PETROLOGY OF FERROAN DIOGENITES, YAMATO 75032 TYPE, ASUKA 881839, AND DHOFAR 700.
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Introduction: The HED (howardites, eucrites, and diogenites) meteorites are the largest group of achondrites, probably derived from the Vestan crust. Eucrites are pigeonite-plagioclase basalts or gabbro, and diogenites are orthopyroxenites. Howardites are essentially mechanical mixtures of eucrites and diogenites.

Yamato (Y) 75032 type, Asuka (A) 881839, Dhofar (Dho) 700 are among the most ferroan diogenites (Mg' (= molar Mg/(Mg+Fe)) of pyroxenes = ~67-70), slightly more magnesian than Mg-rich cumulate eucrites (e.g., Binda) [1,2,3]. Thus, the study of these ferroan diogenites provides clues to understand the petrogenetic relationship with eucrites.

Samples and Analytical Techniques: Y75032 type diogenites are members of Y75032 type achondrites (Y75032 type) [4]. We petrologically studied four Y75032 type diogenites (Y75032, Y791199, Y791202, Y791422) and other Y75032 type achondrites (Y791200, Y791201, Y791439), and two ferroan diogenites, A881839 and Dho 700. For comparison, we studied cumulate eucrites, Moore County, Moama, and Y791195. Polished thin and thick sections (PTSs) of these meteorites were examined optically and with a SEM and EPMA. The bulk chemical compositions of pyroxenes were determined by averaging 5-30 analyses using a broad beam (~30 μm in diameter).

Results and discussion: Y75032 type diogenites are breccias mainly composed of angular to subrounded fragments of pyroxenes (Mg' = ~67-70, Fig. 1) with minor plagioclase (glass), tridymite (glass), and chromite, cemented by dark impact melts [1-4]. Y791200 and Y791201 are similar to Y75032 type diogenites, but contain fragments of cumulate eucrites. Y791439 is a polymict cumulate eucrite. The Mg' of pyroxenes (~70-55) are wider than those of Y75032 type diogenites [5].

Y75032 type diogenites have three types of pyroxenes: orthopyroxene and two types of inverted clinopyroxenes [1,2,4]. One type of inverted clinopyroxene is orthopyroxene with blebby augite (inverted low-Ca pigeonite, or Binda-type). The other type of inverted clinopyroxene is thin wormy augite set in orthopyroxene (inverted very low-Ca clinopyroxene). Binda-type pyroxene was formed by decomposition of pigeonite that crystallized on the pigeonite eutectoid reaction line [1,2]. Inverted very low-Ca clinopyroxene has bulk Ca compositions lower than those of Binda-type but higher than those of high Ca orthopyroxene [1,2]. These observations indicate that pyroxenes in Y75032 type diogenites crystallized as orthopyroxene and/or clinopyroxene. Plagioclase has a wide chemical variation (An79-91). Plagioclase may have crystallized from intercumulus liquid [1,2,3].

A881839 is a breccia composed of pyroxene fragments with minor amount of plagioclase. Many pyroxene grains have thin augite lamellae and tiny irregular to blebby augite set in orthopyroxene matrix. Other fragments in the PTS are Binda-type inverted pigeonite. Thus, the majority of pyroxenes in A881839 crystallized as clinopyroxenes. Dho 700 is an unbrecciated rock, showing a granular texture. The granular pyroxenes have orthopyroxene cores mantled by inverted very low-Ca clinopyroxene. The major element compositions and the presence of inverted very low-Ca clinopyroxene indicate that pyroxenes in Y75032 types, A881839 and Dho 700 may have crystallized under similar conditions.

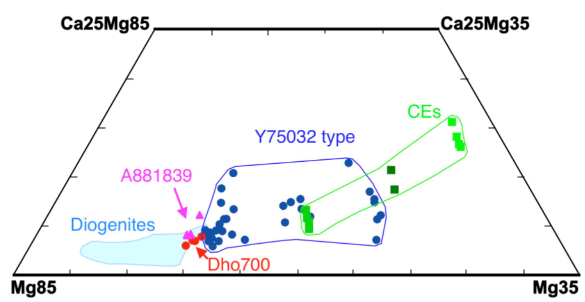

Fig. 1. Portion of pyroxene quadrilateral for Y75032 type achondrites, ferroan diogenites, A881394 and Dho 700, and cumulate eucrites (CEs), Moama, Moore County, and Y791195.

Moore County, Moama, and Y791195 are cumulate eucrites, composed of pyroxenes and plagioclase with minor phases such as tridymite, chromite, and/or ilmenite [e.g., 3,5]. Moore County and Moama are coarse-grained gabbros, whereas Y791195 is a fine-grained recrystallized rock. Moore County has pyroxenes partially inverted to orthopyroxene with fine (100) lamellae set between thick (001) augite lamellae (MC-type) [5]. Moama has completely inverted pigeonite with blebby augite set in orthopyroxene matrix (Binda-type) [5]. Y791195 has pigeonite not inverted into orthopyroxene [5]. The difference of pyroxene textures reflects the subsolidus cooling histories.

On the pyroxene quadrilateral (Fig. 1), bulk pyroxene compositions in the ferroan diogenites are plotted between cumulate eucrites and typical diogenites. The presence of three types of pyroxenes (one type of orthopyroxene, and two types of inverted clinopyroxenes) indicates that Y75032 type diogenites crystallized under special conditions. A881839 is relatively ferroan (Mg' = ~70), consistent with the presence of Binda type and inverted very low-Ca clinopyroxene. Dho 700 has both orthopyroxene and inverted very low-Ca clinopyroxene. Thus, the bulk compositions and the pyroxenes textures of the ferroan diogenites are consistent. This may support the idea that these ferroan diogenites fill a gap between cumulate eucrite and diogenites.

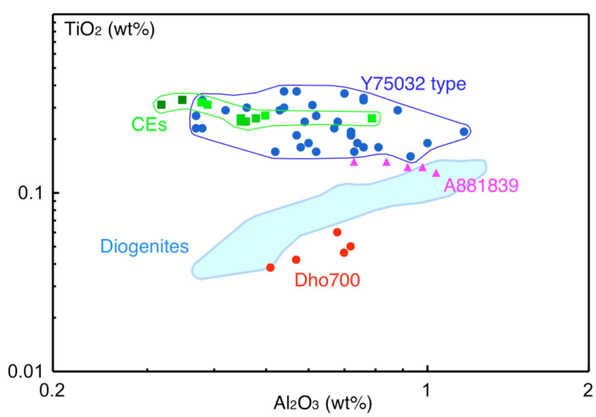

Fig. 2. Al_2O_3 vs. TiO_2 (wt%) for low-Ca pyroxenes in Y75032 type achondrites, ferroan diogenites, A881839 and Dho 700, and cumulate eucrites (CEs), Moama, Moore County, and Y791195. Shaded area represents the data of other diogenites which are not anomalous (typical diogenites) [6].

In contrast to the major element compositions in pyroxenes (Fig. 1), the situation is quite different on the Al_2O_3 and TiO_2 diagram (Fig. 2). Pyroxenes in the Y75032 type diogenites are richer in TiO_2, compared to the two other ferroan diogenites, and typical diogenites (Fig. 2) [3,6,7]. Pyroxenes of the other type of Y75032 types achondrites are plotted in a similar area. The compositions of Y75032 types are similar to those of cumulate eucrites, Moore County, Moama, and Y791195.

Unlike typical diogenites, there is no positive correlation between Al_2O_3 and TiO_2. This behavior may be related to ilmenite crystallization and/or subsolidus precipitation of Ti-rich phases (ilmenite and T-spinel). Moore County and Y791195 have Ti-rich spinel precipitated from pyroxene probably under the solidus conditions [8]. These processes will reduce the TiO_2 abundances in pyroxenes. Thus, the TiO_2 (and Al_2O_3) abundances of pyroxenes reflect differences in the parent magma compositions.

Chromite compositions of Y75032 type diogenites ($Usp_{2\text{-}6}Chm_{71\text{-}81}$) are distinct from those of A881839 ($Usp_{2\text{-}3}Chm_{66\text{-}81}$), Dho 700 ($Usp_{2\text{-}3}Chm_{69}$) and typical diogenites ($Usp_{1\text{-}2}Chm_{57\text{-}86}$) [9], and similar to those of Mama. Moore County and Y791195 have much higher in TiO_2 in chromite ($Usp_{17\text{-}50}$ for Moore County, and $Usp_{24\text{-}43}$ for Y791195), which could be metamorphic products [8]. We did not find such texture and Ti-rich chromite in Y75032 type diogenites. Thus, chromites in Y75032 type did not change significantly during slow cooling. Chromites in A881394 and Dho700 have low Ti (or Usp components) and are within the range of typical diogenites [9]. Thus, Y75032 type diogenites crystallized under different conditions.

In conclusion, typical diogenites, ferroan diogenites such as A881839 and Dho 700, and Y75032 type diogenites formed from different parental melts. Pyroxenes of Y75032 type diogenites and the two ferroan diogenites similar in major element compositions, apparently fill a gap between cumulate eucrites and typical diogenites. However, the minor element compositions of pyroxenes and chromite compositions are very different. The similar TiO_2 and Al_2O_3 relationship and the presence of fragments of cumulate eucrites indicate that Y75032 type diogenites may have crystallized from a liquid akin to eucrite. This study provides additional evidence for multiple parent liquids for diogenites [10].

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