TRIDYMITE POLYMORPH IN CUMULATE EUCRITES INDICATING THEIR THERMAL HISTORIES

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Introduction: Eucrites are one of achondrite meteorite groups and probably came from asteroid 4 Vesta's crust [1]. Eucrites are divided into two subgroups: cumulate and non-cumulate. Since pyroxenes in cumulate eucrites exhibit thick exsolution textures due to slow cooling and their cooling rates are estimated by a width of exsolution lamellae to discuss formation of the Vesta's crust [e.g., 2]. However, pyroxene lamellae can clarify thermal histories only at high-temperature (600-1000 °C) [3]. In order to reveal low-temperature (<600 °C) thermal histories, we have focused on silica minerals in cumulate eucrites. Silica minerals are present in eucrites (about 10 vol.%) [4] and have many polymorphs under various P-T conditions including very low-temperature (<400 °C) range [e.g., 5]. Specifically, tridymite is useful to reveal low-temperature thermal histories because tridymite is known to have six polymorphs below 400 °C [5]. Each tridymite polymorph is mainly classified into four distinct crystal structures, hexagonal, monoclinic, orthorhombic and pseudo-orthorhombic [5]. Transformation processes of tridymite are complicated; for example, monoclinic tridymite is transformed from hexagonal tridymite via orthorhombic tridymite below 400 °C [5]. In this study, we try to estimate thermal histories of cumulate eucrites using tridymite polymorphs.

Samples: We stuided polished thin sections of Moore County, Moama and Yamato (Y) 980433 cumulate eucrites. Moore County is particularly studied and is considered to have experienced at least two-stage cooling processes [3]. The first process occurred with 0.00016 °C/yr cooling during accumulation, and subsequently, the second one happened with 0.3 °C/yr cooling due to an impact event [2]. On the other hand, Moama is estimated to have cooled slower than 0.0004 °C/yr [6]. Although Y 980433 has no report of its cooling rate, it is suggested that the cooling rate of Y 980433 is similar to Serra de Mage cumulate eucrite (0.00018 °C/yr [7]) [8]. Although we have reported observations of silica minerals in these three samples, we add new results and further discussions in this study.

Methods: We analyzed EBSD patterns and Raman spectra to identify silica phases using FE-SEM (JEOL JSM-7100F) and micro-Raman spectrometer (JASCO NRS-1000), respectively, both at NIPR. We also performed quantitative chemical analyses and elemental mapping by electron microprobe (JEOL JXA-8530F) at University of Tokyo.

Results: We previously observed silica minerals in three cumulate eucrites [9]. Although all cumulate eucrites contained monoclinic tridymite, only Moama has lamella-shaped orthorhombic tridymite (width: <26 µm). In Moama, monoclinic tridymite was commonly found as a host phase, and orthorhombic tridymite occurred as lamellae parallel to a particular crystallographic direction. Orthorhombic tridymite contains abundant cracks, while monoclinic one is unfractured. According to electron microprobe analysis, chemical compositions of monoclinic and orthorhombic tridymite are indistinguishable from each other even in minor elements.

Discussions: Since monoclinic tridymite is reported to be stable at room temperature, orthorhombic tridymite transforms to monoclinic tridymite during cooling under an equilibrium condition [5]. Therefore, we consider that the presence of orthorhombic tridymite indicates more rapid cooling than samples not containing orthorhombic tridymite. In this study, Moore County and Y 980433 have only monoclinic tridymite, and Moama has both of monoclinic and orthorhombic tridymite, and therefore we inferred that Moama cooled more rapidly than the others at least below 400 °C. Although Moama has much slower pyroxene cooling rate (<0.0004 °C /yr) than that of Moore County (>0.3 °C /yr) [2], we imply that their cooling rates were reversed during cooling by/below 400 °C. Therefore, we consider that Moama was located at a shallower place compared with Moore County and Y 980433 within the Vesta's crust.

Conclusions: We found monoclinic tridymite in three cumulate eucrites and orthorhombic tridymite lamellae only in Moama. The presence of orthorhombic tridymite in Moama indicates that Moama cooled more rapidly than the other two samples at low temperatures (below 400 °C). This result is different from the slower cooling rate of Moama (<0.0004 °C/yr) than that of Moore County (>0.3 °C/yr, after the shock event) at high temperatures (~900-1000 °C) estimated by the width of pyroxene exsolution lamellae [2]. The difference of the cooling rates may reflect geologic setting after impact excavation from the deep crust. Silica polymorphs are useful to infer thermal histories of meteorites as well as pyroxene and plagioclase.

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