THERMAL ALTERATION OF CI AND CM CHONDRITES: MINERALOGICAL CHANGES AND METAMORPHIC TEMPERATURES

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Introduction: Most CI and CM chondrites experienced only low temperature (<300°C) aqueous alteration in the early solar system. However, >30 CI and CM chondrites that suffered both hydration and thermal metamorphism have been identified from their unusual mineralogy, isotopic compositions and organic chemistry [e.g. 1]. These meteorites were heated to >300°C but questions still remain regarding the mechanism, timing and duration of the thermal metamorphism.

We are systematically characterizing the bulk modal mineralogy, H_2O abundances and spectral features of thermally altered CI and CM chondrites. Our aim is to quantify the relative degree of aqueous and thermal alteration recorded in these meteorites, and examine their relationship with possible parent bodies.

Experimental: Modal mineralogy was determined from powdered bulk samples (~50 mg) of thermally altered CI and CM chondrites using X-ray diffraction (PSD-XRD). Transmission infrared (IR) spectra (7500 – 400 cm^{-1}) were then obtained from ~3 mg aliquots of the same powders, and a further 10 – 15 mg was characterized using thermogravimetric analysis (TGA). For each experiment we also analyzed a range of mineral standards.

Results & Discussion: Thermal metamorphism of hydrated meteorites results in distinct mineralogical and chemical changes that can be used to broadly infer peak metamorphic temperatures [2]. A common process is the dehydration and dehydroxylation of the abundant phyllosilicates. In mildly heated (<500°C) meteorites, such as Jbilet Winselwan (CM), we observe only weak diffraction from the dehydrated phyllosilicates. However, IR spectra and overall H_2O abundances are often not significantly different to non-heated samples. At temperatures >500°C the phyllosilicates can recrystallize back into anhydrous silicates, which in the heated CIs Y-82162 and Y-980115 is reflected in higher abundances of olivine and an intense peak at ~11 μm in the IR spectra [3, 4]. In addition, these samples are depleted in H_2O and the ~3 μm feature – attributed to -OH/H_2O in hydrous minerals – is almost absent.

By combing mineral and H_2O abundances with IR spectral features, it is also possible to resolve subtle differences in the nature of the thermal metamorphism. For example, Y-980115 contains less olivine, more H_2O, and has an increased 3/11 μm band ratio than Y-82162. We interpret this as Y-980115 having experienced less severe dehydration, either because it was heated to a lower metamorphic temperature and/or the duration of heating was shorter. Short-lived heterogeneous heating events were probably caused by impact shocks, and reflectance spectra consistent with mixtures of hydrated and dehydrated phases suggest that this process affected the surfaces of many C-type asteroids [e.g. 5]. Characterizing thermally altered CI and CM chondrites is therefore an important step in preparing for samples returned by the Hayabusa-2 and OSIRIS-Rex missions.

References: [1] Tonui E. et al. 2014 *Geochim. Cosmochim. Acta* 126:284–306 [2] Nakamura T. 2005 *J. Miner. Petrol. Sci.* 100:260–272 [3] King A. J. et al. 2015 *Geochim. Cosmochim. Acta* submitted [4] King A. J. et al. 2015 *Earth Planets Space* submitted [5] Hiroi T. et al. 1993 *Science* 261:1016–1018.