OLIVINE FRAGMENTS IN DHOFAR 307 LUNAR METEORITE AND SURFACE MATERIALS OF THE FARSIDE LARGE BASINS. H. Takeda[1], S. Kobayashi[2], A. Yamaguchi[3], M. Otsuki[4], M. Ohtake[2], J. Haruyama[2], T. Morota[2], Y. Karouji[5], N. Hasebe[5], R. Nakamura[6], Y. Ogawa[7] and T. Matsunaga[8], [1]Dept. Earth & Planet. Sci., Univ. of Tokyo and Chiba Inst. of Technology (Hongo, Tokyo 113-0033, Japan and takeda.hiroshi@it-chiba.ac.jp), [2]JAXA/PSD (Sagamihara, 229-8510, Japan), Japan, [3]Natnl. Inst. of Polar Res. (Tachikawa, Tokyo 190-8518, Japan, yamaguch@nipr.ac.jp), [4]Ocean. Res. Inst., Univ. of Tokyo (1-15-1 Minamidai, Nakano, Tokyo 164-8639 Japan, [5]Res. Inst. for Sci. & Eng., Waseda Univ., Tokyo 169-8555 Japan, [6]Inform, Tech. Res. Inst., Natnl. Inst. of Advanced Industrial Sci. and Tech., Umezono 1-1-1, Tsukuba, Ibaraki, 305-8568, Japan, [7]The University of Aizu, Ikki-machi, Aizuwakamatsu, Fukushima, 965-8580, Japan, [8]Natnl Inst. for Environmental Studies, Tsukuba, Ibaraki, 305-8506, Japan.

Introduction: We reported mineralogy of magnesian olivine fragments and olivine-rich clasts in Dhofar 489 [1], 309, [2] and 307 [3], which have unique chemical compositions in the pair group proposed by Korotev et al. [4,5]. These rocks were derived from the farside on the basis of estimated low concentrations of Th and FeO by the remote sensing data on the farside of the Moon [6]. Preliminary mineralogical reports showed that large olivine fragments are present in the matrix. Now we report more detailed study of the olivines and suggest a preliminary model of formation of such breccia in a large basin of the farside to explain the common origin of the magnesian lithologies with olivine.

The Spectral Profiler (SP) onboard the Japanese lunar explorer Kaguya by Nakamura et al. [7] found that the South Pole-Aitken basin (SPA) are dominated by Mg-rich orthopyroxene (Opx). Ohtake et al. [8] found nearly pure anorthosites by MI (multiband imager) and SP of Kaguya. In order to clarify the relationship between abundant olivine in the above lunar meteorites and Opx detected by the spectroscopic observation, we studied olivine fragments in Dhofar 307 and discuss the preliminary model to produce observed materials.

Samples and Methods: One polished thin section of Dhofar 307,6 prepared at National Inst. of Polar Res. (NIPR) was employed for mineralogical and petrographic studies. Elemental distribution maps of Si, Mg, Fe, Al, Ca, Na and Cr were obtained by electron probe microanalysis (EPMA) at the Ocean Res. Inst. (ORI) of Univ. of Tokyo and NIPR. Chemical compositions of olivine fragments were obtained by EPMA at the ORI and NIPR.

Results: Angular and subround clasts of spinel-troctolitic anorthosites and magnesian anorthosites are embedded in fine-grained recrystallized or devitrified impact melt glassy matrices and fragments of shocked plagioclase. One prominent clast (4.4 × 3.1 mm in size) is a granulitic rock (GR) with a reddish orange colored olivine with subrounded shapes in granoblastic plagioclase, but the granoblastic texture is obliterated by shock effect. The sizes of the olivine in the granulitic clast are comparable to the impact melt (IM) clasts in Dhofar 309 (0.1 × 0.05 to 0.01 × 0.02 mm in size). The Fo contents of olivine (Fo84-86) are similar to those of the Dhofar 489 spinel troctolite (Fo84). Another large clast is coarse-grained troctolite similar to the spinel troctolite (ST) in Dhofar 489. The An contents of Dhofar 307, distribute around An96.

Olivines around plagioclase and in matrices. Elemental distribution maps of Mg (Fig. 1) in 3 regions were obtained by EPMA. The Fo values of wormy olivine grains around large plagioclase crystals range from 70 to 76, which are similar to those of the magnesian anorthosites. Minor olivines with Fo60 to 65 are also present. The Fo of some olivines in other plagioclase range from 75 to 85 and dominant values are from 76 to 79. Fo values of olivine crystals in the granulitic clast are from 81 to 87, and those of the spinel troctolite are from 82 to 90. Some minor pyroxene fragments are present, including $Ca_{13}Mg_{49}Fe_{38}$ pigeonite with lamellae $Ca_{39}Mg_{39}Fe_{22}$ in the host, $Ca_{3.3}Mg_{50.7}Fe_{46.0}$. Large olivine fragments are embedded in the dark devitrified glassy matrices and their sizes range from 1.0 × 0.8 to 0.3 × 0.2 mm in size.

Discussion: Remote sensing data indicate that the nearside and the farside of the Moon are substantially different in terms of inferred chemical compositions and rock lithologies [1,6]. Dhofar 307 PTS contains magnesian GR clast similar to the SP in Dhofar 489 in mineral chemistry [3]. However, we could not observe rapid growth features of the Dhofar 309 IM [2] clast such as elongated lath-shaped plagioclase crystals with minor zonings (An95.0-96.6) and fragments of twinned plagioclase. These features can be explained by rapid growth from an impact melt pool [2].

The range of the modal abundances in volume % of the minerals of these three clasts (Dhofar 489 ST, Dhofar 309 IM, Dhofar 307 GR) obtained from the mineral distribution map are: plagioclase 66-72, olivine 22-27, Opx 1-9, augite 0.5-2, and spinel 0.1-0.5. The mineral assemblages of these clasts are similar to that of ST clast in Dhofar 489 [3]. The modal abundances of the minerals of all three types clast and mineral compositions are practically the same.

Formation model of the Dhofar 489 breccias. The Dhofar 489-type feldspathic lunar meteorites contain more magnesian olivine than those of the FAN of the Apollo samples. In addition, the Dhofar 489 group contains some deep seated rocks such as a spinel troctolite and their granulitic varieties. The very low abundance of FAN and very low Th concentration in the Dhofar 489 is in favor of the farside origin.

The lunar magma ocean (LMO) model initially proposed by Warren and Wasson [9] emphasize that FANs have very little trapped liquid. Loper and Werner [10] proposed that lunar crustal asymmetries are the result of convective processes acting early in the Moon's history, during the LMO phase and after synchronous rotation was established. Buoyant anorthositic crystals were transported to the farside by a large-scale circulation, called tilted convection. Crustal thickening near the equator resulted from the modification of tilted convection by the Coriolis force. The selective transport may have resulted in a nearside excess of incompatible elements, leading to the formation of the PKT [10]. The tilt convection model explains also the enrichment of the KREEP incompatible elements at the nearside magma ocean. The highest point observed by global topographic mapping of the Moon with the laser altimeter onboad Kaguya by Araki et al. [11] may represent the early formed thickest crust near the equator. This hypothesis is consistent with the lowest concentration of Th in a region from north of Dirichlet-Jackson basin, to Hertzsprung and to the West of the Orientale basin, measured by the GRS by Kobayashi et al. [12]

We suggest the following formation model of the Dhofar 489 group breccias in the above lowest Th region. Based on the remote sensing data of Th [12], we assume magnesian anorthosites constitute major parts of the northern farside highland. Spinel troctorites are present ca. 15 km beneath the magnesian anorthosite crust [1]. A large impact, which excavated a basin more than 80 km in diameter, might have produced impact melts at the basin flower and crystallized IM-like clast by rapid cooling. Granulites were produced by thermal metamorphism at the flower of a large basin. Smaller impacts within the basin produced breccias of these materials. Among a few large basins in the above lowest-Th region, Dirichlet-Jackson basin has many craters [13] in the central region (e.g., Raimond, craters North of the highest point), where the Dhofar 307-type breccia might have been developed. Among the second lowest Th region around Moscovience and the west of Mendeleev [12], we could not find a large basin with the above configuration.

The low abundance of Opx fragments in the Dhofar 489 group breccias is difficult to explain. One explanation might be possible by introducing a giant impact into the Procellarium terrane, just before the crystallization of Opx from the magma ocean brough from the farside by the tilt convection [10]. Then, the melt enriched in the Opx component could be splashed away and the remained melt at the farside may not crystalize Opx. This impact may produce a new regional magma sea. Nyquist et al. [14] proposed multiple magma sea on a different basis. This magma sea will crystallize FAN and the melt will be enriched in KREEP, which will be ejected by the Imbrium impact to produce the PKT. Further studies are underway to find mantle olivine by the SP and MI (Matsunaga, personal comm.). Opx is common in the monomict and polymict breccias on the Vesta. These large olivine fragments in the matrix may represent fall-out of the large basin ejecta, where the impact penetrated into deeper olivine-rich rock.

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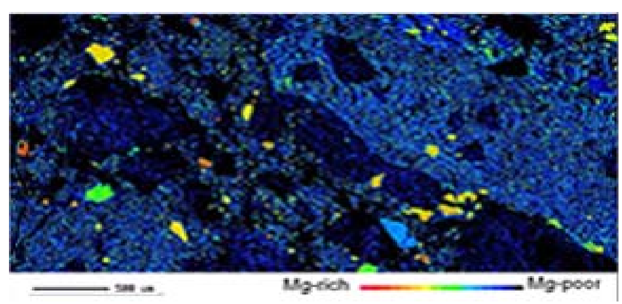

Fig. 1. Elemental distribution maps of Mg, of Dhofar 307. Dark blue fragments from upper left to lower right are pure plagioclase fragments. Orange fragments are magnesia olivine crystals. Scale bar: 500 μm.