMAGED BY KAGUYA GAMMA-RAY SPECTROMETER S. Kobayashi[1,2], M. Kobayashi[3], M. Hareyama[1], N. Hasebe[2], E. Shibamura[4], N. Yamashita[2,5], Y. Karouji[2], T. Okada[1], C. d'Uston[5], O. Gasnault[5], O. Forni[5], R. C. Reedy[6], K, J. Kim[7], H. Takeda[8], T. Arai[3], T. Sugihara[9] , James M. Dohm[10] and Kaguya Gamma Ray Spectrometer team.

[1]Japan Aerospace Exploration Agency, Kanagawa, Japan (e-mail: shingo@planeta.sci.isas.jaxa.jp), [2]Research Institute for Sci. and Eng., Waseda Univ., Tokyo, Japan, [3]Planetary Exploration Research Center, Chiba Inst. of Tech., Chiba, Japan, [4]School of Health and Social Services, Science, Saitama Prefectural Univ., Saitama, Japan, [5]Centre d'Etude Spatiale des Rayonnements, Université de Toulouse, CNRS, Toulouse, France, [6]Planetary Science Institute, Los Alamos, NM, USA, [7]Korea Institute of Geoscience & Mineral Resources (KIGAM), Daejeon, Korea, [8]Dept. Earth & Planet. Sci.,Univ. of Tokyo and Chiba Inst. of Technology, Japan., [9]Japan Agency for Marine-Earth Sci. and Tech., Kanagawa, Japan., [10]Department of Hydrology and Water Resources, University of Arizona, Tucson, USA.

Introduction: Thorium (Th) is known as an incompatible element. During the crystallization of high-temperature magma, Th is not accepted into the crystal structures of major minerals because of its large ionic radius and concentrates in residual liquid phase [1]. The large feldspathic highland in the lunar farside contains little Th and it has been believed to be a magma-ocean floatation-cumulate origin [2]. If the lunar global magma ocean hypothesis is true, the earliest crust that firstly crystallized from the global magma ocean could scarcely contain Th. Thus, the region that contains no or little Th on the lunar surface becomes one of the candidates of the crust or the craton crystallized at earlier stage. By using Kaguya gamma-ray spectrometer (KGRS) that has the excellent energy resolution [3] which helps to reduce the detection limit of Th, the lowest Th regions on the lunar surface were enclosed. In order to get a good counting statistics, the Th map with the large spatial resolution is purposely produced and the lowest Th regions were delineated.

Data processing: The gamma-ray spectrum data obtained by KGRS from Dec. 14, 2007 to Feb. 16, 2008 and from July 7, 2008 to Dec. 14, 2008 (Period 1 + 2) at 100 km altitude was used to produce Th map on the lunar surface. The actual observation time (or live time) is 111.4 days. The energy spectra of the Th peak (2615 keV) are shown in Fig. 1. The Th peak is clearly identified and the energy resolution is 0.96% (full width at half maximum, FWHM) which is about 7 times superior to that of Lunar Prospector gamma-ray spectrometer (LPGRS) [4]. Firstly, the lunar surface was pixilated with 100 km × 100 km quasi-equal areas (3906 pixels) and the gamma-ray spectra which KGRS sent to the ground station every 17 sec in turn were accumulated in the pixels. The intensity of 2615 keV was defined here as the count rate of gamma rays in the energy window from 2550 to 2625 keV and the intensity map of 2615 keV was made. Secondly, the map was smoothed by averaging the intensities of the pixels within a search radius R centered at 0.5º×0.5º grid points. In the averaging process, the intensities were weighted by 2-dimensional weight function, $W(r) = (1+9r^2/R^2)^{-1}$, where r is the distance between a grid point to a center of the pixel along the lunar surface. The weight function determines the spatial resolution of smoothed map, because FWHM of $W(r)$ is 300 km when R=450 km and is considerably wider than that of spatial response function (SRF) that determines the intrinsic spatial resolution of KGRS (~ 130 km [5]).

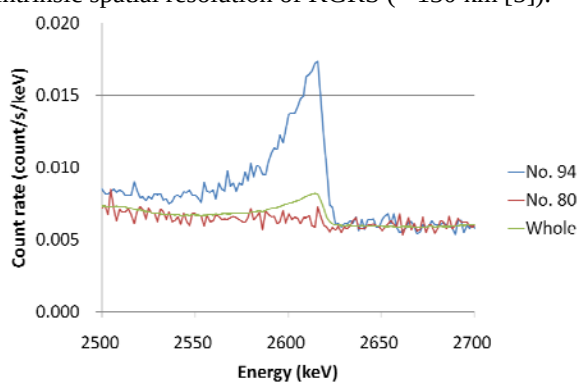

Fig. 1. The energy spectra around Th-^{208}Tl peak (2615 keV) obtained during Period 1+2. Spectra of No. 80 and No. 94 have the lowest and the highest count rates among the quasi-equal area pixels with 450 km × 450 km on the lunar surface, respectively. The spectra accumulated continuously during Period 1 and 2 are also shown (Whole).

Results: The Th map produced by the above method with R = 450 km (Spatial resolution = 300 km) is shown in Fig. 2. The Th is highly concentrated in lunar nearside and Procellarum KREEP Terrane (PKT) defined by [6] is identified from the map. South pole-Aitken basin (SPA) is also seen as the moderate Th concentration in the southern farside.

The lowest Th region: The lowest Th concentration occurs in the zone surrounding SPA. Above all, the two regions have little thorium that are defined by Freundlich-Sharonov, Korolev, Orientale, Hertzsprung and the north of Dirichlet-Jackson (Zone A) and by Moscovience and the west of Mendeleev (Zone B). Our result is well consistent with the measurement of

Apollo 16 gamma-ray spectrometer (AGRS), which flew along the equator in the farside (lat. -5º~+10º). They have reported the moderately high thorium concentration between 150º and 180º of longitude and the low thorium concentration between 180º and 240º[7]. It is a part of Zone A that the low thorium region identified by AGRS is. Whereas, LPGRS have not explicitly mentioned the low Th region so far, but it seems from the maps obtained by LPGRS that the Th concentration in western hemisphere in northern farside is lowest [4].

We found that Zone A and B well coincide with the region that has the thickest crust and the highest elevation recently measured by Kaguya mission [8,9] and where the state of Airy isostacy is supposed to be established [8]. This triple coincidence, i.e., lowest Th, highest elevation, thickest crust, does not deny that the crust crystallized at earlier stage and formed as a magma-ocean floatation-cumulation exists in these low thorium zones as shown in Fig. 2. The lunar meteorite Dhofar 489 that contains extremely low thorium [10] could come from Zone A [11].

Conclusion: The lowest Th region in the lunar farside occurs near the equatorial region (Zone A and B) and it should be noted that the regions well correspond to the lunar highest region and the thickest crust region recently measured by Kaguya mission [8,9].

Acknowledgement: One of the authors S. K. is supported by Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

References: [1] Korotev R.L. (1998) *JGR, 103*, 1691. [2] Wieczorek et al. (2006) *Rev. in Mineral. & Geochem.*(*New views of the Moon*),Ch. 3. [3] Hasebe et al. (2008) *Earth Planet and Space,60*, 229. [4] Lawrence et al. (2000) *JGR, 105*, 20307-20331. [5] Kobayashi S. et al. *Space Sci. Rev.* submitted. [6] Jolliff et al. (2000) *JGR, 105*, 4197. [7] Metgzher et al. (1977) *Proc. Lunar Sci. Conf. 8th*, 949. [8] Ishihara et al. (2009) *GRL, 36*, L19202. [9] Araki et al. (2009) *Science, 323*, 897. [10] Takeda et al. (2006) *EPSL, 247*, 171. [11] Takeda et al. (2009) LPS 41, this volume.

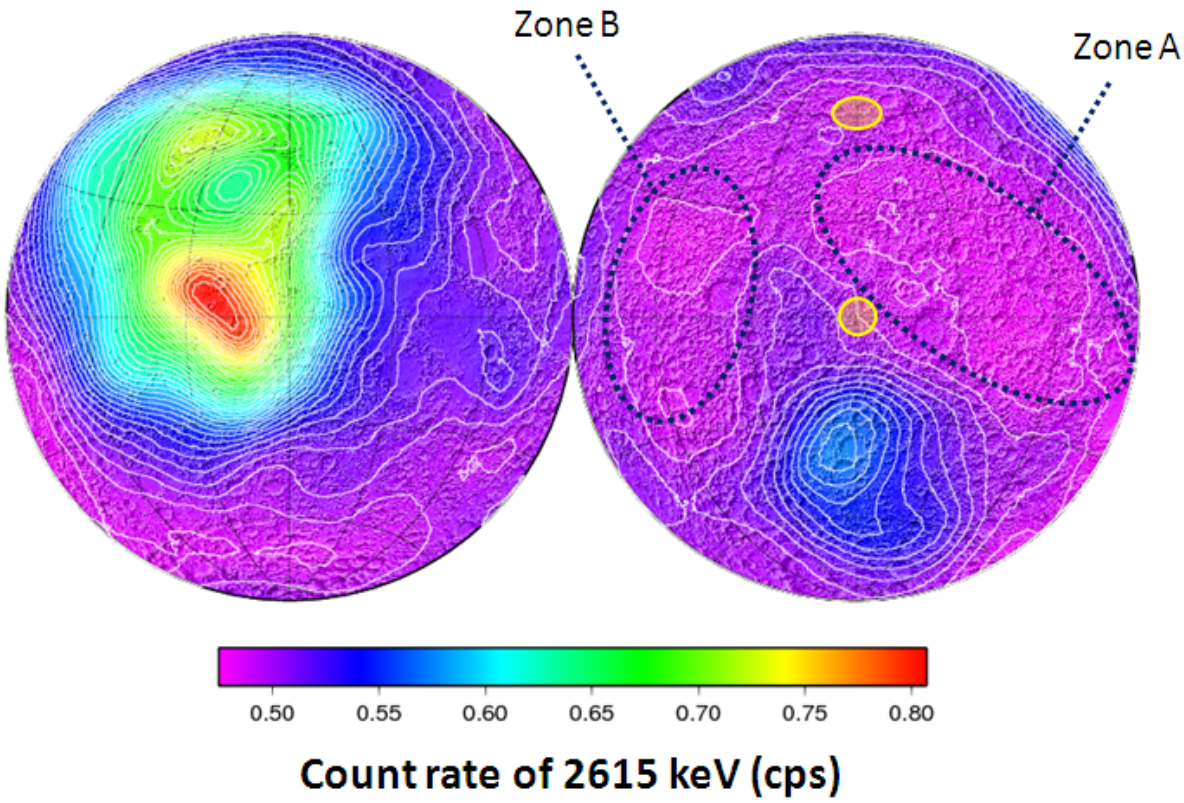

Fig. 2. The gamma-ray intensity map of Th-^{208}Tl peak (2615 keV) smoothed by the 2-dimensional filter using Period 1 and 2 data set obtained by KGRS. The spatial resolution of this map is 300 km. (The diameters of yellow circles are 300 km.) The shaded relief is produced by using Kaguya-LALT data [9].