Formation of silica polymorphs in non-cumulate eucrites as inferred from crystallization experiment

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1.Introduction

Silica minerals have 23 or more polymorphs including metastable phases under various temperature and pressure conditions (e.g., Kihara 2001). For example, tridymite has more than 10 metastable phases at below 400 °C (e.g. Graetsch and Flörke, 1991). It is also known that silica minerals are crystallized under hydrothermal environment. For example in meteorites, quartz veinlets were found in the Serra de Magé cumulate eucrite, which was interpreted to have deposited from water (Treiman et al., 2004). Therefore, silica minerals are considered to be important to understand low-temperature thermal history and possibility of secondary alteration. However, silica minerals are usually reported only as “silica” in meteorites. In our previous studies, we analyzed silica minerals in both cumulate and non-cumulate eucrites to compare their formation conditions at depth and surface of the Vesta’s crust (e.g., Ono et al., 2016). We found that non-cumulate eucrites contained various silica mineral assemblages though their origins were mostly uncertain. Thus, in this study, we performed a crystallization experiment to see which silica mineral is crystallized from a eucritic magma by rapid cooling comparable to the crystallization of basaltic clasts in non-cumulate eucrites.

2.Sample and Method

We selected the Millbillillie non-cumulate eucrite as a starting material. Millbillillie was grinded into ~10 μm powder and compressed into 125 mg pellets. Then, two pellets were put on Pt wire holders and suspended in a Siliconit vertical electric furnace. They were heated and homogenized at 1300 °C for 48 hours before they were cooled down to 850 °C at 1 °C/hr. Total pressure was 1 atm and oxygen fugacity was controlled at logfO_2=IW-1 using gas mixture of CO_2-H_2. Polished thin sections of the experimental charges were prepared. They were observed by an optical microscope and FE-SEM, and elemental mapping was performed using electron microprobe to locate silica phases. Then, silica polymorphs were identified by EBSD patterns and Raman spectra.

3.Results and Discussion

Lathy plagioclase and pyroxene were observed and silica minerals were present at their grain boundaries in the recovered sample. EBSD patterns and Raman spectra revealed that all silica minerals are cristobalite. These results suggest that cristobalite is the first silica mineral crystallized from eucritic magma by rapid cooling. The occurrence of cristobalite indicates that they are crystallized after crystallization of pyroxene and plagioclase. This experimental result has an implication for interpreting the formation of silica assemblages in non-cumulate eucrites. Aggregates of cristobalite and quartz are present in Yamato-75011. Because a hackle fracture pattern is locally found in cristobalite, it is considered that aggregates formed by partial transformation from cristobalite to quartz, which is consistent with experimental result that cristobalite was the first silica phase. In Pasamonte, there are subhedral cristobalite, quartz, and orthorhombic tridymite. The experimental result suggests that cristobalite first crystallized and then transformed to quartz and orthorhombic tridymite by thermal metamorphism after brecciation. Stannern contains only anhedral quartz. Because of thermal metamorphic level of Stannern (type 4), cristobalite was probably completely transformed to quartz by thermal metamorphism. Therefore, cristobalite is crystallized at first, and then other silica polymorphs are formed by secondary alteration in non-cumulate eucrites.

4.Conclusion

In this study, it is clarified that cristobalite first crystallizes from eucritic magma by rapid cooling (1 °C/hr). This result indicates a possibility that silica polymorphs in non-cumulate eucrites involves different transformation degrees from cristobalite. Such transformation is considered to have been occurred by slower cooling than 1 °C/hr or secondary thermal metamorphism.

Keywords: Silica minerals, Eucrite, Crystallization Experiment, Cristobalite, Quartz, Transformation

