SILICA MINERALS IN THE YAMATO-790266 POLYMICT BRECCIATED EUCRITE. H. Ono1,2, T. Mikouchi1,2, A. Yamaguchi3, 1Department of Earth and Planetary Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, 2The University Museum, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, 3National Institute of Polar Research (NIPR), 10-3 Midori-cho, Tachikawa, Tokyo 190-8518, Japan. E-mail: o-haruka@eps.s.u-tokyo.ac.jp.

Introduction: Eucrite is the largest group of basaltic achondrites and comprises an HED (Howardite-Eucrite-Diogenite) clan [e.g., 1]. HED clan meteorites are widely believed to come from asteroid 4 Vesta [e.g., 1]. Eucrites are considered to originate from the Vesta’s crust. Most eucrites are brecciated and roughly divided into two subgroups: cumulate and non-cumulate (basaltic) eucrites [e.g., 2]. Non-cumulate eucrites have experienced various degrees of thermal metamorphism. The metamorphic degrees are classified into 6 types based on their textures and mineralogy [3]. We have previously focused on silica minerals in eucrites because silica can be a good indicator to understand thermal histories of eucrites under various P-T conditions.

Silica minerals have many polymorphs (quartz, cristobalite, tridymite, coesite, etc.) including metastable phases [e.g., 4]. Especially, tridymite has ~10 polymorphs and its transformation processes are complex [e.g., 5]. Two types of tridymite polymorphs are known at room temperature: monoclinic and orthorhombic (including pseudo-orthorhombic) and tridymite in meteorites is usually monoclinic [5]. Monoclinic tridymite is reported to transform from hexagonal tridymite via orthorhombic tridymite during temperature drops below 400 °C (Fig. 1) [5]. Thus, we consider the presence of orthorhombic tridymite indicates incomplete transformation due to fast cooling [6] and silica minerals are good indicators for low-temperature thermal histories.

In our previous studies, we have studied silica minerals in 6 non-cumulate eucrites [e.g., 7-9]. Monoclinic tridymite is found in the samples with high metamorphic type (type 5) [8]. On the other hand, orthorhombic tridymite and cristobalite exist in those with low metamorphic types (types 1 and 2) [7]. By combining with the crystallization experiment of eucrite magma [10] we suggested that silica polymorphs in non-cumulate eucrites were initially cristobalite and transformed to other silica phases by slow cooling or secondary metamorphism (including alterations) [10]. Therefore, we concluded that silica polymorphs were related to thermal metamorphic degrees. In this study, we focus on a non-cumulate eucrite classified into type 3 to further clarify the correlation with silica phases.

Samples and Analytical Methods: We analyzed a polished section of Yamato (Y-) 790266 non-cumulate eucrite. Y-790266 is reported as a polynct breciated eucrite [11]. We observed a polished section using FE-SEM (JEOL JSM-7100F at NIPR). Quantitative chemical analyses were performed using electron microprobe (JEOL JXA-8200 at NIPR). The analytical conditions were 15 kV accelerating voltage and 6 nA beam current for silica minerals. We identified silica phases using Raman shift spectra by a micro Raman spectrometer (JASCO NRS-1000 at NIPR).

Results: We observed isolated silica grains and silica minerals in 5 basaltic clasts.

Isolated silica grains are 200-300 µm in size and they are quartz or orthorbhomic tridymite. For five basaltic clasts, two of them are coarse-grained and the others are fine-grained. One coarse-grained clast (clast size is 700 µm, hereinafter called “clast A”) has an elongated silica grain (280 µm in size). The silica grain is a composite grain of quartz and orthorhombic tridymite. This clast is mostly composed of plagioclase. Plagioclase shows cloudy appearance (having tiny pyroxene inclusions). Small amounts of pyroxene are present in clast A, and pyroxene has very thin exsolution lamellae (~0.2 µm in width). The other coarse-grained clast (clast size is 900 µm, hereinafter called “clast B”) is mainly composed of plagioclase and has a composite silica grain (300 µm in size), similar to clast A. The silica grain is composed of quartz and monoclinic tridymite.

For fine-grained clasts, we found a characteristic clast (clast C) (Fig. 2). The clast C is large (1.2 mm in size) and mostly composed of fine-grained (10-30 µm in size) granular pyroxene and plagioclase. Scattered coarse grains (100-500 µm in size) of pyroxene, plagioclase and silica minerals are present. Pyroxene chemical compositions are homogeneous in orthopyroxene and augite (Fs90En10Wo0-3Fs80En20Wo40). There are different silica minerals in the clast C: monoclinic tridymite, orthorhombic tridymite and quartz. The other two fine-grained clasts contain lath plagioclase (one is clast D and the other is clast E). Clast D is mainly composed of pyroxene and lath plagioclase. Plagioclase and pyroxene show a eutectic texture. Pyroxene has very thin exsolution lamellae (~0.2 µm in width). Chemical composition of clinopyroxene shows minor Mg-Fe and Fe-Ca zoning. We found silica grains (~100 µm in size). Most of silica minerals are cristobalite but small amounts of quartz are also found. Quartz contains tiny opaques. Clast E is also mainly composed of pyroxene and lath plagioclase. Pyroxene has very thin exsolution...
lamellae (0.2 µm in width) and augite has homogeneous chemical compositions (Fig. 3). Silica minerals are aggregates of quartz and cristobalite. The aggregates contain abundant tiny opaques.

Discussions: We observed isolated silica grains and 5 basaltic clasts in a Y-790266 non-cumulate eucrite classified into type 3 in thermal metamorphic degrees. Pyroxene in clasts A, C, D and E has very thin exsolution lamellae and/or chemical zoning. Takeda and Graham [3] reported pyroxene chemical zoning in type 3 is formed by very thin exsolution lamellae. Thus, the presence of very thin exsolution lamellae is one of the criteria for type 3 [3]. Therefore, we determine that clast A, C, D and E are type 3 in thermal metamorphic degrees. In this study, we could not classify clast B into thermal metamorphic degree because we could not find pyroxene in this clast.

We found cristobalite in clasts D and E. In clast D, plagioclase and pyroxene show a eutectic texture indicating rapid cooling. Such texture is similarly found in the run products (1 °C/hr cooling from 1300 to 850 °C) of the crystallization experiment [10]. Thus, we suggest that cristobalite in clast D is an initial silica phase directly crystallized from eucritic magma. In clast E, we found aggregates of quartz and cristobalite. We consider the aggregates were formed by partial transformation from cristobalite due to thermal metamorphism. Cristobalite is previously found in the non-cumulate eucrites with low thermal metamorphic degree (types 1 and 2). We have never observed cristobalite in eucrites with high thermal metamorphic degree (>type 4). Therefore, in this study, we regard that type 3 is a border for the presence of cristobalite.

We found orthorhombic tridymite in clast A and as isolated grains. We also found monoclinic tridymite in clasts B and C. The coexistence of monoclinic and orthorhombic tridymite in the same section indicates distinct thermal history for each clast. Thus, we suggest different thermal histories of each clasts before brecciation are preserved for Y-790266.

Conclusions: We studied silica minerals in Y-790266 type 3 non-cumulate eucrite and found various silica minerals (quartz, cristobalite, orthorhombic tridymite, monoclinic tridymite and aggregates of quartz and cristobalite). We classified 4 basaltic clasts into type 3 based on [3], matching with the previous study [3]. We found cristobalite in these type 3 clasts and conclude that type 3 is a border for the presence of cristobalite. Additionally, both orthorhombic and monoclinic tridymites are found in the same section, suggesting the presence of clasts with distinct thermal histories before brecciation.