SILICA POLYMORPHS IN THE MILLBILLILLIE EUCRITE: IMPLICATIONS FOR THEIR FORMATION CONDITIONS.

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Introduction: Silica minerals are known to have many polymorphs under various pressure and temperature conditions [e.g., 1]. Particularly, tridymite includes 10 or more metastable phases below 400 °C and their transformations are very complex [e.g., 2]. For example, monoclinic tridymite transforms from hexagonal via orthorhombic (space group: $C222_1$) and a pseudo-orthorhombic tridymite (space group: $F1$) transforms from hexagonal [2]. In our previous study, we pointed out that the presence of monoclinic tridymite in cumulate eucrites indicates slow cooling below 400 °C [4]. We also studied silica in basaltic clasts of 3 non-cumulate eucrites, Yamato (Y) 75011, Pasamonte, and Stannern [5] and verified their occurrences by combining with the crystallization experiment of silica from a eucritic magma composition [6]. In these previous studies, we suggested that variation of silica is induced by different thermal metamorphic levels in each non-cumulate eucrite. Because the observed samples so far are categorized into low to intermediate metamorphic levels (types ≤4 [7]), in this study we focus on silica polymorphs in Millbillillie whose thermal metamorphic level is high (type 5 or 6) [8] to explore more variations of silica in non-cumulate eucrites.

Sample and Method: We studied a thin section of Millbillillie and obtained electron back-scattered diffraction (EBSD) patterns of silica minerals using a SEM (JEOL JSM-7100F) at NIPR. Quantitative mineral analyses and elemental mapping were performed using the JEOL JXA-8530F electron microprobe at University of Tokyo. Micro-Raman spectra of silica phases were obtained by the JASCO NRS-1000 at NIPR.

Results: The section studied shows a large variation in grain sizes of pyroxene and plagioclase ranging from 30 μm to 2 mm. Most of plagioclase is lathy and pyroxene contains thin exsolution lamellae (0.3~1.5 μm) in spite of different grain sizes. Silica minerals are only found associated with coarse-grained pyroxene and plagioclase (>0.5 mm) and their occurrences are roughly divided into two types. One is an elongated grain reaching 2 mm (Fig. 1). Raman and EBSD analyses show that such grains are composed of quartz and monoclinic tridymite. Quartz contains tiny sulfide inclusions and vesicles, while monoclinic tridymite is free of such inclusions and vesicles. Hackle fracture patterns [9] are found in these areas as observed in Y 75011 [10]. The other occurrence of silica is a fine-grained mixture with augite (Fig. 1). The EBSD analysis suggests that silica is monoclinic tridymite, but confirmation by Raman is required. Augite is similarly fine-grained, but the presence of exsolution lamellae parallel to one direction shows that fine-grained augite is a large single crystal connected in 3-Ds.

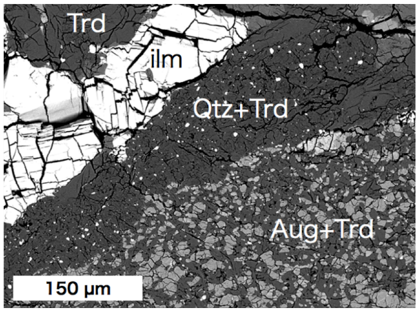

Fig. 1. BSE image of silica in Millbillillie. Qtz: Quartz, Trd: Monoclinic tridymite, Aug: Augite, ilm: Ilmenite.

Discussion and Conclusion: We found two kinds of silica minerals in Millbillillie: quartz and monoclinic tridymite. Millbillillie contains elongated silica grains composed of quartz and monoclinic tridymite with hackle fracture patterns. It is considered that quartz in Millbillillie was transformed from cristobalite by a slow cooling process as is the similar case to silica minerals in Y 75011 (type 1) and Stannern (type 4) [5,9], which was supported by the crystallization experiment [6]. On the other hand, monoclinic tridymite was transformed from orthorhombic tridymite at low temperature below 400 °C. The difference of silica mineral assemblages between Millbillillie and Y 75011 (quartz and cristobalite) could be due to different thermal metamorphic grades. Fine-grained monoclinic tridymite eroding augite probably formed by reaction with Si-rich melt. The presence of monoclinic tridymite in Millbillillie indicates that the cooling rate was slower than the samples containing orthorhombic tridymite (e.g., Pasamonte: type 2) at least blow 400 °C. The preservation of monoclinic tridymite in Millbillillie suggests that the cooling rate was slow after high temperature thermal metamorphism, which probably took place at a deeper place than that of Pasamonte.

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