**BASALTIC CLASTS IN Y-86032 FELDSPATHIC LUNAR METEORITE: ANCIENT VOLCANISM FAR FROM THE PROCELLARUM KREEP TERRANE.** A. Yamaguchi[1], H. Takeda[2], L.E. Nyquist[3], D. Bogard[3], Y. Karouji[4], M. Ebihara[5], [1]National Institute of Polar Research, Tokyo 173-8515, Japan (yamaguch@nipr.ac.jp), [2]University of Tokyo, Graduate School of Sciences, Tokyo 113-0033, Japan, [3]NASA-JSC, Houston, USA, [4]Waseda University, Tokyo 169-8555, Japan, [5]Tokyo Metropolitan University, Tokyo 192-0397, Japan.

**Introduction:** Lunar meteorite, Y-86032 is a fragmental or regolith breccia enriched in $Al_2O_3$ (28-31 wt%) and having very low concentrations of REEs and Th, U [e.g., 1]. Nyquist et al. [2] suggested that Y-86032 contains a variety of lithologies not represented by the Apollo samples. They found clasts with old Ar-Ar ages and an ancient Sm-Nd age, and negative $\varepsilon_{Nd}$ indicating a direct link to the primordial magma ocean. Importantly, the final lithification of the Y-86032 breccia was likely >3.8-4.1 Ga ago. Therefore, any lithic components in the breccia formed prior to 3.8 Ga, and lithic components in breccia clasts in the parent breccia formed even earlier. Here we report textures and mineralogy of basaltic and gabbroic clasts in Y-86032 to better understand the nature of ancient lunar volcanism far from the Procellarum KREEP Terrain (PKT) [3] and the central nearside.

**Results:** Y-86032 contains three lithologies, white (W), light gray (LG) feldspathic breccia, dark gray clastic matrix (DG), and impact melt (IM) [2]. The LG breccia is mostly composed of fragments of anorthosite (An93 anorthosite), set in the DG matrix. We found two basaltic clasts (45B1 and 45B2) in the DG matrix and one gabbroic clast (35C1) in the LG feldspathic breccia.

*45B1 and 45B2.* One basaltic clast, 45B1 (0.40 x 0.38 mm in size) is composed of a plagioclase lath (<0.1 x 0.35 mm; 65 vol%) enclosing anhedral pyroxene grains (~0.1 mm; 29 vol %), blocky to irregular silica minerals (~20-50 µm; 5 vol %), ilmenite (~1 vol %), and very-fine grained (<1 µm) mesostasis. The modal abundance of plagioclase (65 vol%) is anomalously higher than that of any known mare basalts (19.2-43.0 vol%) [4].

The 45B2 clast (~0.4 mm in size) is brecciated and sheared, and does not show basaltic textures. The clasts are composed of anhedral plagioclase and pyroxene with minor minerals such as Fe-rich olivine, silica minerals, ilmenite, ulvöspinel and a very fine-grained aggregate of Fe-rich materials. Plagioclase appears to dominate over pyroxene although the modal abundances are not clear due to brecciation. There is a significant amount of the fine-grained aggregate related to 45B2.

Pyroxenes of the 45B1 clast are zoned widely from low-Ca and Mg-rich cores ($Wo_{4.7}En_{71.3}$) to FeCa-rich rims ($Wo_{24.5}En_{14.8}$), whereas pyroxenes of 45B2 show broader zoning ($Wo_{3.2-39.9}En_{11.4-54.9}$) (Fig. 1) as were found in VLT basalts [4]. $TiO_2$ contents of pyroxenes are 0.08-1.20 wt% for the 45B1 clast and 0.25-1.05 wt% for the 45B2 clast. Mg' (molar Mg/(Mg+Fe)x100) values of ilmenite in 45B1 vary from 1.2-10.6. Olivine of 45B2 is Fe-rich (Fo7.78-13.66). The pyroxenes of 45B1 show a strong correlation between Fe/(Fe+Mg) (Fe#) and Ti/(Ti+Cr) (Ti#), overlapping the range of VLT basalt [5]. Compositions of plagioclase are very limited ($An_{97.6}Or_{0.01}$-$An_{95.0}Or_{0.14}$ for 45B1; $An_{95.3}Or_{0.08}$-$An_{92.0}Or_{0.06}$ for 45B2) compared to other mare basalts [4]. The $K_2O$ contents are very low (<0.03 wt% for 45B1 and <0.07 wt% for 45B2). The FeO contents in plagioclase (0.3-1.6 wt%) are typical of mare basalts and distinctively higher than those of highland rocks. In the 45B2 clast, the olivine composition is Fa86.3-92.2. The compositions of ulvöspinels are $Usp_{66.5-69.6}Chm_{23.0-25.6}$. Ilmenite has low MgO (0.55 wt%). Chromite compositions in the 45B1 clast are $Usp_{7.7-20.9}Chm_{57.9-64.8}$, Mg'=20.9-38.6. The compositions of oxide minerals are generally similar to those of mare basalts [6].

*35C1.* The 35C1 gabbro clast (1.4 x 5 $mm^2$ in size) is moderately brecciated and displays a granular texture composed of augite (~57%) and plagioclase up to ~200 µm in size (~43%) with minor minerals such as ilmenite and chromite. Although the modal abundance may be unrepresentative because of the small size of the clast, the 35C1 clast is significantly enriched in augite.

The augite has closely spaced (~several µm) exsolution lamellae (several µm thick) of low-Ca pyroxene. The chemical compositions of the augite and low-Ca pyroxene are $Ca_{41.0}Mg_{35.5}$ and $Ca_{3.0}En_{38.4}$, respectively. The $TiO_2$ contents of the pyroxenes are 0.50-1.40 wt%, slightly higher than those of non-mare rocks ($TiO_2$ = 0.1-0.5 wt%) [6]. Plagioclase grains have chemical compositions relatively high in Na compared to lunar anorthosites and range $An_{86.0-90.9}$ with an average of $An_{88.9}$. The FeO contents of plagioclase in 35C1 are 0.07-0.45 wt%, slightly higher than those of highland rocks (~0-0.3 wt%) [7]. The $K_2O$ contents are extremely low (<0.05 wt%). Ilmenite is relatively poor in Mg (Mg'=7.3-8.6), and the chromite composition is $Usp_{10.5}Sp_{20.7}Chm_{68.9}$ (Mg'=7.97).

**Discussion:** The presence of basaltic and gabbroic clasts in Y-86032 has implications for basaltic volcanism at the site where Y-86032 was lithified. Basaltic clasts 45B1 and 45B2 occur in the DG matrix dated as more than 3.8 Ga old [2]. Pyroxene in these clasts shows extensive chemical zoning, indicating their formation by rapid cooling near the lunar surface. The relationship between Ti# and Fe# of pyroxenes in 45B1 and 45B2 is similar to that for VLT basalts.

However, the modal abundances of plagioclase in 45B1 are anomalously higher than for typical mare basalts. Anomalously high abundances of plagioclase could be partly due to the small sizes of the clasts. We calculated the major element bulk compositions of 45B1 using the EPMA data and modal abundances. On a plot of $Al_2O_3$ vs MgO (wt%), the compositions of 45B1 plot on the mixing line for pyroxene and plagioclase [8]. Thus, we recalculated the bulk chemical compositions using the mode of typical VLT basalts [8]. The relationships of $Al_2O_3$ and $TiO_2$ with Mg' are similar to those for VLT basalts [6].

The zoning trend of pyroxene of the 45B1 clast (Fig. 1) shows a continuous increase from low-Ca and low-Fe to high-FeCa contents, consistent with crystallization from an Al-rich magma. Early crystallization of plagioclase removes Ca from the liquid, resulting in crystallization from low-Ca pyroxene as an early phase. The predominance of plagioclase over pyroxene, and low-Ca pyroxene over augite, as well as the zoning patterns are rather similar to those of KREEP basalts [9]. However, the bulk composition of the DG matrix has very low abundances of KREEP components [2]. Thus, we suggest that the 45B1 clast is a high-alumina, VLT basalt.

The 35C1 gabbroic clast occurs in the LG lithology that is mostly An93 anorthosite. Formation of the LG breccia was precisely dated at 4.10±0.02 Ga [2]. Because the texture is gabbroic and the pyroxene is well equilibrated, the 35C1 clast is not an extrusive rock, but a plutonic rock. However, mineral compositions of this clast are in some ways similar to those of mare basalts. The relationship between Ti# and Fe# is similar to that for LT basalts. The bulk compositions calculated from the mode and the EPMA have relatively high $Al_2O_3$ (~16-17 wt%). The Mg' (~60) of gabbroic clast 35C1 is much lower than those (Mg' = 65-90) of gabbros and gabbro-norites found in the Apollo samples, and comparable to those of alkali-rich anorthosite (Mg' = 40-70) [6]. It is unlikely that 35C1 is a highly differentiated product of intrusive magmas (e.g., Mg-suite intrusions). The host breccia of the 35C1 clast has very low abundances of trace incompatible elements (CI x ~2-3x) slightly higher than those of FANs [2]. Thus, it seems unlikely that there are any incompatible-element rich components in the LG breccias. We suggest that 35C1 is a fragment of a plutonic rock (gabbro) or a metamorphosed equivalent of high-alumina LT basalts. The close proximity of the An93 anorthosite and 35C1 within the LG breccia suggests that 35C1 is a fragment of a basaltic magma that intruded into the An93 anorthosite. That 35C1 shows evidence of slow cooling suggests that intrusion occurred at considerable depth in the lunar crust.

The variety of lithic clasts in the Y-86032 breccia not represented by the Apollo samples indicates that this meteorite was not derived from the central nearside [2, this work]. The low bulk FeO and Th abundances suggest that Y-86032 was derived from a location distant from the PKT [3]. The final lithification of Y-86032 at >~3.8 Ga ago is almost coincident with the time of the Imbrium event. We suggest that Y-86032 was lithified in the highlands between the nearside and farside before the Imbrium impact. The basaltic and gabbroic clasts in Y-86032 probably originated from such regions, and represent ancient volcanism at prior to 3.8 Ga ago, and before the Imbrium impact. Of several cryptomaria regions considered by [10] as sources of early mare basalts, the Lomonosov-Fleming Region [11] is most suited to be the source region of the basalts in Y-86032.

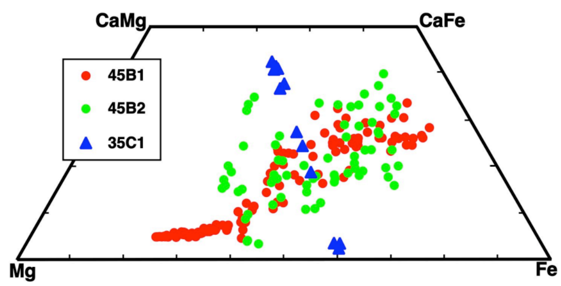


Fig. 1. Pyroxene compositions of basaltic clasts, 45B1 and B2, and a gabbroic clast 35C1.

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