

# ANHYDRITE IN THE JBILET WINSELWAN CM CHONDRITE: IMPLICATIONS FOR THE HEAT SOURCE OF POST-ALTERATION THERMAL METAMORPHISM

W. Fujiya<sup>1</sup>, H. Higashi<sup>1</sup>, A. Yamaguchi<sup>2</sup>, M. Kimura<sup>2</sup>, and K. Hashizume<sup>1</sup>, <sup>1</sup>Faculty of Science, Ibaraki University, 2-1-1 Bunkyo, Mito 310-8512, Japan (wataru.fujiya.sci@vc.ibaraki.ac.jp), <sup>2</sup>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 [2,3]. However, the heat source for this thermal metamorphism has remained poorly understood. 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 Ca-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 tochilinite/cronstedtite intergrowths (TCIs), 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 a 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 TCI clumps, which are commonly found in CM chondrites, are rare in JW. TCIs in JW have lower S/SiO<sub>2</sub> and higher FeO/SiO<sub>2</sub> ratios (~0.16 and ~3.2, respectively) than expected from the correlation between TCI compositions and degrees of alteration [5]. These observations suggest that TCIs in JW were, at least partially, decomposed by heating because tochilinite is unstable at high temperatures of >170 °C [6]. The decomposition of TCIs has also been confirmed for other thermally metamorphosed CM chondrites and an experimentally heated Murchison sample [7].

In many cases, Ca-sulfate grains are surrounding calcite grains, indicating that Ca-sulfate subsequently precipitated after calcite at the same alteration event. The Ca-sulfate is identified as orthorhombic or cubic anhydrite (CaSO<sub>4</sub>), although possible presence of metastable bassanite (CaSO<sub>4</sub> · 0.5H<sub>2</sub>O) cannot be ruled out because of their similar Raman bands (anhydrite at 1017 cm<sup>-1</sup> and bassanite at 1015 cm<sup>-1</sup> [8]). Gypsum (CaSO<sub>4</sub> · 2H<sub>2</sub>O), 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 Ca-sulfate was supplied from TCIs decomposed by heating, and that the compositions of aqueous solutions changed to be favorable for precipitation of sulfate over carbonate. If correct, then Ca-sulfate may have precipitated as anhydrite (or bassanite) at high temperatures of >170 °C, not as gypsum at low temperatures which was subsequently dehydrated and transformed to anhydrite by heating. The intimate association of calcite and anhydrite may be inconsistent with later impact heating. Thus, the energy for the heating of JW was most likely provided from <sup>26</sup>Al decay. We will conduct Mn-Cr dating of calcite to determine the timing of calcite/anhydrite precipitation, and to see whether the formation age of calcite/anhydrite in JW is similar to the ages of typical CM carbonates, namely, ~4563 Ma [9].

**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. [9] Fujiya W. et al. (2012) *Nat. Commun.* 3, 627.