A CRUSTAL ROCK CLAST IN MAGNESIAN ANORTHOSITIC BRECCIA, DHOFAR 489 AND ITS EXCAVATION FROM A LARGE BASIN. Hiroshi Takeda[1], D. D. Bogard[2], Akira Yamaguchi[3], Makiko Ohtake[4] and Kazuto Saiki[5], [1]Research Inst., Chiba Inst. of Technology, 2-17-1 Tsudanuma, Narashino City, Chiba 275-0016 Japan, e-mail: takeda@pf.it-Chiba.ac.jp, [2]ARES, code SR, NASA Johnson Space Center, Houston, TX 77058, U.S.A., [3]National Inst. of Polar Res., Itabashi-ku, Tokyo 173-8515 Japan, [4]Planetary Sci. Dept., Japan Aerospace Exploration Agency (JAXA), 2-1-1 Sengen, Tsukuba, Ibaraki, 305-8505, Japan, [5]Res. Inst. of Materials and Resources, Faculty of Eng. and Resource Sci., Akita Univ., 1-1 Tegatagakuen-machi, Akita, 010-8502, Japan.

Introduction: We report the mineralogy and Ar-Ar age of a spinel troctolite clast with a granulitic texture found in the Dofar 489 lunar meteorite. This anothositic breccia contained magnesian mafic silicates [1] not common in ferroan anorthosites (FAN) from the Feldspathic Highlands Terrane (FHT) of Joliff et al. [2]. The Ar-Ar ages of most FANs in the Apollo sample collection from the Procellarum KREEP Terrane (PKT) [2] and FHT of the near-side of the Moon were reset at around 3.9 Gyr. by the basin forming event of Imbrium [3]. From the older Ar-Ar age of Dho 489, we propose that a large basin formation other than the Imbrium basin may have mixed deep crustal rocks such as spinel troctolites with "pure" anrthosites [1] to produce a magnesian anorthosite brecca. This model is in line with a proposal by Bussey and Spudis [4], who reported that inner rings of large basins display massifs of nearly pure anorthosites.

Samples and experimental methods: Dho 489 weighing 34.4 g is a crystalline matrix feldspathic breccia [1]. Two polished thin sections (PTSs, ,11 ,2-1) of Dho 489 were made from two new slices. We made ^{39}Ar-^{40}Ar analyses of a 64 mg whole rock sample taken from a 6 g block kept at the National Sci. Museum in Tokyo (NSMT). The first Ar extraction (400C) released 75% of the total ^{39}Ar (produced from ^{39}K in the reactor), shows a very young apparent age, and undoubtedly represents Ar release from the extensive terrestrial weathering product present in this meteorite. The next few extractions also show significant influence from weathering products. Chemical compositions of minerals in the lithic clasts were analyzed by JEOL 733 EPMA equipment at the Ocean Res. Inst. of Univ. of Tokyo.

Results: PTS ,11 includes a crystalline clast 4.1_1.3 mm in size. Fig. 1 shows the matrix textures and granulitic textures of the clast with elongated oval shaped olivine crystals (up to 0.69_0.23 mm in size). The plagioclase matrix was finely recrystallized after the shock event. Rounded brownish spinel grains are included both in plagioclase and olivine. The modal abundance of the minerals is: plagioclase 72 vol. %, olivine 27 %, spinel 0.3 % and minor pyroxenes (low and high Ca) in olivines. The Fo contents of olivine (Fo84) represent one peak of the bimodal distribution with their higher frequency compositions at Fo75~77 and Fo84~85 in the matrix of PTS ,1 [1]. The An values of plagioclase of the clast (An96) is in the middle of the distribution (An95~98) of plagioclase fragments in the matrix [1]. Minor pyroxenes are found in the olivine grains. The spinel compositons were plotted in a base projection of the multicomponent spinel prism, as shown in [7]. The Cr/(Cr+Al) atomic ratio of the pleonaste in plagioclase is 0.30 and the Fe/(Fe+Mg) ratio is 0.35; spinels enclosed in olivine are richer in Cr and Fe.

Four lithic clasts were recognized in PTS ,2-1, but the olivine compositions are still more magnesian than those in the FAN trend.. These trends with the lowest pair (An96.5, Fo71.6) define Mg-rich extension of the FAN in the An *vs.* mg# diagram.

Fig. 2 plots the Ar-Ar age and K/Ca ratio for the last 20% of the ^{39}Ar release for temperatures >700C. This portion of the age spectrum represents ~108 ppm K. The increase in Ar-Ar age over 86-93% of the ^{39}Ar release indicates some diffusive loss of ^{40}Ar. However, ages for six extractions (1200-1340C, 93-100% ^{39}Ar release) define an age plateau of 4.27 ±0.13 Gyr. Most of the uncertainty in this age derives from the substantial correction applied for ^{39}Ar produced in the reactor from Ca.

Discussion: The granulitic texture of the large clast in PTS ,11 (Fig. 1) resembles those of granulitic clasts rich in mafic minerals (e.g. Y86032,45), but it is more coarse grained. The mineral assemblage of the Dho 489 clast is similar to that of a spinel troctolite 67435,14 [5], but the the 67435 olivine crystals show more euhedral form. The compositions of a few spinel grains in one small clast in the Dho 489 PTS ,1 and the large clast in PTS ,11 plot close to those of chromian pleonastes in the Apollo spinel troctolites (67435, 72435, 73263) [5, 6]. The Dho 489 pleonastes are a little more Cr-rich than the Apollo ones. Spinels enclosed in olivine in this large Dho 489 clast are Mg-,Al-rich chromite. Such a pair was found in the Apollo 14 breccias [7]. Such minor differences may be attributed to a metamorphic event, which produced the granulitic texture.

Based on the stability relations of the cordierite - to spinel-cataclasite transition, Herzberg and Baker [6] showed that spinel cataclasites from Apollo 15 and 17 were located at depths greater than or equal to about 12 to 32 km prior to excavation. The result in connection with the presence of pure anorthosites excavated from the largest basins as given below will further costrain the origin of D489 breccia.

Ferroan anorthosites have long been known to be a major rock type in the lunar highlands (AHT). Lindstrom et al. [8] reported magnesian anorthosites in Apollo 14 breccia, which are distributed in a regional rather than global manner. Dho 489 differs from such a local product, because of the presence of the spinel troctolites [6]. Because the one common composition of mineral fragments in the matrix is the same as those in the spinel troctolite clast, the Dho 489 breccia can be mixtures of such rocks and pure anorthosites.

Bussey and Spudis [4] performed compositional studies of four large lunar basins by full-resolution of Clementine images. They reported that inner rings of all four basins display massifs of nearly pure anorthosite (FeO < 1 wt %), virtually the only such occurrences of this rock type on the Moon. Crisium displays distinct compositional zoning within exterior sectors of the basin. Lawrence et al. [9] observed a Mg-rich region NW of Crisium by Lunar Prospector gamma-ray data.

Discovery of the spinel troctolite associated with pure anorthosite in Dho 489 suggests that Dho 489 may represent a terrane with mixtures of deep crustal rocks such as spinel troctolite and anorthosites without the FAN-like mafic silicates. We will still look for ferroan mafic silicates, as in the FAN in Dho 489, to address the question as to what kind of mafic silicates are present in the pure anorthosite terrane proposed by Bussy and Spudis [4].

The Ar-Ar age of Dho 489 is older than most ages reported for anorthosite rocks returned by Apollo [3], but it is slightly younger than the age of 4.35-4.4 Gyr for anorthosite Y86032 reported by Bogard *et al.* [10]. The ~4.27 Gyr age for Dho-489 is younger than the measured formation ages for several FANs [3] and may date the time of impact formation of this breccia. That the Ar-Ar age of Dho 489 is older than 3.9 Gyr suggests that one of the large basins responsible for the excavation of Dho 489 is not Imbrium. We will look for more detailed distribution of these two lithologies in the lunar highlands in our future SELENE mission.

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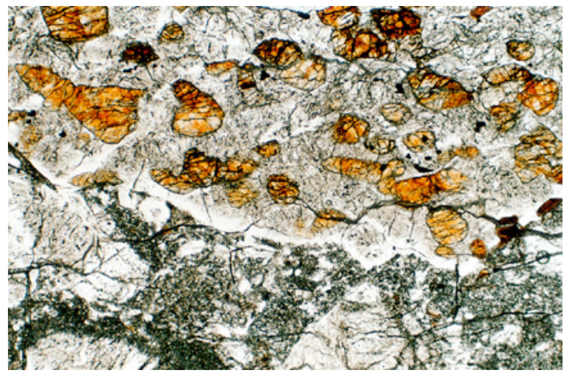

Figure 1. Photomicrograph of the spinel troctolite clast in D489 (top two thirds, width 3.3 mm).

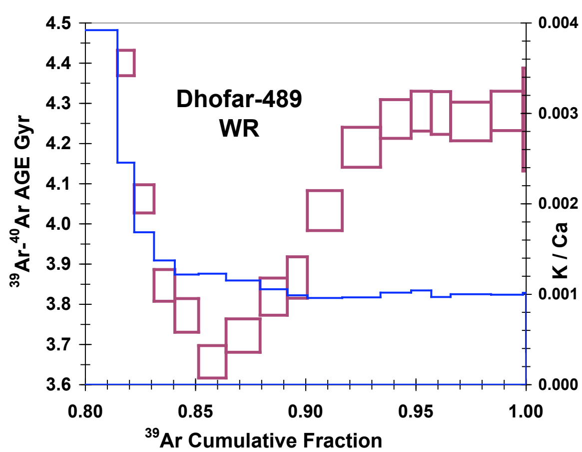

Figure 2. ^{39}Ar-^{40}Ar ages (red) and K/Ca ratios (blue) as a function of cumulative release of ^{39}Ar for stepwise extraction of Dho 489.