水質変質程度の異なるCMコンドライト中TCIの鉱物学的研究
Mineralogical study of TCIs in CM carbonaceous chondrites

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Introduction
TCIs, intergrowths of tochilinite ($6(Fe_{0.9}S)\cdot 5[(Mg,Fe)(OH)_2]$) and cronstedtite (Fe-bearing serpentine) occur in most of CM chondrites, which are considered to be aqueous alteration products on the chondrite parent bodies. Based on the textures and chemistries, they can be divided into two types. Type I appears as massive and are generally found in chondrules, while type II exhibits fibrous textures and are generally found within the matrix. Many researchers support that kamacite in chondrules had been altered into type-I TCIs. However, precursors or alteration processes of type-II TCIs are still remains unknown. TCIs potentially provide important information regarding aqueous environments on chondrite parent bodies. Here, we report microtextures of type-II TCIs in 4 CM chondrites and review the formation process.

Materials and methods
We observed the following CM chondrites; QUE97990 (2.6), Murchison (2.5), Nogoya (2.2), Cold Bokkeveld (2.2). The number in parenthesis are the alteration index for CM chondrites proposed by Rubin et al. (2007), in which they defined the index ranging from 2.6 (moderately altered) to 2.0 (highly altered). Textural observation and chemical analyses were performed using an SEM-EDS (JEOL, JSM6480LAII), and nanometer-scale observations using an STEM-EDS (JEOL, JEM2100F) after processing into thin films using an FIB (FEI, Quanta 3Di).

Results and discussion
In QUE97990 and Murchison, less altered meteorites in this study, the type-II TCIs are distributed in the matrices. They are aggregates of a few μm-sized tochilinite and cronstedtite, where thin tochilinite veins occurred inside cronstedtite, suggesting that tochilinite had formed after the formation of cronstedtite. This gives us a constraint on the aqueous condition of CM chondrites. In Nogoya, the TCIs texture showed that very fine serpentine-rich region is located at core, and toward rim, gradually changed to fibrous cronstedtite and mixed-layer phase (alternate layer phase of tochilinite and cronstedtite structure in nanometer scale). The TCIs of Cold Bokkeveld also showed the core-rim structure, where core is often rich in mixed layer phase, and rim is consists of relatively coarse-grained tochilinite and cronstedtite. In the latter two highly altered CM chondrites, the both core showed very fine, fibrous, and fluffy texture, and no evidence of precursor material, suggesting that type-II TCIs were directly formed from water solution.

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