COMPOSITION OF THE LUNAR HIGHLAND CRUST AND MANTLE AND ITS IMPLICATIONS.

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Introduction: Recent remote sensing data of the lunar surface obtained by lunar exploration missions give us large amounts of geochemical, mineralogical, and morphological information of the lunar surface from which we can derive fundamental knowledge of the lunar highland crust and mantle composition.

Composition of the highland crust: Extremely pure anorthosite (PAN), composed of nearly 100% anorthite, which is significantly higher than previous estimates of 82 to 92 vol.%, are widely observed by the SELENE (Kaguya) Multiband Imager at central peaks of younger and least contaminated craters in the lunar highlands [1]. These PAN rocks are estimated to be uplifted to the lunar surface from depths of 3 to 30 km (possibly even as deep as 50 km) suggesting the presence of a global layer of PAN rock in the crust. The global discribution of the PAN rocks regardless of its original depth is further demonstrated [2]. The abundance of the already low mafic mineral abundance in the PAN rocks appears to further decrease with depth according to the compositional analyses of the ejecta of basins of different size, which corresponds to different depths of origin [3]. All these data suggest that the PAN layer is a main component of the highland crust. The extreme composition of the PAN rocks appears to be difficult to generate in large quantities directly from the magma ocean. However, recent computer simulation [4] of the crustal formation revealed that it is possible to generate pure anorthositic crust as a result of simple cooling, segragation, and accumulation processes, which matches the real observation.

The Mg# (Mg/(Mg+Fe) in mol%) of the mafic mineral phase in the highland crust was found to change laterally and continuously from 50 to 70 on the near side up to 80 on the farside [5]. Contamination by high-Mg# basin ejecta from South Pole-Aitken is not likely to be the source because the mafic mineral abundance decreases as the Mg# increases toward the highest-Mg region from the surrounding basin. The presence of crustal material with higher Mg# on the farside than previously estimated, which is 50 to 70 based mainly on the returned lunar samples collected from the nearside, suggests higher Mg# of the melt during plagioclase crystallization on the farside. This result further implies that the farside crust consists of rocks that crystallized from less-evolved magma than the nearside crust. This interpretation is supported by the independent observation that Thorium abundance in the farside higland crust based on the SELENE gamma-ray data is lower, which suggests the earlier crystallization from the magma, than the nearside crust [6]. A simple yet plausible model for interpreting these observations is asymmetric crustal growth. Also, the higher Mg# of the melt during plagioclase crystallization (which evolved from the bulk LMO) further indicates the possibility of higher Mg of the bulk LMO.

Composition of the mantle: No sample originating directly from the lunar mantle is known among currently available lunar samles and lunar meteorites. Therefore, it is critical to understand the composition of the lunar mantle based on the remote-sensing data of the exposures of mantle materials.

It is suggested that the lunar mantle material exposed at rims of big basins such as Imbrium (1200 km) and within and around SPA basin (2500 km). Mineralogical analyses of these big basins indicate that the major mafic mineral phase observed at SPA (except its central part, where impact melt pool is assumed to be located) is low-Ca pyroxene [7], but olivine is observed [8] at the rim of other relatively smaller basins such as Imbrium. These observations likely suggest vertical heterogeneity (possibly two compositional layers) of the lunar mantle, which apparently correspond to the original depth rather than the results of lateral variation because of the comprehensive occurrence of olivine at basins smaller than SPA [8].

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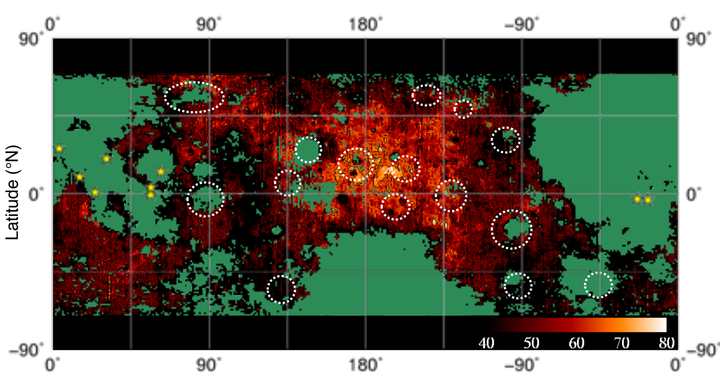

Fig.1 Mg# of the lunar highlands. Dotted circles denote major basins in the highland region. Mare and regions with high HCP/LCP ratios are indicated in sea green. Yellow stars indicate collection sites of the returned lunar samples.