Current understanding of the heterogeneity of the lunar crust and mantle, and its implications

MAKIKO OHTAKE[1]

[1] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, ohtake.makiko@jaxa.jp

Recent remote-sensing data of the lunar surface give us large amounts of geochemical, mineralogical, and morphological information of the lunar surface from which we can derive fundamental knowledge of the lunar crust and mantle heterogeneity.

Extremely pure anorthosite (PAN), composed of nearly 100% anorthite, which is significantly higher than previous estimates of 82 to 92 vol.%, are widely observed 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 an enormous PAN layer in the crust. The abundance of the already small 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. The Mg number (Mg/(Mg+Fe) in mol %) of the mafic mineral phase in the highland crust changes laterally from ~70 at the near side and up to 80 at the farside [2]. The presence of crustal material with higher Mg number on the farside than previously known, which is 50 ~ 70 based mainly on the lunar returned samples collected from the near side, possibly suggests higher Mg number of the bulk lunar magma ocean and bulk Moon.

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) though it is still under discussion. According to the mineralogical analyses of these locations, the major mafic mineral phase observed at SPA is low-Ca pyroxene but olivine is observed at other relatively smaller basins such as Imbrium [3, 4]. These observations likely suggest vertical heterogeneity of the lunar mantle rather than the results of lateral variation because of the comprehensive occurrence of olivine (and non occurrence of pyroxene) at basins smaller than SPA.

All this evidence can be used for modeling solidification of the magma ocean and stratification of the interior, which enables us to understand the evolution of the Moon.

[1] Ohtake, M. et al. (2009) *Nature*, 461, 236-240. [2] Ohtake, M. et al. (2012) *Nature GeoSci.* 5, 384-388. [3] Yamamoto S. et al. (2010) *Nature GeoSci.* 3, 533-536. [4] Ohtake, M. et al. (2014) *Geoph. Res. Lett.* 41, 2738-2745.