Characteristics of mineral compositions of lunar late mare volcanism revealed from Kaguya data

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In order to understand the crystallization of lunar magma ocean and following evolution of the lunar mantle, reconstructing the volcanic history of the Moon is important. The relation between compositions and ages of lunar mare basalts provides insights into the compositional structure and the thermal history of the lunar mantle. According to previous studies of crater counting analysis using remote sensing data, the age distribution of mare basalts shows a second peak at ~2 Ga, which concentrated in the Procellarum KREEP Terrane (PKT). To understand the mechanism for causing the second peak and its magma source is essential to constrain the thermal history of the moon.
In our previous study, we investigated the relation between eruption ages and titanium contents of mare basalts. As a result, we found that a rapid increase in mean titanium content occurred near 2.3 Ga, suggesting the magma source transition. Moreover, the high-titanium basaltic eruptions are correlated with the second peak in volcanic activity at around 2 Ga. We designate volcanisms before and after 2.3 Ga as Phase-1 and Phase-2 volcanism. We propose that Phase-2 volcanism can be explained by the three possible scenarios: (1) the ilmenite-bearing cumulate rich layer in the core-mantle boundary formed after the mantle overturn, (2) the basaltic material layers beneath the lunar crust formed through upwelling magmas, and (3) ilmenite-bearing cumulate blocks remained in the upper mantle after the mantle overturn. We also searched the evidence of the magma source transition in topographic features. As a result, we found a feature like a plateau in the central region of the PKT where most of Phase-2 mare basalts erupted, suggesting that the origin of the plateau might be related to Phase-2 volcanism.
To understand the magma source transition around 2.3 Ga, reconstructing the history of the volcanic activity in the PKT is essential. In this study, we focused on the central region of the PKT and make new geological map of this region. Then, we performed spectral analysis of mare basalts to investigate mineral compositions of mare basalts. At first, we made geological map of the central region of the PKT using KAGYA Multiband Imager (MI) data and digital terrain model (DTM) derived from KAGUYA Terrain Camera data and investigated mineral compositions of mare basalts using KAGYA Spectral Profiler (SP) data. We calculated absorption depths of 950, 1050 and 1250 nm reflectance data from MI to divide highland and mare regions in the central region of the PKT. Also, topographic roughness was calculated from DTM to identify highland regions. We performed principal component analysis for MI 8 band reflectance data to identify each mare basalt unit.
To deconvolute an observed spectrum into individual mineral components, the modified Gaussian model (MGM) is generally used. However, it is difficult to fit the spectrum of complicatedly mixed material such as mare basalts by the MGM because each mineral has multiple absorption bands. Nimura (2011) improved the MGM by investigating the relations between chemical compositions of minerals (the ratio of Fe/(Fe+Mg) in olivine and the ratios of Ca/(Ca+Fe+Mg) and Fe/(Ca+Fe+Mg) in pyroxene) and absorption band parameters (center, width and strength ratio of Gaussian curves). This method was applied to the spectra of asteroids in the previous study and successfully could model mineral and chemical compositions. In this study, we applied this method to the spectra of mare basalts obtained by KAGUYA SP. To avoid the effect of the space weathering, we used spectra of fresh crater wall.
At present, we enhanced the field of the geological map of the PKT and we are performing spectral

analysis of mare basalts. In this presentation, we show the updated geological maps of the PKT and the result of spectral analysis of Phase-1, Phase-2 mare basalts in the Oceanus Procellarum and Mare Tranquillitatis.

Keywords: Moon, volcanism, mineral composition, spectrum