THE ORIGN AND IMPACT HISTORY OF LUNAR METEORITE YAMATO 86032.

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Introduction: Yamato (Y) 86032 is a feldspathic lunar highland breccia having some characteristics of regolith breccia [1,2]. The absence of KREEP components in the "matrix" in Y86032 indicates that these meteorites came from a long distance from Mare Imbrium, perhaps from the far-side of the moon [e.g., 3]. One ferroan anorthosite (FAN) clast in Y86032 has a very old Ar-Ar age of ~4.35-4.4 Ga [4]. The negative ε_{Nd} of this clast may suggest a direct link with the primordial magma ocean [5]. The facts indicate that Y86032 contains components derived from a protolith of the original lunar crust. Detailed petrologic characterization of each component in this breccia is essential to understand the early impact history and origin of the lunar highland crust. We made a large slab (5.2 x 3.6 cm x 3-5 mm) (Fig. 1) of Y86032 to better understand the relationship of various lithologies and their petrologic origin.

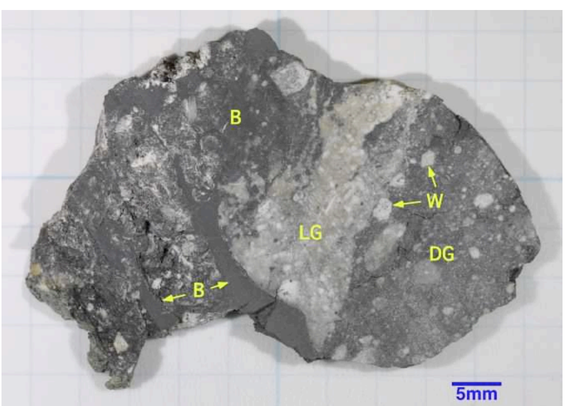

Figure 1. *Photograph of the sawed surface of Y86032. W: white lithology; LG: light-gray lithology; DG: dark-gray lithology; B: black impact melt.*

Results and discussion: The sawed surface of Y86032 (Fig. 1) shows a complicated breccia texture, composed of white lithology (~5%), light-gray lithology (~20%), dark-gray lithology, and black impact melt (~20-30%). Eight polished thin sections (PTSs) were made from representative portions from the slab, and were examined by optical and scanning microscopes and by electron microprobes. Portions of each lithology will be examined by isotopic and bulk chemical analyses.

The white lithology is a rounded or subrounded fragment (up to 3 mm in size) of anorthosite with minor mafic minerals (<1-5 vol%). It seems that many of the white lithologies are petrologically similar to white portions in the light-gray lithology. One large anorthite grain (An_{95}) (PTS ,132) contains small grains of fine-grained low-Ca pyroxene ($Wo_{3.43}En_{70.99}$) with an igneous contact.

The light-gray lithology (PTSs ,31 ,32-1 ,32-3 and ,35) is a breccia mostly composed of fragments of anorthosite, pyroxene, olivine, silica minerals, and chromite. A portion of this lithology (4.5 mm^2) consists of anorthite (95 vol%), olivine (4 vol%), orthopyroxene (1.5 vol%), augite (1.0 vol%), silica minerals (0.6 vol%), and chromite. Olivine compositions are mostly $Fo_{78.05-82.38}$. There are some relatively Fe-rich olivine grains ($Fo_{66.42-64.61}$). Compositions of pyroxene vary significantly: low-Ca (<5 mol% Ca) pyroxene are mg' (= Mg/(Mg+Fe) x 100) = 41.0-81.3. Plagioclase compositions range from $An_{88.53}$ to $An_{95.91}$. The X-ray mapping (PTS ,45) indicates that the light-gray lithology contains at least two or three groups of plagioclase. There is a grain of Mg-rich (mg'=41.63), Al-chromite ($Usp_{2.20}Sp_{42.47}$). We found a moderately, brecciated clast, composed of plagioclase ($An_{88.9}$) and Fe-rich augite grains ($Wo_{39-41}En_{31-39}$) (<0.2 mm in size). The augite grains have fine planar exsolution lamellae of low-Ca pyroxene. On the An versus mg' diagram (Fig. 2), this clast is plotted outside the regions of pristine nonmare rock groups, and near to a similar portion to an augite-rich anorthosite, 76504,18 [6]. The light-gray lithology may be composed of fragments from augite-bearing anorthosite plus anorthosites with An-rich plagioclase and Mg-rich mafic minerals.

The dark-gray lithology (PTSs ,31 ,27-1 ,27-2 and ,45) consists of more variable types of clasts such as glassy clast, granulitic clasts, and mineral fragments. The high abundance of dark-glassy (or devitrified glass) clasts makes the dark appearance of the surface of the slab (Fig. 1). Olivine compositions vary from $Fo_{8.7-83.28}$, and the mg' of pyroxenes, 38.33-81.2. Plagioclase compositions are $An_{68.8-97.9.}$ On the An versus mg' diagram (Fig. 2), two granulitic clasts (Gr1 and Gr2) are plotted between the FAN and Mg-suite fields, like those find in the Apollo granulites [9]. There is a clast (0.4 x 0.38mm in size) having zoned pyroxene ($Wo_{4.7}En_{71.3}$-$Wo_{24.5}En_{14.8}$), plagioclase ($An_{95.9-97.4}$) and minor silica minerals. This clast may be a fragment of mare basalt. In the brecciated matrix, the grain boundaries of clasts and mineral fragments are cemented by very fine vesiculated glass, indicating the grain boundary melting by shock.

The black impact melt portions (PTSs ,35 and ,45) in some cases have sharp contacts with the dark-gray and light gray lithologies. In most cases, the melt is mixed with the other lithologies. The texture of the melt portion is very fine-grained (or glassy) composed of (sub-micron size) crystals. Fragments in the matrix are often rounded, and are similar to the components in the other lithologies.

These observations suggest that Y86032 is a complicated breccia formed by at least two stages of brecciation, deformation, and mixing, being consistent with previous studies [1-3]. The presence of the grain boundary melting in the dark-gray lithology indicates that this rock was shocked at ~20 GPa and the bulk temperature could be ~50-100°C (in the case of solid) [7]. The significant amount (~20-30 vol%) of impact melt would have increased the temperature >400°C shortly after thermal equilibration [8]. It is not clear how these shock events are related to the Ar-Ar age [4]. Ar-Ar dating of the black impact melt is planned.

On the An versus mg' diagram, the chemical variations of mafic minerals and plagioclase in the dark-gray lithologies including two granulitic clasts are similar to those of previous studies [1,2,9]. In contrast, the light-gray lithology is composed of slightly different types. The range of An content in plagioclase in the light-gray lithology is slightly more Na-rich than the FAN clast found in Y86032 [2,5] (Fig. 2). If these fragments are genetically related, the hypothetical igneous trend could be from near the upper-right corner to the lower-left corner on the squared field (LG) on Fig. 2. The augite-bearing clast would be one of the most evolved components. It seems plausible that this trend is not easy to produce this trend by simple mechanical mixing of known nonmare components. Instead, this hypothetical trend might be formed by mixing of unknown highland lithologies.

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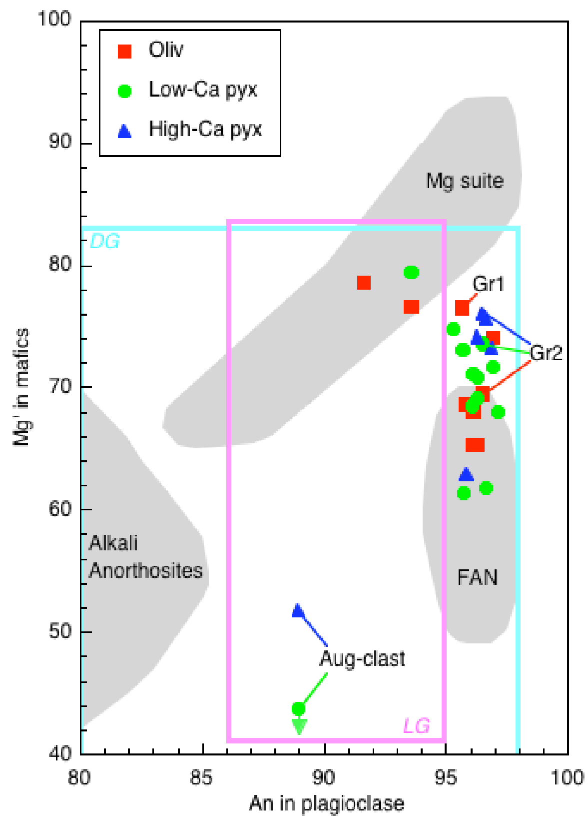

Figure 2. *Plot of mg' in mafic minerals vs. An in plagioclase. Except for "Aug-clast" (augite-bearing clast from the light-gray lithology), all data are clasts from dark-gray lithology including two granulitic clasts (GR1 and GR2). Squared fields are the ranges of compositions of plagioclase and low-Ca pyroxene in the light-gray (LG) and dark gray (DG) lithologies. Shaded areas are for the pristine rock suites [9].*

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