INVESTIGATION OF THE SOUTH POLE-AITKEN BASIN REGION USING GIS AND SELENE ELEMENTAL INFORMATION K. J. Kim[1], J. M. Dohm[2], J.-P. Williams[3], J. Ruiz[4], B.-H. Yu[5], T. M. Hare[6], N. Hasebe[7], N. Yamashita[7], Y. Karouji[7], S. Kobayashi[8], M. Hareyama[8], E. Shibamura[9], M. Kobayashi[10], C. d'Uston[11], O. Gasnault[11], O. Forni[11], and R. C. Reedy[12] , *[1]KIGAM, Daejeon, Korea.(kjkim@kigam.re.kr),[2]University of Arizona, Tucson, AZ, 85721, USA, California Institute of Technology, Pasadena, CA 91125, USA, [4]CSIC-Universidad AutÓnoma de Madrid, 28049 Cantoblanco, Madrid, Spain, [5]University of Science & Technology, Daejeon, Korea, [6]U.S.G.S, Flagstaff, Arizona, 86001, USA, [7]RISE, Waseda University, Japan, [8]Japan Aerospace Exploration Agency, Japan, [9]Saitama Prefectural University,343-8540 Japan, [10]Chiba Institute of Technology, Narashino, Chiba 275-0016 Japan, [11]CESR ,Toulouse, France,[12]Planetary Science Institute, USA.*

Introduction: Using Geographic Information Systems (GIS), we performed comparative analysis among stratigraphic information and the Kaguya (SELENE) GRS data of the ~2,500-km-diameter South Pole-Aitken basin and surroundings. Our results indicate that the crustal materials are average to slightly above average in K and Th with respect to the rest of the Moon. The heavily cratered highlands represent ancient deep-seated crustal and possibly mantle igneous materials harvested in part from the giant South Pole-Aitken impact event, as well as subsequent impact cratering events up until the end of the Late Heavy Bombardment, which includes intensive impact-related mixing of ejecta materials and lava flows.

The geologic history of the South Pole-Aitken basin is distinct from the Procellarum-Imbrium region. The former records mainly pre-Nectarian activity such as the giant impact with minor mare volcanism during the Upper Imbriam, whereas the latter was largely resurfaced by activity such as the Imbrium impact event and subsequent emplacement of voluminous mare-forming lavas during the Lower Imbriam and Upper Imbriam, Eraatosthenian, and Copernican, respectively. These distinct geologic histories bear on the mineralogic and elemental signatures. In addition, the localized mare lavas within the South Pole-Aitken basin, which have remained following the end of the period of Late Heavy bombardment, are elementally distinct from older rock materials within the basin through this GIS-based comparative analysis among the stratigraphic and Kaguya GRS data.

Method: We determine the spatial and temporal extent of the rock materials (map units) and the total area of the South Pole-Aitken basin region. To determine the temporal extent of the South Pole-Aitken basin region, our approach requires the definition of major stages of geologic activity for the region. Based on the geologic investigation of Wilhelms (1987)[1] and radioactive dates determined from Apollo rock samples, we choose Pre-Nectarian and Nectarian activity, which includes the South Pole-Aitken event (stage 1--type locality is Apollo 17 with an absolute date of 4.5 Ga), the Imbrium and Orientale impact events (stage 2--type locality is Apollo 14 with an absolute date of 3.9 Ga), and mare volcanism that occurred subsequent to the Imbrium and Orientale impact events (stage 3-- type locality is Apollo 12 with an absolute date of 3.5 Ga) as the major stages of geologic activity of the Moon. We assign the map units of published USGS geologic maps a stage. For example, the pre-Nectarian polygons were assigned stage 1, the Lower Imbrian polygons related tothe Orientale and Imbrium mpact impact events stage 2, and the Upper Imbriam units related to Mare-forming volcanism stage 3.

Using GIS, the areal extent of polygons of a specific stage can be then be readily tallied for comparison with the elemental information. For example, we calculated: (1) the total areas of the South Pole-Aitken basin region, (2) the total area of stage 1, stage 2, and stage 3 materials within the South Pole-Aitken basin region, outside of the South Pole-Aitken basin region, and for all of the Moon, and (3) the average elemental abundance of each stage of materials within the South Pole-Aitken basin region, and outside the South Pole-Aitken region, as well as for all of the Moon, using KGRS Th and K map information.

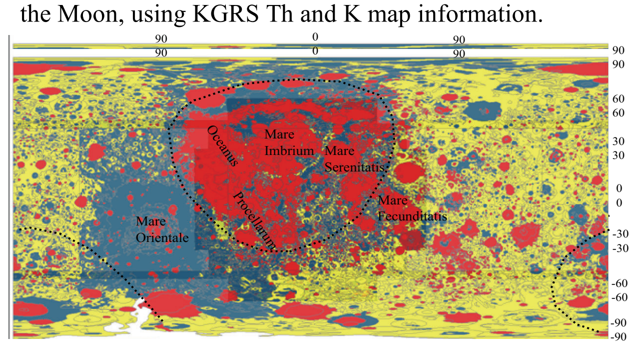

Fig. 1. Stage assignments of the map units using the published USGS geologic maps, L-0703, L-0948, L-1034, L-1047, L-1162[2-7].

Results: associate the KGRS information with the stratigraphic information (stage 1-3 described above) based on the mapping of Wilhelms and McCauley (1971), Wilhelms and El-Baz (1977), Scott et al. (1977), Stuart-Alexander (1978), Lucchitta (1978), and Wilhelms et al. (1979) [2-7], we co-located the KGRS [8-10] and stratigraphic information into a GIS for analysis (Figure 1). Area calculations for the total South Pole-Aitken basin region, the total region outside of the South Pole-Aitken basin region, and the total area of Stage 1-3 materials within each region were computed using an Equal-area Sinusoidal projection. The KGRS-based information of Figure 2 was then read into our GIS as simple point locations. Lastly, we used areas (cookie cutouts) of the stage 1, stage 2, and stage 3 polygons for each region to determine mean counts for K and Th.

From an elemental perspective, when compared to the rest of the Moon (Figure 3), the South Pole-Aitken basin region is one of two elementally distinct regions (the other is Procellarum-Imbrium), which includes enrichment in Fe [8], FeO and TiO_2 [11] and Mg [12,13]. In addition, the stage 3 materials are distinct from stage 1 and stage 2 materials that both reflect nearly equivalent K and Th signatures within the South Pole-Aitken basin region. This is partly due to the difference in approaches, as this GIS-based investigation reveals the mean counts of stages 1-3 materials, which is based on geologic mapping investigations rather than identifying the relative elemental abundance of a specific part of the basin [14,15].

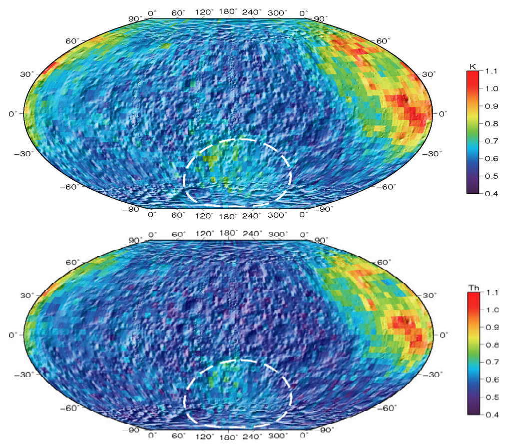

Fig. 2. The global map of potassium (K) gamma-ray counting rate map in counts per second as measured by KGRS (modified after Karouji et al., 2009).

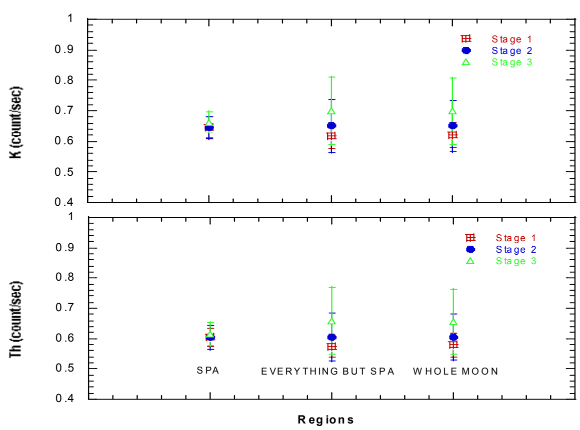

Fig. 3. Average count of K and Th for each region of interest. The error bars denote the standard deviations in K and Th values within the defined study areas.

Discussion: As one of the largest, deepest (~8.5-12 km), and oldest recognized basins in the solar system [16], the South Pole-Aitken impact may have resulted in the emplacement of thick lower crustal and mantle-rich ejecta deposits over a significant portion of the lunar surface [17] during the Pre-Nectarian [1].

Ancient enormous impact events such as South Pole-Aitken would have resulted in giant basins with impact-driven manifestations at great depths and lateral extent (perhaps resulting in global resurfacing), tapping into deep-seated (lower crustal and possibly mantle) material and distributing these materials perhaps Moon-wide. At a general inspection of the elemental information, the Moon appears elementally homogeneous with the exception of two anomalous regions. These regions happen to be the regions of the giant impact basins, hypothesized Procellarum and South Pole-Aitken.

We interpret the results of our investigation as marking an ancient period (mostly pre-Nectarian) of impact crater mixing during the period of heavy bombardment (a large percentage of the rock outcrops reflect pre-Nectarian South Pole-Aitken and subsequent impact crater events of regional extent outside of South Pole-Aitken basin region such as Orientale). Unlike the Procellarum-Imbrium region, which was highly modified by impact events such as Imbrium and mare volcanism, the ancient record of the South Pole-Aitken region was not significantly subdued. Compared with the magma generation in the Procellarum-Imbrium region of the nearside, the unproductive generation in the farside mantle, as pointed out by Taylor (2009)[18], could be explained by a lack of relatively large impacts such as Imbrium to reactivate faults and provide a source of heat to possibly remelt part of the lunar interior and/or tap into magma sources from the lower crustal/mantle boundary. More work is required which includes a GIS-based investigation among the stratigraphy and elemental compositions of the South Pole-Aitken basin and the Procellarum-Imbrium region.

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