Quartz and tridymite in the Yamato 980433 cumulate eucrite: Implications for its thermal history

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Introduction: It is known that there are more than 23 silica polymorphs under various temperature and pressure conditions (e.g., Sosman, 1965). Their phase transitions are complex, particularly transformation of tridymite below 400 °C. For example, monoclinic tridymite that is often found in meteorites is transformed from hexagonal via orthorhombic as temperature drops (e.g., Graetsch and Flörke, 1978). In our previous study of silica minerals in cumulate eucrites, we found monoclinic tridymite in Moore County, Moama and Yamato 980433 (Y 980433) (Ono et al., 2016a). Additionally, unusual lamellae of orthorhombic tridymite were found in Moama. The presence of different tridymite phases indicates different cooling histories below 400 °C among cumulate eucrites studied (Ono et al., 2016b). Unlike Moore County and Moama, Y 980433 contains quartz as well as tridymite. In this abstract we report detailed mineralogy of two silica phases (quartz and tridymite) in Y 980433, especially association of a shock melt vein in this sample.

Sample: We studied two polished thin sections of Y 980433 supplied from National Institute of Polar Research (NIPR). This meteorite is a Japanese Antarctic meteorite collected by JARE and classified into a cumulate eucrite (Takeda et al., 2011a). It is considered to be paired with Y 980318. Y 980433 shows thick exsolution lamellae of pyroxene indicating that this sample formed in slowly cooling magma (Takeda et al., 2011b).

Methods: We first observed the Y 980433 sections by an optical microscope. Then, the sections were analyzed with the JEOL JXA-8530F electron microprobe at University of Tokyo to perform elemental mapping in order to locate the positions of silica minerals. We obtained electron back-scattered diffraction (EBSD) patterns of silica minerals using a FEG-SEM (JEOL JSM-7100F) at NIPR. Micro Raman spectra of silica phases were obtained by the JASCO NRS-1000 at NIPR.

Result and Discussion:
Petrography: The sections studied show a gabbroic texture composed of large pyroxene and plagioclase (2~4.5 mm). There are exsolution augite lamellae that consist of both thick (75 μm in width) and fine lamellae (2 μm in width) in low-Ca pyroxene. Both pyroxene and plagioclase have many cracks and show weak wavy extinction under polarizing microscope. Two kinds of glassy veins are crossing both thin sections (Fig. 1). One is light brown color with abundant bubbles (about 200 μm in width). This vein crosscuts the other vein and shows isotropic characteristics under polarizing microscope. Boundary of this vein is sharp. These observations indicate that this vein is considered to be fusion crust penetrating the section. The other vein is black in color (about 120 μm in width). It shows branching and penetrates pyroxene and plagioclase. The pyroxene penetrated by the vein is brecciated. Plagioclase around the vein shows mosaic extinction and is partly isotropic (similar to "maskelynite"). These observations suggest that this vein was induced by shock.

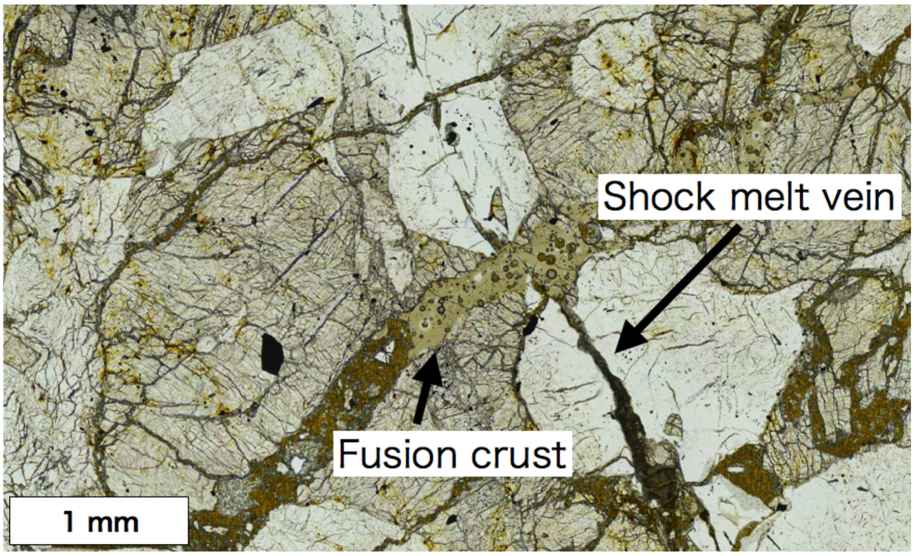

Figure 1. Optical photomicrograph (open nicol) of two kinds of glassy veins in Y980433

Silica minerals: In both thin sections, tridymite is present as monoclinic (about 400~600 μm in size) (Fig. 2a). Monoclinic tridymite is present only far from the shock melt vein and these tridymite grains contain many cracks. In contrast, quartz is present only around the shock melt vein and has no cracks (below 100 μm in size) (Fig. 2b). These quartz crystals are considered to have been formed by re-crystallization from shock melt because of its close proximity to the shock melt vein. We consider that only monoclinic tridymite was originally present in Y 980433 at first as similar to other cumulate eucrites. When this meteorite was subjected to a shock event, the local shock melt was produced. Subsequently, quartz crystallized from the shock melt. The solid transformation from tridymite to quartz might not occur because such transformation is known to be unlikely (e.g., Heaney, 1994). In fact, quartz grains are smaller than tridymite and scattered only around shock melt veins. Also, co-existence of quartz and tridymite in a single grain or their reaction rims were not observed, indicating that the formation of quartz occurred locally within the shock-melted area. The crystallization of quartz from the shock melt indicates that the temperature of shock melt veins was higher than the crystallization temperature of quartz.

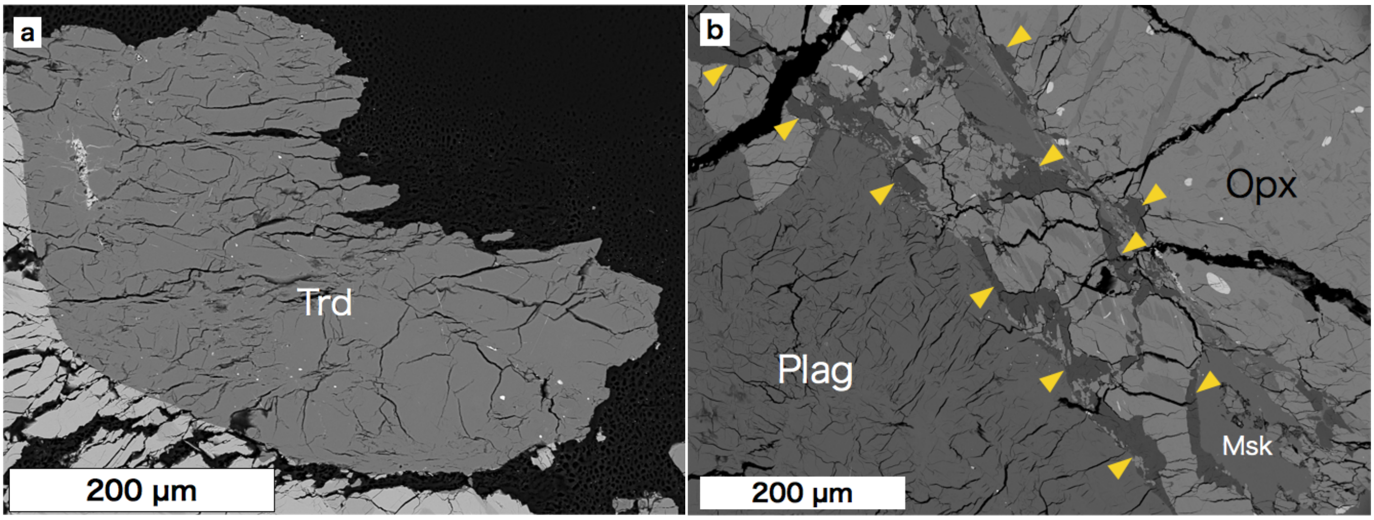

Figure 2. (a) Back-scattered electron (BSE) image of monoclinic tridymite in Y 980433. (b) BSE image of small quartz grains (dark phases indicated by small yellow triangles) around the shock melt vein in Y 980433. Trd: tridymite. Opx: orthopyroxene. Plag: plagioclase. Msk: Maskelynite.

Conclusions: In our sample, only Y 980433 contains quartz. The quartz crystals exist along a shock melt vein and neither co-existence of quartz and tridymite in a single grain nor their reaction rims was observed. Therefore, quartz in Y 980433 is considered to have crystallized from shock melt.

References

Graetsch H. and Flörke O. W. X-ray powder diffraction patterns and phase relationship of tridymite modification. Zeitschrift für Kristallographie. 195:31-48. 1991.

Takeda H., Yamaguchi A., Hiroi T., Nyquist L. E., Shih C.-Y., Ohtani M., Karouji Y. and Kobayashi S. Comparisons of mineralogy between cumulate eucrites and lunar meteorites possibly from the farside anorsothitic crust. Lunar and Planetary Science Conference XLII. #1632. abstract, 2011a.

Takeda H., Ohtake M., Hiroi T., Nyquist L. E., Shih C.-Y., Yamaguchi A. and Nagaoka H. Mineralogy of inverted pigeonite and plagioclase in cumulate eucrites Y-980433 and Y-980318 with reference to early crust formation of Vesta-like body. 34th Symposium on Antarctic Meteorites. abstract, 2011b.

Heaney J., Reviews in Mineralogy, 29, 1994.

Ono, H.; Takenouchi, A.; Mikouchi, T., "Silica polymorphs in cumulate eucrites." Lunar and Planetary Science Conference, Lunar and Planetary Institute, XLVII, #1929, 2016a.

Ono H., Takenouchi A., Mikouchi T, and Yamaguchi A, "Mineralogical study of coexisting silica polymorphs in several cumulate and non-cumulate eucrites", The Seventh Symposium on Polar Science, 2016b.

Sosman R. B., "The phases of silica", Rutgers University Press, pp. 388. 1965.