

Ca-sulfate in the Jbilet Winselwan CM chondrite: Implications for the heat source of post-alteration thermal metamorphism

Hisato Higashi¹, Wataru Fujiya^{1,*}, Akira Yamaguchi², Makoto Kimura², and Ko Hashizume¹

¹*Faculty of Science, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan.*

*(*Corresponding to wataru.fujiya.sci@vc.ibaraki.ac.jp)*

²*National Institute of Polar Research, Midoricho10-3, Tachikawa, Tokyo 190-8518, Japan.*

Introduction: CM chondrites are aqueously altered in their parent body [e.g., 1]. Some of them apparently underwent post-alteration thermal metamorphism associated with changes in their mineralogy and chemical composition, although the heat source remains poorly understood [2,3]. Here we report petrology and mineralogy of the Jbilet Winselwan (JW) CM chondrite, especially focusing on the evidence for post-alteration heating. We note that this meteorite contains Ca-sulfate, a rare mineral in CM chondrites [4]. The presence of sulfate in JW suggests a unique physicochemical condition of aqueous alteration not common for typical CM chondrites.

Experimental: A polished thin section of JW was observed with a Scanning Electron Microscope (SEM) at NIPR (JEOL JSM-7100F). The chemical compositions of the so-called poorly characterized phases (PCPs; cronstedtite-tochilinite intergrowths), a unique material which can be found only in CM chondrites, were determined with an Electron Probe Micro Analyzer (EPMA) at NIPR (JEOL JXA-8200). Polymorphs of Ca-sulfate were identified with Raman spectroscopy at NIPR (JASCO NRS-1000).

Results and discussion: The chondrules in the JW thin section have an average diameter of ~0.29 mm. The chondrule phenocrysts are mildly altered, while the chondrule mesostases are completely replaced by phyllosilicate. Carbonate minerals in JW are predominantly calcite. Fe-Ni metal grains account for ~0.26 vol.%, which are present mainly in the chondrule interior. These features are consistent with those of CM chondrites with petrologic subtype of 2.3 [5].

Sulfide minerals in JW are pyrrhotite with abundant pentlandite blebs, indicating mild heating as category B defined by Kimura et al. [3]. Large PCP clumps, which are commonly found in CM chondrites, are rare in JW. PCPs in JW have lower S/SiO₂ and higher FeO/SiO₂ ratios (~0.16 and ~3.2, respectively) than expected from the correlation between PCP compositions and degrees of alteration [5]. These observations suggest that PCPs in JW were, at least partially, decomposed by heating because tochilinite is unstable at high temperatures of >170 °C [6]. The decomposition of PCPs has also been confirmed for other heated CM chondrites and a Murchison sample experimentally heated [7].

In many cases, Ca-sulfate grains are surrounding calcite grains, indicating these minerals precipitated at the same alteration event. The Ca-sulfate is identified as orthorhombic or cubic anhydrite (CaSO₄), although possible presence of metastable bassanite (CaSO₄ · 0.5H₂O) cannot be ruled out because of their similar Raman bands (anhydrite at 1017 cm⁻¹ and bassanite at 1015 cm⁻¹ [8]). Gypsum (CaSO₄ · 2H₂O), which is stable at low temperatures of <110 °C [8], is absent. The absence of gypsum also indicates that JW underwent heating.

In summary, JW was heated after aqueous alteration. Because we found substantial amounts of Ca-sulfate, Ca-sulfate is one of the main carriers of sulfur. We propose that sulfur in sulfate was supplied from PCPs decomposed by heating, which resulted in lower pH of aqueous fluids favorable for precipitation of sulfate over carbonate. If correct, and if Ca-sulfate precipitated from aqueous fluids, then Ca-sulfate may have precipitated as anhydrite (or bassanite) at high temperatures of >170 °C under the presence of liquid water. The intimate association of calcite and Ca-sulfate may be inconsistent with later impact heating. Thus, the energy for the heating of JW was most likely provided from ²⁶Al decay. The physicochemical conditions of aqueous alteration in CM chondrites (temperature, fluid composition, pH, etc.) may have been more variable than previously thought.

References: [1] Brearley, A. J. (2006) in *Meteorites and the Early Solar System II*, D. S. Lauretta & H. Y. McSween Jr., Eds. (The Univ. of Arizona Press, Tucson), pp. 587-624. [2] Nakamura, T. (2005) *J. Mineral. Petrol. Sci.* **100**, 260–272. [3] Kimura, M. et al. (2011) *Meteorit. Planet. Sci.* **46**, 431-442. [4] Lee, M. R. (1993) *Meteoritics* **28**, 53-62. [5] Rubin, A. E. et al. (2007) *Geochim. Cosmochim. Acta* **71**, 2361-2382. [6] Zolensky, M. E. (1984) *Meteoritics* **19**, 346–347. [7] Nakato, A. et al. (2008) *Earth, Planets and Space* **60**, 855–864. [8] Prieto-Taboada, N. et al. (2014) *Anal. Chem.* **86**, 10131–10137.